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Finite element analysis of newly introduced plates for mandibular condyle neck fracture treatment by open reduction and rigid fixation

Metoda elementów skończonych w ocenie nowo wprowadzanych płytek do ograniczenia otwierania i sztywnej stabilizacji w leczeniu złamania szyjki wyrostka kłykciowego żuchwy

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Abstract

Background. Fractures of the mandibular condyle have been a topic of controversy and discussion in the area of maxillofacial trauma for many years. Any treatment should provide accurate reduction and stability of fractured bony fragments to enable further uncomplicated mandibular function. Recently, 2 novel plates were introduced: strut and rhombus.

Objectives. To compare the newly introduced plates for mandibular condyle neck fracture treatment.

Material and methods. A total of 6 variants of fixing by 5 screws were tested by finite element analysis: strut plate in the normal position (T1), strut plate in an inverted position (T2), rhombus plate with 2 screws positioned close to the lower border sliding middle holes (T3), rhombus one with a mesial screw positioned close to the upper border of the sliding hole and distal screw positioned close to the lower border of the sliding hole (T4), rhombus one with both screws in sliding holes positioned close to the upper border of the holes (T5), and modified rhombus plate where all holes are round (T6). Equivalent maximal stress in the fixing material and relative displacement in the fracture line were calculated, and the influence of the act of mastication on fatigue failure was evaluated.

Results. The position of the plate and location of the fixing screws are crucial for stabilization of the reduced bone fragments. Any adjustments of these 2 plates by bending, flattening or cutting are unsafe. Mean relative displacement in the fracture line and equivalent maximal stress were T1: 958 ±312 μm (the worst $p < 0.05$), 869 MPa; T2: 463 ±130 μm, 915 MPa; T3: 625 ±222 μm, 1150 MPa; T4: 624 ±273 μm, 1160 MPa; T5: 485 ±192 μm, 544 MPa; and T6: 467 ±172 μm, 549 MPa, respectively.

Conclusions. It should be noted, comparing both plates, that the rhombus plate equipped only with round holes (not sliding holes) presented its superiority within this pairing. It is mechanically relatively resistant and relatively durable in spite of the design being only partially according to compression and traction force propagation in the mandibular condyle.

Key words: treatment, finite element method, fracture, mandibular condyle neck, fixing material

Słowa kluczowe: leczenie, metoda elementów skończonych, złamanie, szyjka wyrostka kłykciowego żuchwy, materiał zespalający

Fractures of the mandibular condyle have been a topic of controversy and discussion in the area of maxillofacial trauma for many years. For decades, closed reduction has been the preferred method, but it requires intermaxillary fixation, followed by functional therapy.[1] Only in the pediatric population is it the gold standard. Any treatment should provide accurate reduction and stability of fractured bony fragments to enable further uncomplicated mandibular function. There is now greater consensus about performing open reduction, considering the better results.[2–4]

Recently, 2 manufactures have introduced new plates (Table 1): a strut plate by DePuy Synthes[5] and a rhombus by KLS Martin.[6] The strut plate is a very innovative concept, taking into account force distribution in the condyle region. The manufacturer reports that 1) the small size allows placement using multiple surgical approaches such as intraoral, retromandibular, submandibular and preauricular, 2) for placement, the straight 3-hole segment should be nearly parallel to the posterior border and aligned with the condylar head, 3) it is adjustable to fit patient anatomy (superior holes can be bent independently), and 4) the middle hole can be left empty for more "vertical" fractures. On the other hand, the rhombus is a typical development of the stiff triangle plate. The manufacturer explains that the most distinctive features of the Rhombus 3D Condylar Fracture Plate are: 1) it can be used for the surgical treatment of deep, medium and high condylar process fractures, 2) the rhombus shape of the plate provides for optimal transmission of the tensile and compressive forces present in the mandible, and 3) closely positioned screw holes in the proximal part of the plate allow secure placement of the osteosynthesis screws even under difficult spatial conditions.

The objective of this study is to compare the newly-introduced plates for mandibular condyle neck fracture treatment.

Material and methods

The plates

The DePuy Synthes strut plate (art. no. 04.503.832) was compared to the KLS Martin rhombus 3D plate (art. no. 25-285-05-09), both 5-hole condylar plates (Table 1). The locking screw system was assumed. All holes were used to fix the plate by screws. The strut plate was investigated in 2 positions: the one recommended by manufacturer and upside-down. The rhombus plate was tested in 4 configurations depending on the arrangement of the screw positioning: position 1 – 2 screws (i.e. screw no. 3 and no. 4) are positioned close to the lower border oval holes (typical clinical fixation which is recommended by the manufacturer, ref 90-131-99-10), position 2 – the mesial screw (screw no. 4) positioned close to the upper border of the oval hole and the distal screw (screw no. 3) positioned closed to the lower border of the oval hole, position 3 – both crews in the oval holes positioned close to the upper border of the holes (opposite to the typical clinical fixation), position 4 – a modified rhombus plate where all the holes are round (a design close to the KLS Martin angle-stable, locking plate).

Table 1. Basic features of compared plates. Numbers in rhombus plate layout are chronological standard sequence of screw fixing according to manufacturer

	Strut plate	Rhombus plate
Layout		
Height	28 mm	20 mm
Width	14 mm	13 mm
Thickness	1 mm	1 mm
Dedicated screws	2.0 mm	2.0 mm
Number of holes	5	5
Side dedication	yes (right-side presented)	no
Pre-bent	convex	plain

The clinical protocol considered did not apply post-operational maxillo-mandibular fixation.

Material properties

Material properties of the titanium alloy Ti-6Al-4V grade 5 were applied in this study. There were: Young's modulus 104 GPa, Poisson coefficient 0.3, yield stress 934 MPa, ultimate tensile stress 1650 MPa, and elongation to break approximately 10%. Plastic modulus (Ep = 1040 MPa) was used in the nonlinear calculations (a plastic modulus in engineering practice is used as hundredfold smaller than Young's modulus). The assessment of fatigue strength was adapted to the maxillofacial situation. The authors approximated the number of mastication cycles during a 6-week healing period (42 days). It was evaluated that 5 series, each a 40-bite action per day (i.e. 5 short meals), gave 200 × 42 = 8400 evolutions per healing period (approximately 10^5). Later calculations were based on the study by Pekedis & Yildiz, 2011.[7]

Finite element analysis

For the boundary conditions,[8] the incisors were fixed in 3D coordinates, and the condyle could translate and rotate on the plane surface of a support. The load application was for a mouth closing up to 5 mm on the incisors. It is the most critical situation in the condylar

processes.[9] The muscular functions applied were similar to those used previously[8,10,11] and 5 pairs of gross muscles/actions were modelled: deep masseter (vector: X = 7.78 N, Y = 127.23 N, Z = 22.68 N), superficial masseter (X = 12.87 N, Y = 183.50 N, Z = 12.11 N), medial pterygoid (X = 140.38 N, Y = 237.80 N, Z = –77.30 N), temporalis (X = 0.06 N, Y = 0.37 N, Z = –0.13 N), and medial temporal (X = 0.97 N, Y = 5.68 N, Z = –7.44 N). The suprahyoid muscles were omitted due to their lack of action during mouth closing. The finite element model (FEM) used in the present study was composed of tetrahedral linear elements with 4 nodes and 5,200,000 degrees of freedom (DOF). The constructed model had not dentition because the presence of teeth has a marginal influence on the biomechanics and behavior of the mandibular condyles.[11,12] The Ansys R14.5 program (Ansys Inc., Canonsburg, Pennsylvania, USA) was used for FEM calculation.

The mandible cortical bone layer was considered to have a Young's modulus of 14.7 GPa and a Poisson coefficient of 0.3, similar to models used previously.[8,11,13–15] Cancellous bone Youngs modulus was used as 1.4 GPa. The width of the fracture line after open reduction was established at 0.32 mm.[8] The plate was applied to the right side of the mandible. The implant position with respect to the mandible was defined by the level of fracture. The middle condylar neck fracture was chosen to test the plates, because it was impossible to utilize these plates for high condylar neck fracture treatment.[16] To simulate the behavior of the screws, they were considered to be completely surrounded by cortical bone. The screw-implant contact was modelled as a touching contact situation. No contact between the implant and bone (0.3 mm distance) was modelled. This lack of contact was important for the test of the plates as a load bearing device. Stress and displacement in the fracture line were analyzed on the external surface of the mandible and plates.[8]

Nonlinear calculations estimated on the basis of plastic modulus (Young's modulus to yield point, and plastic modulus beyond it) were applied in the models where maximal equivalent stress highly exceed yield stress (i.e. the rhombus plate with screw position 1 and 2).

Statistical analysis

ANOVA was applied to check which plate position generated the lowest relative movement during loading of the mandible. Statgraphics Centurion XVI (Statpoint Technologies, Inc., Warrenton, Virginia, USA) was used and statistical significance was indicated as $p < 0.05$.

Results

The calculated results are presented in Fig. 1–5 (displacement and stress) and Table 2 (relative movement in fracture line – positive value means extension traction). The strut plate tested in the normal position, i.e. positioned according to the manufacture's recommendation, is presented in Fig. 1. Maximal stress was σ_{red} = 869 MPa. There are 5 dangerous regions due to exceeding the maximal equivalent stress on the bone-facing side of the plate. The strut plate in the inverted position, i.e. positioned upside-down, is presented in Fig. 2. Maximal equivalent stress is 915 MPa. There are 2 dangerous regions due to exceeding the maximal equivalent stress on the bone-facing side of the plate in the posterior region, including 1 penetrating entirely through the plate – an evident break risk in the posterior part of the plate.

Two rhombus plate fixations were calculated in a nonlinear way (Fig. 3 and 4), based on the plastic modulus beyond the yield stress. Screw position 1 (Fig. 3) still revealed a high level of equivalent stress – $\sigma_{max\ red}$ = 1155 MPa – and a series of risky sites of deformation. These were lo-

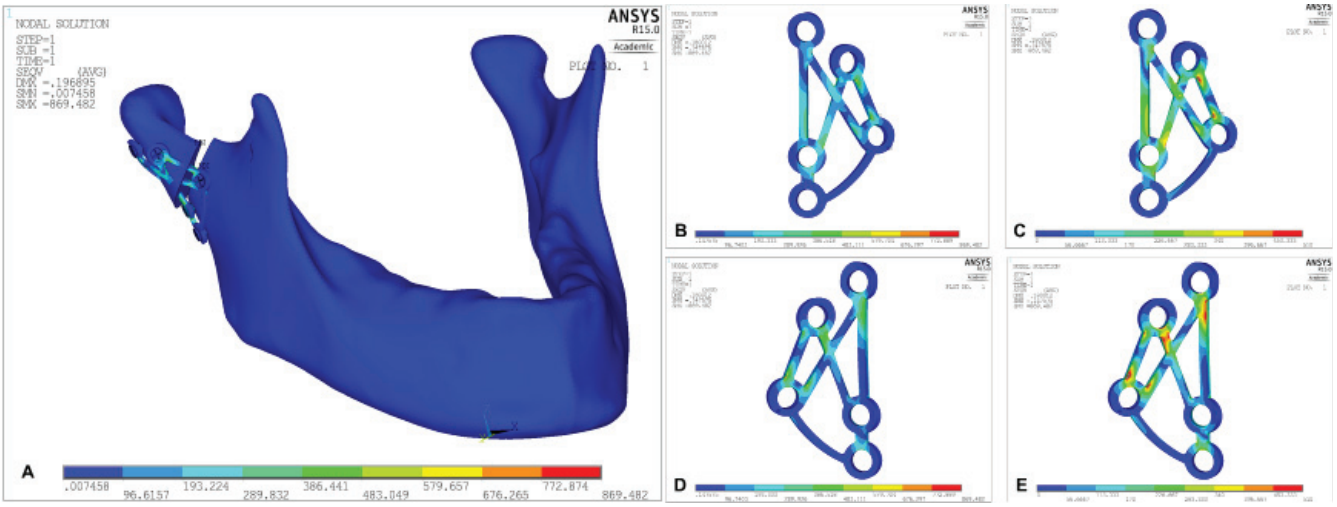

Fig. 1. Strut plate finite element analysis in the normal position, i.e. positioned according to the manufacturer recommendation.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress is σ_{red} = 869 MPa). B. Outer surface of the plate. C. Outer surface of the plate in a scale limited up to the fatigue failure stress for titanium alloy grade 5, i.e. 510 MPa. D. Bone-facing surface of the plate. E. Bone-facing surface of the plate in a scale limited up to fatigue failure stress.
There are 5 dangerous regions due to exceeding the maximal equivalent stress on the bone-facing side of the plate.

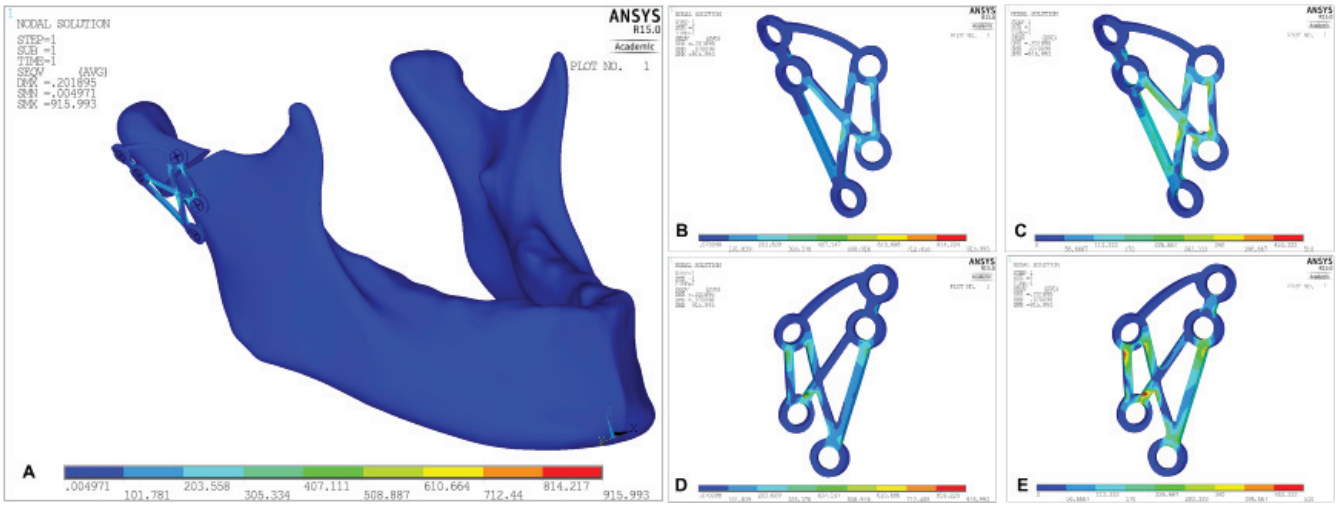

Fig. 2. Strut plate finite element analysis in the inverted position, i.e. positioned upside-down.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress is σ_{red} = 915 MPa). B. Outer surface of the plate. C. Outer surface of the plate in scale limited up to fatigue failure stress for titanium alloy grade 5, i.e. 510 MPa. D. Bone-facing surface of the plate. E. Bone-facing surface of the plate in scale limited up to fatigue failure stress.
There are 2 dangerous regions due to exceeding the maximal equivalent stress on the bone-facing side of the plate in the posterior region including 1 penetrating entirely through the plate. Evident break risk in the posterior part of the plate.

cated around screw/hole no. 3 and 4 (856 MPa). As far as the second modality was concerned: in position 2 (Fig. 4), the equivalent stress around the modified screw location no. 4 had been reduced below fatigue failure stress (i.e. below 510 MPa). For only the plate, it was $\sigma_{max\ red}$ = 973 MPa. This was contrary to the unmodified screw/hole no. 3, where 4 fatigue failure stress risk regions were still observed. Maximum stress for the whole fixing material was $\sigma_{max\ red}$ = 1160 MPa, for the plate it was 892 MPa, and for the screws, 989 MPa (Fig. 4).

The rhombus 3D plate with screw position 1, i.e. 2 screws positioned close to the lower border of the sliding (oval) holes, is presented in Fig. 3. Four dangerous regions were observed in the bone-facing side and 3 of them were visible on the outer side of the plate – break risk in the posterior part of the plate. The problem of the plate with the screw position recommended by the manufacturer is the chamfer of sliding holes, because the chamfer head of the screw can slip outside of the hole edge during loading. The rhombus 3D plate with screw position 2, i.e.

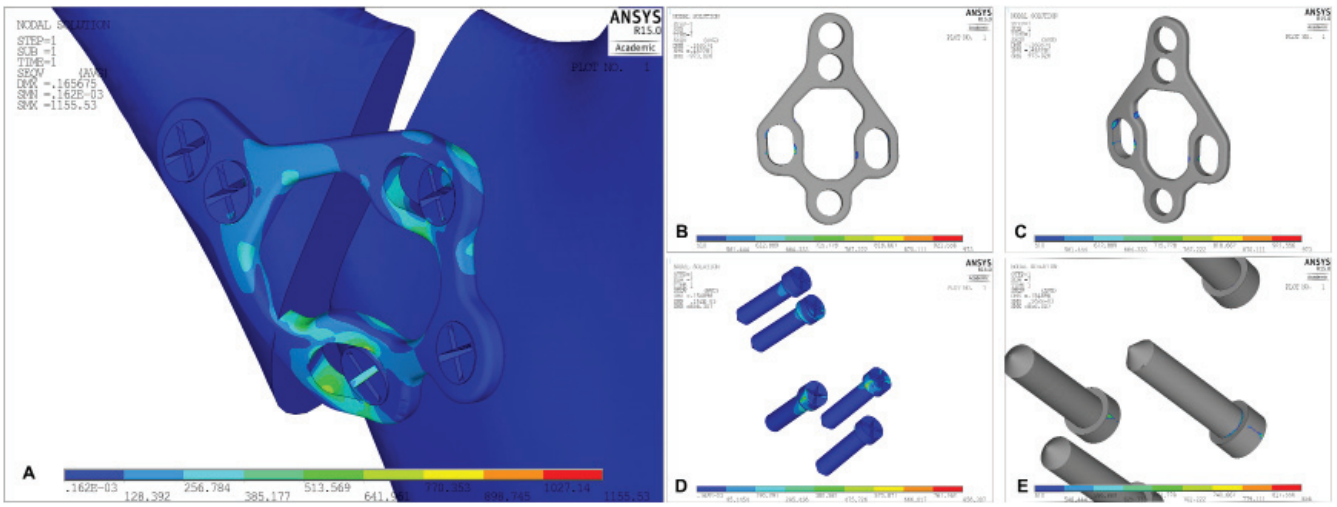

Fig. 3. Rhombus 3D plate finite element analysis with screw position 1, i.e. 2 screws are positioned close to the lower border of sliding (oval) holes.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress in the plate is σ_{red} = 1155 MPa). Images B, C and E present regions of stress over the fatigue failure stress (the fatigue failure stress of titanium alloy grade 5 is 510 MPa, and yield stress is 934 MPa).
Seven regions have fatigue failure stress risk around hole no. 3 (4 risk regions) and 4 (3 risk regions). Note (B, C), there are linear entire high stress concentration regions corresponding to the screw head thread's last contact to the plate in hole 3 and 4 (Table 1). Similar linear risky regions are in screw heads (D, E). They are the possible sites of the slipping of the screw head out of the plate hole.
The small plate has a low stiffness (high displacements in the fissure line) as screws are located according to producer requirements. The maximal stress in the plate is between the screws and the plate in connection sites on the edge of the screw. It creates local failure on the plate surface, and the fatigue destruction of the fixing material can begin at that place.

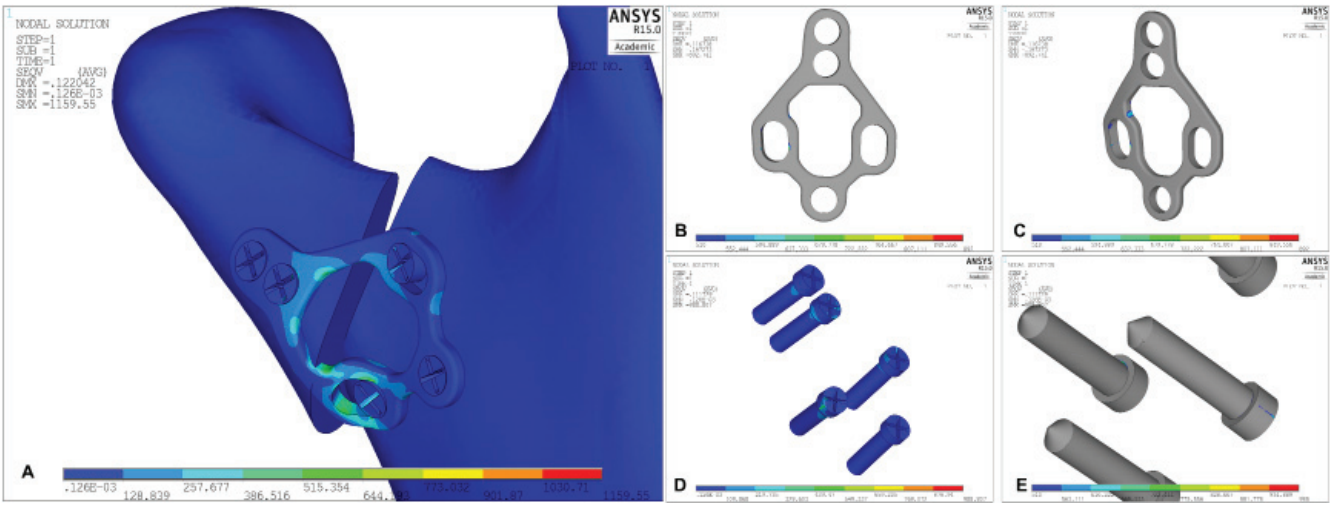

Fig. 4. Rhombus 3D plate finite element analysis with screw position 2, i.e. the mesial screw positioned close to the upper border of the sliding hole and the distal screw positioned close to the lower border of the sliding (oval) hole.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress is σ_{red} = 1160 MPa). Images B, C and E present regions of stress over the fatigue failure stress (fatigue failure stress of titanium alloy grade 5 is 510 MPa, and yield stress is 934 MPa). Four fatigue failure stress risk regions are around hole no. 3 (Table 1) where the fixing screw is located in the lower position (B, C). It is a typical clinical choice for screw location, but the worst one from a biomechanical point of view. Decreased stress in screw head no. 4 due to correction of the position to more upper. The linear area of fatigue failure stress lasts in the head screws no. 3 (D, E).
The change of position of one screw does not improve the stability of bone fragments. It improves mechanical conditions in the anterior part of the plate but deteriorates in the posterior aspect.

the mesial screw positioned close to the upper border of the sliding hole and the distal screw positioned closed to the lower border of the sliding (oval) hole, is presented in Fig. 4. High maximal stress in the plate is the result of the sliding holes, leading to weakness of the plate construction. There are 3 potential places for the plate to crack in the region of the distal sliding hole (hole no. 3, Table 1) and 2 additionally in the upper connecting arm of the plate. The maximal stress was observed in the fixing screw in sliding hole no. 3. Three dangerous crack regions are around both lower holes, together with 2 regions in the upper part of the plate and 1 just below the head of the posterior screw in hole no. 3. The rhombus 3D plate with screw position 3, i.e. both screws in sliding holes positioned close to the upper border of the holes, is presented in Fig. 5. The maximal stress was $\sigma_{max\ red}$ = 544 MPa, and only 1 dangerous region for cracking was located in the anterior upper connecting arm. Maximal stress in the screws was 740 MPa. The modified rhombus 3D plate with screw position 4, i.e. all holes are round (a design

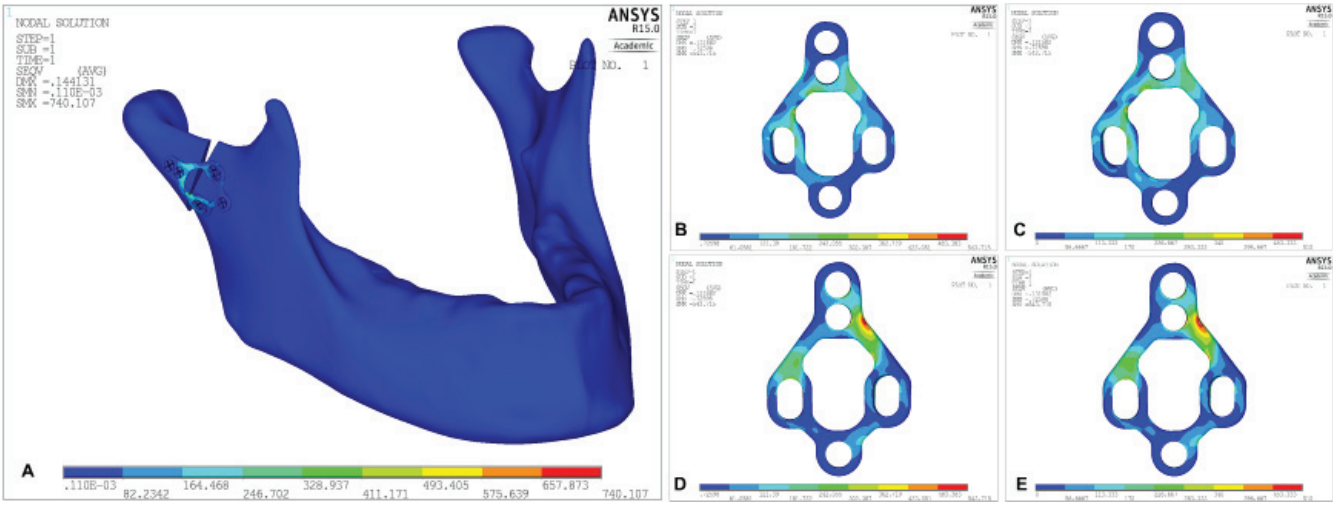

Fig. 5. Rhombus 3D plate finite element analysis with screw position 3, i.e. both screws in sliding holes positioned close to the upper border of the holes.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress is σ_{red} = 544 MPa). B. Outer surface of the plate. C. Outer surface of the plate in scale limited up to fatigue failure stress for titanium alloy grade 5, i.e. 510 MPa. D. Bone-facing surface of the plate. E. Bone-facing surface of the plate in scale limited up to fatigue failure stress. One dangerous region for cracking located in the anterior upper connecting arm.
The proposed new screw positions improve the stability of the bone fragments. The point stresses are at limited range together with the smaller displacement of the bone fragments

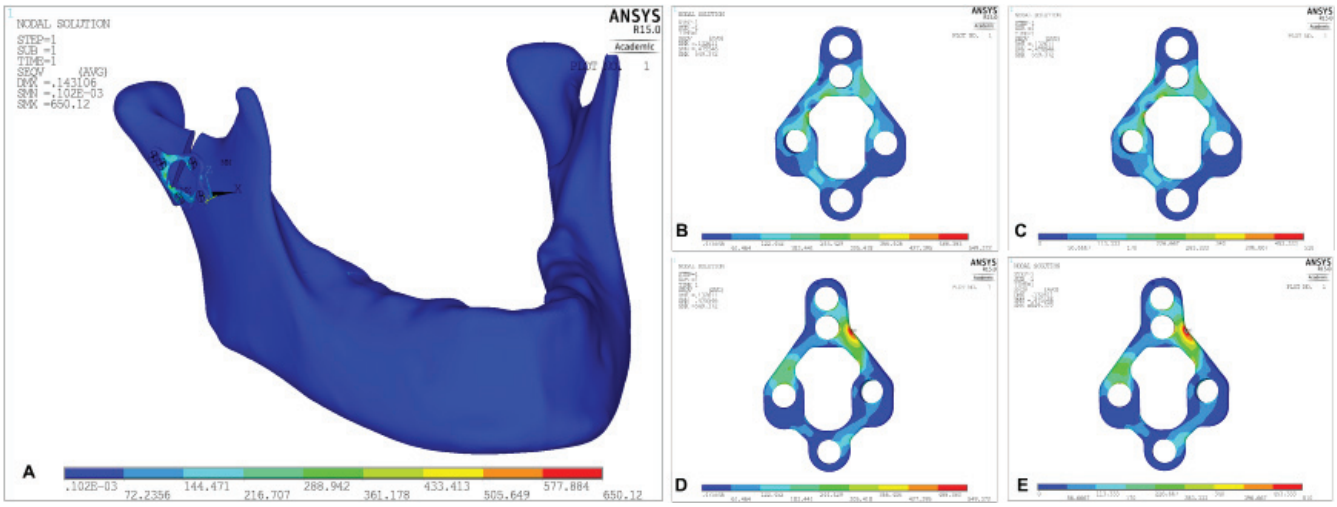

Fig. 6. Modified rhombus 3D plate finite element analysis with screw position 4, i.e. all holes are round.
A. Displacement of the bone fragment after ORIF is overscaled to improve the visualization. The bottom scale shows equivalent stress (maximal stress is σ_{red} = 549 MPa). B. Outer surface of the plate. C. Outer surface of the plate in scale limited up to fatigue failure stress for titanium alloy grade 5, i.e. 510 MPa. D. Bone-facing surface of the plate. E. Bone-facing surface of the plate in scale limited up to fatigue failure stress. There is 1 dangerous potential region (on the bone-facing side of the plate) of initiation of fatigue failure near upper hole no.1 (Table 1).
The general biomechanical conditions are the same as in Figure 5, but the stress in the material of the plate is the lowest in the whole experiment. The maximal stress is as low as at an A-shape condylar plate[8] but the displacement in the fracture line is 3 times smaller in the ACP case.

close to the KLS Martin angle-stable locking plate, art. no. 25-28-05-09), is presented in Fig. 6. Maximal stress was $\sigma_{max\ red}$ = 549 MPa. There is 1 dangerous region (in the bone-facing side of the plate) with the potential for initiation of fatigue failure, near upper hole no. 1 (Table 1). The lowest observed equivalent stress was in the screws (σ_{red} = 650 MPa).

Fatigue failure stress corresponding to the approx. 10^4 cycles of mastication is 510 MPa for every grade 5 titanium plate. Note, however, that during the healing period, which is initiated at the beginning of mandibular fixation, the bone already begins sharing the load carried by the plate. The distribution of stress shown in the figures in real life after 8400 cycles will not be observed practically due to the completed healing of the fracture. But initially post-operationally, fatigue failure is possible after occlusal loading, which leads to local stress of only approx. 500 MPa. This is approx. half as much as typical masticatory forces (for a strut plate positioned upside-down: 915 MPa/510 MPa = 1.8) or even in much weaker mastication (half as much for the rhombus plate fixed typically: 1155 MPa/510 MPa = 2.3).

The mean relative displacement of the fracture fragments along the fracture line was measured in 6 models (Table 2). The best fixing method (i.e. the lowest mean relative movement) was reached by the strut plate placed upside-down (463 ±130 μm, but stress in the plate is significantly high in that position), next by the rhombus plates with holes that were modified to a round shape (position 4: 467 ±172 μm), the rhombus plate with both screws in the oval holes positioned close to the upper border of the holes (position 3: 485 ±192 μm) and the rhombus with a mesial screw (screw 4 in Table 1) positioned close to the upper border of the oval hole and the distal screw (screw 3 in Table 1) positioned close to the lower border of the oval hole (position 2: 624 ±273 μm). And nearly the same in the rhombus plate screws in position 1 (acc. to manufacturer instructions), i.e. 625 ±222 μm. No statistical significance between all the above was observed. The strut plate fixed in the normal position revealed the worst

Table 2. Stabilization of rigid fixation. Measurements of the condylar fracture fissure after loading (relative displacement)

Location of measurement	Relative displacement					
	strut plate		rhombus 3D plate			
	normal position	inverted position	screw position 1	screw position 2	screw position 3	screw position 4
Anterior	570 μm	540 μm	400 μm	270 μm	360 μm	360 μm
Lateral	1420 μm	540 μm	560 μm	550 μm	330 μm	330 μm
Posterior	1130 μm	570 μm	1020 μm	1100 μm	850 μm	790 μm
Medial	870 μm	350 μm	630 μm	650 μm	500 μm	490 μm

Explanation of tested variants: strut plate in normal position, i.e. recommended by DePuy Synthes; strut plate in inverted position, i.e. upside-down; rhombus plate with screw position 1, i.e. according to KLS Martin recommendation: 2 screws positioned close to the lower border sliding middle holes; rhombus plate with screw position 2, i.e. mesial screw positioned close to the upper border of the sliding hole no. 3 (see Table 1) and distal screw positioned close to the lower border of sliding hole no. 4 (see Table 1); rhombus plate with screw position 3, i.e. both screws in sliding holes positioned close to the upper border of the holes; modified rhombus plate with screw position 4, i.e. where all holes are round.

statistically confirmed result: 958 ±312 μm of movement in the fracture line ($F = 6.33$, $p < 0.001$). It was the only statistically significant result.

Discussion

Maximillian Titus Huber published a crucial paper addressing the failure of brittle materials in 1904, and stated the criterion of distortional energy in tension as being important.[17] He proved that compression of brittle materials did not generally cause failure. Later, Richard von Misses in 1913 and Heinrich Hencky in 1925 published their papers concerning the same topic.[18,19] Nowadays, the open reduction and rigid fixation (ORIF) in a plate numerical evaluation is possible thanks to them. Although few studies have used the finite element method,[20–23] the results of in vitro studies are similar in some ways to those found in computational studies, regarding the use of 2 stable titanium miniplates in such fractures. In addition, future clinical trials, applying the methodology with finite elements or not, are postulated to better indicate the most appropriate techniques for osteosynthesis in cases of mandibular condyle fractures.[24]

Moreover, the intense discussion of the best surgical management of condylar is still ongoing, including assortment of the fixing material. Application of positioning lag screws,[25] which is the predicted method of treatment in high condylar fractures, can have a better prognosis than using a titanium plate and obviously much better than the removal of the condylar fragment.[26] The technique of the application of 2 strait plates is debatable.[27] Microplates limit dissection, providing excellent fixation for intracapsular condylar head fractures, provide adequate rigidity for the fixation of condylar neck fractures, yielding excellent functional and radiographic results. Additionally, the rate of complications after microplate fixation is equal to those in the miniplate.[28] Next, smaller plates can be successfully used with the endoscopic intraoral approach and are suitable for fractures of the lower neck and subcondylar.[29]

ORIF by both investigated plates, and in all plate and screwing positions, achieved higher mean relative movements in the fracture line (4–15 times worse) than the 2 plain plate fixations,[27] the Medartis 9-hole delta or A-shape plate.[8] It derives from the weak construction and small dimensions that is the endoscopic dedication compromise. Surprisingly, the fracture fissure has relatively low movement (approx. 0.5 mm extension when bit; due to the 3 screws used in the proximal fragment) as fixation is done by strut plates screwed upside-down, contrary to the high maximal stress in the plate ($\sigma_{red} = 915$ MPa). It looks as if the slight movement is paid for with high stress in the structure of the endoscopic plate. And the maximal equivalent stress of 915 MPa leads the surgeon to the border of risk (fatigue failure after occlusal loading in the post-operational period). Any adjustments of these 2 plates by bending, flattening or cutting are unsafe in light of the calculations shown here. A reasonable compromise is the rhombus plate with only round holes (cat. no. 25-283-05-09). Its design, despite the small dimensions of the plate, is biomechanically suitable.

With biomechanical considerations, where the stress in real structure connectors, for example fracture line fixation, exceed yield stress, the nonlinear material model should be used. The mechanical properties defined only by Young's modulus and Poission ratio are inadequate in such kind of calculations. The plastic material model is required. The yield point is well known in mechanical problems. This means that the mechanical properties of the material are defined to the yield point only by Young's modulus for an isotropic structure, and by the plastic modulus beyond that point until the ultimate tensile or compression stress. It was found here that the elastic behaviors of 2 variants of rhombus plate fixation transverse to a rather plastic state due to exceeding the yield strength in local points and even ultimate tensile stress significantly (in linear modeling). It is obviously a local problem in the plate, but local foci of plastification risk may initiate gradual plate deformation and displacement of bone fragments during healing.

Undoubtedly, the advantage of both investigated plates is the possibility of endoscopic application, which would be difficult in bigger plates like the lambda, inverted Y or A-shape. In the case of small "endoscopic" plates (triangle, rhombus), inverted fixation (upside-down) is possible. And sometimes the inverted location is tempting, as 2 horizontal screws would be located in the condylar head and 2 vertical screws in the condylar neck. Validation of the inverted fixation of these plates brings this analysis. In the case of strut plates, it is clearly prohibited due to high stress generation. On another hand, in the case of rhombus one with 2 oval holes, a series of screw positions are possible. Surprisingly, the typically-used lower position of adaptation screws in clinical application leads to risky displacement and increased stress in the plate. The safest fixation in the rhombus plate is reached as one uses a plate with only round holes. The rhombus plate with oval sliding holes should be avoided in clinical applications. Based on the finite element analysis, the manufacturer chronological standard sequence for screw fixing should be changed from 1-2-3-4-5 (Table 1) to 1-2-5(with traction and screwing eccentrically for sliding)-3(in the upper part of the holes, passively)-4(in the upper part of the holes, passively). Then the biomechanical effect will be much better.

The plates tested are dedicated to lower (or intermediate) condylar fractures (contrary to manufacturer information). They cannot be used for high neck fractures. So, it is difficult to refer the FEM results obtained to the plates dedicated for fixation of high condylar fractures.[8] It seems that a high fracture fixation is a more mechanically challenging objective.[30]

Conclusions

It should be noted, comparing both plates, that the rhombus 3D plate equipped only with round holes presented its superiority within this comparison. It is mechanically relatively resistant and relatively durable in spite of the design being only partially according to compression and traction force propagation in the mandibular condyle. Application of these endoscopic plates is sensitive to the position of screws and requires intermaxillary fixation or an extremely cooperative patient due to the fragility of the fixing material.

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Fluoride release from fluoride varnish under in vitro and in vivo conditions

Uwalnianie fluorków z lakierów fluorowych w warunkach *in vitro* i *in vivo*

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Background. Fluoride varnishes are commonly used in the prevention of caries.

Objectives. To compare the newly introduced plates for mandibular condyle neck fracture treatment.

Material and methods. The measured amounts of Colgate® Duraphat® 50 mg/mL Varnish Dental Suspension containing sodium fluoride 5% (22.600 ppm F) were applied on the teeth of 10 subjects and onto 30 specimens prepared from extracted human teeth. Levels of fluoride release in vivo study were assessed in unstimulated saliva at the baseline and after 1, 2 and 168 h from the application, and in vitro study after 1, 2, 24, 48 and 168 h from the baseline with the use of ion specific electrode. The specimens were immersed into artificial saliva with pH adjusted to 4, 5 and 7, 10 specimens per each medium, and stored in room temperature.

Results. Under in vivo conditions, after 1 h following the application, the fluoride level increased 16-fold. After 2 h it slightly dropped to 15-fold higher, and after 168 h to 5-fold higher from the baseline (0.55 ±0.49 ppm). Under in vitro conditions, the cumulative fluoride release within 168 h was the highest to the medium with pH 4 (9.95 ppm), slight lower with pH 5 (9.39 ppm) and substantially lower with pH 7 (5.72 ppm). Regression analysis showed that fluoride release into artificial saliva was associated with time and pH; however, the acidity of the medium showed the higher impact than the time of release.

Conclusions. The varnish released the maximum amount of fluoride to saliva within the first hours after application and the levels decreased at each period thereafter. Under in vivo conditions, a single application of the varnish maintained the salivary fluoride levels above the baseline up to 168 h, whereas under in vitro conditions the release of fluoride from the varnish was related to the acidity of the immersion medium.

Key words: fluoride release, fluoride varnish

Słowa kluczowe: uwalnianie fluorków, lakiery fluorowe

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Currently, more than 30 fluoride varnishes are available on the market, varying in composition and delivery system and in the content of fluoride, which is either 2.26%, 0.77% or 0.1%.[1,2] Some of them, apart from 5% sodium fluoride, can contain additional potentially active chemical compounds (e.g. casein phosphopeptide-amorphous calcium phosphate – ACP-CPP, calcium sodium phosphosilicate – CSPS, tricalcium phosphate – TCP).

Fluoride varnish is a convenient form for topical fluoride application providing prolonged contact of fluoride with the dental surface. The first varnish, marketed in the 1960s, was Duraphat® containing 5% sodium fluoride (2.25%, i.e. 22,600 ppm F) in ethanol-resin (colophonium) system and its yellowish color facilitates the control of application. The second fluoride varnish, introduced in the 1970s, was silane fluoride varnish Fluor Protector® containing 1000 ppm F.[3] Duraphat has been the most commonly used fluoride varnish and has been subjected to many in vivo and in vitro studies.[3–9] It is indicated for both caries control and dentin hypersensitivity.[5,10]

The Cochrane reviews on the use of fluoride therapies in caries prevention concluded that fluoride varnishes applied 2–4 times a year substantially reduces carious lesions in children by 37% in primary dentition and by 43% in permanent dentition.[5] The expert panel of the American Dental Association (ADA), based on a meta-analysis of numerous studies, confirmed with moderate certainty the benefit of 2.26% fluoride varnish applied at least twice per year for caries prevention in the primary teeth among children aged 6 months to 8 years and for caries prevention in permanent teeth among children aged 5 to 15 years, but with low certainty for root caries prevention in adults.[1,11]

The aim of the study was to assess fluoride release under in vivo and in vitro conditions after a single application of Colgate Duraphat Varnish 50 mg/mL Dental Suspension.

Material and methods

Fluoride varnish Colgate Duraphat Varnish 50 mg/mL Dental Suspension containing 1 mL 50 mg of sodium fluoride equivalent to 22.6 mg of fluoride was used to assess fluoride release under in vivo and in vitro conditions. The other ingredients of this product are ethanol 96%, white wax, shellac, colophony, mastic, saccharin, and raspberry essence.[12] Ten young adult volunteers were involved in the in vivo study. They fulfilled the following criteria: age over 18, at least 24 natural teeth, no unfilled carious decays, no prosthetic appliances, orthodontic appliances, gingivitis or periodontitis and mucositis as well as no asthma or allergies, and no reported professionally applied fluoride specimens in the period of the last 6 months. Fluoride varnish was applied on dried labial/buccal and occlusal dental surfaces. The subjects were asked to refrain from food and beverages consumption for at least 1 h after the procedure. Before and after application of the measured amount of fluoride varnish, samples of unstimulated mixed saliva were collected from the subjects at time point 0 (the baseline), and 1, 2 and 168 h later. In centrifuged salivary samples, fluoride levels (expressed in ppm) were assessed with the use of ionic selective electrode (Orion® 9609). Material for the in vitro study comprised 15 extracted human third molars, obtained with the patient's permission, with sound enamel, free of carious lesions, demineralization and enamel defects, which were stored in thymolized saline until use. Two 5 × 5 mm sections were cut from each tooth. There were 3 groups with 10 specimens; each consisted of 5 buccal and 5 lingual enamel surfaces. Samples were rinsed and cleaned to remove debris, and then dried. Red nail lacquer was applied to all dentine surfaces leaving the enamel surface exposed. The amount of fluoride varnish painted on each specimen was measured by weighing the specimen with the use of an analytical balance before and after the application of, on the average, 0.01 (0.003) mL, i.e. 0.226 mg of fluoride. The painted specimens were immersed into 5 mL of artificial saliva with pH adjusted to pH 4, 5 and 7, with 10 specimens per each medium at a different pH, and stored in room temperature with agitation. Artificial saliva consisted of NaCl (0.4 g), KCl (4.0 g), urea (1 g), $Na_2S{\cdot}9H_2O$ (0.005 g), $NaH_2PO_4{\cdot}2H_2O$ and $CaCl_2{\cdot}2H_2O$, and 1 M NaOH or 1 M HCl to adjust pH to 4.0, 5.0 or 7.0. At the determined testing intervals (i.e. after 1, 2, 24, 48 and 168 h from the baseline), the specimens were transferred to 5 mL of fresh artificial saliva in new vials. The fluoride levels in the left media were assessed with the use of an ionic selective electrode. The cumulative release of fluoride ions and their emission between the measurements at each of the time points was expressed as ppm.

The study protocol was approved by the Bioethics Committee of the Wroclaw Medical University (KB 45/2016).

Statistical analysis

The obtained data was analyzed for normality and equality of variance, and the means were compared using a one-way ANOVA with Tukey's post hoc test using Statistica 12.0 software. The null hypothesis, verified by multiple regression analysis, posited that there would be significant differences in fluoride ions release associated with the time from application, amount of varnish used, salivary fluoride level at baseline, and pH of artificial saliva. For all statistical tests, the significance level was set at $p < 0.05$.

Results

In vivo study

In the clinical study, the mean amount of the applied varnish was 0.17 (0.05) mL, i.e. 3.86 (1.06) mg of fluoride. Salivary fluoride level at the baseline was 0.11 (0.04) ppm,

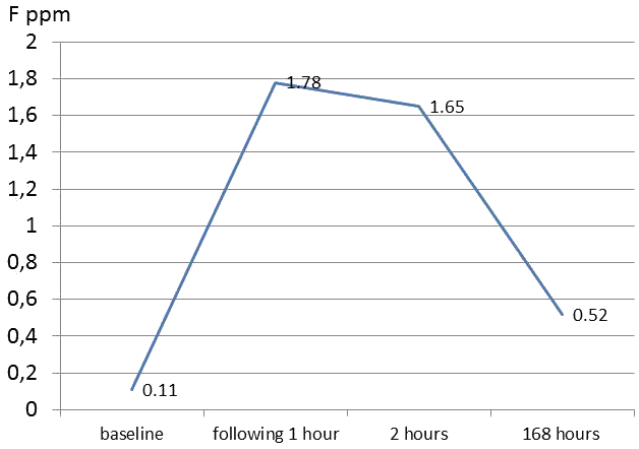

Fig. 1. Fluoride concentration in saliva before and after the varnish application (in vivo study)

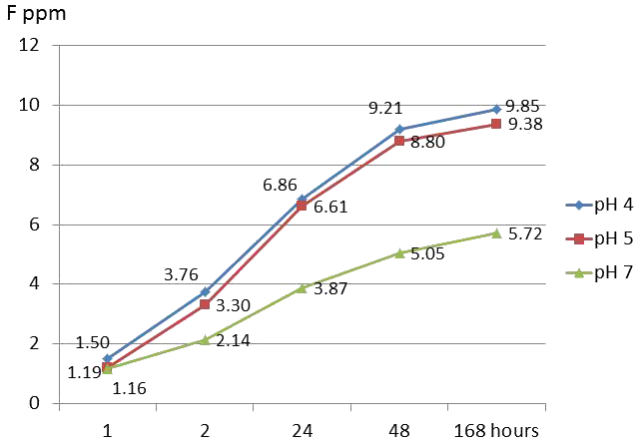

Fig. 2. Cumulative fluoride release (in vitro study)

ranging from 0.06 to 0.18 ppm. After 1 h following the fluoride varnish treatment, the concentration increased ca. 16-fold, and was 1.78 (0.63) ppm. After the next hour (2 h following the application), it dropped slightly to 15-fold higher (1.65 (1.01) ppm) and after 168 h from the baseline to 5-fold higher (0.55 (0.49) ppm) (Fig. 1).

Data of the regression analysis (Table 1) showed that none of the calculated regression coefficients for the analyzed variables was statistically significant ($p > 0.05$); therefore, it was not possible to construct a prediction model of fluoride release to saliva. Admittedly, the rate of reduction of salivary fluoride release following the use of varnish was rather high. The regression coefficient b was 0.0039 ppm per hour, but it was not statistically significant ($p = 0.063 > 0.05$).

In vitro study

In the in vitro study, the mean amount of applied varnish was 0.010 (0.003) mL, i.e. 0.226 (0.067) mg of fluoride, and did not differ significantly between groups.

Cumulative fluoride release showed that the lowest ions emission was to the artificial saliva with pH 7 and only slightly lower at pH 5 compared to the medium with pH 4 (Fig. 2).

Fluoride release between the measurement time points is seen in Table 2. Greater ion emission was observed between 1 and 2 h than within 1 h from the time the samples were placed into artificial saliva with pH 4 and 5, contrary to the medium with pH 7, where the utmost increase was noticed after 1 h.

Data of regression analysis showed that the reduction of fluoride release to the artificial saliva was associated with time and pH. The acidity of the medium presented the higher impact than the time of release (Table 3).

Discussion

The integrity of the tooth hard tissues is associated with the saturation of the surrounding oral fluids with calcium and phosphate ions in relation to the dental

Table 1. Results of multiple regression analysis for in vivo study

Effect	F (ppm)		
	b	SE_b	p-value
Free term	0.055	0.889	0.951
F0 (ppm)	4.974	3.977	0.219
Fa (ppm)	0.143	0.155	0.362
t (hour)	–0.004	0.002	0.063

Table 3. Results of multiple regression analysis for in vitro study

Effect	F (ppm)		
	b	SE_b	p-value
Free term	3.542	0.318	< 0.001
pH	–0.288	0.057	< 0.001
t (hours)	–0.007	0.001	< 0.001

$F = 3.54 - 0.0071 \times t - 0.288 \times pH$.

Table 2. Mean values of fluoride release (ppm) in vitro for the time periods between

Time point	1 hour	1 and 2 h	2 and 24 h	24 and 48 h	48 and 168 h
Artificial saliva	x (SD)	x (SD)	x (SD)	x (SD)	x (SD)
pH 4	1.49 (0.35)	2.26 (0.95)	3.10 (0.33)	2.35 (0.37)	0.63 (0.16)
pH 5	1.19 (0.30)	2.11 (0.61)	3.31 (1.03)	2.19 (1.04)	0.58 (0.17)
pH 7	1.16 (0.52)	0.98 (0.78)	1.73 (1.06)	1.18 (0.30)	0.67 (0.17)

mineral. The chemical equilibrium from a saturated state with respect to hydroxyapatite to an unsaturated state is changed due to the formation of acids in the course of metabolism of dietary fermentable carbohydrates by dental biofilm bacteria. If the local pH at the tooth-biofilm interface drops lower than the critical pH 5.5, the solution is undersaturated and the mineral will tend to dissolve until the solution becomes saturated, i.e. a new saturation state is re-establish (demineralization). Conversely, if the pH of the solution is above the critical pH, then the solution is supersaturated with respect to the mineral, and more mineral will tend to precipitate out (remineralization). The presence of fluoride ions inhibits demineralization at the crystal hydroxyapatite surfaces during acid challenge and enhances the remineralization processes forming a layer of fluorapatite-like material on the crystal surfaces.[13,14] The ability of fluoride to modify the demineralization-remineralization processes depends on the fluoride ions delivery from the used product and their presence in the oral environment at the proper time and concentration.[15] In vitro studies suggest that even low salivary fluoride levels can reduce demineralization and enhance remineralization.[16] After fluoride varnish application, salivary fluoride levels represent the fluoride available for caries prevention. Based on in vitro studies, fluoride levels exceeding 0.03 ppm in the surrounding solutions of the dental hard tissues result in caries prevention.[17–19]

The main cariostatic mechanism of fluoride varnish is the formation of calcium fluoride-like globules as well as fluoride uptake into the enamel with fluorapatite formation. The deposited globules act as a fluoride reservoir releasing over time calcium and fluoride ions during acids attack, and providing durable cariostatic effect.[13,14] Fluoride varnishes could also have some antibacterial influence; however, the obtained data is inconsistent. Some studies have not reported any effect on the levels of *Streptococcus mutans* in saliva or dental plaque,[20] but others presented some inhibitory impact under in vivo and in vitro conditions.[21,22] Studies carried out under in vitro conditions presented rapid fluoride release to the medium from fluoride varnishes within the first hours and slower release thereafter, lasting up to 6 months.[3,6–8] Our data confirmed the highest fluoride release to artificial saliva during the first 2 h independently on the medium pH. However, different brand varnishes despite the same concentration of fluoride (2.26% as sodium fluoride) can release differing amounts of fluoride ions. Shen and Autio-Gold noticed a lower percentage of fluoride release to artificial saliva from Duraphat in comparison to Duraflor® and CavityShield® varnishes but similar slowdown ions emission within 7 to 213 h.[6] Milburn et al. examining fluoride release into artificial saliva from Duraphat varnish found that the mean cumulative fluoride release was 1.028 ±0.174 ppm, the rate of fluoride depletion over the first 4 h 0.126 ppm, and no detectable fluoride ions emission at three weeks.[8] In contrast to the data, our results displayed higher cumulative fluoride release within the first 2 h. Castillo and Milgrom,[7] and Jablonowski and Bartoloni[3] noticed sustained and gradual fluoride release from Duraphat varnish. Lippert observed that fluoride release from some fluoride varnishes varied considerably, and it was dependent on the pH of the dissolution medium.[23] Fluoride varnishes CavityShield, Nupro®, ProFluorid® and Vanish® showed higher fluoride release to saliva than during the first 5 min of acid exposure, whereas other varnishes (Acclean®, Enamel-Pro®, MI Varnish, Vella®) revealed the opposite behavior. Our data also showed that the acidity of artificial saliva was associated with levels of fluoride release. Regression analysis displayed that the acidity of the medium had a greater impact than the immersion time of fluoride varnish in the medium.

However, the fluoride levels measured in the in vitro models have no exact clinical implication. In a clinical setting, a reduction of fluoride levels would be more rapid due to the effects of saliva on fluoride retention, along with the effects of such oral functions as including chewing, swallowing, dietary acidic challenges, teeth brushing, flossing and tongue movement. Additionally, saliva is constantly changing in terms of temperature and pH due to food consumption. Therefore, due to numerous variables there is not possibility to predict a pattern of fluoride release and retention in saliva on an individual level as we have shown in our study. Hence, fluoride release into artificial saliva is no measure for the efficacy of a fluoride varnish. Twetman et al. assessed fluoride concentration in whole saliva after a single application of 3 different varnishes with various fluoride concentration 6% (Bifluorid® 12), 2.26% (Duraphat) and 0.1% (Fluor-Protector).[9] They found a significant elevation of fluoride in saliva 1 h after application of Bifluorid 12 and Duraphat, which lasted 6 h. Our data displayed a substantial increase of salivary fluoride within the first 2 h after the varnish application, which decreased with the time; however, after 168 h it was still higher compared to the baseline. Therefore, at least within 7 days (168 h) a single application of the fluoride varnish increases the fluoride in saliva on the cariostatic level (i.e. over 0.03 ppm).

Conclusions

Under in vitro conditions, fluoride release from Colgate Duraphat Varnish 50 mg/mL Dental Suspension was dependent on the acidity of the immersion medium. Under in vivo conditions, fluoride release from the varnish was maintained above the baseline the salivary fluoride levels up to 168 h (i.e. 7 days). The varnish released the maximum amount of fluoride into the saliva in the first hours after application, and the levels decreased at each period thereafter.

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Effects of 980 nm diode laser application protocols on the reduction of *Enterococcus faecalis* intracanal biofilm: An in vitro study

Efekty zastosowania promieniowania laserowego o długości fali 980 nm na redukcję wewnątrzkanałowego biofilmu bakteryjnego *Enterococcus faecalis* – badania *in vitro*

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D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Background. *Enterococcus faecalis* is associated with a great number of refractory endodontic infections. There is a need to investigate antibacterial properties of laser radiation and create a new alternative technique for root canal disinfection.

Objectives. The purpose of the study was to investigate the effectiveness of a single and repeated high-power diode laser irradiation protocol on the elimination of a 1-week-old *Enterococcus faecalis* intracanal biofilm.

Material and methods. A total of 46 single-rooted human teeth were subjected to the in vitro observation. They were chemomechanically prepared, sterilized, infected with a clinically isolated strain of *Enterococcus faecalis* and subjected to 1-week incubation under microaerobic conditions. The experimental procedures included: a single cycle of 980 nm laser diode irradiation, second application of the same laser protocol, 5.25% NaOCl irrigation, and 2 control groups. Quantitative evaluation of bacterial colonies in the root canals was performed based on the CFU/mL method, after different sterilization methods had been applied.

Results. A statistically significant reduction in the number of intracanal *Enterococcus faecalis* colonies, after a single and repeated 980 nm diode laser application, was confirmed. The first cycle of laser irradiation eliminated 52.5% of *E. faecalis* colonies, whereas the second application increased disinfection effectiveness to 87.6%.

Conclusions. The 980 nm diode laser demonstrated statistically significant antibacterial activity. High-power diode laser treatment might be considered as an adjunctive to conventional chemomechanical endodontic treatment.

Key words: *Enterococcus faecalis*, diode laser, 980 nm, endodontic disinfection

Słowa kluczowe: *Enterococcus faecalis*, laser diodowy, 980 nm, dezynfekcja endodontyczna

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Enterococcus faecalis is associated with a great number of refractory endodontic infections.[1] It has developed elaborated mechanisms of antibiotic resistance, as well as the ability to organize in biofilm and overcome low-nutrient conditions. These adaptations cause the modulation of a host's immune response and make *E. faecalis* very difficult to eradicate by available medications and disinfectants applied as part of endodontic therapy.[2] To eliminate bacteria not affected by the traditional chemomechanical debridement, new antibacterial strategies should be investigated.

Diode lasers are electrically pumped semiconductor lasers. They are manufactured with many designated applications that also include medicine and dentistry. In contrast to the other laser systems they are characterized by relatively low purchase and maintenance costs, great versatility and compact size. Diode lasers equipped with small irradiation tips, open up new fields of application in endodontics. Thin flexible fibers easily reach even the curved shaped root canals. Diode laser wavelengths have good penetration potential, high absorption peaks in melanin and hemoglobin, and low interaction with water and hydroxyapatite,[3,4] which result in photothermal interaction with root canal dentine. These properties seem to be adequate for the purpose of root canal disinfection. The photothermal effect of high-power laser radiation strictly depends on the power density, irradiation frequency, wavelength, duration of a cycle and dentine thickness.[5] Proper selection of the laser parameters yields a therapeutic effect, but also helps to avoid injury to the periodontal ligament cells and alveolar bone. The photothermal effect, that leads to a temperature increase of 10°C for longer than 1 minute, can cause irreversible changes to the root dentine and the surrounding tissues.[6]

The aim of the study was to assess the effectiveness of a single and repeated high-power diode laser application in the elimination of intracanal *Enterococcus faecalis* biofilm. To date, the potential of 980 nm diode laser in root canal disinfection has seldom been addressed and the most efficient protocol of irradiation has not been determined. Tissue safe application parameters have been chosen for the purpose of the study. To avoid morphological alterations of the dentine and thermal damage of the surrounding tissues, the fiber was moved constantly in a circular motion during activation in the root canals. Microbiological assessment was performed after a single and repeated cycle of laser irradiation. A clinically isolated strain of *E. faecalis* was used for the purpose of the study.

Material and methods

Isolation of *Enterococcus faecalis* clinical strain

A patient, age 31 was admitted to the Department of Conservative Dentistry, Medical University of Warsaw. A panoramic radiograph was taken to establish the further treatment plan. The lower left first molar was diagnosed with chronic periapical inflammation, based on the presence of an osteolytic lesion surrounding the root apex. An endodontic filling material was visible in the coronal part of the roots and the tooth was asymptomatic. The patient agreed to the proposed revision of endodontic treatment and a microbiological analysis of the intracanal pathogenic microflora.

Tooth 36 was isolated with a rubber dam and an access cavity was performed. The root canals were initially chemomechanically prepared with the use of hand K files (VDW) to ISO #25. Sterile 0.9% NaCl was the only irrigant used. After the preliminary removal of residual remnants of filling material, the roots were filled with sterile 0.9% NaCl, and ISO #25 K file was introduced to perform scrubbing motions and to collect dentine shavings. Subsequently, ISO #25 paper points were placed into the canals for 60 s to adsorb material for microbiological analysis. Revision of root canal treatment was continued according to the accepted standards of endodontic therapy with the use of complete irrigation protocol.

Paper points were transferred to tubes containing 3 mL of brain heart infusion broth (BHI) and were subjected to 24 h of incubation at 37°C. The serial dilutions were performed and aliquots of 100 µL were inoculated on plates with BHI (Oxoid) agar and on Slanetz and Bartley LAB-AGAR (Biocorp) plates (selective-differential medium for quantitative determination of *Enterococci*, on which *E. faecalis* forms from dark pink to dark brown colonies).

Strain identification

With the use of a commercial kit (A&A Biotechnology, Poland), chromosomal DNA was isolated. According to standard protocol, polymerase chain reactions (PCRs) were performed with PrimeStar HS DNA Polymerase (TaKaRa). The universal primers F27 (5'-AGAGTTTGATCMTGGCTCAG-3') and R1492 (5'-TACGGYTACCTTGTTACGACTT-3'),[7] which target universally conserved regions and permit the amplification of an approximately 1,500-bp fragment, were used to obtain 16S rRNA gene in the course of PCR. Oligonucleotide synthesis and DNA sequencing were performed by Genomed SA, Warsaw, Poland. The nucleotide sequences were analyzed using BLAST and compared to the nucleotide database on the NCBI website. The highest identity, 99%, was related to the nucleotide sequence of the 16S rDNA gene of *E. faecalis* JF85 (GeneBank KT343158.1). The taxonomic position of the isolated clinical strain was identified as *E. faecalis*.

Specimens' preparation

A total of 46 single-rooted human teeth were extracted based on the periodontal of orthodontic referral. All of the teeth were collected after the adult patients gave

consent. The experiment included only mature, intact teeth with a single canal, and no signs of root resorption. The teeth were stored in 0.1% sodium azide solution. All samples were decoronated with a diamond bur (Meisinger 859L.016) to acquire 15 mm long roots and the working length was established at 1 mm. Initial chemomechanical preparation was performed with the use of hand K files to ISO #25 with 5.25% NaOCl as irrigation solution. Further canal enlargement was performed to an apical size 40 (R40) using Reciproc rotary instruments (VDW, Munich, Germany). Irrigation protocol included 5.25% NaOCl and 17% EDTA for final smear layer removal. The root apex of each sample was sealed with glassionomer cement, and the outer surface was covered with 2 layers of nail varnish to prevent reverse contamination of the dentinal tubules. All specimens prepared according the described protocol were autoclaved at 121°C for 15 min. A group of 10 roots was subsequently used to evaluate the effectiveness of the sterilization process. They were subjected to irrigation with sterile 0.9% NaCl. The liquid was plated on blood agar and after 24 h of incubation no bacterial growth was observed.

Root canals contamination

The clinically isolated strain of *Enterococcus faecalis* was cultured overnight in Tryptic Soy Broth at 37°C, under microaerobic conditions (5% O_2, 10% CO_2, 85% N_2). Subsequently, dilutions of OD_{600} 0.7–0.8 were prepared and plated on BHI agar. This allowed us to determine the number of bacterial colonies to be 1–3 × 10^8 CFU/mL. Each sterile experimental unit was placed in a screw-cap plastic vial with 1 mL of TSB and 1 mL of bacterial suspension. To obtain biofilm formation on the walls of root canals, specimens were incubated for 7 days (37°C, microaerobic conditions).[8] Every 48 h TSB medium was replaced. Kishen et al. investigated the process of *E. faecails* biofilm formation on the internal surface of a root canal dentine.[8] They have confirmed that after 1 week of incubation, bacterial cells aggregate on the dentine surface, forming a characteristic interconnecting network of polymer strands. In this stage of biofilm development, signs of dentine structure dissolution were also detected.

Experimental protocol

The study included 5 groups (Table 1). The specimens from group 0 (n = 10) were used for the assessment of the sterilization process, and were excluded from the experiment. The positive control group (control) was irrigated with sterile 0.9% NaCl to determine the number of *E. faecalis* colonies before the application of any disinfecting methods. The CFU/mL microbiological method was used for the quantitative assessment of the bacterial growth.

Table 1. Experimental groups

Group	Number of specimens	Experimental procedure
0	10	negative control group-evaluation of sterilization process
Control	12	positive control group-irrigation with 0.9% NaCl
1 × 980 nm	12	single 980 nm laser radiation protocol – 3 W/100 Hz, 20 s
2 × 980 nm	12	double 980 nm laser radiation protocol – 3 W/100 Hz, 20 s
NaOCl	12	5.25% NaOCl irrigation – 5 min

The second group (1 × 980 nm) was subjected to a single 980 nm laser radiation protocol. The laser source was a semiconductor 980 nm diode laser (Smart M, Lasotronix, Poland). Radiation was delivered to the root canal walls with the use of 200-μm-diameter flexible optical fiber. The working length of the fiber was adjusted to 13 mm with the use of a rubber stopper. The device was activated to deliver a beam with a power of 3 W, and 100 Hz frequency. Helicoidal forward-backward movements of the optical fiber were performed in contact with the root canal dentin. The duration of each laser cycle was 20 s. To eliminate any changes in the laser light distribution from the used optic fiber tip, 1 mm of the fiber was cut off after each application.

In the third group (2 × 980 nm), specimens from the group 1 × 980 nm were used to repeat the same protocol of laser irradiation. There was a 1 minute break between protocols to reduce the temperature of dentin.

The last experimental group (NaOCl) was subjected to the chemical disinfection with the use of 5.25% NaOCl solution. Irrigation was performed with 10 mL of the disinfectant, which was subsequently left in the roots for 5 min. The chemical disinfection was followed by 0.9% NaCl irrigation.

In each of the groups, the number of *E. faecalis* colonies remaining in the root canals after the completion of the experiment was determined based on the CFU/mL method. Canals were filled with a sterile 0.9% NaCl solution. Hand K files size 30 (VDW, Munich, Germany) were placed into each canal for 15 s to perform scrubbing motions. Sterile paper points R40 (VDW, Munich, Germany), used as absorbents of microbiological material, were introduced into canals for 60 s to be finally transferred to Eppendorf type probes with 1 mL of TSB. All probes were kept in a container filled with ice before being transported to the laboratory.

Tubes with paper points were agitated for 60 s to perform 10-fold serial dilutions. Aliquots of 0.1 mL were incubated on TSB agar plates in 37°C. After 72 h of incubation, *E. faecalis* colonies were counted. Based on the known dilutions, the actual number of bacterial colonies was calculated and given as CFU/mL (colony-forming units per milliliter).

Statistical analysis

Experimental data (Table 2) was subjected to statistical analysis with the use of Statistica 12 software and based on Shapiro-Wilk test, Cochrane's C test, the Mann-Whitney U test and Wilcoxon test. A < 0.05 was considered to be statistically significant.

Table 2. The count of *E. faecalis* colony-forming units after experimental procedures

Measurement conditions	M	SD	Min	Max
Control	$1.3 * 10^6$	$1.0 * 10^6$	$1.0 * 10^5$	$3.2 * 10^6$
1 × 980 nm	$0.6 * 10^6$	$1.2 * 10^6$	$0.4 * 10^5$	$4.6 * 10^6$
2 × 980 nm	$1.6 * 10^5$	$1.4 * 10^5$	$1.5 * 10^4$	$4.9 * 10^5$
5% NaOCl	$0.2 * 10^3$	$0.6 * 10^3$	0.0	$2.0 * 10^3$

M – mean value; SD – standard deviation; min – minimum value; max – maximum value; PDT – 1 cycle of photodynamic therapy; 2PDT – 2 cycles of photodynamic therapy.

Results

Based on the Shapiro-Wilk test, the distribution of the parameters between research groups was verified. In unrelated experimental groups with normal distribution, Cochrane's C test was applied. It allowed us to confirm a statistically significant difference between the control and 2 × 980 nm group (p = 0.003; t = 3.8).

To compare the data without normal distribution, a non-parametric Mann-Whitney U test was applied. Statistically significant differences were observed between the control group and 1 × 980 nm group (p = 0.043; Z = –2.0), as well as between control conditions and NaOCl irrigation (p = 0.000; Z = 4.2). Statistically significant differences were also confirmed between 2 laser applications and NaOCl irrigation (p = 0.000; Z = 4.2), as well as between a single laser protocol and chemical disinfection with the use of NaOCl (p = 0.000; Z = 4.2) (Fig. 1).

The observations in 1 × 980 nm and 2 × 980 nm groups were performed on the same specimens. The resulting measurements without normal distribution were subjected to a Wilcoxon test (p < 0.05). A statistically significant difference between the number of bacterial colonies between 1 × 980 nm and 2 × 980 nm (p = 0.012; t = 7.0) was confirmed.

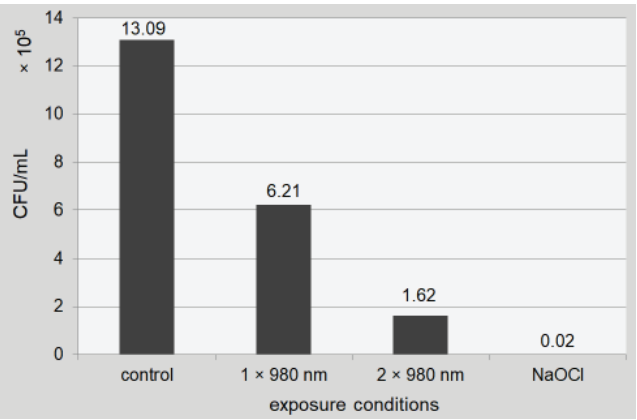

Fig. 1. Mean value of CFU/mL for each of the groups subjected to observations

A single cycle of 980 nm laser application eliminated 52.5% of the *Enterococcus faecalis* colonies from infected root canals (Fig. 2). After a second cycle of laser disinfection, significantly more bacterial colonies were eradicated, and the number of bacteria was reduced to 12.4% of the initial number. Chemical irrigation with 5.25% NaOCl recorded the highest level of disinfection with an efficiency of 99.7%.

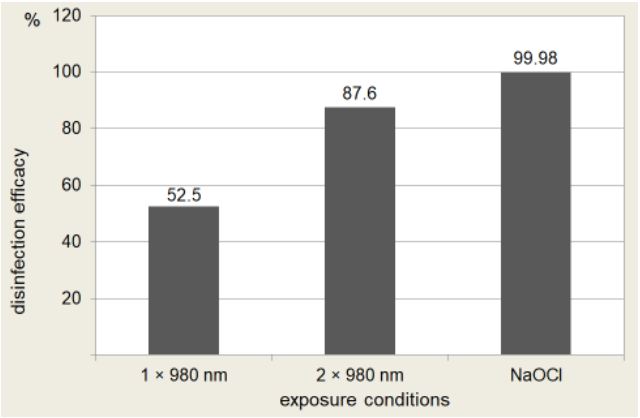

Fig. 2. The efficacy of different antibacterial procedures presented by percentage of eliminated *E. faecalis* colonies

Discussion

Sodium hypochlorite is the most common chemical disinfecting substance used during root canal preparation. Its antimicrobial properties[9] and ability to dissolve organic tissues[10] are crucial for the effectiveness of endodontic therapy. However, improper application may lead to very harmful side effects. Sodium hypochlorite is very cytotoxic when inadvertently injected to periapical tissues,[11] since it promotes dentine deproteination[12] and adversely affects bond strength of adhesive material to dentine tissue.[13] In rare cases of NaOCl allergy,[14,15] the use of this substance is contraindicated.

The described experiment confirmed the high dentine disinfecting potential of 5.25% NaOCl. However, results of in vitro experimental model should be considered as overvalued. When treatment is performed under in vivo conditions, the properties of hypochlorite are weakened by the presence of the organic matter.[16] Pulpal tissue fragments, dentinal collagen, bacterial debris and inflammatory exudates are present within infected root canals. They consume NaOCl and impair its disinfecting action. It was also proved that the penetration depth of the irrigants is limited to a small area close to the surface of the root canal[17] and, a maximum penetration of sodium hypochlorite is 130 μm.[18] To improve the decontamination of root canals, new alternative disinfection techniques need to be tested.

In this experiment the high-power diode laser radiation resulted in a clinically significant reduction of *Enterococcus faecalis* colonies from the infected specimens. Based on other published studies, 980 nm diode laser at the parameters of 3 W/100 Hz, which were applied in the experimental model, not only disinfects but also changes the dentine structure. Modified organic matrix layer with an amorphous form, the melting of the intracanal dentine surface and tubule visibility were observed in Marchesan et al. experiment.[19] Jhingan et al. confirmed diode laser treatment leads to excellent removal of smear layer and dentinal debris from the root canal surfaces.[20] In the same study, the authors attempted to measure the size of dentinal tubules resulting from 5.25% NaOCl irrigation and 980 nm laser radiation. The mean width after chemical disinfection was 2.4701 μm, whereas after laser therapy 0.1975 μm. The authors concluded that 0.1975 μm width of dentinal tubule is difficult for the microorganisms to pass through and in consequence reduces the possibility of reinfection. Changes of the dentine structure can be attributed to the thermal effect caused by laser energy.[21] 980 nm diode laser is located in the near infrared region of electromagnetic spectrum.[22] When laser radiation is applied at this wavelength, some energy is absorbed by dentine mineral content, like phosphate and carbonate. This results in a crystalline arrangement and hard tissues melting.[22] As a consequence, laser parameters of application have to be carefully chosen for the purposes of endodontic disinfection.

The mechanisms regarding the antibacterial properties of a high-power diode laser are based on the thermal and photodisruptive effect of the emitted radiation.[23] 980 nm diode lasers are characterized by high-energy radiation. When the energy is absorbed by the water molecules in the tissues, it is converted to heat. As a consequence, evaporation of water causes cell destruction and death of microorganisms. But there are also other published theories regarding bacterial cell death caused by laser radiation. A possible assumption is that after irradiation temperature rises momentarily to an extremely high level and the intensive heat results in the immediate destruction of the bacteria.[23] Another theory[24] assumes that immediate cell death may not occur during laser irradiation, but sublethal damage. Sublethal damage is explained as a disruption of cell wall integrity and the accumulation of denaturated proteins. Those changes cease the cell growth and result in cell lysis. This last thesis was also described by Moritz et al.[25] They infected dentin slices with *E. faecalis* stain and used high- power laser radiation to eliminate the bacteria. Single cycle of 1.0 W 15 pps and 1.5 W 15 pps did not cause degenerative alterations of the bacterial cells. The repetition of 1.5 W 15 pps laser radiation cycle resulted in substantial morphologic changes, and a significant decrease of colony forming units. The authors concluded that the lethal effect of laser irradiation on *E. faecalis* is based on a cumulative effect. Heat, caused by the laser application, is a stress factor that causes nonlethal reversible damage, which might be transformed into lethal damage after repetition of the stress.[26] This theory explains the results of the conducted experiment and significant differences in the number of bacterial colonies after single and repeated laser irradiation protocols.

The effectiveness of a high-power diode laser in root canal disinfection has seldom been addressed. The parameters of irradiation power, such as frequency and time of a single cycle, have to be chosen carefully, to avoid damaging the root canal dentine, and to remain effective. Kanumuru et al. investigated the bacterial efficiency of $Ca(OH)_2$ against *E. faecalis* compared with 3 dental lasers.[27] 980 nm diode laser proved to be 2 times more effective than the chemical agent with a high pH. However, researchers did not include information about the power and time of irradiation of the laser device. Mithra et al. investigated the bactericidal effect of 980 nm diode laser, 3% NaOCl, 2% CHX, and their combination with laser in *E. faecalis* infected root canals.[28] The power of 2.5 W in continuous mode was applied in 3 cycles of 5 s. Chemical disinfection with 3% NaOCl was the most effective antibacterial protocol. 980 laser radiation was significantly more effective than 2% CHX, and in combination with 2% CHX it was as effective as 3% NaOCl irrigation. An in vitro research conducted by Souza et al. was also focused on the effectiveness of a high-power diode laser in association with chemical auxiliary substances on bacterial decontamination of root canal system.[29] A total power of 3 W was applied in 4 short cycles of 6 s each. Four cycles of laser radiation were able to reduce 65.4% of *E. faecalis* colonies. In combination with 2% CXH, 93.48% of bacteria was eliminated. The best results of disinfection, 99.42%, were observed after combining the action of 980 nm laser radiation and 2.5% NaOCl solution. Grącka-Mańkowska et al. also investigated the bactericidal efficacy of different diode laser operation modes against *Enterococcus faecalis* under in vitro conditions.[30] Bovine teeth were infected with the bacterial strain and a high-power diode laser was applied with the parameters of 1.5 W CV and 3 W impulse irradiation. In both experimental groups, the mean number of bacterial cells was reduced: in 1.5 W group by 97%, and in 3 W by 93%. However, authors did not reveal the time of single 980 nm diode laser irradiation protocol.

All cited experiments and the described in vitro study confirmed the effectiveness of antibacterial properties of the high-power diode laser. However, parameters of application differ between the studies, and it is difficult to establish the most effective and still safe protocol of irradiation. The power of a laser exceeding 3 W in continuous mode may cause irreversible damage to the dentine structure. Marchesan et al. after 20 s of 3 W/CW laser radiation observed sparse lava-like melting and a scaly surface of root canal dentine.[19] Alfredo et al. confirmed that the power of 3 W, in the pulse mode, applied for 20 s is a safe threshold for the 980 nm diode laser application.[31]

It does not cause a dangerous increase of temperature in the targeted tissues. The extended time of 1 irradiation cycle may be damaging for the dentine and surrounding soft tissues because of the heat dispersion. The results of the described experiment have shown that repeating the laser irradiation is an effective modulation of the therapy. To minimize dangerous thermal effects of 980 nm diode laser application, and to increase the effectiveness of the therapy, the cycle should be repeated. Further studies with multiplied number of laser applications could bring new significant data.

Conclusions

In the study, we confirmed a positive impact of the repeated 980 nm laser radiation in the elimination of intracanal *Enterococcus faecalis* biofilm. The disinfecting potential of the applied protocol did not allow for the complete elimination of the pathogenic cells from infected specimens. Irrigation with 5.25% NaOCl was the most effective method of root canal disinfection. However, the high-power diode laser therapy might be considered as an adjunctive application to chemomechanical endodontic treatment.

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Occurrence of selected bacteria in periodontal pockets of various depths in chronic and aggressive periodontitis

Występowanie wybranych periopatogenów w kieszonkach przyzębnych różnej głębokości w przewlekłym i agresywnym zapaleniu przyzębia

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Abstract

Background. Periodontitis has a complex etiology, with bacteria constituting the main etiological factor. It is not a classic infectious disease, because it is not caused by a specific pathogen. Instead, it is caused by a shift in the microbiological composition, so that the microorganisms, which physiologically inhabit the oral cavity, become pathogenic.

Objectives. The aim of this study is to discuss whether the presence of specific bacteria depends on the form of the disease or on the depth of the periodontal pocket.

Material and methods. The study included 60 patients with chronic or aggressive periodontitis. Periodontal parameters were evaluated and the microbiological material from periodontal pockets was collected.

Results. *Porphyromonas gingivalis* occurred more frequently in patients with chronic periodontitis, *Aggregatibacter actinomycetemcomitans* was observed only in patients with aggressive periodontitis. The occurrence of *Treponema denticola* and *Aggregatibacter actinomycetemcomitans* differed depending on the pocket depth.

Conclusions. The bacterial spectrum and count is not directly related to the pocket depth, so it is not only an effect of the disease progression. Although some relations between bacterial species and particular forms of periodontitis have been observed, they cannot constitute the basis of the diagnosis and differentiation between chronic and aggressive periodontitis. Microbiological testing of the subgingival biofilm would gain more value if extended to studies related to antibodies to selected bacteria.

Key words: chronic periodontitis, aggressive periodontitis, *Porphyromonas gingivalis*, *Aggregatibacter actinomycetemcomitans*, pocket depth

Słowa kluczowe: przewlekłe zapalenie przyzębia, agresywne zapalenie przyzębia, *Porphyromonas gingivalis*, *Aggregatibacter actinomycetemcomitans*, głębokość kieszonek

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Periodontitis has a complex etiology, with bacteria constituting the main etiological factor. It is not a classic infectious disease, because it is not caused by a specific pathogen. Instead, it is caused by a shift in the microbiological composition, so that the microorganisms, which physiologically inhabit the oral cavity, become pathogenic. Moreover, bacteria are responsible only for initiating the disease, whereas tissue destruction depends on host defense, further modified by genetic and environmental factors.[1]

The oral cavity is normally colonized by approximately 700 bacterial species.[2,3] Some of them remain in an unbound form, the so-called plankton, others colonize the surfaces of hard and soft tissues forming a biofilm. Despite such a vast diversity of species inhabiting the oral cavity, biofilm colonization by various species is not a random process. The order and degree of colonization demonstrate certain patterns. Socransky et al. isolated 40 bacteria and, on the basis of their metabolic preferences, divided them into 5 complexes conventionally marked with colors: yellow, purple, orange, red and green.[4] These complexes differ mainly in the pathogenicity of constituent bacteria and the order of tissue colonization. The best-described periopathogens include 3 red complex bacteria: *Porphyromonas gingivalis (P. gingivalis), Treponema denticola (T. denticola), Tannerella forsythia (T. forsythia)* and one of the green complex – *Aggregatibacter actinomycetemcomitans (A. actinomycetemcomitans)*.

The periodontal pocket is a reservoir of periopathogens. An increase of its depth leads to the change of the environment from aerobic to anaerobic and a change in metabolism conditions, which leads to a gradual colonization of subgingival biofilm by other bacterial species. According to Socransky, the composition of newly formed biofilm in gingival pockets 2–3 mm deep differs from that of mature biofilm in pockets 5 mm or 10 mm deep.[4] The issue that so far has not been clearly explained and attracts a lot of attention in current studies is the extent to which bacteria, in quantitative and qualitative terms, are responsible for the development of periodontitis. Furthermore, it is necessary to explain to what extent their presence or increased numbers results from the disease itself, i.e. the emergence of deeper periodontal pockets constituting a perfect niche for development. Moreover, there is another valid question of high clinical importance: whether the occurrence or increased numbers of specific bacterial species vary depending on the form of periodontitis. The possibility of differentiating particular forms of periodontitis by specific bacteria identification would be a great facilitation in clinical practice as there are no explicit criteria that determine the diagnosis. Yet, recent studies are inconclusive whether the presence and number of specific bacteria is related straight to each periodontits form or is it just an effect of the emergence of deep periodontal pockets.

The aim of the study was to assess the total number of bacteria as well as the presence and number of various species depending on the periodontal pocket depth and on diagnosis.

Material and methods

The study group consisted of 60 individuals referred to the Department of Periodontology in Warszawa between October 2013 and December 2014. The patients were divided into 2 groups depending on the diagnosis – 30 patients with chronic periodontits (CP) and another 30 patients with aggressive periodontits (generalized AgP). The diagnosis was based on clinical and radiological examination according to AAP classification.[5]

Inclusion criteria for the study were: active, untreated periodontitis and presence of at least one pocket 5 mm deep and one periodontal pocket of 7 mm or deeper. Exclusion criteria for the study were: a coexisting general disease that might affect the course of periodontal disease, chronic intake of drugs that could modify the course of periodontal disease (antibiotics, steroids, anti-inflammatory, immunosuppressive and antiepileptic drugs, calcium channel blockers) within 6 months prior to the study, pregnancy, smoking (both active and past), current orthodontic treatment, scaling within 6 months prior to the study, and topical application of antibacterial or bacteriostatic agents within 6 months preceding the study.

The study group included 26 males and 34 females. Among the patients diagnosed with generalized AgP, 70% were females, while among the subjects with the CP, 43.3% were females. The mean age was 30.7 years, and 56.9 years for patients with generalized AgP and CP, respectively.

The study consisted of a clinical and a laboratory examination. The clinical part included general and dental history, periodontal measurements including hygiene indices – Plaque Index (PI), and API, bleeding index – BOP, pocket depth – PD, clinical attachment level – CAL, and samples of microbiological material from selected periodontal pockets.[6–8] The bacterial DNA testing from the gingival cervical fluid (GCF) using real-time polymerase chain reaction (PCR) was performed. Ready-made PET diagnostic kits by MIP Pharma (PET® Plus Kit, MIP Pharma, Germany) consisted of sterile paper-points, color-marked vials and transport box. According to the manufacturer's recommendations, after isolating the examined pockets from, dental plaque was removed from the gingival margin with a cotton swab, then the area was dried. Sterile tweezers were used to place one paper-point in each of the 2 selected periodontal pockets, one 5 mm deep, the other ≥ 7 mm deep (the deepest one for the patient was chosen). The paper-points were placed full depth in periodontal pockets for 20 s, then removed and immediately packed in individual, labeled vials and later sent to the manufacturer's laboratory.

The laboratory part of the examination aimed at a quantitative and qualitative identification of bacteria in the collected material. Using polymerase chain reaction (Real Time PCR) the total bacteria count in the sample and the numbers of an individual species, selected for purpose of the study (*P. gingivalis, T. denticola* and *A. actinomycetemcomitans)*, were recorded.

The following tests were used for statistical analysis: the Mann-Whitney test for continuous variables, the Spearman rank correlation test and the Wilcoxon test for dependent samples, the χ^2 test for categorical variables. Linear regression was used for multivariable analysis. The threshold of statistical significance was assumed at p = 0.05.

The study received consent of the Bioethic Comission of Medical University of Warsaw.

Results

Results of periodontal examination

Depending on the diagnosis, statistically significant differences concerning patients' gender and age were observed. Seventy percent and 43.3% of the patients were females among with generalized AgP and CP, respectively. The mean age of patients with generalized AgP was significantly lower (30.7 years) compared with patients with CP (56.9 years).

Statistically significant differences in the average PI and API indices were observed between generalized AgP and CP groups. These values were significantly lower among patients with generalized AgP (PI: 86.2%, 61.9% in CP, API: 93.8% in generalized AgP, 74.4% in CP).

Mean values of BOP and PD measurements demonstrated no significant differences between patients with generalized AgP and CP, whereas mean CAL was significantly higher in patients with CP, when compared with generalized AgP (4.7 mm and. 3.4 mm, respectively).

Significant differences were observed between the total number of teeth. In the patients with CP the median was significantly lower (22 teeth) compared to patients with the generalized AgP (29 teeth) (Table 1).

Results of microbiological assessment

No statistically significant differences were noted between the total number of bacteria depending on the PD, both for the entire study group as well as for individual CP and generalized AgP groups. High variability of this parameter was observed in all groups (Table 2).

Table 1. Group characteristics

Parameters	Chronic periodontitis n = 30 mean (±SD)	Aggressive periodontitis n = 30 mean (±SD)	Comparison (Mann-Whitney test)
Age – years	56.9 (±8.9)	30.7 (±5.9)	p < 0.0001
Plaque Index – %	86.2 (±16.4)	61.9 (±24.4)	p = 0.0001
API – %	93.8 (±13.4)	74.4 (±25.3)	p = 0.0014
BOP – %	81.5 (±18.3)	80.4 (±21.5)	p = 0.9463
PD – mm	4.0 (±0.7)	4.1 (±1.1)	p = 0.7282
CAL – mm	4.7 (±1.3)	3.4 (±1.7)	p = 0.0006
Number of teeth	21 (±5.4)	28.5 (±3.2)	p < 0.0001

Table 2. Total numbers of bacteria depending on periodontal pocket depth and diagnosis

Parameters	Bacterial count in patients with CP n × 10^3 (±SD)	Bacterial count in patients with AgP n × 10^3 (±SD)	Comparison according to diagnosis (Mann-Whitney test)
PD = 5 mm	10.4 (±27.3)	9.5 (±16.8)	p = 0.9646
PD ≥ 7 mm	13 (±18.3)	8.1 (±13.6)	p = 0.3951
Comparison depending on pocket depth (Wilcoxon test for dependent samples)	p = 0.0656	p = 0.9344	–

The presence of *Porphyromonas gingivalis* was observed in 44 (73.3%) patients (in 53.3% of patients with generalized AgP and in 93.3% of patients with CP). The differences were statistically significant. In pockets of 5 mm and pockets ≥ 7 mm, the occurrence of *P. gingivalis* was significantly more frequent among patients with CP (80% and 86.7%, 43.3% and 53.3% in generalized AgP). However, there were no significant correlations between the prevalence of *P. gingivalis* and the pocket depth in the entire study group, as well as in the generalized AgP and in CP groups. The presence and number of *P. gingivalis* was significantly higher in patients with CP, both in pockets 5 mm and ≥ 7 mm deep (on average 123.1 and 157.4 × 10^3, 72 and 139.9 × 10^3 in generalized AgP). None of the study groups demonstrated any correlation between the number and the depth of pockets (Table 3).

The presence of *T. denticola* was observed in 54 (90%) of all patients. The occurrence was comparable between CP and generalized AgP patients, whereas there was no correlation with PD. Among patients generalized AgP, the number of *T. denticola* was statistically significantly higher in deep pockets (28.8 × 10^3 and 0.43% vs 32 × 10^3 and 0.58%) (Table 4).

The presence of *A. actinomycetemcomitans* was found only in patients with generalized AgP. The number of *A. actinomycetemcomitans*was statistically significantly higher in pockets 5 mm deep (Table 5).

Discussion

The role of bacteria in the etiology of periodontitis is undeniable. They influence the periodontal tissues directly (by the use of toxins) and indirectly (by the immune system activation). It is proven that some bacteria species occur in higher numbers in patients with periodontits. Recent studies reveal that different types of bacteria may occur in different forms of the disease. It is still not certain whether bacterial spectrum changes due to the pocket depth and has no relation to the form and stage of the disease or if the occurrence and number of particular microorganisms are precisely related with the diagnosis. The link between the type of periodontitis and bacteria species could be an important diagnostic tool.

Table 3. Occurrence and numbers of *Porphyromonas gingivalis* depending on periodontal pocket depth and diagnosis

Occurence/ /Numbers	Parameters	Patients with CP	Patients with AgP	Comparison according to diagnosis (Mann-Whitney test)
Occurence	total; n (%)	28 (93.3%)	16 (53.3%)	p = 0.0013*
	PD = 5 mm; n (%)	24 (80.0%)	13 (43.3%)	p = 0.0079*
	PD ≥ 7 mm; n (%)	26 (86.7%)	16 (53.3%)	p = 0.0112*
	comparison depending on pocket depth*	p = 0.7290	p = 0.6054	–
	correlation between presence in pockets 5 mm deep and ≥ 7 mm*	p = 0.3473	p < 0.0001	–
Number	PD = 5 mm; n × 10^3 (±SD)	123.1 (±329)	72.0 (±183.1)	p = 0.0243
	PD ≥ 7 mm; n × 10^3 (±SD)	157.4 (±298)	139.9 (±340.7)	p = 0.0309
	comparison depending on pocket depth**	p = 0.0856	p = 0.2052	–
	correlation between level in pockets 5 mm deep and ≥ 7 mm***	r = 0.56 p = 0.0013	r = 0.78 p < 0.0001	–

* – χ^2 test, ** – Wilcoxon test for dependent samples, *** – Spearman test.

Table 4. Occurrence and numbers of *Treponema denticola* depending on periodontal pocket depth and diagnosis

Occurence/ /Numbers	Parameters	Patients with CP	Patients with AgP	Comparison according to diagnosis (Mann-Whitney test)
Occurence	total, n (%)	28 (93.3%)	26 (86.7%)	p = 0.6670 *
	PD = 4–6 mm, n (%)	22 (73.3%)	20 (66.7%)	p = 0.7782*
	PD ≥ 7 mm, n (%)	27 (90.0%)	26 (86.7%)	p = 1.0000 *
	comparison depending on pocket depth (χ^2 test)	p = 0.1820	p = 0.1270	–
	correlation between presence in pockets 4–6 mm deep and ≥ 7 mm*	p = 0.3354	p = 0.0136	–
Number	PD = 4–6 mm; n × 10^3 (±SD)	41.0 (±132.6)	28.8 (±118.1)	p = 0.3374
	PD ≥ 7 mm; n × 10^3 (±SD)	44.5 (±72.5)	32.0 (±68)	p = 0.2278
	comparison depending on pocket depth**	p = 0.0776	p = 0.0271	–
	correlation between number in pockets 4–6 mm deep and ≥ 7 mm***	r = 0.37 p = 0.0458	r = 0.38 p = 0.0382	–

* – χ^2 test, ** – Wilcoxon test for dependent samples, *** – Spearman test.

Table 5. Occurrence and numbers of *Aggregatibacter actinomycetemcomitans* depending on periodontal pocket depth and diagnosis

Occurence/ /Numbers	Parameters	Patients with CP	Patients with AgP	Comparison according to diagnosis (Mann-Whitney test)
Occurence	total	0	11 (36.7%)	p = 0.0008*
	PD = 5 mm, n (%)	0	10 (33.3%)	p = 0.0018*
	PD ≥ 7 mm, n (%)	0	6 (20.0%)	p = 0.0314*
	comparison depending on pocket depth*	n/a	p = 0.3811	–
	correlation between level in pockets 4–6 mm deep and ≥ 7 mm*	n/a	p = 0.0155	–
Number	PD = 5 mm; n × 10^3 (±SD)	0	3.69 (±9.70)	p = 0.0007
	PD ≥ 7 mm; n × 10^3 (±SD)	0	0.77 (±3.13)	p = 0.0110
	comparison depending on pocket depth**	n/a	p = 0.0367	–
	correlation between level in pockets 5 mm deep and ≥ 7 mm***	n/a	r = 0.59 p = 0.0006	–

* – χ^2 test, ** – Wilcoxon test for dependent samples, *** – Spearman test.

Characteristics of the study group reflect the criteria used to distinguish chronic and aggressive periodontitis. The average age of patients with aggressive periodontitis was statistically lower than in patients with chronic form (respectively 30.9 and 56.9 years). Faveri et al. also observed statistically significant differences between the age of patients with aggressive and chronic periodontitis, reporting the mean values of 25.2 and 42 years respectively.[9] Riep et al. reported that the average age of patients with aggressive and chronic periodontitis was 34.4 and 55.2 years, respectively.[10] These results indirectly confirmed the typical, early onset of aggressive periodontitis. The age at the onset, although not considered in the official primary and secondary characteristics, constitutes an important parameter for the diagnosis and differentiation of aggressive periodontitis. Certainly, it cannot be the

single criterion for making the diagnosis, because it is not always possible to determine the age at the onset of symptoms, and the patient's age at the time of examination has no diagnostic value. It is necessary to analyze other clinical parameters, which together constitute the clinical picture of the disease.

Significant differences in the oral hygiene indices confirmed that the oral hygiene might be a key parameter differentiating chronic and aggressive periodontitis. Important differences referred to both simplified plaque index and to approximal plaque index, achieving significantly lower average values among patients with generalized AgP. The concurrent lack of differences between mean values of PD and BOP and between individuals with CP and generalized AgP confirmed different ethiopathogenesis of these two forms. Similar values of parameters indicating active inflammation, despite significant differences in the status of oral hygiene, emphasized a major role of the immunoinflammatory response in the course of aggressive periodontitis. They also confirmed that one of the primary features of generalized AgP, oral hygiene disproportionate to the severity of the disease, is a characteristic of real diagnostic value. These findings were reflected in studies by other authors.[9,11]

No reports on significant differences regarding CAL in generalized AgP and CP groups have been previously described in the literature. In the study, statistically significant differences in CAL between individuals with CP and generalized AgP were most likely associated with disease duration. This relationship was statistically insignificant ($p = 0.815$ and $p = 0.0006$) after adjusting for age in multivariate analysis. This means that after adjusting for age, the mean CAL did not vary depending on the diagnosis.

Significant differences regarding the gender of patients (43.3% of females in the CP group and 70% of females in the generalized AgP group) may suggest a higher prevalence of the aggressive form in women. Only a few studies confirmed this relationship. In 2002 Cortelli et al. studied 600 patients with generalized AgP and observed a positive correlation between females and the prevalence of generalized AgP.[12] The American Academy of Periodontology did not include the gender among the criteria established for generalized AgP, and most studies denied such a relationship.[9,11] The group of patients in this study was, however, too small to permit conclusions of epidemiological nature. The fact that 70% of individuals with diagnosed generalized AgP were females might indicate higher health awareness and better care of oral hygiene when compared to men, especially since they were individuals under 37 years of age, with relatively good oral hygiene, and periodontal tissue destruction was largely a result of immune response disorders. In patients with CP, the major cause of the disease is hygienic negligence. It can be assumed that significant differences regarding gender concerned not so much the presence of particular forms of periodontitis, but rather the need of female patients to be treated.

An analysis of microbial composition in periodontal pockets in patients with CP and generalized AgP did not lead to clear conclusions that could constitute the basis for the differentiation of these two forms.

An assessment of the total number of bacteria in a selected periodontal pocket has no diagnostic value. No significant differences were observed in the numbers of bacteria depending on the pocket depth and on the diagnosis. Moreover, high values of standard deviation, sometimes exceeding the mean values twofold, proved that the variability of bacteria between patients was very high. This means that the total number of bacteria in the subgingival biofilm was typical neither for a specific pocket depth nor for particular forms of periodontitis, but rather constituted an individual feature of the patient. Although the total number of bacteria in pockets ≥ 7 mm among patients with CP appeared to be higher compared to patients with generalized AgP (13035×10^3 in CP, vs 8188×10^3 in generalized AgP), high variability of these values did not permit us to establish statistical significance.

Previous studies pointed out that initiation and progression of periodontitis was not related to the overall increase in the number of bacteria but to an imbalance in the microbial composition, which was individual for each patient.[13,14] Recent studies emphasized a special role not of bacteria and not of an increase in their number, but in their percentage, i.e. in the change of proportions of the microbial composition. In the present study, numerous significant correlations were observed between the presence and the number of individual periopathogens depending on initial diagnosis, as well as on the pocket depth.

The presence of particular pathogens was not related to the pocket depth; it was comparable in pockets both 5 mm and ≥ 7 mm deep. Similar findings were reported in a study on 58 patients.[15] A similar occurrence of specific pathogens in pockets ≥ 4 mm was observed: *T. denticola* in 82.7%, *P. gingivalis* in 72.4%, and – least frequently – *A. actinomycetemcomitans* in 29.9% of individuals. In a study on 34 patients with periodontitis and pockets deeper than 5 mm[16]. *T. denticola* was observed in 88.2%, *P. gingivalis* in 50% of patients, whereas *A. actinomycetemcomitans* in 23.3% – and it was also the least frequent of all selected bacteria. Another study reported *A. actinomycetemcomitans* in 93% of patients. Low detection of *A. actinomycetemcomitans* in patients with generalized AgP in the present study might be associated with the bacterial ability to penetrate epithelial and connective tissue.[17] It may also be attributed to the phenomenon of false negative reading, typical for microorganisms with low occurrence (in case of a small number of examined samples).[18]

A significant difference in the occurrence of periopathogens was observed depending on the diagnosis. *P. gingivalis* was detected significantly more frequently among patients with CP (93.3%, 53.3% in generalized AgP).

A. actinomycetemcomitans was found only in patients with the generalized AgP, but the presence of this pathogen was observed only in 11 of 30 (36.7%) individuals with generalized AgP. The presence of the *T. denticola* species was comparable in both groups of patients.

In another study, significantly higher incidence of *A. actinomycetemcomitans* among patients with generalized AgP was found; however, no difference was observed between the presence of *P.g.* and *T. denticola* among groups. Another study confirmed a higher incidence of *P. gingivalis* among patients with CP and of *A. actinomycetemcomitans* in patients with generalized AgP, whereas there was no difference in the incidence of *T. denticola* between two groups of patients.[10] The authors also emphasized that the pocket depth had a much more significant impact on the occurrence of these pathogens than the form of periodontitis. These correlations were observed especially for *P. gingivalis* and *T. denticola*, and the only pathogen whose presence was not dependent on the pocket depth was *A. actinomycetemcomitans* In the present study, no correlation between the occurrence of any of the tested pathogens and the pocket depth was found.

Although other reports confirmed a significantly higher occurrence of *A. actinomycetemcomitans* in generalized AgP, it was also observed (although less frequently) in patients with CP., unlike in this study. Mombelli et al. found that in 8 of the 11 studies there was an association between the presence of *A. actinomycetemcomitans* and aggressive periodontitis, and in only 7 of them an absence of *A. actinomycetemcomitans* in CP was reported.[20] Sanz et al. compared a group of 61 patients with CP, 31 individuals from Spain and 30 from the Netherlands.[21] The results of the study showed significant differences between the groups in terms of the presence of particular bacteria. *P. gingivalis* was observed significantly more frequently in individuals from Spain, whereas *A. actinomycetemcomitans* in Dutch patients. Furthermore, a significantly higher incidence of *A. actinomycetemcomitans* among patients with generalized AgP does not constitute a rule (36.7% according to own research, 47% according to Kowalski).[19] Differences in the composition of biofilm may also be associated with race, age or geographical location. In different parts of the world there are significant differences in the microbial composition of periodontal pockets. Therefore, detecting *A. actinomycetemcomitans* in a diagnosed patient does not permit an explicit identification of aggressive periodontitis. Also, the absence of this pathogen in the tested pocket may not be the basis for excluding generalized AgP.

Results of other studies related to the relationship between the number of individual bacteria and the form of periodontal disease primarily confirm more numerous presence of *A. actinomycetemcomitans* in the course of aggressive periodontitis.[11,22–24] Many reports also confirmed a greater number of the pathogen in periodontal pockets not exceeding 6 mm compared to deeper pockets, which is consistent with the results of this study.[9,11,12,25] Presumably *Aggregatibacter actinomycetemcomitans* is not sufficiently resistant to conditions prevailing in deep periodontal pockets and to competition of other periopathogens.[9,26] This confirms the assumption that *A. actinomycetemcomitans* is primarily responsible for starting the disease, whereas its progression involves a broader bacterial spectrum. These findings also have clinical significance. This information should be considered when taking material for microbiological tests, and instead of collecting material intuitively from the deepest pockets, it is worthwhile to take an aggregate sample which would also include pockets not exceeding 6 mm.

Recent studies emphasized that the number of individual periopathogens, which increases with the severity of periodontal disease, was not related to the form of the disease but resulted from the increasing depth of periodontal pockets and their internal conditions which are favorable for some species and unfavorable for others, and from immune response of the host.[9,10,27] The present study did not support this theory. The results permit us to assume that the number of bacteria is a value that primarily depends on the patient's predispositions. An assessment of an objective number of bacteria responsible for the onset and progression of periodontal disease is not possible, as it is individual for each patient. While a given number of pathogens will result in increased immune response and large inflammation in one patient, in another it will remain a subthreshold value, not leading to the formation of periodontitis, or leading to its less severe form. Microbiological testing of the subgingival biofilm in the diagnosis and differentiation would undoubtedly gain more value if extended to studies related to antibodies to selected bacteria. This does not mean that microbiological tests themselves have no diagnostic value – certainly, they allow for more accurate selection of chemotherapeutic agents, both topical and general.

Concluding, the bacterial spectrum and count are not directly related to the pocket depth, so it is not only an effect of the disease progression. Although some relations between bacterial species and particular forms of periodontitis have been observed, they cannot constitute the basis of the diagnosis and differentiation.

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An evaluation of the relationship between the range of mandibular opening and the condyle positions in functional panoramic radiographs

Ocena związku między zakresem opuszczania żuchwy a pozycjami wyrostków kłykciowych na czynnościowych zdjęciach pantomograficznych

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Abstract

Background. Radiographic diagnostics in dentistry is one additional examination which facilitates an accurate clinical diagnosis and, as a result, the initiation of appropriate treatment. Despite various limitations, functional panoramic radiograph (OPG) images of the temporomandibular joints (TMJ) provide a great deal of valuable information and seem to be the first-choice modality in the diagnosis of temporomandibular disorders.

Objectives. The aim of this study was to evaluate any relationship between the range of mouth opening and the condyle positions during this movement, on the basis of functional OPG images.

Material and methods. To evaluate the distance between the condyle positions, 10 functional OPG images of the TMJ were used. The relationship between the measurements taken during clinical examination of the patients and the measurements obtained from functional OPG images were evaluated. The research hypothesis assumed that there was a positive correlation between the clinical range of mouth opening and the measurement of condyle movement from a centric occlusion position to its maximum opening.

Results. The analysis of measurements showed no statistical correlation between the distances between the condyle positions obtained from radiographic images and clinical measurements of the range of mouth opening.

Conclusions. In young, healthy patients without clinical symptoms of TMJ dysfunction, functional OPG images of the joint should not be compared with the range of mandibular opening.

Key words: temporomandibular joint, X-ray images, condylar pathway

Słowa kluczowe: staw skroniowo-żuchwowy, zdjęcia rentgenowskie, droga stawowa

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Radiographic diagnostics in dentistry is one additional examination which facilitates accurate clinical diagnosis and, as a result, the initiation of appropriate treatment. In recent years, the quality of the images produced has improved, and the options of using X-rays for human body imaging have expanded significantly along with a simultaneous reduction in the ionising radiation dose necessary to obtain images of clinically acceptable quality.[1–3]

Clinical and radiological diagnostics of temporomandibular joints (TMJ) is extremely complex.[4] Symptoms reported by patients are often seemingly unrelated to the joints themselves and analysis of the radiological images of the TMJ may present difficulties due to their anatomical complexity.[1,5] Therefore, appropriately selecting the type of additional examinations and interpreting their results seem to be even more important. One should keep in mind, however, that regardless of the technique and view in which images are captured, X-ray images are meant to complement clinical and instrumental examinations and should only be interpreted with their results in mind.[6]

Currently, a range of imaging modalities to visualise TMJ structures are available, such as magnetic resonance imaging (MRI), cone beam computed tomography (CBCT), computed tomography (CT), and panoramic radiograph (OPG). A distinctive feature of MRI examination is that it allows soft-tissue imaging, which enables one to evaluate the position of the articular disk and the surrounding soft tissues in TMJ disorders. As three-dimensional imaging methods, CBCT and CT examinations provide a visualisation of bone structures. The CT method exposes patients to the highest ionising radiation dose of all TMJ imaging methods. MRI is a detailed examination considered in the literature to be the 'gold standard' in diagnostics of TMJ abnormalities; however, it is not commonly used in everyday dental practice due to economic factors.[7] On the other hand, in order to protect the patient, each radiological examination should be supported by appropriate indications, and the number of such procedures should be limited to the bare minimum. One of the basic plain examinations of the TMJ is an OPG, commonly used and widely available in dental treatment.[8] Admittedly, the image obtained is a flat reflection of the curved surface of the maxilla and a composite image of the tissues located in the X-ray's path; however, it provides a sufficiently accurate visualisation of the bone structures around the TMJ.[8,9] A functional OPG is a modification of an OPG examination and is performed in the following positions: habitual occlusion (maximum contact between the teeth of opposing arches) and maximum opening (maximum opening of the mandible in relation to the maxilla), each separately for the right and left sides (a separate image for each TMJ). As a result, 4 images on one film are obtained. Analysing such images enables one to evaluate the bone components of both joints and, indirectly, the articular disk, and provides information on the condylar range of motion between the position of habitual occlusion (maximum intercuspation) and maximum opening of the mandible in relation to the maxilla. When evaluating X-ray images, the anatomy of the left and right joints is compared. This allows both the exclusion of any potential deviations from normal geometry, and at the same time control over the relationship between the 2 joints during their function, i.e., at the beginning and at the end of opening movement. The unquestionable advantages of the examination also include its ready availability, low costs of performance, and non-invasiveness. One of the major weaknesses of OPG images is their magnification, which results from the radiographic technique applied. Although the magnification factor is fixed, differences in magnification occur even within the same radiograph. Due to the layered nature of this examination, shadows of other anatomical structures are superimposed over the captured image, which make interpretation of the image difficult. Despite these limitations, functional OPG images of the TMJ provide a great deal of valuable information and seem to be the modality of choice in the diagnosis of temporomandibular disorders. There are no publications available that discuss the interpretation of these images, hence the need to undertake the study below.[10,11]

The aim of this paper was to evaluate any relationship between the range of mandibular opening and the condyle positions during this movement on the basis of functional OPG images.

Material and methods

To evaluate the distance between the condyle positions, functional OPG images of the TMJ captured in intercuspation and maximum mandibular opening positions were used. The images were obtained from 10 randomly selected 18-year-old volunteers (from a group of 260 individuals) taking part in a project supported by the Polish Ministry of Science and Higher Education no. N N403 589138.[12]

All images were obtained with the same ProMax® scanner (Planmeca, Helsinki, Finland 2005), by the same radiology technician, using the same radiation parameters in current (14.0 mA) and voltage (70 kV).[7] A stomatognathic system examination was performed in all project participants by one calibrated examiner in accordance with the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD).[13] Presenting individuals were informed of the project's objective and that they can withdraw at any time without giving a reason. Volunteers provided written informed consent to participate in the study. The study was approved by the Bioethical Committee of the Jagiellonian University under the number KBET/89/B/2009 and was conducted in accordance with the principles laid down in the Declaration of Helsinki and Good Clinical Practice (GCP). Ten patients were selected randomly from the group of 260 examined individuals, regardless of gender. Data regarding the maximum range

of the mandible opening (pain-free opening), midline coincidence between upper and lower incisors in a centric occlusion position, range of vertical incisal distance, and curve of movement path were obtained from the RDC/TMD Axis I Clinical Examination Form after clinical examination was done by a single calibrated specialist in prosthodontics (MG).[12] The study inclusion criteria included the following: no symptoms of temporomandibular disorders according to RDC/TMD, no midline deviation, and a straight line of the mandibular opening.

Using data regarding the range of opening of the mandible collected during a clinical examination performed in accordance with RDC/TMD Axis I, further analysis was carried out. Values for vertical range of motion (pain free opening) obtained from the form were added to the overbite distance, and thus the actual opening range of motion was obtained.

Image evaluation methodology

Each radiographic image was analysed by one examiner (MM). Figure 1 shows all elements drawn. On images made in the maximum intercuspation position (designated as I), pathways were drawn according to the shape of the cusp and the articular fossa (I.1), and the condylar head and ramus of the mandible (I.2).[14] Next, the highest point of the articular fossa (I.1.a) and the highest point of the condylar head (I.2.b) were marked on the pathways drawn. The measurements consisted of measuring the distance between the highest point of the condylar head and the highest point of the articular fossa (connecting points I.1.a and I.2.b), and determining the angle between the tangent passing through the penultimate point on the curve of the mandibular ramus and the line parallel to the x-axis (I.4).

The next step of the analysis was to transfer the pathways, along with the points marked on them, to images showing the TMJ in the maximum opening position (designated as II). Pathways corresponding to the picture of the cusp and the articular fossa along with its highest point (II.1.a), and the picture of condylar head with its highest point (II.2.b), were created. The distances between points II.1.a and II.2.b (the distance between points a and b and the shift towards the x-axis [horizontal] and towards the y-axis [vertical]) were measured, and the angle between the tangent passing through the penultimate point on the curve of the mandibular ramus and the line parallel to the x-axis (II.4) was determined.

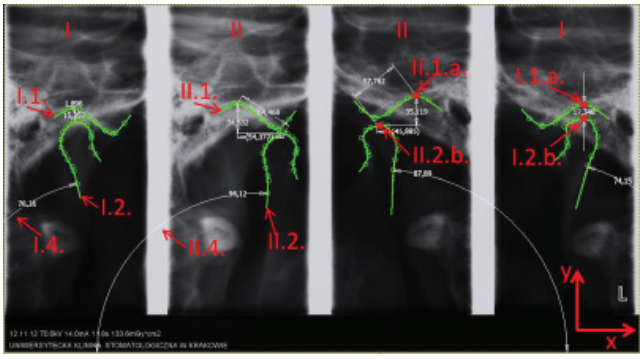

Fig. 1. An example image with points, pathways, and measurements drawn. I images – condylar heads in maximum intercuspation; II images – heads of the mandible in maximum opening. L – patient's left side. I.1 – the curve corresponding to the curvature of the cusp and articular fossa; I.2 – the curve corresponding to the condylar head and mandibular ramus; I.1.a – the highest point of the articular fossa; I.2.b – the highest point of the condylar head; I.4 – the angle formed between the tangent passing through the penultimate point on the curve of the mandibular ramus and the line parallel to the x-axis. Analogous designations for II images

When analysing individual measurements, the right and left sides in each patient were compared to the right and left sides in all patients. The relationship between the measurements taken during clinical examination of the patients (measurements between the incisal edges of the lower and upper dental arches in the maximum opening position, increased by the range of the overbite distance [actual range of opening]) and those obtained from X-ray images was evaluated. The research hypothesis assumed that there was a positive correlation between the clinical range of opening of the mandible and the measurement of the condylar head movement from centric occlusion to maximum opening.

For statistical analysis of the results obtained, Student's t-test with a significance level of $p = 0.05$ was applied.

Results

All 10 of the radiographic images which were randomly selected from a group of 260 individuals (including 192 women and 68 men) and then evaluated were images received from women. Table 1 shows the measurements obtained from the analysis of OPG images. No direct impact of the segment lengths from points II.1.a to II.2.b on the values of the range of opening of the mandible which were received during the clinical evaluation was identified (Table 1). The analysis of measurements showed no statistical correlation between the distances from the condyle positions obtained from radiographic images and clinical measurements of the range of opening of the mandible (Fig. 2, 3).

Discussion

Analysis of the results obtained suggests a lack of correlation between the clinical measurements of the range of opening of the mandible and the range of motion of the mandibular heads when their position is changed from maximum intercuspation to maximum opening, shown using radiological imaging in the form of functional OPG images.

This may be due to the characteristics of OPG imagery, which is a composite picture with anatomical structures

Table 1. Mean results obtained from the analysis

Image points	Unit	Mean – right side	Standard deviation	Mean – left side	Standard deviation	Difference	Standard deviation, right side and left sides
I.1.a-I.2.b distance	[mm]	2.01	0.6	1.89	0.88	0.12	0.08
I.4. angle	[°]	49.09	6.62	47.66	7.67	1.43	1.01
II.1.a-II.2.b distance	[mm]	8.95	1.32	9.46	1.72	0.51	0.36
II.1.a-II.2.b distance on the x-axis	[mm]	7.84	1.24	8.47	1.92	0.63	0.45
II.1.a-II.2.b distance on the y-axis	[mm]	4.26	0.96	3.96	1.19	0.3	0.21
II.4 angle	[°]	65.92	8.01	64.83	5.81	1.10	0.78
Difference between I.4 and II.4 angles	[°]	16.84	3.49	17.17	3.72	0.33	0.23

I – condylar heads in maximum intercuspation, II – heads of the mandible in maximum opening.
I.1.a the highest point of the articular fossa, I.2.b the highest point of the condylar head, I.4 angle formed between the tangent passing through a penultimate point on the curve of the ramus of the mandible and the line parallel to the X-axis. Analogous designations for images II.
mm – millimetre, ° – degree

superimposed. This issue was particularly visible when the angular values of a change in position of the mandibular ramus were determined. On the other hand, the methodology of performing such an examination seems to have no impact on the results obtained, as the examination is performed at almost the same time for the right and left sides, and the position of the anatomical components of both sides is recorded during the same (one) movement performed by the patient. In view of such results, the question is whether the use of OPG images of the TMJ to determine the size of the joint space gives accurate results? Some authors use such images and measure the size of the joint space on a baseline image at the beginning of prosthetic treatment, and then compare the measurements to a post-prosthetic treatment image. In this case, the measurements of the three-dimensional joint's components are made on a two-dimensional image. The issue of the repeatability of these images is also interesting; however, it was not the objective of this study. Studies were found in the literature whose objective was to evaluate the impact of a change in a patient's head position during a panoramic radiography examination on vertical measurement results in the ramus and condylar area of the mandible. The greatest asymmetry of right and left sides with differences of up to 6% was noted by the authors when the head was tilted down.[15]

The results obtained and the lack of expected correlation may also be due to the fact that the group of patients studied was small. Additionally, on the one hand, the young age of the examined patients ensured homogeneity within the group; on the other hand, it was not possible to compare with other age groups.

The use of computed tomography (CT) or magnetic resonance imaging (MRI) scans for measurements of the lengths and widths of particular structures of the TMJ seems to be the most appropriate.[16] Studies comparing TMJ anatomical preparations to their CT and MRI scans showed no statistical differences between the measure-

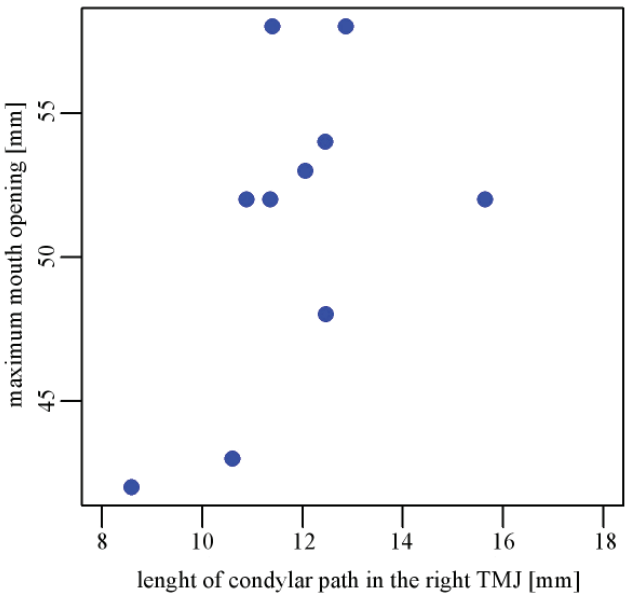

Fig. 2. The correlation between the maximum opening and length of the condylar pathway in the right TMJ

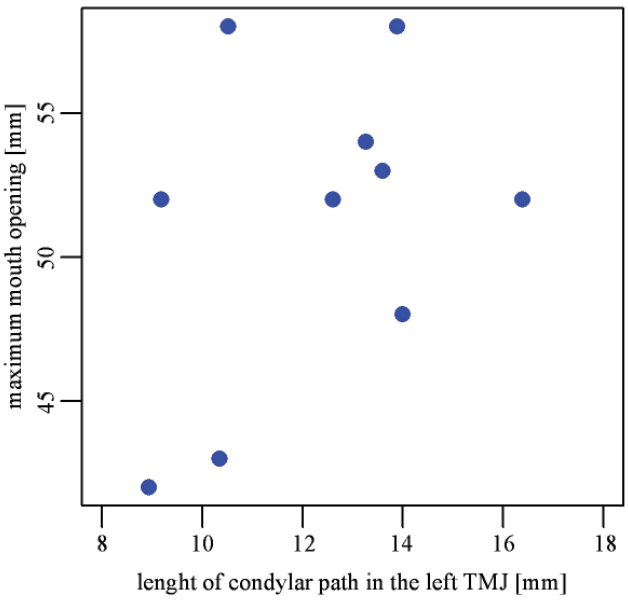

Fig. 3. The correlation between the maximum opening and length of the condylar pathway in the left TMJ

ments of respective points within bone structures.[17] Unfortunately, the availability of these imaging methods in everyday dental practice is limited.

Currently, cone-beam computed tomography (CBCT) is becoming increasingly popular, in diagnostics of TMJ disorders as well. It enables one to view the joint's hard tissues in 3 planes – sagittal, coronal, and axial – and to perform their three-dimensional reconstruction, which provides additional information on the anatomy of the joint and the position of the mandibular head in the glenoid fossa.[18] Compared to a CT examination, CBCT offers higher resolution and requires a radiation dose even 20–30 times lower. It is also possible to select the scanning region size.[19]

When interpreting TMJ images, one should also keep in mind that according to the definition of centric relation, a central position of the condyle in the articular fossa is not the most optimal and stable position, as in individuals with no symptoms of masticatory functional disorders, the mandibular head may take various positions in the articular fossa.[20] From a clinical perspective, missing pathological symptoms on the part of the masticatory system are the most important, rather than the position of condylar head in the articular fossa of the TMJ on the radiographic image.[4]

Conclusions

In young, healthy patients without clinical symptoms of TMJ dysfunction the functional OPG images should not be compared with the range of the mandibular opening. Further studies in this area are recommended, taking into account the selection of cases for analysis in terms of the presence of potential symptoms of masticatory functional disorders.

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The influence of the condylar fracture treatment method on mandible dynamics

Wpływ metod leczenia złamania kłykciowego na dynamikę ruchów żuchwy

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D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Background. Among commonly adopted condylar fracture treatment methods, there is the open reduction and closed reduction method. For the purpose of evaluating the therapeutic effect of a given method and the functional state of the temporomandibular joints, it is possible nowadays to conduct an instrumental analysis with the use of modern devices such as the axiograph.

Objectives. The study was aimed at a long-term assessment of the function of the stomatognathic system, in particular assessment of the range of the condylar path in the temporomandibular joints, depending on the method of condylar fracture treatment (open or closed).

Material and methods. The study involved 60 patients in total (mean age in the study group was 33.3 years), including 24 women (40%), who were divided into 2 groups. The 1st group included 40 patients in whom condylar fractures were surgically managed. The other group consisted of 20 patients in whom the closed reduction method of treatment was applied. Patients were qualified for surgery under general anesthesia or for treatment by means of standard splints and maxillomandibular fixation. After 6 months following the conclusion of treatment, each patient was scheduled for a follow-up appointment, during which an axiographic examination aimed at the registration of the condylar path in the temporomandibular joints was performed. The values registered were subject to a statistical analysis and compared between the groups.

Results. A significant difference ($F = 5.36$; $p = 0.0241$) in the length of the condylar path in the sagittal plane was observed, depending on the method of condylar fracture treatment. In the case of open reduction, the values were higher than in the case of closed reduction.

Conclusions. Miniplate osteosynthesis disturbs the mandibular dynamic pattern to a lesser degree but the technique should constantly be improved in order to limit the traumatization of sensitive periarticular structures.

Key words: axiography, temporomandibular joint, mandibular condyle fracture

Słowa kluczowe: aksjografia, staw skroniowo-żuchwowy, złamanie wyrostka kłykciowego żuchwy

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As it follows from epidemiological data, mandibular fractures constitute about 2/3 of all fractures in the craniofacial area. The mandible, although it is a bone characterized by considerable strength, often undergoes injuries due to its location and the lack of protection from other structures. Among mandibular fractures, a specific group of condylar fractures, statistically constituting about 25–35% of the whole group, can be distinguished.[1–3] The majority of these fractures occurs indirectly through the application of force in a remote site (usually in the mental region), therefore condylar fractures are the most frequently diagnostically overlooked type of mandibular fracture (Fig. 1).[4] In spite of the known epidemiological and clinical features of the above fractures, the discussion on a method of their treatment is still in progress. Among the available methods, the open reduction method (surgical) and the closed reduction method (standard splints and maxillomandibular fixation) can be distinguished. Due to the considerable development of surgical techniques, equipment and materials, and as a result of the increasingly smaller invasiveness of the surgery itself, the open reduction treatment of condylar fractures by means of miniplate osteosynthesis is becoming more and more popular.[5] Stable miniplate osteosynthesis eliminates the necessity of using maxillomandibular fixation, which preserves the function of the temporomandibular joints (TMJs), the muscles of the stomatognathic system, and ensures better nutritional conditions for the patient.[6] Therefore, it would seem that it is the gold standard of treatment. It should be taken into account, however, that the surgical fixation of fragments, although it enables early TMJ mobilization, also involves the potential risk of damaging the structures of the joint area such as the facial nerve, masticatory muscles or articular disc, which may have an influence on the later rehabilitation of the stomatognathic system.[7–9]

The specificity of mandibular fracture treatment, and particularly of condylar fractures, consists of, on one hand, the early repositioning and fixation of bone fragments, and on the other hand, the earliest possible mandibular mobilization, aimed at enabling the basic functions of the stomatognathic system such as mastication, speaking and swallowing. The fundamental functional and morphological element of the stomatognathic system which ensures the performance of the above-mentioned functions are the temporomandibular joints. The proper function of TMJ and the complexity of its movements (the rotational and translational components) result not only from their characteristic structure but also from their interdependence on the remaining structures of the stomatognathic system, particularly muscles and occlusion.[10] Therefore, it can be assumed that the functional state of the temporomandibular joint (TMJ) is an important marker of the functioning of the stomatognathic system as a whole.

In order to characterize the function of the temporomandibular joint and the mandibular dynamic pattern precisely, an instrumental analysis with the use of modern devices such as the electronic axiograph can presently be carried out (Fig. 2). The so-called condylar path is registered each time in the course of the opening movement of the mandible, protrusion and laterotrusion (mediotrusion).[11–14] On the basis of long-term research, Slavicek draws attention to the repetitiveness of graphs obtained in the axiographic examination and suggests that the condylograph, that is the dynamic pattern of the condylar movement, can possess a diagnostic value in itself.[10,11] Numerous studies have made it possible to determine the proper (physiological) range of the condylar path, which enables the objectivization of research conducted with the use of this data. The range and character of the condylar path can be influenced by masticatory muscles, pain of TMJ and acoustic symptoms – TMJ clicks (dislocations of the articular disc) – as well as restrictions of mandibular mobility of various origin.[11–13] In the available literature, there is a scarcity of reports on the impact of the method of condylar fracture treatment on the length of the TMJ condylar path.[15]

The aim of this study was a long-term assessment of the functioning of the stomatognathic system (especially assessment of the range of the TMJ condylar path), depending on the method of condylar fracture treatment.

Fig. 1. Fracture of the left mandibular condylar process in CT reconstruction

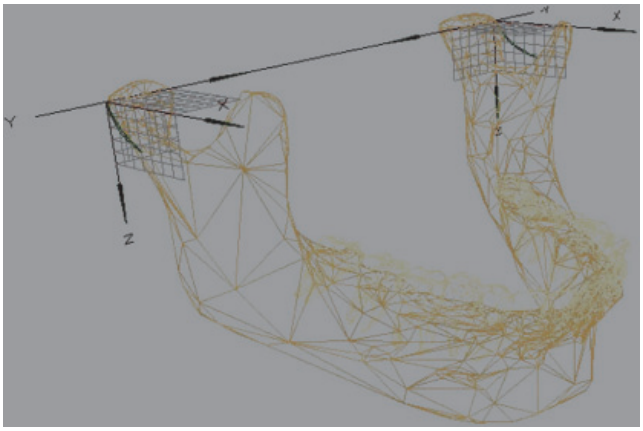

Fig. 2. Axiographic examination enables the registration of the condylar path in 3 planes – sagittal, frontal and horizontal (according to Gamma Dental/Cadiax Compact II®)

Material and methods

The study was conducted in the Department of Cranio-Maxillofacial Surgery and Dental Surgery of the Autonomous Public Hospital of the Medical University of Silesia in Katowice, Poland, in the period from May 2016 to May 2017. Sixty patients were included in the study. Mean age in the study group was 33.3 years and the total age range was from 16 to 62 years. The subjects were divided into 2 groups:

- 40 patients with condylar fractures treated surgically were qualified to the open reduction group (group 1);
- 20 patients treated by closed reduction, in whom standard splints and elastic maxillomandibular fixation were used for a period of 4 weeks on average (group 2).

The exclusion criteria were as follows:

- history of diseases/disorders of the temporomandibular joints;
- systemic diseases;
- craniofacial traumas in the past;
- occlusion making it impossible to mount the axiograph – supraocclusion, edentulism.

A thorough physical examination, including elements of the functional test of the stomatognathic system, were carried out in each patient. The subsequent stages of the examination included: a general and detailed anamnesis, an analysis of the trajectory and range of mandibular opening, palpation of the masticatory muscles and palpation and auscultatory examination of the temporomandibular joints, and an intraoral check (occlusion analysis, marking of the tooth chart). Additional X-ray diagnostic examinations (panoramic radiographs, mandibular PA, oblique lateral projection of the mandible, CBCT of the facial skeleton) were performed in order to determine the type of fracture. The characteristic symptoms of condylar fractures, that is occlusion defects (open bite), restricted mandibular opening and facial asymmetry were observed. The type of fracture was determined according to an elaborated classification based on Lindahl's classification, which distinguishes the following types of fractures: condylar head fractures, condylar neck fractures and subcondylar fractures.[1] Then the subjects were qualified for open reduction (group 1) or closed reduction (group 2).

Open reduction treatment was carried out under general anesthesia. Each time, an incision surrounding the mandibular angle (retromandibular incision) was employed. Fractured condylar processes were fixed with miniplates (Synthes®, DePuy Synthes Companies, Massachusetts, USA) or trapezoidal plates (Medartis®, AG, Basel, Switzerland). Each time, passive mandibular mobility and the patient's occlusion obtained were checked, and drainage and multiple layer suturing of the wound were applied. X-ray documentation, aimed at checking the correctness of the fixation carried out, was performed (Fig. 3).

Closed reduction in patients from group 2 was conducted with the use of standard splints mounted to the upper and lower arch teeth with wire loops and by applying elastic maxillomandibular fixation. The patients were recommended a liquid diet and to report to weekly follow-up appointments in order to replace maxillomandibular fixation. Standard splints were removed after 4–5 weeks.

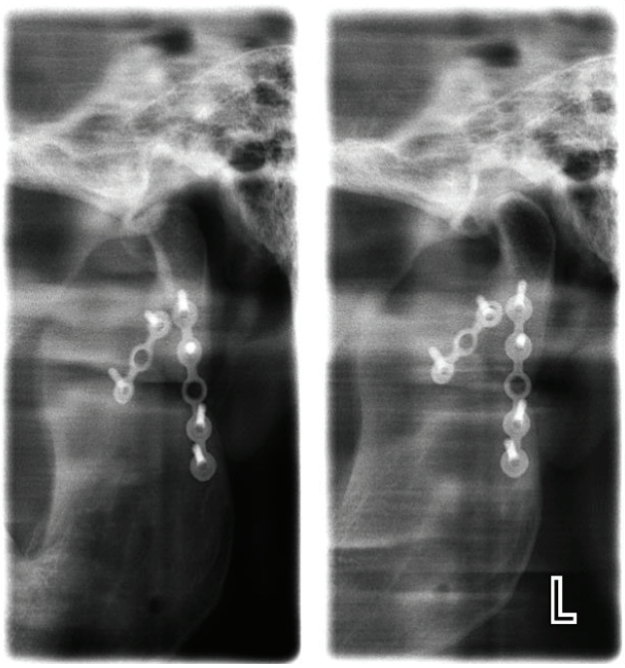

Fig. 3. X-ray image (projection of the temporomandibular joint) revealing a fixed subcondylar fracture on the left side

Axiographic examination

The key element of the examination was a follow-up appointment after 6 months from the surgery or from the conclusion of treatment by closed reduction. An axiographic examination was performed by means of the Cadiax Compact II® (Gamma Medizinisch, Vienna, Austria) system to assess the mandibular dynamic pattern (the arbitrary hinge axis of TMJ) in 3 planes (Fig. 4).

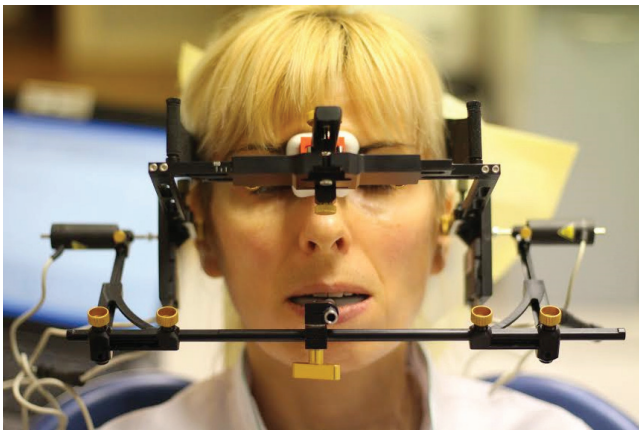

Fig. 4. Registration of mandibular movement (the condylar path) by means of Cadiax Compact II®

This system is comprised of the upper and lower face bow, special electronic plates and telescopic markers. The lower face bow is mounted to the lower teeth with the use of a paraocclusal clutch, which does not disturb the natural occlusal support zones and enables the registration of the entire range of movement in protrusion, laterotrusion and opening from the so-called reference position to the maximum range.[16]

After the performance of the axiographic analysis, the data was collected and the analyses of the results were carried out using the PQStat v. 1.6 statistical package (PQStat Software, Poznań, Poland). The range of the condylar path in the sagittal plane (mandibular opening movement/closing movement) [in mm], depending on the side, was analyzed using the Student's t-test for related variables. The range of the condylar path in the sagittal plane [in mm], depending on the group of patients, was compared by means of the analyses of variances for repeated measurements with grouping factors, that is, a group with respect to the method of treatment, type of fracture, trauma-treatment initiation time and the employment of mandibular immobilization (before/after treatment). For significant results, the test probability was adopted at the level of $p < 0.05$, and for highly significant results, the test probability was adopted at the level of $p < 0.01$.

Results

On the basis of the inclusion and exclusion criteria, the study included 60 patients (Table 1).

There was a significant difference ($F = 5.36$; $p = 0.024$) in the length of the condylar path in the sagittal plane [mm], depending on the method of condylar fracture treatment. The values were higher in the case of open reduction than in the case of closed reduction. The difference between the left and right side was not significant ($F = 0.04$; $p = 0.844$) and the interaction between the group and the side of measurement was not significant as well ($F = 0.15$; $p = 0.698$) (Fig. 5).

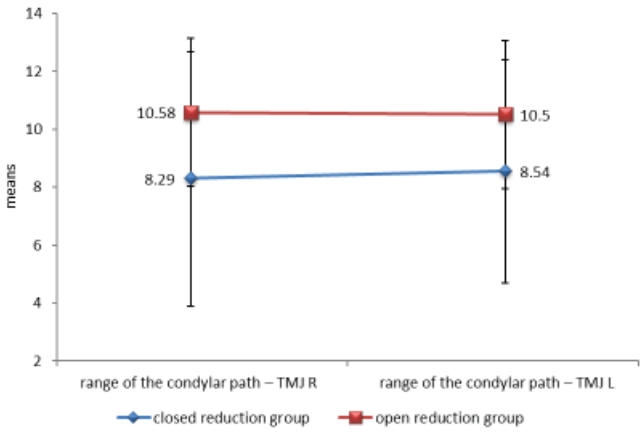

Fig. 5. Range of the condylar path in the sagittal plane [mm], depending on the group of patients with respect to applied treatment

In the follow-up examination half a year after the conclusion of treatment, TMJ clicks were found in 35% of the subjects, malocclusion was observed in 15% and the mandibular opening trajectory was described as asymmetric in the majority of the subjects (52%).

There was a significant difference ($F = 2.71$; $p = 0.029$) in the results of the condylar path in the sagittal plane [mm] depending on the type of fracture. In the case of unilateral fractures, the results were higher (significantly longer condylar path) than in the case of bilateral fractures. The difference between the left and right side was not significant ($F = 0.11$; $p = 0.740$), and the interaction between the group and the side of measurement was not significant as well ($F = 0.65$; $p = 0.661$) (Fig. 6).

The majority of the subjects, i.e., 56.67%, started treatment after more than 3 days from the trauma. In the statistical analysis, a significant difference

Table 1. Study group summary (group I – open reduction; group II – closed reduction)

Study group summary I – open reduction, II – closed reduction									
Examined parametr		n (%)	I	II	Examined parametr		n (%)	I	II
age (arithmetic mean)		33.30	35	32	preoperative immobilisation (open reduction group)	no	26 (65%)	26	0
gender	women	24 (40%)	12	12		yes	14 (35%)	14	0
	men	36 (60%)	28	8	postoperative immobilisation (open reduction group)	no	7 (17.5%)	7	0
type of fracture	unilateral condylar head fracture	8 (14%)	2	6		yes	33 (82.5%)	33	0
	bilateral condylar head fracture	5 (8%)	2	3	follow-up examination: TMJ clicks	no	39 (65%)	25	14
	unilateral condylar neck fracture	18 (30%)	13	5		yes	21 (35%)	15	6
	bilateral condylar neck fracture	5 (8%)	4	1	follow-up examination: mandibular opening trajectory	symmetric	29 (48%)	23	6
	unilateral subcondylar fracture	17 (28%)	13	4		asymmetric	31 (52%)	17	14
	bilateral subcondylar fracture	7 (12%)	6	1	follow-up examination: malocclusion	no	51 (85%)	33	18
trauma-treatment initiation time	up to 24 h	7 (12%)	5	2		yes	9 (15%)	7	2
	up to 3 days	19 (32%)	12	7	range of condylar path (arythmetic mean)	TMJ right	9.06	10.6	8.29
	above 3 days	34 (56%)	23	11		TMJ left	9.20	10.5	8.54

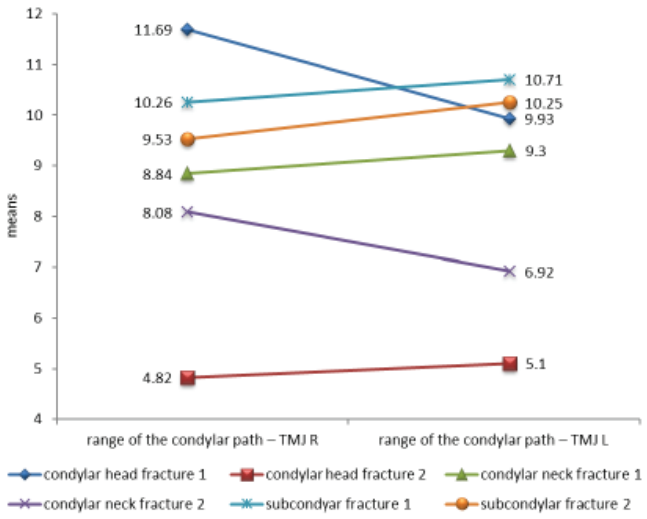

Fig. 6. Range of the condylar path in the sagittal plane [mm] depending on the group of patients with respect to type of fracture

(F = 0.63; p = 0.534) of the ranges of the condylar path in the sagittal plane depending on the time which passed from the trauma to the treatment initiation, was not observed (Fig. 7).

The analysis of the correlation between the range of the condylar path and the employment of pre- and postoperative maxillomandibular immobilization in the open reduction group did not reveal any significant differences. There was a significant difference (F = 1.20; p = 0.281) in the results of the condylar path in the sagittal plane [mm] depending on preoperative immobilization. A significant difference (F = 0.72; p = 0.401) in the results of the condylar path in the sagittal plane [mm], depending on postoperative immobilization, was not found as well. The difference between the left and right side was not significant (F = 0.25; p = 0.622) and the interactions between the groups and the side of measurement were not significant, either (p > 0.005).

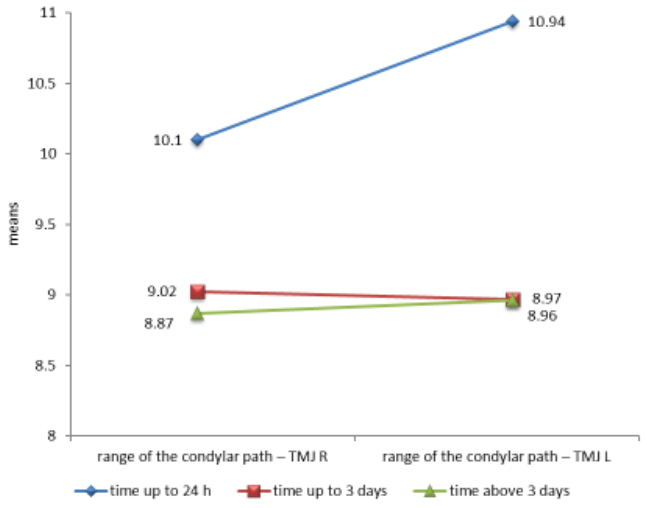

Fig. 7. Range of the condylar path in the sagittal plane [mm], depending on the group of patients with respect to time from fracture to the initiation of treatment

Discussion

The results of the above examination show the superiority of the open reduction method of condylar fracture treatment in the context of the later return of the stomatognathic system to full function. A statistically significant larger range of the condylar path was observed in patients after the open reduction of fractures compared to patients treated by closed reduction.

According to other authors, the closed reduction method of treatment is recommended in particular clinical situations such as: condylar process fractures, which do not cause the shortening of their length, fractures without dislocation, condylar head fractures (intra-articular) without the possibility of the osteosynthesis of tiny fragments and fractures in children and adolescents.[17] What is more, some authors even prefer the conservative method of treating condylar fractures in children. There have been studies recently proving a well-tolerated removal splint therapy which enabled good occlusion in all the patients, along with unimpaired function and good development of the mandible in those patients.[18]

In spite of the many advantages, the open reduction method of condylar process osteosynthesis has its limitation because it involves the risk of damaging crucial periarticular structures. In the above studies, a retromandibular incision was used in patients treated by open reduction. The skin, the subcutaneous tissue and the fascia in the area behind the mandibular angle were incised, the masseter muscle was delaminated and access to the place of fracture was gained through the blunt dissection of tissues. Schneider et al. consider the lack of explicitly the best surgical approach (retromandibular, preauricular, intraoral) and difficulties in the repositioning of chipped fragments to be the main causes of the controversies over open reduction of fractures.[15] Simultaneously, the authors draw attention to the fact that the more rarely used intraoral approach is justified only in situations of the lateral dislocation of a fractured process and the shortening of the mandibular ramus. Chrcanovic, on the other hand, states that each time the articular disc, which acts as a barrier preventing ankylosis of TMJ, should be repositioned intraoperatively.[17] The lateral pterygoid muscle should not be delaminated from a chipped fragment because it impairs the vascularization of the bone and delays the regeneration of the masticatory muscles, which may have an impact on mandibular mobility. He et al., examining patients with condylar fractures (intra-articular), came to the conclusion that stable miniplate osteosynthesis is the best method of treating such fractures.[19] It enables, i.a., the reconstruction of the proper height of the condylar process and restores the proper function of the temporomandibular joint. In order to achieve this, a few conditions must be met: good intraoperative visibility, stable repositioning

without damaging the articular surface of he process and the lateral pterygoid muscle, and the repositioning of the articular disc.

In another study, Throckmorton and Ellis analyzed a group of 136 patients with a unilateral condylar fracture after open reduction and closed reduction.[20] The main aim of their research was the qualitative and quantitative assessment of mandibular movements in a given group. They observed a gradual return to proper function during the subsequent follow-up appointments after 6 months and 1, 2, and 3 years. What is significant, the rehabilitation was faster in patients treated with open reduction than in patients treated by means of the closed reduction method but the full rehabilitation of the range of mandibular movements was achieved only after 3 years from the conclusion of treatment. Sforza et al. also raised the subject of the qualitative assessment of mandibular dynamics in a group of patients after open reduction and the rehabilitation of condylar fractures.[21] The researchers analyzed the ranges of maximum mandibular opening, distinguishing the rotational and translational components of this movement. They also examined, using electromyography (EMG), the tone of the masticatory muscles and neck while clenching the teeth (MVC – maximum voluntary clenching). In comparison to the control group (healthy subjects), the work of the masticatory muscles in the EMG examination in subjects from the study group was characterized by larger asymmetry, which translated into bigger mandibular deviations from the symmetry line in the position of maximum mandibular opening. In our research, we observed a high percentage of subjects with an asymmetric trajectory of mandibular opening (52%) and clicks in the temporomandibular joint, which may prove the rehabilitation of the stomatognathic system to be incomplete or improper. Particularly persistent clicks in the temporomandibular joint in patients treated by closed reduction may prove the articular disc and articular disc ligaments, together with the chipped fragment of the condylar process, to be irreversibly dislocated.

What draws attention is the mean range of the condylar path in the sagittal plane observed in our study, which amounted to 9.06 mm for the right TMJ and 9.20 mm for the left TMJ, respectively, and was below the adopted norm for the range of this movement, which amounts to 10–16 mm.[10,11] That means that after half a year from the conclusion of the fundamental treatment, the majority of patients still demonstrated considerably restricted mandibular mobility.

What matters greatly in the regeneration of the temporomandibular joints after condylar fractures is the widely understood physical therapy implemented from the early postoperative days, which is also emphasized by other authors.[15,22–24] In our study group, each patient was subject, in the period of hospitalization, to physical therapy treatments: biostimulation laser therapy and light therapy (the Bioptron® lamp, Bioptron® AG, Switzerland) adjusted to the early complications observed after the surgery (pain, hematoma, edema, wound dehiscence). Each time, the patient was recommended the rehabilitation of the masticatory muscles through active and passive muscular exercises (mechanotherapy) and muscle self-massages. It was also recommended to start the following exercises even 2–3 days after the surgery:

– active opening, protrusion and mediotrusion performed by the patient in front of a mirror in order to control the range and straight trajectory of the movements;
– in the case of a lack of functional progress on the 7th day after the surgery, the implementation of passive, mild therapy involving stretching with fingers, spatulas or wooden wedges.

The effectiveness of these treatments depends largely on patients' self-discipline. Unfortunately, we often observed failure to comply with the recommendations to do muscular exercises in our study group, which also explains the restricted mobility of TMJ in these patients 6 months after the conclusion of treatment.

The axiographic examination performed revealed a shortening of the translational component of the condylar path in subjects from the study group. It should be stressed that proper masticatory function is conditioned by the 3-dimensional interaction of translational movements of both joints. If the translation in the joint is disturbed, masticatory function will be impaired.[10] Moreover, combining the work of both joints means that the impairment of the function of one of them leads to the impairment of the work of the entire musculo-articular system.

Similar observations were made by Hochban et al. during the examination of patients with condylar fractures treated by open reduction from the intraoral approach and by closed reduction.[25] In the group treated by closed reduction, he found that in 20% of the subjects, the length of the condylar path had a value of only 1/3 of the proper range, while in 8% of the subjects the only possible movement of TMJ was the rotation of the mandibular head. It had an influence on the considerable impairment of mandibular dynamics in these patients, including masticatory function. In our research, in the group treated by open reduction, a limitation of the translation movement in the joint was also observed but general clinical assessment revealed that these patients recovered better.

Conclusions from this research confirm the superiority of the open reduction method of treating condylar fractures over closed reduction in the context of the rehabilitation of TMJ function, which corresponds with the reports of other authors.[15,20,21,23] Open reduction compared to closed reduction disturbed the function of the stomatognathic system and mandibular dynamics to a lesser degree. However, there is still a need to improve the surgical technique in order to limit the traumatization of sensitive periarticular structures.

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Prevalence and determinants of extrinsic origin dental erosion among children and adolescents from Wrocław

Występowanie i uwarunkowania zewnątrzpochodnych erozji szkliwa u dzieci i młodzieży z Wrocławia

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Background. The results of studies have revealed some increase of dental erosion prevalence; however, the data concerning the prevalence of erosive lesions in a Polish population is scarce.

Objectives. To evaluate frequency and severity of dental erosion in children and adolescents.

Material and methods. A total of 240 subjects of both sexes, aged 12 to 18 years, living in Wrocław were examined and surveyed. Erosive lesions were assessed with the use of indices by Lussi, O'Sullivan and BEWE. A questionnaire consisting of 33 parameters related to oral hygiene and dietetic habits was used. The data obtained was analyzed in reference to the frequency, severity and location of dental erosion.

Results. The frequency of dental erosion was 16.25%; it was slightly higher in boys than girls and significantly higher in lower compared to upper teeth. The indices used identified the same number of erosion-affected teeth but not their severity due to different descriptive criteria. However, the erosive lesions were mostly limited to enamel and located in lower molar teeth. The mean cumulative BEWE score was 2.23 ±1.42, which could place the subjects into a low dental erosion risk group. The development of erosive lesions was significantly correlated with intake of cola, energy/sports drinks and other carbonated beverages, as well as acidic food and bananas.

Conclusions. Dental erosion could become a more important problem of dental health among children and adolescents due to the frequent consumption of acidic beverages and food. Therefore, there is a need to promote awareness in dentists to make an early diagnosis and to assess the dietetic factors conducive to the development of erosive lesions.

Key words: dental erosion, prevalence, children, adolescents

Słowa kluczowe: erozja zębów, rozpowszechnienie, dzieci, młodzież

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According to the Consensus Report of the European Federation of Conservative Dentistry (EFCD) from 2015, dental erosion, named as erosive tooth wear (ETW), is a chemical-mechanical process resulting from cumulative loss of hard dental tissues, which is not caused by bacteria and characterized by loss of the natural morphology and contour of the teeth. ETW is a multifactorial lesion with acids as the prevailing cause.[1] Acids causing dental erosion can be of extrinsic origin (mostly from food and beverages as well as from some oral medicines) or intrinsic origin (chronic vomiting, acidic gastroesophageal reflux disease), or environmental, related to vocational exposure to acids. However, the development and severity of dental erosion is a sequel of the simultaneous interaction, lasting for an appropriate time, of various chemical, biological and behavioral factors, as well as a general health condition.[1–3] Among the acidic extrinsic factors, the most essential is nutrition which is based on frequent and large consumption of acidic food (fresh fruits, especially citrus, vegetables and processed products) and beverages (fruit juices and flavored carbonated and still drinks), and their pattern of consumption. The erosive potential of nutrition is influenced, not only by pH levels but also the acid type and concentration, titratable acidity, and content of calcium and phosphates, which can reduce the erosive effect. Citric acid, being a flavor-enhancer in a great number of food products, also has a chelative effect and forms calcium complexes. Likewise, frequent and long-term orally-taken medicines in a liquid, lozenge or chewing tablet form containing ascorbic acid (vitamin C) or acetylsalicylic acid (Aspirin), and inhaled medicines used for asthma treatment (low pH, reduction of salivary secretion) have an impact on the risk of dental erosion development.[3–6]

The initial signs of erosion are sometimes difficult to detect, as they manifest by loss of surface texture (perikimata), localized silky and shiny area, sometimes dull dental surface, flattening of occlusal surface and formation of rounded dimples. More advanced lesions present shallow and wide or fissurated concavities, rounded cusps, on the facial surface a rim of intact enamel along the gingival margin (due to buffering of acids by sulcus fluid), and exposed or shimmered dentin through the thinned enamel. In the later stage, the whole occlusal morphology disappears, exposing the deeper part of the dentin, restoration can stand out of the adjacent dental surface and dentin hypersensitivity can occur.[1,6]

Other types of tooth wear due to physical (mechanical) loss of hard dental tissues are attrition, abrasion and abfraction. However, in clinical conditions, most tooth wear lesions are a combination of dental wear processes in which one of them plays a dominant role.

Clinical differentiation of erosive lesions from other types of tooth wear is based on manifestation and causative behavioral factors. Attrition presents flat shiny areas with clear margins on the occlusal surface and corresponding lesions on antagonistic teeth. Abrasion produces deep but not wide lesions with sharp edges on a smooth surface. It is mainly caused by traumatic toothbrushing. Abfraction leads to wedge-shaped lesions at the cervical region with depth clearly exceeding width and sharp margins. The lesion is observed on a single tooth or non-adjacent teeth. Loss of dental structure is hypothesized to be a result of eccentrically applied occlusal forces generating tensile and compressive forces leading to tooth flexure and breakage of the enamel and dentin.[7–8]

The aim of the study was to determine the frequency and severity of dental erosion among children and youth living in Wrocław, Poland.

Material and methods

A total of 240 children and adolescents (92 males and 148 females) aged 12 (n = 71), 15 (n = 75) and 18 years (n = 94), randomly selected, were involved in the clinical and questionnaire study. The inclusive criteria were as follows: completed 12, 15 and 18 years of age, no chronic systemic diseases, completed questionnaire, written informed consent of a parent for 12- and 15-year olds, written informed consent completed by 18-year olds, and readiness to cooperate. Dental erosion was assessed with the use of 3 indices: the index developed by Lussi, the one developed by O'Sullivan and the Basic Erosive Wear Examination – BEWE.[9–11] Clinical examination was carried out with use of a ball-end explorer (WHO 621) under an artificial light.

The index developed by Lussi separately categorizes lesions located on facial and oral/occlusal surfaces.[9] Grading on facial surfaces is as follows: grade 0 – no erosion; grade 1 – concavity in enamel more wide than deep without involvement of dentin, cervically to the lesion an intact rim enamel; grade 2 – exposure of dentin less than 50% of the dental surface; grade 3 – exposure of dentin more than 50% of the dental surface. In contrast, grading of oral/occlusal surfaces is as follows: grade 0 – no erosion; grade 1 – slight erosion, rounded cusps, edges of restoration protruding out of the level of adjacent dental surface, grooves on occlusal surface, loss of enamel without dentin exposure; grade 2 – severe erosion, more advanced signs than in grade 1 and with dentin exposure. The data was presented as frequency of occurrence of the particular categories of erosion severity in the subjects.

The dental erosion index described by O'Sullivan is based on a grade of severity of the lesions.[10] Codes are as follows: 0 – normal enamel; 1 – matt appearance of enamel surface without loss of contour; 2 – loss of enamel only (loss of surface contour); 3 – loss of enamel with dentin exposure (dentin-enamel junction visible); 4 – loss of enamel and dentin beyond dentin-enamel junction; 5 – loss of enamel and dentin with pulp exposure; 9 – unable to assess (for example due to large restoration, crowned tooth), location

on each tooth surface (codes: A – labial or buccal only; B – lingual or palatal only; C – occlusal or incisal only; D – labial and incisal/occlusal; E – lingual and incisal/occlusal; F – multi-surface) and area dimension of the lesion on the affected surface (codes: – less than half; + more than half of the affected surface).

BEWE index evaluates the lesions on all dental surfaces.[11] All teeth in sextants, except 3th molars, are assessed, but only the surface with the highest score in each sextant is recorded. The total BEWE score (cumulative score) is a sum of the scores in 6 sextants. Scores for the diagnosis of erosion are as follows: 0 – sound tooth; 1 – initial loss of surface texture; 2 – clear loss of hard dental tissues with less than 50% of the surface area affected, dentin is often exposed; 3 – pronounced loss of hard dental tissues with more than 50% of the surface area and dentin often exposed. Based on the cumulative score of all sextants, the BEWE index also assesses a level of erosion risk and provides management procedures. The risk level of dental erosion is "none" when the total score is less than or equal to 2, "low" between 3 and 8, "medium" between 9 and 13, and "high" for a score of 14 and over. The data and erosion risk level in the affected subjects were presented in aspect of distribution and seventy of erosive lesions.

The questionnaire survey was comprised of parameters referring to oral hygiene (frequency, duration and time of tooth brushing, brushing teeth immediately after intake of acidic food and beverages, type of toothbrush used – hard, medium, soft, electric powered, usage of fluoridated or nonfluoridated dentifrice) and dietetic habits (frequency of consumption of orange, apple or vegetable juices, carbonated and noncarbonated beverages, beverages with vitamin C, cocoa, milk, yogurt, herbal tea, oranges, apples, bananas, ketchup, mustard, vinegar dressing, sauerkraut, pickles), usage of chewing gum and use of a swimming pool. In the paper, only parameters showing a significant relationship with dental erosion were presented.

Statistical analysis of the data obtained was conducted with use of STATISTICA v. 12 PL (StatSoft, Inc., Tulsa, Oklahoma, USA) and Microsoft Excel spreadsheet using descriptive statistics, giving ranks for questionnaire replies. The hypothesis regarding no correlation with specified features was estimated with use of Pearson's χ^2 test with Yates correction or Fisher's exact test of independence and Spearman's rank correlation coefficient at significance level of $p < 0.05$.

The approval of the Bioethics Committee of the Wroclaw Medical University for the study was obtained (KB-291/2013).

Results

Frequency of dental erosion in all subjects amounted to 16.2%, and it was only slightly higher in boys compared to girls (18.5% vs 14.9%). Significantly more frequently the erosive lesions were present in lower teeth than in upper ones (Table 1). Even though a higher prevalence of the lesions was observed along with age (12.7% at the age of 12, 14.7% at the age of 15, and 20.2% at the age of 18), the differences were statistically insignificant. Only 3 subjects had lesions occurring simultaneously in both jaws (Table 2). Among all subjects, erosive lesions affected 86 teeth, which constituted 1.31% of present teeth in the oral cavity (86/6559). On the average, 2.2 teeth were affected by erosion.

According to the index reported by Lussi, more lesions restricted to the enamel or involving enamel and dentin were located on occlusal surfaces than facial ones (81.39% or 11.63% vs 6.98%).[9] Moreover, some lesions on occlusal surfaces already exposed the dentin (11.63%). We did not find any lesions located on the lingual surface of the teeth (Table 3).

Table 1. Frequency of dental erosion in all subjects

Frequency of erosive lesions	All subjects (n = 240)		Female (n = 148)		Male (n = 92)		Pearson's χ^2 test with Yates correction
	n	%	n	%	n	%	
Whole dentition	39	16.25	22	14.86	17	18.47	p = 0.577
Maxilla	12	5.00[a]	8	5.40	3	3.26	p = 0.951
Mandible	30	12.50[a]	15	10.13	16	17.39	p = 0.422

Significant difference between [a–a] at $p < 0.01$ level.

Table 2. Frequency of dental erosion in age groups of subjects in reference to the whole dentition, and upper and lower teeth

Frequency of erosive lesions	Age						Pearson's χ^2 test with Yates correction
	12 (n = 71)		15 (n = 75)		18 (n = 94)		
	n	%	n	%	n	%	
Whole dentition	9	12.67	11	14.67	19	20.21	p = 0.389
Maxilla	2	2.81	2	2.67	8	8.51	p = 0.135
Mandible	7	9.86	9	12.00	14	14.89	p = 0.722

Table 3. Grading of dental erosion according to the erosion index by Lussi in the whole dentition of all subjects

	Grade		n/N	%
Facial surfaces	1	concavity in enamel more wider than deep without involvement of dentin, cervically to the lesion intact enamel	6/86	6.98[a]
	2	exposure of dentin less than ½ of the dental surface	0	0
	3	exposure of dentin more than ½ of the dental surface	0	0
Occlusal surfaces	1	slight erosion, rounded cusps, edges of restorations protruding out of the level of adjacent dental surface, grooves on occlusal surfaces, loss enamel without dentin exposure	70/86	81.39[ab]
	2	severe erosion, more advanced signs than in grade 1 with dentin exposure	10/86	11.63[b]

Significant difference between [a–a], [b–b] at $p < 0.01$ level (Fisher's exact test of independence).

Based on the index developed by O'Sullivan, 72.1% of all affected teeth revealed erosion limited to the enamel, and the rest of them exposed the dentin.[10] Most of the erosive lesions were located on the occlusal surface (81.39%) and less of them on the labial/buccal surface (4.65%). More than 1 dental surface involved by the lesion was noticed in 3 subjects. Over half of the teeth presented the lesion area involving less than half of the dental surface (Table 4).

The dental erosion assessment with the use of the BEWE index showed that the lesions occurred almost symmetrically in posterior sextants of the maxilla and mandible, but most often in the 4th and 6th sextants. In a few subjects, the erosive lesions affected upper anterior teeth, while lower anterior teeth were untouched (Fig. 1). The mean value of the BEWE cumulative score was 2.23 ±1.42 (median 2), which could categorize the subjects in the group with low risk level of dental erosion.

The values of correlation coefficients between the potential erosion-associated factors and location of erosive lesions on dental surfaces categorized according to the indices of Lussi and O'Sullivan, as well as in sextants in accordance with the BEWE index are presented in Table 5.[9,10] Some differentiation of the significant correlations was noticed, which probably resulted from the different descriptive criteria of the indices. Generalizing, one could find the correlation of erosion occurrence

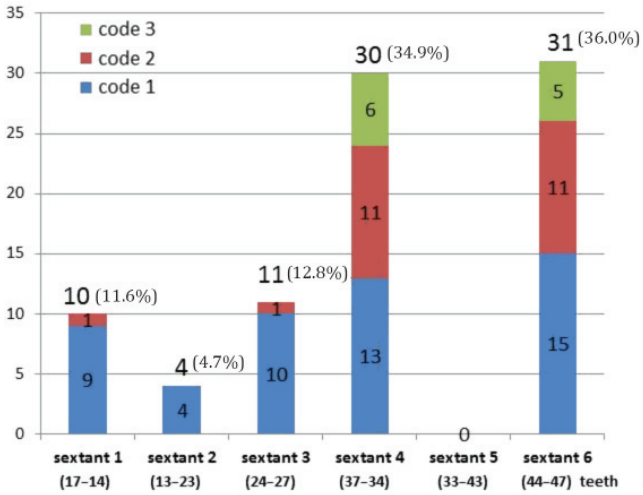

Fig. 1. Distribution o f dental erosion in sextants according to BEWE index

on labial/buccal surfaces with the consumption at least once a day of acidic vegetables and bananas (the last one only based upon the evaluation according to the index by Lussi).[9] In contrast, the presence of the lesions on occlusal surfaces was correlated with tooth brushing immediately after intake of acidic food, consumption at least once a day of cola, other carbonated and energy/sports beverages, acidic vegetables and ketchup (the last one

Table 4. Severity of erosive lesions according to the erosion index by O'Sullivan in the whole dentition of all subjects

Lesion severity	Whole dentition		Lesion location on dental surface	Whole dentition	
	n/N	%		n/N	%
Code 1: matt appearance of the enamel surface without of loss of contour	16/86	18.60	Code A: labial or buccal	4/86	4.65[a]
Code 2: loss of enamel only	46/86	53.50	Code B: lingual or palatal	0	
Code 3: loss of enamel with dentin-enamel junction visible	16/86	18.60	Code C: occlusal or incisal	70/86	81.39[a,b,c]
Code 4: loss of enamel and dentin beyond dentin-enamel junction	8/86	9.30	Code D: labial and incisal/occlusal	9/86	10.46[b]
Code 5: loss of enamel and dentin with the pulp exposure	0		Code E: lingual and incisal/occlusal	0	
Code 9: unable to assess	0		Code F: multi- surface	3/86	3.50[c]
Area of surface affected by erosion	**All lesions**		**Area of surface affected by erosion**	**All lesions**	
	n/N	%		n/N	%
< 50%	48/86	55.81	> 50%	38/86	44.19

Significant difference between [a–a], [b–b], [c–c] at $p < 0.01$ level (Fisher's exact test of independence).

Table 5. Values of Spearman's rank correlation coefficients (rho) between components of erosion indices and hygienic and dietetic parameters

Parameter	Erosion index by Lussi[9]		Erosion index by O'Sullivan[10]		BEWE erosion index		
	dental surface		location: dental surface		Sextants		
	facial	occlusal	C: occlusal	D: labial and occlusal	2 teeth 13–23	4 teeth 37–34	6 teeth 44–47
Frequency of brushing teeth immediately after consumption of acidic food*	rho = –0.010 p = 0.383	rho = 0.168 p = 0.010	rho = 0.146 p = 0.024	rho = –0.010 p = 0.873	rho = –0.010 p = 0.873	rho = –0.010 p = 0.873	rho = 0.106 p = 0.101
Frequency drinking of cola**	rho = –0.031 p = 0.637	rho = 0.171 p = 0.008	rho = 0.141 p = 0.030	rho = –0.031 p = 0.637	rho = –0.031 p = 0.637	rho = 0.177 p = 0.006	rho = 0.097 p = 0.134
Frequency drinking of energy/sport beverages**	rho = –0.013 p = 0.836	rho = 0.218 p = 0.001	rho = 0.197 p = 0.002	rho = –0.013 p = 0.836	rho = –0.013 p = 0.836	rho = 0.149 p = 0.021	rho = 0.156 p = 0.016
Frequency drinking of carbonated beverages**	rho = 0.064 p = 0.326	rho = 0.052 p = 0.420	rho = 0.072 p = 0.265	rho = 0.064 p = 0.326	rho = 0.174 p = 0.007	rho = 0.028 p = 0.671	rho = 0.053 p = 0.415
Frequency consumption of acidic vegetables**	rho = 0.498 p = 0.001	rho = 0.262 p = 0.001	rho = 0.226 p = 0.001	rho = 0.498 p < 0.001	rho = –0.008 p = 0.897	rho = 0.266 p < 0.001	rho = 0.288 p < 0.001
Frequency consumption of ketchup**	rho = –0.043 p = 0.508	rho = 0.087 p = 0.177	rho = 0.144 p = 0.026	rho = –0.043 p = 0.508	rho = –0.043 p = 0.508	rho = 0.070 p = 0.279	rho = 0.094 p = 0.148
Frequency consumption of bananas**	rho = 0.135 p = 0.036	rho = –0.026 p = 0.691	rho = –0.055 p = 0.398	rho = –0.058 p = 0.373	rho = –0.058 p = 0.373	rho = –0.057 p = 0.379	rho = –0.029 p = 0.649

* – never or sometimes vs always, ** – once a week, once a month or less than once a month vs at least once a day or more.

only based upon the evaluation with use of the index by O'Sullivan).[10] In turn, according to the BEWE index, erosion occurrence in anterior upper teeth was correlated with the consumption of bananas and in posterior lower teeth with the drinking of energy/sports beverages and consumption of acidic vegetables, and only in teeth from the 4th sextant with the drinking of carbonated beverages.

Discussion

The prevalence of dental erosion in permanent teeth among children and adolescents is highly differentiated in different countries. It ranges from 5.5 to 65.34%; at the age of 12 years from 13 to 56.1%, at the age of 15 years from 24 to 44.2%, and at the age of 18 years from 22.2 to 55.5%.[12–18] Moreover, a comparison of the data from the literature regarding frequency and severity of dental erosion is hindered by the use of various scoring systems (e.g., the Eccles index, Tooth Wear index by Smith and Knight, Simplified-Tooth Wear Index, Evaluating Index of Dental Erosion, index by O'Brien, index by Lussi, index by O'Sullivan and BEWE scoring system).[19,20] In Polish youth, erosive lesions occurred at close to the same rate as those reported in the literature, aged 15 years 24.7% and aged 18 years 42.3% (evaluation according to the BEWE index).[21,22] However, among adolescents aged 15 years living in the Lower Silesia region (including Wrocław), the frequency of dental erosion was higher than in Poland generally (36.1% vs 24.7%).[23] Our data indicated a lower frequency of dental erosion among children and adolescents from Wrocław aged 12–18 years: 16.2% (at the age of 12 years – 12.7%, at the age of 15 years – 14.7%, and at the age of 18 years – 20.2%). The observed increase of dental erosion frequency along with the age of the subjects was noticed in previously published papers.[13,18] It probably resulted from longer time of the teeth's presence in the oral environment and longer exposure onto erosive factors. An earlier study performed in 12-year-olds from Wrocław with use of the index by Lussi showed lower than the current erosion frequency (8.3% vs 12.7%), which could suggest a progressive increase of this pathology.[24]

A more frequent occurrence of erosive lesions in males compared to females was found by Arnadottir et al. and McGuire et al., and in our study the same tendency was also noticed (18.47% vs 14.86%, respectively).[25,26]

All of the indices used in our study identified the same number of erosion-affected teeth but not their severity; according to the index by Lussi, the lesions limited only to the enamel involved 76 teeth, and 10 teeth with lesions exposing the dentin, whereas in accordance with the criteria of the index by O'Sullivan, there were 62 and 24 affected teeth, respectively. A similar inconsistency regarding the severity of erosive lesions and, moreover, differences in frequency was reported by Margaritis et al., who, for dental erosion assessment, simultaneously used 3 indices – the BEWE, Simplified Tooth Wear Index (STWI) and Evaluating Index of Dental Erosion (EVIDE).[27] Therefore, a comparison of the data requires taking into account the diagnostic criteria of the indices used or to apply a commonly accepted index. The European Federation of Conservative Dentistry recommends as a suitable index for classification of dental erosion the BEWE, which links the grading of lesions with clinical management.[1,9] In our study, the erosive lesions classified in accordance with the BEWE revealed that the most frequently affected were lower molars and mainly the lesions were restricted to the enamel. The BEWE cumulative score calculated per all affected subjects was

2.23 ±1.42, which could place the subjects in the group with a low risk level of dental erosion. At this risk level, the recommended clinical management is based on the following procedures: oral hygiene and dietary assessment, advice, routine maintenance and observation repeated at 2-year intervals.[9]

Studies have shown a significant relationship between the prevalence of dental erosion and the frequency and quantity of acidic beverages drunk by children and adolescents.[13,15,16] Dugmore and Rock evaluated the nutritional habits of subjects from Great Britain at the age of 12 and again at the age of 14 years.[15] They showed that the consumption of carbonated beverages among the subjects aged 12 years caused a 1.46-fold increase of erosion risk and among the subjects aged 14 years the erosion risk was 2.21 times higher. When the consumption of these beverages was 4 or more times a day, a significantly higher risk was observed, 2.23-fold for those aged 12 years and 5.13-fold higher for those aged 14 years. However, intake of other fruits than citrus or apples caused little risk of erosion development. Al-Dlaigan et al., studying British adolescents at the age of 14 years found a significant positive correlation between the frequency of erosive lesions on the buccal/lingual dental surfaces with the drinking of carbonated and noncarbonated beverages and energy drinks and consumption of fresh fruits (apples, oranges, bananas, grapes), as well as intake of tablets with vitamin C.[28] In turn, Okunseri et al. found some increase of dental erosion prevalence along with frequency of drinking apple juice among 13–19-year-olds from the USA.[13] Hasselkvist et al. also observed a significant correlation of dental erosion prevalence with soft drink intake among 13–14-year-olds and 18–19-year-olds from Sweden.[18] Our results have confirmed the previously reported links between nutritional habits and dental erosion development. They also indicate that, at least once a day, drinking cola, carbonated beverages or energy/sports drinks and consumption of pickled vegetables, ketchup and bananas was significantly related with dental erosion development. Bananas are perceived, in general, as sweet fruits, however their pH is in the acidic range (from 4.50 to 5.20).[29] A relationship between dental erosion and declared tooth brushing directly after intake of acidic foods also was found in our study. In such situations, the enamel softened by dietetic acid is easily lost due to less resistance to the abrasive influence of the toothbrush and dentifrice.

Preventive management against dental erosion is directed to diminish or arrest lesion progression and therapeutic procedures to restore the loss of hard dental tissues and elimination of dentin hypersensitivity, if present, in connection with preventive measures.

The present study had a limitation because of the relatively small sample of the subjects. More research should be done to determine the main risk factors of the development of dental erosion in the young population.

Conclusions

The frequency of dental erosion in children and adolescents aged 12 to 18 years was 16.25%. Mostly, the erosive lesions were limited to the enamel and located on lower molar teeth. The subjects revealed low dental erosion risk according to the BEWE criteria. The occurrence of erosive lesions was significantly correlated with drinking cola, energy drinks and other carbonated beverages as well as consumption of acidic food and bananas. Dental erosion can become a more important problem of oral health among children and adolescents due to frequent consumption of acidic beverages and food. Therefore, there is a need to promote awareness in dentists to make an early diagnosis and to assess the dietetic factors promoting to development of erosive lesions.

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Oral health parameters in the regional study among young seniors in an urban area of Wrocław

Wykładniki zdrowia jamy ustnej w regionalnym badaniu młodych seniorów miejskiego rejonu Wrocławia

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Abstract

Background. Regional cross-sectional surveys are a vital addition to nationwide epidemiological studies. They are characterized by greater intensification of risk factors distribution, and the conclusions drawn therefrom are better suited to local gerostomatological treatment needs.

Objectives. The aim of the study was to examine young seniors (aged 65–74) in the Wrocław urban area and to assess the number of teeth, the prevalence of caries and periodontitis, as well as clinical lesions in oral mucosa. Also, the aim was to confirm the influence of local and general classical risk factors associated with these pathologies.

Material and methods. The following indexes were assessed: PI, API, BoP, PD, CAL, DMFT index and its components, number of teeth and occlusal supporting zones. CPI index was assessed based on periodontal examination, and then a periodontal diagnosis was given if present pathological lesions were noted.

Results. The average number of remaining teeth is 13.2 in the entire study group, the proportion of subjects with edentulism is 14.1%. DMFT index amounts to 17.45, and the percentage of people with periodontitis is 42%, including 18.9% with a severe form. The study has revealed a very high prevalence of treated hypertension (almost half of the subjects) and cardiovascular diseases, very high prosthetic needs for more than 70% of subjects, and very poor oral hygiene: only 20% of subjects brush their teeth correctly, and only 7% clean their interdental spaces. A significantly higher prevalence of dental caries and higher periodontal exponents have been found in men. It has been shown that current tobacco dependence had a significant negative impact on the reduction of the number of teeth and severity of periodontitis. Socioeconomic factors had the biggest impact upon the number of remaining teeth and oral hygiene.

Conclusions. The study has shown an increase in the remaining teeth number in young seniors of Wrocław, despite the absence of a notable improvement in the incidence of dental caries and periodontitis, and it has also confirmed a significant influence of classical risk factors related to tooth loss and periodontitis.

Key words: periodontitis, epidemiology, periodontitis prevalence, tooth loss

Słowa kluczowe: zapalenie przyzębia, epidemiologia, występowanie zapaleń przyzębia, utrata zębów

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The theory of demographic transition, formed at the end of the 20th century, emerged from profound changes in Europe's post-industrial societies in the sphere of values, standards, behaviors, and attitudes, leading primarily to a decline in the willingness to marry, a tendency to marry later in life, a decrease in the number of children in a family, and a trend to bear children later in life. The consequence of the so-called second demographic transition is a decline in birth rate, a decrease in population or – at least – a stabilization of the population, a distinct change in the age structure, with a tendency for a decline in the working-age population, faster aging of societies, and prolonged life span. In Europe, the proportion of people over 65 years of age is currently around 16.4%, and it is estimated to reach 27.6% in 2050.[1] In Poland, the percentage of people over the age of 65 accounted for 15.5% in 2015, and it is estimated that in 2050 this proportion may reach 26.9%.[2] These changes involve an increased interest in many aspects of the health of the elderly, including the evaluation of oral health indicators and the determination of gerostomatological treatment needs. Epidemiological studies reveal that main oral pathologies in the elderly are tooth loss, tooth decay, periodontitis, and oral pre-cancer and cancer lesions.[1] In 2010, the disability-adjusted life years (DALYs) per capita index for different regions of the world shows highest values for all oral conditions for Eastern (357) and Central Europe (334), and its global values related to dental conditions are highest for severe periodontitis (108), severe (less than 10) tooth loss (106) and untreated dental caries (73).[3] For the elderly in developing countries, however, the main dental problem is tooth loss and the need for prosthetic treatment. An analysis of a 20-year trend for most world countries indicates a 45% reduction in the prevalence of tooth loss with the peak in incidence remaining around the age of 65.[4] Still, these positive changes affect Eastern Europe in the slightest degree. In Europe, 3 countries with the highest average number of teeth in the elderly exceeding 20 is Sweden – 24.5, Denmark – 22.4, and Switzerland – 22.2.[5] Therefore, one of the WHO's announced objectives regarding the presence of more than 20 teeth in 80-year-old people is met only in these 3 countries. The lowest proportion of edentulism in the 65–74 age group also occurs in these 3 countries: Sweden – 2.7%, Switzerland – 6.7%, and Denmark – 6.8%; and the highest is reported for the Czech Republic – 18.7%, Slovenia – 19.2%, and the Netherlands – 27.6% (the comparative analysis is based on data from 15 countries, excluding Poland).[5] The varying numbers of remaining teeth reflect rather national differences in the focus of oral health care between prevention and repair. This assessment stems from the fact that there are no significant changes in the global prevalence and incidence of dental caries and periodontitis,which are the main medical causes of tooth loss.[6–8] The prevalence and incidence of untreated dental caries in older patients has remained unchanged over the past 20 years, with the third peak of incidence around the age of 70. This is partly due to the occurrence of dental root caries at this age. The incidence peak for periodontitis occurs about the age of 38, and the prevalence of severe periodontitis reaches its maximum around the age of 40, and then it remains stable.[6,7] The loss of connective tissue attachment, progressing with age, causes the proportion of pathological changes in the elderly's periodontium to remain at a high level (especially if we apply the definition of periodontal inflammation, taking into account this parameter), leading to gum recession in a greater degree rather than to generalized new cases of severe periodontitis. The majority of the elderly suffer from persistent, localized and moderate forms of periodontitis, because the most severe forms cause tooth loss usually between the ages of 40 and 60. Attention should be paid to the methodological shortcomings of the CPI previously used in epidemiological studies among the elderly in Europe (underestimation of real prevalence and the extent of periodontal inflammation). Therefore, in modern studies, it is vital to determine both pocket depth and loss of attachment. In an epidemiological examination of an elderly patient's oral health, it is necessary to assess the clinical pathology of the mucous membrane, in particular pre-cancerous and cancerous lesions. They are not frequent, but they can have catastrophic individual consequences, especially in people with synergistic effects of nicotine and heavy alcohol abuse or with an infection caused by oncogenic forms of human papillomavirus (HPV).

All of the most common oral pathologies in the elderly have a multifactorial etiology. The level of epidemiological examination allows for the assessment of the influence of local factors, oral hygiene or health promotion and general behaviors, smoking, obesity, selected systemic diseases, and social and economic conditions. Particularly interesting are the two-way relationships between systemic pathologies frequent at this age (diabetes, obesity and metabolic syndrome) and oral health. Confirming the real impact of general and/or local factors allows for applying more causal and personalized multi-specialist action by, for instance, eradicating smoking or establishing the metabolic control of diabetes, as well as using the risk assessment tool.[9]

Attention is drawn by significant differences in the global prevalence of edentulism, number of remaining teeth, morbidity, and incidence of dental caries and periodontitis. In 2010, severe periodontitis ranged from 4.5% reported for the population of Oceania, to 20.4% reported for inhabitants of Southern Latin America.[6] These differences may be substantial, even within a country; for instance, the fourth German Dental Health Survey of 2005 shows that differences in the number of teeth between seniors aged 65–74 years from the western and eastern Länder were 14.1 vs 12.5, respectively.[10] Therefore, a representative regional research is a valuable supplement to a nationwide epidemiological research. Regional research is characterized by less diversified distribution of risk factors such as social and economic ones, and conclusions derived therefrom are more suited to local gerostomatological treatment needs.

The aim of this cross-sectional epidemiological study of the inhabitants of Wrocław aged 65 to 74 years is to evaluate the number of remaining teeth and related prosthodontic treatment needs, assess the prevalence of dental caries and periodontal disease as well as lesions in oral mucous membrane, and to confirm the influence of local classical risk factors associated with these pathologies. The findings regarding the examined population will also be compared with the contemporary Polish and European regional epidemiological studies on the oral health of young seniors.

Material and methods

The study was conducted in Wrocław (Department of Periodontology, Wroclaw Medical University) and in Oława, a town located 40 km from Wrocław, with 35,000 inhabitants (private dental practice in Oława). At the Ministry of the Interior and Administration in Warszawa, a group of 1,000 people aged 65–74 years was randomly selected for Wrocław by means of a two-tier drawing method, and a group of 600 people was randomly selected for Oława in the same way. Therefore, a total of 1,600 inhabitants of Wrocław region were selected, with a symmetrical age and gender structure. The project leader invited (by letter and, if possible, by phone) the persons drawn to take part in the study at their own convenience. In the period between June 25th 2017 and August 1st 2017, 256 inhabitants of Wrocław (response rate 25.6%) and 77 inhabitants of Oława (response rate 12.8%) responded to the invitation. These persons submitted their written consent to participate in the study and to data processing by signing statements approved by the Bioethics Committee of Wroclaw Medical University (approval number 481/2013). The applied exclusion criteria for periodontal examination were as follows: general contraindications (e.g., the history of bacterial endocarditis) and local contraindications (e.g., acute odontogenic infection).

The examination was performed in artificial lighting, with the use of a dental mirror and WHO-621 periodontal probe. On one side the probe was marked with 1 mm sections, on the other side it was marked at 3.5 mm, from 3.5 to 5.5 mm, 8.5 and 11.5 mm, and had a 0.5 mm sphere end. The collected data was archived in the epidemiological research form used in previous surveys commissioned by the Ministry of Health in the years 2013–2014.[11]

The following information was obtained in the interviews: age, education (primary, intermediate, higher), income per family member (up to 800 PLN, 801–1,500 PLN, 1,501–2,500, and over 2,500 PLN), nicotine addiction (never smoked – person who never smoked or have smoked less than 100 cigarettes; former smoker – persons who used to smoke at least 1 cigarette a day, currently not smoking and the abstinence period is longer than 365 days; current smoker – person who smoke at least 1 cigarette a day and person who have smoked for at least 6 recent months), selected systemic diseases (diabetes, cardiovascular diseases including cardiomyopathy or stroke, hypertension, osteoporosis), cause of tooth loss (dental caries, periodontitis, other), oral health promoting behaviors (average number of dental appointments per year in the recent 5-year period, the most frequent reason to seek dental treatment, frequency of daily tooth brushing, toothbrush replacement intervals, regular cleaning of interdental spaces, dental treatment funding – only in state-financed facilities, only in private facilities, or mixed way). Weight and height of the subjects were measured to calculate the body mass index (BMI). The following aspects were assessed in a clinical examination: number of teeth (excluding the third molar teeth), number of occlusal supporting zones of natural teeth or fixed prosthetic restorations, plaque on vestibular and lingual surfaces (PI index according to O'Leary et al. was assessed) and also on interdental surfaces (API index according to Lange et al.), bleeding on probing at 4 points around the tooth: distal-buccal, mid-buccal, proximal-buccal and mid-lingual (inflammation extension index, BoP, according to Ainamo and Bay[14]), sulcus/pocket depth in 4 analogous points (average PD value for all examined sites and pockets more than 5 mm), and clinical attachment level – CAL (number of sites with attachment loss on interproximal surfaces greater than or equal to 3 mm, greater than or equal to 5 mm and number of gingival recession index greater than or equal to 3 mm).[12–14] Community Periodontal Index (CPI) was assessed based on the result of periodontal examination, and then a periodontal diagnosis was given in line with the recommendations of Centers for Disease Control and the American Academy of Periodontology (CDC/AAP).[15–17] PEF index and its components were also assessed. Clinical examination of pathological lesions in oral mucosa was conducted (no developmental defects and lesions that do not require treatment were taken into account, e.g., displaced sebaceous glands or varicose veins).

All the investigators (periodontology specialists) were calibrated at the Department of Periodontal and Oral Mucosa Diseases at the Medical University of Warsaw before the project started.

Mean values, medians, ranges (min–max), variances, and standard deviations (SD) of the assessed continuous parameters were calculated for all groups in descriptive statistics. The hypothesis of equality of means in 2 groups was verified with the Mann-Whitney test due to the absence of normal distribution, as verified by the Kolmogorov-Smirnov test with the Lilliefors correction. The hypothesis of equality of means in more than 2 groups was verified with the ANOVA variance analysis, and for groups with non-homogeneous variance with the nonparametric test of Kruskal-Wallis on ranks (variance homogeneity was checked with Levene's test). For parameters that showed statistically significant differences in the comparison of all 3 groups, post-hoc tests were used (Scheffé's contrast analysis). For discrete parameters, the frequency of features in groups was analyzed by

the χ^2 df test (sometimes with the Yates correction) with the corresponding degrees of freedom df = (m – 1)(n – 1), where m = number of rows, n = number of columns. For each test p-value < 0.05 was considered statistically significant. Statistical analysis was performed with the use of STATISTICA v. 13.1 computer package.

Table 1. Characteristics of the study population

Variables	Values				
Gender	women: 175 (52.5%)		men: 158 (47.4%)		
Education	8 y: 72 (21.6%)		12 y: 170 (51.1%)		16 y: 91 (27.3%)
Income	very low: 43 (12.9%)	low: 138 (38.4%)	low-middle: 105 (31.5%)	middle and high: 57 (17.1%)	
Smoking	non: 185 (55.5%)		former: 96 (28.8%)		smokers: 52 (15.6%)
BMI	< 25: 92 (27.6%)		25–30: 145 (43.5%)		> 30: 96 (28.8%)
Systemic diseases	diabetes: 63 (18.9%)	cardiovascular: 98 (29.4%)	infarction/stroke: 41 (12.3%)	hypertension: 160 (48%)	osteoporosis: 38 (11.4%)
Number of teeth	13.21 ±8.3 median: 15		persons with less than 10 teeth: 70 (21%)		persons with more than 20 teeth: 71 (21.3%)
Tooth loss	total: 4920		due to caries: 3987 (81.1%)		due to periodontitis: 933 (18.9%)
Edentulism	47 (14.1%)				
Functional masticatory units	4: 39 (11.7%)	3: 38 (11.4%)	2: 43 (12.9%)	1: 41 (12.3%)	0: 172 (51.6)
Prosthodontic treatment needs	no: 91 (27.3%)				
	yes: 242 (72.6%)		fixed: 188		removable: 288
Dental caries	DMFT: 17.45 ±6.49	D: 1.0 ±1.91	M: 11.97 ±7.7	F: 4.42 ±4.14	
Oral hygiene	PI mean: 50.8 ±32.2		< 20: 59 (20.6%)		> 60: 118 (41.2%)
	API mean: 66.7 ± 28.0		< 25: 20 (7%)		> 70: 124 (43.3%)
BoP	mean: 36.6 ±26.7		< 10: 49 (17.1)		> 50: 75 (26.2%)
PD	2.52 ±0.71 (median 2.29)			PD > 5 mm: 88 (26.4%)	
CAL	CAL ≥ 3 mm: 267 (93.3)			CAL ≥ 5 mm: 130 (45.5)	
CPI	CPI0: 0	CPI1: 38 (11.4%)	CPI2: 72 (21.6%)	CPI: 85 (25.5%)	CPI4: 86 (25.8%)
Periodontitis according to CDC/AAP	140 (42%)	mild – 15 (4.5%)			
		moderate – 62 (18.6%)			
		severe – 63 (18.9%)			
Seeking dental treatment	less than once a year: 105 (31.5%)	once a year: 119 (35.7)	twice a year: 67 (20.1%)	more than 3 times a year: 42 (12.6%)	
The main reason of dental visit	pain: 138 (41.4%)	control: 132 (39.6%)	prosthetic treatment: 46 (13.8%)	periodontal problems: 12 (3.1%)	esthetics: 5 (1.5%)
Tooth brushing per day	less than once a day: 27 (8.1%)	once a day: 67 (20.1%)	twice a day: 189 (56.7%)	more than 3 times a day: 50 (15%)	
Frequency of toothbrush replacement	less than once a year: 28 (8.4%)	once a year: 47 (14.1%)	two to four times a year: 198 (59.4%)	more than four times a year: 60 (18%)	
Regular flossing	no: 270 (81.1%)			yes: 63 (18.9%)	
Type of payment for dental treatment	reimbursed services: 111 (33.3%)		private treatment: 120 (36%)		mixed: 102 (30.6%)

BMI – body mass index; BoP – Bleeding on Probing; PD – Probing Depth; CAL – Clinical Attachement Level; CPI – Community Periodontal Index; CDC/AAP – Center for Disease Control/American Academy of Periodontology.

Results

The overall characteristics of the entire study group is shown in Table 1. The average number of the remaining teeth is 13.2, the proportion of people with edentulism is 14.1%, DMFT amounts up to 17.45, the percentage of people with periodontitis according to the CDC/AAP is 42%, including 18.9% with a severe form. Attention is drawn to the relatively low socioeconomic status of the patients, as only 17% declare income above 2,500 PLN per family member, and as only 27% of patients declare having a college degree, high prevalence of treated hypertension (almost half of the subjects) and cardiovascular diseases, very high prosthetic needs for more than 70% of patients, and very poor oral hygiene: only 20% brush their teeth correctly, and only 7% clean their interdental spaces (less than 19% of seniors declare performing this procedure). Less than 1/3 of the subjects have regular dental appointments or checkups, and only 1.5% of the subjects wish to have their dental esthetics improved. For the entire group, 27 clinical diagnoses of pathological lesions in oral mucosa have been made. These are given here in descending order of frequency: denture-related stomatitis and hemangiomas – 21 cases; fibroma – 14; angular cheilitis – 10; scrotal tonque – 9; keratoses – 6; xerostomia and lichen planus – 5; leukoplakia and coated tongue – 4; candidosis, herpes labialis, smoker's palate, geographic tongue, and black hairy tongue – 3; recurrent aphthous stomatitis, Sjögren syndrome, burning mouth syndrome, melanotic macules, naevi, lingua crenata, and papilloma – 2; gingival epulis, halitosis, papillary epithelial hyperplasia, tongue cancer, leukoedema – 1.

The association between the place of residence and dental indicators and oral health behaviors is presented in Table 2. It can be seen that the number of remaining teeth among young seniors in Wrocław is significantly higher

Table 2. Comparison of dental and behavioral parameters between inhabitants of big city (Wrocław) and town (Oława)

Dental and behavioral parameters		Wrocław (n = 256)	Oława (n = 77)	p-value
Number of teeth	means	13.98 ±8.17	10.63 ±8.26	0.001
	< 10 (%)	63 (24.6%)	8 (10.4%)	0.007
	> 20 (%)	51 (19.9%)	19 (24.7%)	0.001
Edentulism (%)		30 (11.7%)	17 (22.07%)	0.022
Remaining min. 2 masticatory units (%)		99 (38.7%)	21 (27.3%)	0.06
Prosthodontic treatment needs (%)		184 (71.8%)	58 (75.3%)	0.56
Caries	DMF	17.05 ±6.36	18.8 ±6.8	0.029
	D	1.04 ±2.03	0.87 ±1.45	0.65
	M	11.35 ±7.48	14.08 ±8.1	0.008
	F	4.58 ±4.2	3.92 ±3.94	0.21
Probing depth means		2.55 ±0.73	2.42 ±0.63	0.15
Persons with PD > 5 (%)		72 (28.1%)	16 (20.7%)	0.19
Persons with CAL ≥ 3 (%)		207 (80.8%)	60 (77.9%)	0.57
CPI1 (%)		25 (9.8%)	13 (16.9%)	0.08
CPI3 + CPI4 (%)		134 (52.3%)	37 (48.1%)	0.51
CPI4 (%)		70 (27.3%)	16 (20.7%)	0.25
Periodontitis according to CDC total (%)		114 (44.5%)	26 (33.8%)	0.09
Periodontitis according to CDC severe (%)		53 (20.7%)	10 (12.9%)	0.12
PI		47.6 ±31.7	62.9 ±31.6	0.001
API		65.2 ±28.0	72.7 ±27.6	0.051
BoP		36.2 ±27.2	38.2 ±25.1	0.55
Regular dental appointments (at least once a year) (%)		178 (69.5%)	50 (64.9%)	0.45
Regular brushing (at least twice a day) (%)		191 (74.6%)	48 (62.3%)	0.0359
Regular flossing (%)		54 (21.1%)	9 (11.7%)	0.06

Table 3. Gender stratified dental and behavioral parameters

Dental and behavioral parameters		Wrocław (n = 256)	Oława (n = 77)	p-value
Number of teeth	means	13.65 ±8.14	12.81 ±8.46	0.32
	> 20 (%)	37 (23.4%)	34 (19.4%)	0.37
	< 10 (%)	34 (21.5%)	36 (20.5%)	0.83
Edentulism (%)		18 (11.3%)	29 (16.6%)	0.17
Remaining min. 2 masticatory units (%)		61 (38.6%)	59 (33.7%)	0.35
Prosthodontic treatment needs (%)		122 (77.2%)	120 (68.6%)	0.77
Caries	DMF	16.81 ±6.51	18.04 ±6.43	0.15
	D	1.33 ±2.32	0.7 ±1.38	0.002
	M	11.16 ±7.41	12.7 ±7.88	0.09
	F	4.23 ±3.84	4.6 ±4.4	0.67
Probing depth means		2.62 ±0.76	2.42 ±0.66	0.008
Persons with PD > 5 (%)		51 (32.2%)	37 (21.1%)	0.021
Persons with CAL ≥ 3 (%)		129 (81.6%)	138 (78.8%)	0.52
CPI1 (%)		12 (7.6%)	26 (14.8%)	0.037
CPI3 + CPI4 (%)		88 (55.6%)	83 (47.4%)	0.13
CPI4 (%)		50 (31.6%)	36 (20.6%)	0.021
Periodontitis according to CDC total (%)		75 (47.5%)	65 (37.1%)	0.056
Periodontitis according to CDC severe (%)		36 (22.7%)	27 (15.4%)	0.087
PI		60.18 ±31.35	41.81 ±30.51	0.0000
API		75.77 ±25.15	58.15 ±28.01	0.0000
BoP		42.27 ±28.08	31.21 ±24.36	0.0005
Regular dental appointments (at least once a year) (%)		105 (66.4%)	123 (70.3%)	0.45
Regular brushing (at least twice a day) (%)		99 (62.6%)	140 (80%)	0.0004
Regular flossing (%)		13 (8.2%)	50 (28.6%)	0.0000

DMF – Decay, Missing, Filling; PD – Probing Depth; CAL – Clinical Attachement Level; CPI – Community Periodontal Index; CDC – Center for Disease Control; PI – Plaque Index; API – Approximal Plaque-Index; BoP – Bleeding on Probing.

due to the greater frequency of tooth removal caused by caries in smaller towns. This probably leads to a greater prevalence of edentulism in this age group, although the difference in severe tooth loss (< 10) is not significant. The indicators of periodontitis do not differ significantly between residents of these 2 urban environments. Younger seniors from a large city are more likely to brush their teeth regularly, which contributes to less plaque on the vestibular and lingual surfaces. As far as flossing and cleaning of interdental spaces are concerned, the trend is similar, although it is not at the level of statistical significance. The most common pathologies of oral mucous membrane found among the inhabitants of Wrocław are: denture-related stomatitis – 17 cases, haemangiomas – 16, fibroma – 12; among the inhabitants of Oława: hemangiomas – 5 cases, denture-related stomatitis, angular cheilitis, and xerostomia – 4 cases. A recurrence of tongue cancer (following removal) has been diagnosed in a 66-year-old female resident of Oława.

The influence of gender has been particularly visible in oral health promoting behaviors (Table 3). Regular brushing and flossing have been found considerably more frequently among women, which is probably the main reason for the remarkably better oral hygiene and less extensive gingivitis than in men. On the other hand, among men the incidence of dental caries was significantly higher (p = 0.002), along with periodontal indicators (deeper periodontal pockets, higher percentage of subjects with pockets deeper than 5 mm and higher percentage of subject with CPI4). Sexual dimorphism related to clinical dental parameters did not translate into differences in the number of teeth and incidence of edentulism.

The control group for the occurrence of systemic diseases comprised of subjects who did not have the history of a systemic disease affecting oral health, in the light of current medical knowledge, or were not treated for a long time (80 people). No statistical relationship between diabetes and cardiovascular diseases and the analyzed dental indicators and oral hygiene behavior descriptors has been shown (Table 4). Considerably more frequent extractions of periodontal teeth and a lower DMFT index were found in patients with previous myo-

Table 4. Association of dental and behavioral parameters with systemic diseases

Dental and behavioral parameters		Diabetes (n = 63)	Cardiovascular disease (n = 96)	Infarction/ stroke (n = 41)	Osteoporosis (n = 38)	Hypertension (n = 78)	Control (n = 80)
Number of teeth	means	11.8 ±8.0	12.2 ±8.4	11.7 ±8.8	14.6 ±8.6	14.4 ±8.2	12.8 ±8.1
	> 20 (%)	9 (15.0%)	18 (18.7%)	6 (14.6%)	12 (31.5%)	16 (20.5%)	15 (18.7%)
	< 10 (%)	10 (15.8%)	19 (19.9%)	5 (12.2%)	7 (18.4%)	14 (17.9%)	21 (26.2%)
Edentulism (%)		10 (15.8%)	18 (18.7%)	10 (24.4%)	4 (10.5%)	9 (11.5%)	11 (13.7%)
Caries	DMF	17.2 ±6.4	16.4 ±7.41	14.6 ±7.3[a]	18.0 ±6.1	17.7 ±6.5	17.8 ±6.6
	D	0.97 ±1.6	0.96 ±1.0	1.09 ±2.2	0.84 ±1.5	0.8 ±1.4	1.35 ±2.5
	M	12.4 ±7.3	11.6 ±8.0	9.97 ±7.5	11.9 ±8.3	11.9 ±8.0	12.1 ±7.4
	F	3.6 ±3.9	3.7 ±3.8	3.6 ±3.5	5.2 ±4.9	5.0 ±4.1	4.3 ±3.9
PD	means	2.48 ±0.58	2.59 ±0.73	2.62 ±0.8	2.5 ±0.7	2.44 ±0.6	2.62 ±0.88
	persons with PD > 5 OR 95% CI	1.15 (0.9–1.4)	1.0 (0.8–1.07)	1.07 (0.9–1.3)	0.92 (0.8–1.1)	1.07 (0.9–1.3)	Ref.
Persons with CAL ≥ 3 OR		0.96 (0.8–1.1)	0.93 (0.9–1.0)	0.95 (0.8–1.1)	1.02 (0.9–1.1)	1.05 (0.9–1.1)	Ref.
Periodontitis as cause of tooth loss		3.69 ±6.9	4.2 ±7.4	6.27 ±9.2[b]	1.42 ±4.1	1.59 ±5.3[c]	3.0 ±4.7
CPI	CPI0 OR 95% CI	0.96 (0.6–1.5)	0.76 (0.5–1.2)	0.79 (0.4–1.5)	0.99 (0.5–1.3)	1.35 (0.8–2.3)	Ref.
	CPI3 OR 95% CI	1.08 (0.8–1.5)	0.99 (0.7–1.4)	1.13 (0.7–1.9)	0.97 (0.6–1.6)	1.29 (0.9–1.9)	Ref.
	CPI4 OR 95% CI	0.88 (0.6–1.2)	1.06 (0.6–1.8)	0.83 (0.4–1.6)	1.01 (0.5–2.2)	0.93 (0.5–1.7)	Ref.
Periodontitis according to CDC/AAP Severe OR 95% CI		1.17 (0.3–4.5)	2.19 (0.7–6.8)	2.48 (0.5–11.4)	1.14 (0.3–4.3)	0.18 (0.04–0.76)	Ref.
Oral hygiene	PI	56.8 ±32.0	50.2 ±32.3	48.4 ±32.4	40.7 ±29.7	51.9 ±29.8	52.4 ±33.2
	API	67.2 ±27.9	70.5 ±27.3	68.7 ±29.3	54.7 ±28.8[d]	65.7 ±25.8	68.3 ±27.2
BoP		38.7 ±29.3	39.7 ±27.5	42.0.7 ±28.6	40.4 ±28.1	33.7 ±24.9	38.3 ±29.2
Regular dental appointments (at least once a year) OR		1.16 (0.8–1.6)	1.25 (0.9–1.7)	1.14 (0.7–1.8)	1.22 (0.8–1.8)	0.87 (0.6–1.2)	Ref.
Regular brushing (at least twice a day) OR		0.88 (0.6–1.4)	1.05 (0.9–1.7)	1.1 (0.7–1.8)	0.8 (0.5–1.3)	1.25 (0.8–1.9)	Ref.
Regular flossing OR		1.29 (0.5–3.3)	2.01 (0.8–5.1)	2.44 (0.6–9.5)	0.3 (0.1–0.84)	0.42 (0.2–1.1)	Ref.

DMF – Decay, Missing, Filling; PD – Probing Depth; CI – Confidence Interval; CAL – Clinical Attachement Level; OR – Odds Ratio; CPI – Community Periodontal Index; CDC/AAP – Center for Disease Control/American Academy of Periodontology; PI – Plaque Index; API – Approximal Plaque-Index; BoP – Bleeding on Probing.
[a] p = 0.027; [b] p = 0.049; [c] p = 0.026; [d] p = 0.013.

cardial infarction or stroke. Osteoporosis patients showed significantly better hygiene in interdental spaces as a result of significantly more frequent regular cleansing, possibly related to female gender. Furthermore, patients with hypertension underwent a lower number of periodontal teeth removals, and they rarely had severe periodontal disease according to CDC/AAP.

The analysis of the relationship between smoking and body weight and clinical dental exponents and selected oral health related behaviors of the examined subjects is presented in Table 5. No significant relationship was found between body mass stratification in line with BMI and dental and behavioral parameters. Still, there has been shown a significant negative impact of current tobacco dependence on the reduction of the number of teeth and the presence of more than 20 teeth (functional dentition), dental caries exponents (higher number of cavities and a lower number of fillings), periodontal parameters (higher mean pocket depth and the percentage of subjects with pockets deeper than 5 mm, more frequent occurrence of 3 mm CAL, more frequent occurrence of severe periodontitis according to CDC/AAP and CPI4 Code, and less frequent occurrence of CPI0 Code), and oral hygiene (higher mean PI and API scores). Current nicotine addicts also showed significantly worse oral health attitudes by comparison to non-smokers (less frequent regular tooth brushing and interdental spaces cleaning). Also, in the former nicotine addicts, there was a persistence of significantly worse clinical indicators related to oral health compared to those of non-smokers: significantly lower (by almost 3 teeth) average number of teeth, higher number of subject with severe tooth loss (< 10) and lower number of subjects with remaining functional dentition (> 20) and lower number of fillings. Current smokers, by comparison with the former ones, had significantly more dental caries defects as well as a higher mean PD.

Table 5. Association of dental and behavioral parameters with smoking and body mass index

Dental and behavioral parameters		Smoking			BMI		
		current (n = 52)	past (n = 96)	never (n = 185)	obese (n = 96)	overweight (n = 145)	normal (n = 92)
number of teeth	means	11.8 ±8.01	11.6 ±7.8[a]	14.4 ±8.5	12.5 ±8.7	14.0 ±7.5	12.7 ±9.0
	> 20 (%)	6 (11.5%)[b]	14 (14.6%)[c]	51 (27,6%)	18 (18.7%)	29 (20%)	24(26%)
	< 10 (%)	10 (19.2%)	27 (28.1%)[d]	33 (17.8%)	20 (20.8%)	33 (22.7%)	17(18.5%)
Edentulism (%)		10 (19.2%)	13 (13.5%)	24 (12.9%)	17 (17.7%)	12 (8.3%)	18(19.6%)
Caries	DMF	17.5 ±7.4	18.3 ±6.6	17.0 ±6.3	17.6 ±6.9	17.2 ±6.2	17.7 ±6.6
	D	1.88 ±2.6[ef]	1.08 ±2.3	0.71 ±1.3	0.89 ±1.5	1.16 ±1.9	0.85 ±2.2
	M	12.4 ±8.3	13.4 ±7.4	11.1 ±7.6	12.5 ±8.0	11.5 ±7.2	12.3 ±8.1
	F	3.25 ±3.2[g]	3.7 ±3.7[h]	5.1 ±4.6	4.1 ±4.4	4.6 ±3.8	4.5 ±4.4
PD	means	2.94 ±0.89[ij]	2.56 ±0.71	2.39 ±0.61	2.54 ±0.63	2.49 ±0.7	2.55 ±0.81
	persons with PD > 5 OR 95% CI	177.5[k]	145.4	133.6	143.5	142.1	145.9
Persons with CAL≥3 OR		173.8[l]	149.1	132.7	145.1	143.0	142.6
Periodontitis as cause of tooth loss		3.84 ±7.5	2.95 ±6.3	2.42 ±5.9	3.04 ±4.8	2.51 ±5.9	3.01 ±6.4
CPI	CPI0 OR 95% CI	102.2[m]	132.5	156.4	143.4	138.4	145.0
	CPI3 OR 95% CI	165.2	136.5	137.7	144.1	143.5	135.2
	CPI4 OR 95% CI	177.5[n]	141.0	132.7	139.2	142.0	143.1
Periodontitis according to CDC/AAP Severe OR 95% CI		166.5[o]	148.2	135.1	144.6	142.1	144.9
Oral hygiene	PI	65.7 ±32.4[p]	54.4 ±32.8	45.0 ±30.5	57.3 ±32.7	48.2 ±31.4	48.5 ±32.6
	API	79.2 ±26.0[r]	66.9 ±29.7	63.5 ±26.9	70.0 ±28.7	65.3 ±28.6	66.0 ±26.5
BoP		43.7 ±27.8	38.1 ±26.4	34.0 ±26.5	39.9 ±29.4	36.3 ±24.4	33.7 ±28.0
Regular dental appointments (at least once a year) OR		155.9	155.5	176.1	158.2	173.1	166.6
Regular brushing (at least twice a day) OR		140.0	160.2	178.1[s]	164.9	163.6	174.6
Regular flossing OR		154.7	158.0	175.1[t]	163.3	164.2	175.3

DMF – Decay, Missing, Filling; PD – Probing Depth; CI – Confidence Interval; CAL – Clinical Attachement Level; OR – Odds Ratio; CPI – Community Periodontal Index; CDC/AAP – Center for Disease Control/American Academy of Periodontology; PI – Plaque Index; API – Approximal Plaque-Index; BoP – Bleeding on Probing.
[a] p = 0.0022 vs never; [b] p = 0.0171 vs never; [c] p = 0.014 vs never; [d] p = 0.046 vs never; [e] p = 0.0004 vs never; [f] p = 0.046 vs past; [g] p = 0.014 vs never; [h] p = 0.022 vs never; [i] p = 0.0000 vs never; [j] p = 0.015 vs past; [k] p = 0.0008 vs never; [l] p = 0.0056 vs never; [m] p = 0.0002 vs never; [n] p = 0.001 vs never; [o] p = 0.0066 vs never; [p] p = 0.0008 vs never; [r] p = 0.005 vs never; [s] p = 0.012 vs current; [t] p = 0.039 vs current.

Table 6 contains the results of an analysis showing the crucial influence of social and economic factors (education, income and dental treatment type – public/private) on the number of teeth. All 3 factors had a significant influence on the average number of remaining teeth, the presence of more than 20 teeth, the proportion of edentulism, and the number of teeth removed for cariological and periodontal reasons. In each case, these indicators are by far the worst in subjects treated only in public health care facilities, with the lowest income per family member, and with primary education only. Socioeconomic factors did not significantly affect caries (the number of D and DMFT, except for the one significantly lower in patients treated privately, but this was due to caries-related extraction) and periodontal disease (PD, CAL, CPI codes and diagnosis of periodontitis according to CDC/AAP). It has also been found that these determinants have a significant influence on health promoting behaviors. The higher the income, education and self-paid dental treatment, the better the standard of oral hygiene, the smaller the extent of gingivitis, the more frequent dental treatment, and the more frequent brushing and cleaning of interdental spaces.

Discussion

Only 3 Polish cross-sectional studies on oral health of persons aged 65 to 74 years have been found in the available medical literature from the last decade.[18–20] The sam-

Table 6. Association between socioeconomic factors/type of dental service and dental/ behavioral parameters

Dental and behavioral parameters		Education			Income			Dental service	
		8y: (n = 72)	12y: (n = 170)	min. 16y: (n = 91)	Lowest: (n = 43)	Medium: (n = 233)	High: (n = 57)	Reimb.: (n = 111)	Private: (n = 120)
Number of teeth	means	9.94 ±8.4	12.5 ±8.1	17.08 ±7.1^{ab}	7.93 ±7.9	14.6 ±7.8^{a}	17.7 ±6.9^{bc}	8.26 ±7.9	17.37 ±7.2^{a}
	> 20 (%)	9 (12.5%)	30 (17.6%)	32 (35,1%)^{cd}	3 (6.9%)	45 (19.3%)	23 (40.3%^{de}	9 (8.1%)	47 (39.2%^{b}
	< 10 (%)	18 (25%)	40 (23.5%)	12 (13.1%)	11 (25.6%)	52 (22.3%)	7 (12.2%)	31 (27.9%^{c}	17 (14.2%)
Edentulism (%)		18 (25%)^{e}	25 (14.7%)^{f}	4 (4.3%)	15 (34.8%^{fg}	31 (13.3%)^{h}	1 (1.7%)	35 (31.5%^{d}	5 (4.1%)
Caries	DMF	18.1 ±7.6	17.7 ±6.5	16.46 ±5.4	17.7 ±8.3	17.2 ±5.6	16.12 ±5.9	18.8 ±8.1^{e}	16.4 ±5.5
	D	1.23 ±2.0	0.87 ±2.0	1.07 ±1.6	1.44 ±3.4	0.87 ±1.5	0.85 ±1.6	1.28 ±2.3	0.88 ±1.6
	M	13.9 ±8.8^{g}	12.4 ±7.6^{h}	9.6 ±6.3	14.1 ±9.1^{i}	11.3 ±6.9	9.2 ±6.7	15.1 ±8.7^{f}	9.4 ±6.7
	F	2.97 ±3.7	4.4 ±4.2^{i}	5.6 ±3.9^{j}	2.18 ±3.0	4.96 ±4.2^{j}	5.92 ±3.9^{k}	2.36 ±3.3	6.01 ±4.5^{g}
PD	means	2.55 ±0.7	2.5 ±0.7	2.55 ±0.76	2.74 ±0.94	2.46 ±0.63	2.61 ±0.88	2.55 ±0.75	2.54 ±0.78
	persons with PD > 5 OR 95% CI	147.5	138.6	149.2	98.9	85.4	96.7	133.9	151.0
Persons with CAL ≥ 3 OR		143.5	140.1	149.2	94.2	86.8	96.6	137.8	149.3
Periodontitis as cause of tooth loss		4.14 ±7.72^{k}	3.05 ±6.52	1.28 ±3.9	5.93 ±9.1^{l}	2.1 ±4.9	0.98 ±4.1	4.62 ±8.1^{h}	1.2 ±4.1
CPI	CPI0 OR 95% CI	129.2	140.6	150.6	79.4	90.6	92.5	127.6	152.7^{i}
	CPI3 OR 95% CI	135.8	137.6	151.5	85.4	84.4	100.4	129.3	144.5
	CPI4 OR 95% CI	142.6	137.5	147.4	93.6	85.1	95.3	131.7	149.9
Periodontitis according to CDC/AAP Severe OR 95% CI		149.1	143.6	139.9	100.1	90.6	87.2	144.0	141.8
Oral hygiene	PI	59.7 ±32.4^{l}	51.5 ±32.2	44.0 ±30.9	69.1 ±26.5^{mn}	46.2 ±31.8	44.3 ±31.2	62.1 ±34.0^{j}	46.8 ±28.8
	API	72.5 ±29.4	66.5 ±27.9	63.6 ±27.0	81.5 ±20.4^{op}	63.7 ±29.3	62.7 ±22.7	75.3 ±27.2^{k}	60.9 ±26.1
BoP		48.6 ±30.4^{mn}	34.6 ±25.4	32.5 ±24.7	54.0 ±33.0^{rs}	34.6 ±25.0	31.6 ±24.5	44.4 ±30.0^{l}	33.7 ±27.3
Regular dental appointments (at least once a year) OR		124.8	171.7^{o}	191.5^{p}	72.8	106.6	119.2^{t}	119.6	202.0^{m}
Regular brushing (at least twice a day) OR		126.3	173.5^{r}	187.1^{s}	81.5	106.5	112.9^{u}	131.3	191.3^{n}
Regular flossing OR		142.4	166.8	186.7^{t}	83.8	106.8	110.3^{w}	143.0	184.1^{o}

DMF – Decay, Missing, Filling; PD – Probing Depth; CI – Confidence Interval; CAL – Clinical Attachement Level; OR – Odds Ratio; CPI – Community Periodontal Index; CDC/AAP – Center for Disease Control/American Academy of Periodontology; PI – Plaque Index; API – Approximal Plaque-Index; BoP – Bleeding on Probing

[a] p = 0.0000 vs 8y; [b] p = 0.0000 vs 12y; [c] p = 0.001 vs 8y; [d] p = 0.001 vs 12y; [e] p = 0.0003 vs 16y; [f] p = 0.02 vs 16y; [g] p = 0.001 vs 16y; [h] p = 0.0017 vs 16y; [i] p = 0.045 vs 8y; [j] p = 0.0002 vs 8y; [k] p = 0.0156 vs 16y; [l] p = 0.018 vs 16y; [m] p = 0.002 vs 8y; [n] p = 0.004 vs 12y; [o] p = 0.002 vs 8y; [p] p = 0.0000 vs 8y; [r] p = 0.003 vs 8y; [s] p = 0.0000 vs 8y; [t] p = 0.001 8y;

[a] p = 0.0000 vs lowest; [b] p = 0.0000 vs lowest; [c] p = 0.045 vs medium; [d] p = 0.0004 vs lowest; [e] p = 0.0008 vs medium; [f] p = 0.0000 vs high; [g] p = 0.0005 vs medium; [h] p = 0.024 vs high; [i] p = 0.005 vs high; [j] p = 0.0006 vs lowest; [k] p = 0.0000 vs lowest; [l] p = 0003 vs medium high; [m] p = 0.003 vs high; [n] p = 0.0031 vs medium; [o] p = 0.015 vs high; [p] p = 0.012 vs medium; [r] p = 0.0013 vs high; [s] p = 0.0032 vs medium; [t] p = 0.002 vs lowest; [u] p = 0.01 vs lowest; [w] p = 0.003 vs lowest;

[a] p = 0.0000; [b] p = 0.0000; [c] p = 0.01; [d] p = 0.0000; [e] p = 0.009; [f] p = 0.0000; [g] p = 0.0000; [h] p = 0.0002; [i] p = 0.023; [j] p = 0.0001; [k] p = 0.0001; [l] p = 0.0082; [m] p = 0.0000; [n] p = 0.0000; [o] p = 0.0000

Table 7. Comparison of selected regional cross-sectional studies conducted in young seniors

Dental and behavioral parameters		INVEST[21,22] (Whites 133)	SHIP[22,23] (n = 554)	Turin[24] (n = 191)	Wrocław (n = 333)
Age (means or intervals)		70.8 ±6.9	65–74	60–75	69.53 ±2.74
Female (%)		57.4	50%	52.3	52.5
Number of teeth (means)		19.0	10.6a	20.62	13.21 ±8.3
Edentulism (%)		10.1	15.8	1	14.1
Probing depth persons with PD > 5	means	2.2	2.8a	ND	2.52 ±0.71
	(%)	30.1	28.1	ND	26.4
CAL	persons with CAL ≥ 3 (%)	ND	99.4	ND	93.3
	persons with CAL ≥ 5 (%)	63.0	80.2	ND	45.5
Periodontitis acc. to CDC/AAP	moderate (%)	43.7	52.3	36.1	18.6
	severe (%)	14.3	30.0	51.3	18,9
Current smokers (%)		7.4	13.7[a]	23.5	15,6
Obesity acc. BMI (%)		30.25	33.1[a]	ND	28.8
Diabetes (%)		13.9	18.2[a]	5.8	18.9
BoP		22.1	43.3[a]	ND	36.6 ±26.7
Regular brushing (at least twice a day) (%)		73.2	78.8[a]	ND	71.7
Regular flossing (%)		55.6	31.5[a]	ND	18.9
Response rate (%)		70%	50.1	47%	12.8

ND – no data;
[a] data from SHIP conducted in 1997–2001.

ple size in our own study was the highest. All observations were made among the inhabitants of cities (Wrocław, Oława, Szczecin, Police, Białystok, Lublin), and inhabitants of rural areas were included only in the Lublin survey.[18] The average number of teeth in young seniors in Wrocław was similar to the average in Białystok (13.21 vs 13.36) and significantly higher than in Lublin (only 7.8 in persons over 60 years of age – 7.0 in rural areas).[18,19] The proportion of persons with remaining chewing function (> 20 teeth) was highest in West Pomeranian Voivodship (35.7%), compared to 27.8 in Białystok and 21.3% in own research.[19,20] The percentage of people with edentulism was by far the highest in the Lublin area (49.9% in persons over 60 years of age), compared to 14.1% in Wrocław, 12.5% in Białystok, and 11.9% in West Pomeranian Voivodship.[18–20] In Białystok, the average number of remaining teeth was noticeably higher in men and the proportion of edentulism was higher in women;[19] in Wrocław these values were similar, although not statistically significant. In the Lublin area, the number of remaining teeth was significantly higher in men as well.[18]

The place of residence and education significantly influenced the number of remaining teeth in the area of Wrocław and Lublin (the protective effect of a large city and higher education).[18] Some similarities related to dental caries were found in West Pomeranian Voivodship, the average DMFT index in persons treated exclusively in private facilities was 20.06 (D – 0.9, M – 9.7 and F – 9.43), compared to 16.4 in the Wrocław area (D – 0.88, M – 9.37 and F – 6.29).[20] The comparison of periodontal status between residents of Białystok and Wrocław indicates a rather worse condition in young seniors in the capital of Lower Silesia (BoP 36.2% vs 26.7%, mean PD 2.55 vs 2.13, CPI0 0% vs 8.3%, CPI3 + CPI4 52.3% vs 40%).[19]

The oral hygiene status in the residents of both cities is equally bad (the proportion of persons who brush their teeth properly is 21% in Wrocław and 14.3% in Białystok; the proportion of persons who clean their interdental spaces properly is 7.4% in Wrocław and 12.7% in Białystok). In both cities, the periodontal status was generally worse in men, while in Wrocław it was more often at the level of statistical significance. The analysis of recent nationwide oral health surveys among persons aged 65 to 74 years in-

Table 8. Comparison of selected oral health behaviours among seniors in regional and national studies

Study and year			Regular dental appointment (at least once a year)	Regular tooth brushing (at least twice a day)	Regular usage of inter-dental care devices (every day)	Other details
National studies	Poland[31] 2013–2014	N = 807 age: 65–74	78.2%	76.2%	17.2%	ND
	Germany[10] 2005	N = 787 age: 65–74	88.8%	80%	41.7%	electric toothbrush – 18.3%
	USA[50] 2009–2012	N = 897 age: 65–74	76.3%	ND	75%	dental implants – 5.1%, 0.13 pro p
Regional studies	Wrocław Region 2017	N = 333 age: 65–74	68.4%	71.7%	18.9%	dental implants – 1.5%, 0.045 pro p
	Pisa (Italy)[58] 2011	N = 350 age >53	70%	77%	27%	electric toothbrush – 32%
	Washington and Oregon[59] 2008-2011	N = 368 age >60	ND	63.3	79.9%	ND
	Carlos Barbosa (Brazil)[60] 2004	N = 388 age >60	12.3%	82.9% (1 per day)	56.4%	ND

ND – no data.

dicates that there are notable differences between country regions, especially with regard to the number of remaining teeth and prevalence of edentulism.

Three comparable, most closely related foreign cross-sectional studies in oral hygiene among young seniors were chosen (Table 7). Infection and Vascular Disease Epidemiology Study (INEST) was conducted in 1999–2003 among New Yorkers residing within Northern Manhattan.[21] The examination was performed around maximum 28 teeth, at 6 assessment points (full-mouth estimates). Due to the significant racial differences, only data regarding Caucasian subjects was included in the analysis. Study of Health in Pomerania (SHIP) was conducted in Germany in 1997–2001 and 2008–2012, among racially homogeneous inhabitants of urban and rural areas in the north-eastern region of the country.[22,23] The dental examination was performed around maximum of 14 teeth, at 4 assessment points (half-mouth recording). The Italian survey was conducted in 2009–2010 in line with a full-mouth protocol among 3-tier randomly selected group of Turin residents (northern Italy).[24]

Attention is drawn by low representativeness of own research. There is also a noticeable difference in the number of remaining teeth (from 10.6 to 20.6), the proportion of toothless persons (1 to 15.8%), and the periodontal parameters such as prevalence of severe periodontitis according to CDC/AAP ranging from 14.3 to 51.3 in the examined population. Exposure to systemic (co-occurrence of cardiovascular and cerebrovascular diseases, diabetes, hypertension) and behavioral factors (nicotine and obesity) was similarly high in the compared populations. Poles still display the lowest level of oral hygiene procedures. The differences found in the study are probably partly due to differences in the methodology of dental examination, and the periodontal exponents are related to the number of remaining teeth. However, such notable gradients must also have other factors, e.g., socioeconomic.

In own observation, dental caries were the main medical cause of tooth loss (81% of all teeth and an average of 12 teeth per patient were removed due to cariological indications). This regularity can be explained by the cohort effect related to people born in the 1940s, who for decades were exposed to "extraction dentistry" stemming from prevailing Eastern European theories of infection foci and incorrect behavior of medical personnel and health promoting behavior of the population. For example, in the national Hungarian study, the median M in the DMFT index was 18.9 in the 65–74 age group and 9.07 in the 45–64 age group.[25] In the 21st century, there is a visible global and local trend for the number of remaining teeth to increase and to reduce the proportion of edentulism. This is indicated by local cohort studies in young seniors, e.g., 5-year cohort study of Swedes from Orebro and Ostergotland from 1992–2012, or 5-year German cohort related to SHIP study in 2002–2006, and cross-sectional national research, e.g., the American study from 1957 to 2012 and the British one from 1988 and 2009.[26–29] This is also confirmed by national Polish studies: the average number of teeth and the percentage of edentulism in the group of 811 Poles aged 65–74 years from all voivodships were 6.3 and 41.6%, respectively, and in the group of 807 persons from 5 voivodships these values were at the level of 13.7 and 28.9%.[30,31]

This trend cannot be explained only by favorable changes in the main medical conditions: dental caries and periodontitis (the morbidity of periodontitis does not decline in the best case scenario!). Our study shows that the average number of remaining teeth was affected by the following factors (given in descending order of strength degree): personal income, type of dental treatment funding, education and place of residence. There were no statistically significant effects of gender, assessed systemic diseases and body weight. With respect to functional dentition, the influence of income, type of dental treatment funding, education, nicotine addiction, and place of residence was the strongest. There is a significant correlation between the prevalence of edentulism and personal income, type of dental treatment funding, education, and place of residence. Multivariate analysis models including confounders confirm our own observations. In the SHIP cohort study, the incidence of tooth loss was in a significant and most escalating relationship to current nicotine addiction, education period shorter than 10 years, fourth quartile of BMI, and the lowest personal income threshold (given in descending order).[27] A Norwegian telephone survey showed that the number of remaining teeth amounting to at least 20 statistically was in the strongest relationship with regular dental appointments, highest personal income, complete abstinence from smoking, and living in the city.[32] The probability of edentulism was significantly correlated with asthma, primary education and smoking in the past (income was defined by the level of wealth, quite diverse in the analyzed studies from 6 countries).[33] Therefore, the social-economic gradient greatly influences the number of remaining teeth. The impact of income (personal or family) seems most clear, which is confirmed by a meta-analysis showing a cumulative odds ratio of 1.66 (with confidence interval of 1.48–1.86) only after it was adjusted for potential confounders in 8 contemporary surveys regarding the association between lowest income bracket and tooth loss.[34] High income may indirectly affect the quality of dental treatment and tooth preservation strategies, and is linked, as a rule, to better education and more appropriate oral health behaviors (regular dental treatment, follow-up visits, greater availability of oral hygiene products). On the other hand, absence of own financial means for dental treatment restricts access to medical procedures (sometimes subjects seek only pain-reducing extraction) and exerts a negative psychological effect upon the decision to have a dental appointment. Using only private dental care allows patients to seek conservative dental treatment (in Polish conditions this

may be endodontic treatment of back teeth, permanent prosthetic restorations, or periodontal surgery). Although own findings and the observations of other authors confirm the dependence of the dental status on education, the observed shift which sometimes occurs of such a relationship to a non-significant level together with adjusting for potential confounders (e.g., income, nicotine addiction, cleansing of interdental spaces) may indicate that the effect of educational gradient is not causal and works exclusively through other factors.[26–28,32,33]

Our findings and the observations of other authors confirm unequivocally the influence of tobacco addiction on the decline in the number of teeth.[26,27,32,35,36] Gathered evidence indicates that the nature of this relationship is causal and does not depend on other factors.[35] The strength of this relationship compound is moderate (greater in men), and there is a dose-response relationship. Biologically, the base of this relationship is the well-known effect of nicotine upon periodontal supportive tissues and upon the development of dental caries and its fostering of microbiological shift towards periopathogens. The negative impact of former nicotine addiction on the number of teeth is also noticeable by comparison with non-smokers – in own studies former smokers had a significantly lower average number of teeth and they were more often diagnosed with tooth loss (below 10) also fully functional dentition was found less frequently. The risk of tooth loss due to nicotine addiction diminishes gradually, reaching a level comparable to non-smokers only after 20 years.[36]

Our studies show a higher number of teeth in men (13.65 vs 12.81, prevalence of functional dentition higher by 4%) and the proportion of edentulism higher by 5.3% in women. These differences were not statistically significant. The significance of these differences in contemporary studies of Białystok inhabitants aged 65 to 74 years has been shown by Sulewska et al.[19] Polish national studies show a visible tendency to blur the gender impact on the number of teeth (in 2002 the average number of remaining teeth was higher by more than 2 in men, and the proportion of edentulism was higher by 7.6% in women; in 2014 the differences were 1.6 and 3%, respectively).[30,31] The findings of foreign authors are controversial in this regard, as some do not report any notable sexual dimorphism in terms of dental status while others prove it.[24,27–29,33,37] This may indicate a regional specificity in this regard.

No significant link has been found between the number of teeth and the selected systemic diseases (diabetes, cardiovascular disease, myocardial infarction, stroke, osteoporosis, and hypertension) in the inhabitants of Wrocław. Presumably, this is due to the small sample size.

A notable influence of diabetes upon the number of teeth was shown in the population of over 70,000 American diabetics aged more than 65 years.[38] The important relationship between the number of remaining teeth and mortality, irrespective of medical, social and economic factors, was determined by observing 4 cohorts of over 1,800 Swedes aged over 70 years.[39] The findings regarding tooth loss as an independent weak risk factor for stroke was made on the basis of a survey of more than 13,000 Americans aged over 60 years.[40]

In young seniors in Wrocław, no meaningful relationship was found between body mass expressed by BMI index and number of teeth. This is consistent with the observations of the Brazilian authors.[41] Also, Ostberg et al. did not observe any significant relationship between tooth loss and general and abdominal obesity in individuals over 60 years of age.[42]

The DMFT index for the whole group of young seniors in Wrocław is 17.45, and the main component determining its height is the cariologic extraction, with an average of 12 teeth per person. Only 1 reference point has been found in the available contemporary Polish literature: DMFT value 16.31 (DT 2.95, MT 10.91 and FT 2.45) in a regional study of men from Białystok.[43] The comparison with an analogous indicator of dental caries in males from Wrocław shows a similarly high frequency of tooth removal due to caries, a lower number of teeth with ongoing disease, and twice as many filled teeth. The comparison of the DMFT index of the last 5 national German studies for this age group (17.7: DT 0.5, MT 11.1 and FT 6.1) indicates better control and treatment of caries in German seniors.[44] The lowest DMFT index values in own studies were shown in individuals with the highest personal income – 16.12, and in persons treated exclusively in private practices – 16.4 (in this group the number of filled teeth is also the highest – 6.1). The effect of the socioeconomic gradient on the indicators of caries was confirmed. Another significant element was the increasing influence of male gender, living in a small town and an active (and former, in the case of the number of fillings) tobacco addiction upon the indicators of caries. In a systematic contemporary review of the literature on nicotine-carcinogenicity, only 1 study was conducted among the elderly who had a significantly higher DMFT index value at the age of 75, and MS value in current smokers by comparison to persons who have never smoked at the age of 65 and 75.[45] One of the factors that may aggravate the development of caries (also in root) in the elderly may be the effect of polypragmia causing reduced saliva secretion.

In own research the full-mouth estimates methodology was used with a modification of 4 assessment points. It is now considered to be the gold standard for epidemiological study of periodontal condition, and it allows for referring to the definition of periodontitis based on PD and CAL measurements. This methodology has been proposed in the USA and currently it is used exclusively in epidemiological studies,whereas in Europe it is only now introduced.[16,17,21,24,46] Eke et al. have shown that the use of a periodontal examination protocol other than a comprehensive oral examination may lead to underestimating the morbidity of periodontitis even by 50%.[16]

In our study, the negative effect of male gender (higher average PD, the proportion of persons with PD > 5 mm, lower proportion of males with CPI1 and higher with CPI4) and current nicotine addiction (higher average PD, higher proportion of persons with PD > 5 mm, higher proportion of persons with CAL ≥ 3 mm, lower average number of sextants with CPI0, higher average number of sextants with CPI4, more frequent occurrences of periodontitis according to CDC/AAP) upon periodontium was confirmed. These are the standard risk factors for periodontal inflammation and they are generally found to be consistent in contemporary literature on both regional, but primarily on national research.[10,22,31,46–49] More controversial is the influence of sexual dimorphism upon the morbidity of periodontitis in people over 65 years old. There are few observations that do not confirm the worse clinical condition of male seniors.[24] Eke et al. in recent American national studies have observed the differential blurring of differences among sexes in periodontitis prevalence as defined by the CDC/AAP, which has been explained by the postmenopausal condition of women, when estrogen deficiency increases destructive processes within the periodontium.[46] It should be borne in mind that the negative impact of the male gender may result from other factors associated with it, such as more frequent tobacco addiction or considerably worse oral hygiene (confirmed by own studies). The impact of the current tobacco addiction upon the development and clinical course of periodontitis is clear and strong. In our own observations, this was the only factor closely related to severe periodontitis according to the CDC/AAP. There is general agreement as to the causal nature of existing nicotine addiction in the development of periodontitis (the compatibility of many studies, the moderate strength of the dose-response effect, reversibility). Particularly important is the information on the fast disappearance of the negative effects of nicotine on the periodontium after quitting,which strengthens the importance of minimal anti-nicotine intervention in the secondary prevention of periodontal inflammation.[50] Particularly dangerous for the periodontium is the persistence of nicotine addiction in postmenopausal women, in whom its interaction with osteoporosis exerts a synergistic effect on the resorption of alveolar bone.[46] In the future, a gradual improvement in the condition of the periodontium should be expected, resulting from the decline of the population of tobacco addicts (most frequently the elderly quit smoking after a sudden medical event).

The strength of the link between periodontal disease and systemic diseases is most often poor, at the limit of importance after adjusting the risk for confounding, which is particularly true for the elderly population due to frequent co-morbidity. The meta-analysis of 5 cohort studies involving 86,092 people indicated a significant increase in the risk of developing coronary heart disease during periodontitis, but only by 14%.[51]

Dietrich et al. analyzed 12 or more cohort and clinical control studies and reported weak or moderate (risk score was generally not greater than 2) strength of the relationship between periodontitis and incidents of atherosclerotic cardio-cerebrovascular disease, which was attenuated to irrelevant in people over 65 years of age.[52] In this context, it is understood that there is no significant relationship between the periodontal status and systemic diseases analyzed in the elderly population in Wrocław. The only exception were more frequent extractions of teeth due to periodontal indications in patients with previous myocardial infarction or stroke (which should not be negatively assessed). The absence of a notable association with periodontal indicators was also related to the most common disease in the studied population – hypertension (only 78 out of 160 hypertension cases were included in the study, as the remaining ones co-existed with the assessed systemic diseases). The observation of the rare occurrence of severe periodontitis according to CDC/AAP in this group of individuals appears to be accidental. Opinions on the relationship between oral health and hypertension are divergent. The meta-analysis of 12 cross-sectional studies, including those adjusted for confounder risk measures, indicated a considerable 16% increase in risk of hypertension occurrence in the presence of periodontitis.[53] In contrast, in a 9-year cohort study of 5,895 subjects aged 65 years and over, no significant correlation was found between the dental parameter and hypertension.[54] In own assessment, no statistically significant relationship between periodontal condition and body weight was observed. This is in line with other authors' observations.[22,47,50,55] Even in the meta-analysis which shows a significant relationship between clinical indicators of periodontitis and obesity, it is observed that in the elderly this relationship is weaker, which is associated with the inability to control all factors that interfere with these observations (diabetes, metabolic syndrome, nicotine, gender, oral hygiene).[56]

In own analysis, socioeconomic factors, beside their influence upon extraction decisions due to periodontal indications, were not significantly related to clinical parameters and periodontal diagnoses in line with CPI and CDC/AAP. This observation is in opposition to the findings of most national studies.[46–50] This is particularly evident in American studies, where, apart from classical factors in the form of income and education, very diverse racial-ethnic factors come into play, even along with marital status (with biggest negative impact upon the divorced) and the frequency of dental appointments, with worse condition of the periodontium in more often treated subjects.[16,46,50] The latter seemingly astonishing observation stems from the fact that American seniors seek periodontal treatment. This has also become evident in recent national German studies reporting an increasing tendency among young seniors to seek periodontal, implant and prosthetic treatment using fixed restorations.[57]

The elderly in the urban area of Wrocław declare that pain is their main reason to seek dental treatment, and periodontal problems are the reason for only 3% of the cases. In this respect, the impact of the cohort effect as well as the relatively low economic gradient among Polish retirees may be significant.

Of the 131 cases diagnosed with clinical pathology of oral mucosa, 38.9% are cancer and pre-cancer lesions. Out of all reported pathological lesions, 42.7% require immediate treatment. These observations prove the need for examining oral mucosa during every dental appointment. With regard to the nationwide Polish study among subjects of this age, attention is drawn to the greater prevalence of denture stomatitis and fewer occurrences of leukoplakia and oral mycosis.[31]

It is important to emphasize the very poor oral hygiene in the examined group of older people in the Wrocław urban area. Even worse results were reported in a regional study of young seniors in Białystok (average PI is 50.8 vs 57.8, and average API is 66.7 vs 60%).[19] Considerably worse result for brushing (the highest PI values) in Wrocław appeared in the following order: persons with lowest income, current nicotine users, small town residents, persons treated solely in national healthcare facilities, men and persons with primary education. For cleaning interdental spaces (highest average API), the order was as follows: persons with lowest income (average API 81.5!), current smokers, men, and persons treated solely in national healthcare facilities. These observations confirm the well-known claim about the close link between poor oral hygiene and low socioeconomic status, male gender, tobacco dependence, and place of residence away from bigger towns. Also, the health promoting behaviors of the people we examined are unsatisfactory (pain is still the main reason to make a dental appointment; almost one third of the subjects only occasionally make dental appointments). The comparison of selected oral health related behaviors of the elderly with foreign regional surveys and national research is presented in Table 8.[10,31,50,58–60] Basically, it is concluded by comparison that the awareness of Polish young seniors of the need to clean interdental spaces, that is to perform a prophylactic procedure extremely important in caries and periodontitis prevention, is the lowest. Americans lead in cleaning interdental spaces and Germans have dental appointments most regularly – currently 90% of dental patients make appointments to check oral health.

Our research is limited in numerous ways and these limitations demand caution in making generalizations. The first is the elderly's low response to the invitations, which determines their low representativeness in the examination. The second is the inherent feature of a typical cross-sectional study that did not resolve the temporal relationship between 2 medical events. The third limitation is the fact that many variables (especially these related to general health) were determined anamnestically with a risk of error for temporally distant events such as the question about the cause for tooth removal in the past. Another limitation results from the fact that the study was conducted solely in the urban environment, with the exclusion of the countryside areas, which could also influence the evaluation of oral health. The impact of other variables not yet deemed as risk factors, but potentially able to affect oral health, e.g., diet, physical activity or marital status, has not been taken into account. Finally, for full compliance with the protocol for comprehensive dental examination, 2 measurement points on lingual surfaces of teeth were evaluated.

The conducted regional cross-sectional epidemiological study has shown an increase in the number of remaining teeth in young seniors in Wrocław despite no significant improvement in the incidence of dental caries and periodontitis. The influence of classical risk factors for tooth loss and periodontitis has been confirmed, with the exception of significant associations with analyzed systemic diseases, which resulted probably from the sample size. The population is characterized by low dental treatment requirements and poor habits related to oral health. Targeted regional preventive and intervention programs have to emerge from representative epidemiological studies taking into account the impact of as many variables as possible. Cohort studies – not yet conducted – would definitely deepen this knowledge. Special emphasis should be placed on the ultimate definition of the possible causal nature of the impact of social-economic factors on oral health.

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Dental prosthetic treatment needs in Mexican elders: Influence of socioeconomic position

Potrzeby leczenia protetycznego u starszych Meksykanów – wpływ czynnika socjoekonomicznego

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Abstract

Background. According to the Global Burden of Oral Conditions in 1990–2010 report, oral diseases are highly prevalent. Tooth loss is also a prevalent oral condition. Poor oral health compromises healthy aging, as it impacts an older person's quality of life and general health.

Objectives. The aim of this study was to determine the influence of various indicators of socioeconomic position on dental prosthetic treatment needs in Mexican adults aged 60 and over.

Material and methods. A cross-sectional study was carried out in older adults aged 60 and over who were residents in 2 nursing homes and a senior citizen club in the city of Pachuca, Mexico. By means of a clinical exploration, tooth loss and dental rehabilitation status were determined, which was our dependent variable. This was dichotomized as 0 = subjects with loss of teeth but rehabilitated with a dental prosthesis; and 1 = subjects with loss of teeth and in need of dental prosthesis treatment. Using a questionnaire, a series of sociodemographic, socioeconomic, behavioral and health variables were collected. A statistical analysis was performed in Stata 13 using the χ^2 test.

Results. The mean age was 79.03 ±9.81 years. Most of the subjects included in the study were women (68.8%). The prevalence of dental prosthetic treatment needs was 53.6%. Higher dental prosthetic treatment requirements ($p < 0.05$) were observed among subjects who did not have access to health insurance, in those with education less than elementary, among those who attended a publicly funded nursing home and those who did not have the social benefit of being retired/pensioned.

Conclusions. This sample of elderly people presented high dental prosthetic treatment needs for more than half of the subjects studied. It was observed that the variables indicating socioeconomic position had a great impact on the dental prosthetic needs, which represents the existence of inequalities in oral health.

Key words: elderly, oral health, tooth loss, health needs

Słowa kluczowe: osoby starsze, zdrowie jamy ustnej, utrata zębów, potrzeby zdrowotne

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The main oral health problems around the world continue to be dental caries and periodontal diseases. Dental biofilm is an important biological determinant common for the development of both diseases. The diseases share common risk factors and social determinants that are essential for their prevention and control. According to the Global Burden of Oral Conditions in 1990–2010 report, oral diseases are highly prevalent, collectively affecting about 3.9 billion people around the world, thus representing major oral public health problems. In that study, the most common disease of all conditions evaluated, and with the highest burden of disease globally was untreated dental caries in the permanent dentition, affecting 35% of people in all age groups, while severe periodontitis was the 6th most prevalent condition, affecting 11% overall.[1–4] As chronic diseases are cumulative throughout life, once they occur, their manifestation persists throughout life, so the results are more likely to be observed among the elderly. Its main consequence is tooth loss, which is also a prevalent oral condition; in fact, severe tooth loss is the 36th most prevalent condition, with an overall estimate of 2%.[5]

In recent years, progress in the prevention and treatment of dental caries and periodontal diseases has resulted in better oral health and greater retention of teeth in the adult population. However, the aging of the population and the growing expectations of a good quality of life related to oral health at an advanced age pose enormous challenges for society in general, as well as for clinical care and the health systems in particular; since there are several demands and health needs specific to older adults that need to be covered.[6,7] To achieve this, it is necessary to have highly qualified economic, technological and human resources.[8] Therefore, due to the increasing number of older adults, the need to carry out epidemiological studies on oral health centered on this population has arisen.[9] One of the first steps in planning dental services is to compile up-to-date information on the prevalence of oral diseases. With this information, it is possible to evaluate future treatment needs and service demands. At the same time, estimating the need for treatment is an essential requirement in planning oral health care. With regard to tooth loss, standard treatment involves the placement of prosthetic devices such as total or partial prosthesis.[10]

According to recent research, there is strong evidence of an association of low socioeconomic position with an increased risk of having dental caries experience and a higher prevalence of periodontitis. This is typical of the phenomenon known as "socioeconomic inequalities in health", which refer to the different health-related opportunities and resources that people of different social classes have. The most disadvantaged groups present a worse state of health than their better-positioned counterparts, a situation which has its origin in the inequalities of the economic and social policies that exist in society.[11] In this regard, studies carried out in several countries around the world, both developed and developing, reveal the existence of socioeconomic inequalities in various aspects of health, observing that the socioeconomically disadvantaged population is the one with the lowest levels of health.[12]

Several studies on dental prosthetic needs have been conducted in several countries, principally in developing ones. For example, in India, Bhardwaj et al. found that in a sample of adults aged 18–58 years, 33.2% had prosthetic requirements and that these were associated with their socioeconomic position.[13] Another study reports dental prosthetic needs in 81.2% of people aged 60 and over.[14] In Saudi Arabia, Peeran et al. performed a study in adults aged 35–74 years and observed that about 56% of the participants had dental prosthetic needs.[15] On the other hand, in Thailand, prosthetic needs reach 60% in subjects aged 60–75 years.[16] The determination of prosthetic needs in Mexico is a little-explored subject so the objective of the present study was to determine the influence of various indicators of the socioeconomic position on prosthetic needs in elderly Mexicans of 60 years and over.

Material and methods

Design and study sample

A cross-sectional, observational, analytical study was performed on subjects aged 60 years and over in 2 nursing homes and a club for the elderly located in the city of Pachuca, Hidalgo, Mexico, where several oral health indicators were measured. Part of the methodology has been previously published, covering various oral health topics.[17–21] Once the appropriate permits had been obtained, the subjects were invited to participate in the study. They were informed of the objectives of the investigation, the confidentiality of data management, and instructed that they could stop participating at any time. The inclusion criteria were: 1) people who wished to participate in the research and they or their relatives authorized it; 2) people who were enrolled in the aforementioned groups; and 3) have lost at least 1 tooth, whereas the exclusion criteria were: 1) they had any auditory or language defects that made the interview difficult; and 2) with a physical disability that prevented the oral examination. No sampling was performed; the participants were all volunteers who agreed to participate in the study. The total sample at baseline consisted of 151 subjects. Out of these, 13 refused to take part in the study or were disqualified according to the criteria so in the end 138 subjects were studied.

Variables and data collection

The dependent variable was formed by the state of tooth loss and the use of any dental prosthesis, which was dichotomized as: 0 = subjects with loss of teeth, but rehabilitated with a dental prosthesis; and 1 = subjects with

loss of teeth and in need of a dental prosthesis (not rehabilitated). Questionnaires were used to collect information on sociodemographic variables such as age, sex, and marital status as well as socioeconomic variables such as type of nursing home, health insurance, schooling and retirement/pension social benefits; in addition to various behavioral and exposures factors such as frequency of dental brushing and presence of chronic diseases (multimorbidity).

To determine the status of the dentition (missing teeth) and the needs for dental prosthetics, a clinical examination was performed on each of the subjects. Clinical examinations were performed by a single examiner who had been previously standardized and trained in the criteria, using a flat dental mirror and a WHO-type periodontal probe, with the patient comfortably seated in a room with an artificial light.

Analysis of data

The information collected from the questionnaires and the clinical examination was analyzed in Stata 13.0®. First, a descriptive analysis of the sample was carried out, reporting measures of central tendency and dispersion for the quantitative variables as well as the frequency and percentages for the qualitative variables. Subsequently, a bivariate analysis was performed to determine the existence of differences in the distribution of dental prosthetic needs and independent variables using the χ^2 test with the level of significance $p < 0.05$.

Ethical Considerations

The completion of this study was complied with the specifications of the general health law in research of Mexico and with the scientific principles of Helsinki. All individuals signed an informed consent form. The protocol was approved by the Postgraduate and Research Unit of the Academic Area of Dentistry of the Autonomous University of the State of Hidalgo (UAEH-DI-ICSA-ODO-CF-008).

Results

The results of the descriptive analysis are shown in Table 1. The mean age was 79.03 ±9.81. Most subjects included were women (68.8%). Almost half (44.9%) of them were divorced or widowed at the time of the survey. More than half (53.6%) had no access to health insurance. Out of the elderly people in our sample, 64.5% had failed to complete even elementary schooling. The majority (60.1%) attended a publicly funded nursing home. Only 1 in 5 had the social benefit of being retired/pensioned. 27.5% of subjects had multi-morbidity. Just over a half reported brushing their teeth at least once a day.

Table 1. Description of the characteristics of subjects included in the study

Variables	Frequency	Percentage
Sex		
male	43	31.2
female	95	68.8
Age		
60 to 74 years	47	34.1
75 to 84 years	46	33.3
85 and more	45	32.6
Marital status		
single	52	37.7
in a relationship	24	17.4
divorced/widowed	62	44.9
Type of location		
publicly funded	83	60.1
private	31	22.5
adult day center	24	17.4
Health insurance		
yes	64	46.4
no	74	53.6
Schooling		
elementary school and more	49	35.5
less than elementary school	89	64.5
Pension/retirement		
no benefit	104	75.4
with benefit	34	24.6
Multi-morbidity		
0 or 1 disease	100	72.5
2 or more	38	27.5
Tooth brushing frequency		
less than once/day	65	47.1
at least once or more times/day	73	52.9

Table 2 shows the description of tooth loss (at least 1) and the state of oral rehabilitation. With this data we determined that the prevalence of dental prosthetic needs was 53.6%.

Table 3 shows the results of the bivariate analysis. The variables that show significant results were related to the socioeconomic position. Thus, greater dental prosthetic needs were observed when the subject did not have access to health insurance (68.9% vs 35.9%) than when they did ($p < 0.001$). Likewise, the percentage of dental prosthetic needs was higher in those with incomplete elementary schooling (64.0% vs 34.7%) than in those with more extensive education ($p < 0.01$). Subjects attending a publicly funded nursing home had higher dental prosthetic needs

Table 2. Description of tooth loss and state of dental rehabilitation in elderly Mexicans

Variables	Frequency	Percentage
Dental status		
edentulous with prosthesis	27	19.6
lost teeth with prosthesis	37	26.8
edentulous without prosthesis	27	19.6
lost teeth (<21) without prosthesis	33	23.9
lost teeth (>20) without prosthesis	14	10.1
Dental prosthetic needs		
no prosthetic needs	64	46.4
with prosthetic needs*	74	53.6

* – It refers to subjects who had at least 1 missing tooth and were not rehabilitated with any type of dental prosthesis.

Table 3. Bivariate analysis of dental prosthetic needs and independent variables

Varibles	Dental prosthetic needs		p-value
	with need	without need	
Sex			
male	15 (34.9)	28 (65.1)	$\chi^2 = 3.3178$
female	49 (51.6)	46 (48.4)	p = 0.069
Age			
60 to 74 years	23 (48.9)	24 (51.1)	$\chi^2 = 0.7139$
75 to 84 years	19 (41.3)	27 (58.7)	p = 0.700
85 and more	22 (48.9)	23 (51.1)	
Marital status			
single	23 (44.2)	29 (55.8)	$\chi^2 = 0.1999$
in a relationship	11 (45.8)	13 (54.2)	p = 0.905
divorced/widowed	30 (48.4)	32 (51.6)	
Type of location			
publicly funded	30 (36.1)	53 (63.9)	$\chi^2 = 20.0606$
private	13 (41.9)	18 (58.1)	p = 0.000
adult day center	21 (87.5)	3 (12.5)	
Health insurance			
yes	41 (64.1)	23 (35.9)	$\chi^2 = 15.0113$
no	23 (31.1)	51 (68.9)	p = 0.000
Schooling			
elementary school and more	32 (65.3)	17 (34.7)	$\chi^2 = 10.9472$
less than elementary school	32 (36.0)	57 (64.0)	p = 0.001
Pension/retirement			
no benefit	39 (37.5)	65 (62.5)	$\chi^2 = 13.3750$
with benefit	25 (73.5)	9 (26.5)	p = 0.000
Multi-morbidity			
0 or 1 disease	45 (45.0)	55 (55.0)	$\chi^2 = 0.2768$
2 or more	19 (50.0)	19 (50.0)	p = 0.599
Tooth brushing frequency			
less than once/day	29 (44.6)	36 (55.4)	$\chi^2 = 0.1533$
At least once or more times/day	35 (47.9)	38 (52.1)	p = 0.695

(63.9%) than those who attended a private nursing home (58.1%) or a club for the elderly (12.5%) ($p < 0.001$). Finally, if they did not have the social benefit of being retired/pensioned, they had a higher prevalence of dental prosthetic needs (62.5% vs 26.5%) than those who were retired/pensioned ($p < 0.001$).

Discussion

The results of this study in a sample of elderly Mexicans showed a high need for dental prosthetic care (53.6%), which was associated with various indicators of socioeconomic position. In other studies, a prevalence ranging from 33.2 to 81.2% has been observed, depending on the population group studied.[13–16] Although there have been substantial improvements in the oral health of populations in several countries, different dental problems persist worldwide. The burden of oral diseases is particularly high in socioeconomically disadvantaged populations, which can be observed in both developing and developed countries. Oral diseases such as dental caries, periodontopathies, tooth loss, oral mucosal lesions and oropharyngeal cancers, oral diseases related to human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) and dental trauma injuries are important public health problems worldwide, and it has been shown that poor oral health has profound effects on health and quality of life.[22] Despite this scenario, the World Health Organization has demonstrated the existence of limited availability or inaccessibility of oral health services, which makes its utilization rates particularly low among some vulnerable groups of the population. Also, it is estimated that in high-income countries the curative dental care consumes between 5 and 10% of public health expenditure.[23]

The impact of the socioeconomic position on different oral health indicators has been amply demonstrated.[7] Similarly, studies in India have also revealed that dental prosthesis requirements are increasing among subjects with the lowest socioeconomic position.[13] In this sense, we find 4 variables that refer to the socioeconomic position (health insurance, schooling, type of nursing home and retiree/pensioner). The exact mechanism by which the socioeconomic position of the individuals or the context in which they live is associated health effects is not very clear, because the socioeconomic position is a multidimensional construct.[12] Some authors have proposed several mechanisms to try to explain this association. For example, a molecular basis such as the modulation of the immune system response via infections.[24] Other authors mention the influence of the various exposures of the community in which the subjects live. For example, in neighborhoods characterized by low educational level, health outcomes are modified, even independently of the level of schooling and social class. A combination of community and individual measures is also possible.[25] Other researchers say that health can be affected by unhealthy lifestyles and behaviors as well as by access to poor quality services for people with poor socioeconomic status.[26]

Social pressure to maintain esthetics and function may be the driving force that influences subjects of better socioeconomic position to replace their missing teeth. In addition to this, a more positive attitude toward dental care, awareness and the cost of dental treatment could also be an important factor determining a person's dental prosthetic condition.[13] In this sense, in Mexico, it has been consistently observed that the subjects with the best socioeconomic position are also those who use dental health services more than their counterparts with the lowest socioeconomic position, both preventive and curative services.[27]

In Mexico, oral diseases such as dental caries and periodontal diseases remain the main public oral health problems in the general population, and are the most common reason for the extraction of teeth in the adult population.[28] Consequently, the prevention and control of these diseases as well as the prevention of tooth loss is a commitment of oral health workers in the population and in individuals. Prosthetic rehabilitation with conventional complete dentures or with removable dentures results in an overall upgrade in patients' quality of life.[29]

Conclusions

Based on the results obtained in the study, we can conclude that this sample of elderly people presented high dental prosthetic needs, in more than half of the subjects studied. Also, it was observed that variables indicating the socioeconomic position had a great impact on dental prosthetic needs, which represents the existence of inequalities in oral health. It is necessary to eliminate the barriers (such as economic, access, geographical) that prevent people with a worse socioeconomic position to rehabilitate their dental status, and thus reduce oral health gaps between different levels of socioeconomic position.

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Utility of the visual analog scale for the assessment of dental anxiety

Przydatność skali wzrokowo-analogowej do oceny poziomu lęku stomatologicznego

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Abstract

Background. Psychometric scales can be used to assess the level of dental anxiety, but for practical reasons these are not routinely used in practice. This provides the opportunity to look for a simpler method that can be applied in the everyday work of a dentist.

Objectives. The study was designed to determine the utility of the visual analog scale (VAS) for dental anxiety assessment.

Material and methods. The study involved 315 patients who were awaiting their appointments; they were asked to complete a survey consisting of a scale and questionnaires: Modified Dental Rating Scale (MDAS), Kleinknecht's Dental Fear Survey (DFS), Dental Beliefs Survey (DBS), and Visual Analog Scale (VAS) of anxiety.

Results. An assessment of anxiety level measured by the MDAS scale showed that the majority of patients in the study group were patients with an average level of anxiety (68%), 25% with low and 7% with high levels of anxiety (phobia). The DFS found that 45% were patients with low anxiety levels, 48% with an average level, and 7% with phobias. By using the DBS scale, it was observed that the vast majority of respondents showed average confidence (70%), 26% high trust and only 4% did not trust the dentist. There is a high correlation between VAS scores and MDAS and DFS scales.

Conclusions. The VAS scale can be a simple and reliable tool for assessing anxiety in patients before dental surgery.

Key words: dental anxiety, dental treatment, visual analog scale

Słowa kluczowe: lęk dentystyczny, leczenie stomatologiczne, skala wzrokowo-analogowa

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Dentophobia is manifested by very intense anxiety, accompanied by strong symptoms from the autonomic nervous system. The consequence of increased anxiety is a worsening of oral hygiene, because a patient who is "obsessively" afraid of dental treatment tends to avoid appointments, and if the patient decides to be treated, it is a very traumatic experience for the him or her, and this adversely affects and aggravates their general well-being and quality of life.[1] Irregular visits or discontinuations undermine the effectiveness of therapy and rehabilitation and can delay recovery.[2] Given the above, an assessment of dental anxiety level provides very valuable information for the dentist, because it can affect the entire process of treatment and patient care, including the appointment schedule, an adaptation visit, plan of and proposed treatments, anesthesia techniques or the necessity of pharmacological premedication. Among the many methods most commonly used are psychometric scales, which are standard patient-completed questionnaires. We can mention here the Corah Dental Anxiety Scale (CDAS), Modified Dental Anxiety Scale (MDAS), Kleinknecht's Dental Fear Survey (DFS), and others.[3–6] Despite the availability of these tools for evaluating anxiety, practice indicates that they are rarely used in clinical settings because filling out questionnaires by patients as well as their interpretation by physicians is time-consuming. The above factors highlight the lack of a simple and "friendly" but credible tool that can be used in the daily work of the dentist to assess the severity of anxiety.

Numerous studies indicate that the primary source of dental anxiety is fear of pain during extraction, anesthesia or drilling.[7] Simplified scales are used to assess the severity of pain in many medical fields, but primarily in oncology, palliative medicine and anesthesiology. These allow the patient to quickly and reliably record the intensity of the pain. These scales include the Visual Analog Scale (VAS). The VAS is a segment of 10 cm: from 0 (no pain) to 10 (unbearable pain). The patient's task is to mark with a vertical line the point on the scale corresponding to the current intensity of pain. Similar to the subjective feeling of pain is the feeling of fear. Unfortunately, only individual reports can be found in the available literature in which the VAS (taken from the pain assessment methodology) has been used to assess anxiety in hospitalized patients awaiting surgery.[8] In the Polish literature, however, there is no study on the use of VAS to evaluate dental anxiety.

Objectives

The purpose of the study was to: (1) estimate the correlation between the VAS and typical MDAS and DFS dental scales; and (2) determine the suitability of the VAS for evaluating anxiety levels in adult patients prior to dental treatment.

Materials and methods

The study included 315 patients aged 18–81 who reported to the dental office at Non-Public Health Care Facility at Dworcowa 1 Str. 46-020 Czarnowąsy. The questionnaire was delivered daily to the first 2 to 3 patients reporting for dental treatment. The study was conducted between January and December 2015. Respondents filled out the questionnaires themselves. Mid-level medical staff distributed the questionnaires, and their participation in the study was limited to the minimum, i.e. explaining the aims and purpose of the survey, and being told how to complete and distribute questionnaires.

Patients awaiting a dentist's appointment were asked to complete a survey containing (1) demographics, (2) questions related to the source of the most unpleasant experiences during dental treatment, (3) questions associated with the reason for the dental appointment, (4) a modified scale of dental anxiety assessment (MDAS), (5) a scale of dental fear evaluation (DFS), (6) a scale of trust in the dentist (Dental Beliefs Scale, DBS), and (7) to mark the level of anxiety on the VAS scale.

The MDAS consists of 5 questions that relate to the specific circumstances related to the dental treatment, about which a choice is made, categorized on the Likert scale of 5, to assess anxiety in a given situation. For a specific statement, the patient was given the choice of one of the following answers: relaxed (1 point), a little restless (2 points), tense (3 points), nervous (4 points), and very upset, sweating, physically sick (5 points). The results were in the range of 5–25 points, and the higher the result, the higher the anxiety. This scale was originally dichotomous, i.e. the results of 19 points or more were defined as very high anxiety or phobia, while results below this value indicated either the presence of anxiety or the lack thereof. At present, there are also studies in which the raw data is categorized at 3 or 4 levels, and these were also used in this study to generalize (in graphical form) the intensification of the dental anxiety of the studied population. There were 4 categories: no anxiety (5 points), low anxiety (6–10 points), moderate anxiety (11–18 points), and high anxiety (19–25 points). In the literature, there is a great deal of freedom in terms of the point ranges that define a given category.[6,9–11] MDAS has been translated into the Polish language and validated by Dubielecka et al.[12]

DFS is used to assess the level of dental fear in 20 typical situations, such as appointments, listening to the sound of the drill or seeing the needle for anesthesia – rated on the Likert scale from 1 (no fear) to 5 (very anxious). The scores range from 20 to 100. The scale was also originally dichotomized, i.e. results of 63 points or higher refer to patients with very high anxiety (phobia), while results below 63 points indicate the presence or absence of anxiety. Also, as with the MDAS scale, one can find studies in which the raw results are categorized at 3 or 4 levels, and these were also used in this study. The following was used:

no fear (20 points), low anxiety (21–41 points), moderate anxiety (42–62 points), and high anxiety (63–100 points). In the literature, as in the case of the MDAS scale, there is a great deal of freedom in terms of the point ranges for a given category.[4,5,12] DFS has not been validated in the Polish language, though there is a bulk of studies that confirm its utility in dental fear assessment.[13,14]

It must be added that terms like dental fear and dental anxiety are frequently used indiscriminately, but they represent different progressive degrees of the same psychological condition. Dental fear refers to a normal unpleasant emotional reaction to specific threatening stimuli occurring in situations during dental treatment. Conversely, dental anxiety is an excessive and unreasonable negative emotional state experienced by dental patients and results from the premonition that something undesirable is about to happen. Altogether, the results from the DFS and MDAS are qualitatively slightly different but, as mentioned above, used in dentistry interchangeably.

The DBS scale of trust in a dentist developed by the Getz team is comprised of 15 questions on issues such as information provided by the doctor, behavior of the doctor, qualifications, competencies, and the patient's ability to ask questions. Some researchers use a scale of 16 questions.[15,16] In our study, a 15 item Getz scale was employed. Patients assess their trust in the dentist using a 5-point Likert scale, where the patient can agree with a specific question fully (5 points), mostly (4 points), partly (3 points), to a lesser extent (2 points) or disagree (1 point). The sum of the points, in the range of 15–75, gives an overview of the patient's subjective perceptions about the dentist and the course of the appointment. The raw results have allowed 3 categories to be identified: high confidence level (15–34 points), medium confidence level (35–54 points), and low confidence level (55–75 points). In the further statistical analysis, as with other scales (MDAS, DFS), the raw results were used.

Respondents were also asked to highlight the severity of anxiety on the VAS scale at that moment, i.e. immediately prior to the visit to the dental office. The VAS scale is a 100-mm segment where the patient's vertical line indicates the level of his or her anxiety. The results were assessed by measuring (in mm) the distance from the beginning of the scale to the spot marked by the patient. The value of "0" means no fear, while "100" is the maximum intensity of anxiety that a person can imagine.

Statistical analysis

Statistical analysis was performed with STATISTICA v. 8.0 PL (StatSoft, Inc., Tulsa, USA) and MS Excel 2007. The analysis used parametric tests, i.e. Student's t-test, one-way analysis of variance and the Newman-Keulus post-hoc test. Non-parametric data was analyzed with the χ^2 test. Spearman's test was used to evaluate the correlation. The $p < 0.05$ or 0.001 values were statistically significant. Interpretation of the correlation coefficient was based on the following classification: $r = 0$ – no correlation; $0.0 < r \leq 0.2$ – very weak correlation; $0.2 < r \leq 0.4$ – weak correlation; $0.4 < r \leq 0.7$ – average correlation; $0.7 < r \leq 0.9$ – high correlation; $0.9 < r \leq 1.0$ – very high correlation; $r = 1$ – full correlation.

Results

A total of 315 people participated in the survey of anxiety intensity in patients before visiting the dental office; 9 questionnaires were completed incorrectly; therefore, 306 surveys were included in the further analysis. Of the surveyed patients, women accounted for 52% and men 48%. Regarding age categories, the largest groups of respondents were under 30 years (26%) and 41–50 years (24%). Patients aged 31–40 years accounted for 18% of the respondents, 51–60 years 14% and over 60 years 17%. Of the respondents, 33% had higher education, 34% vocational education, 29% secondary education and 4% primary education only.

By analyzing the reasons for the respondents' appointments with the dentist, 48% reported tooth treatment, 14% tooth extraction, 10% hygienic treatment, 4% surgery, 11% a general check-up, and 12% could not clearly determine the reason for the appointment or the type of treatment. As the source of the most unpleasant experiences during the appointment, 77% of the respondents described pain during the procedure, 12% waiting for the procedure, 5% pain during anesthesia, 3% reported an inappropriate approach by the physician, and 3% other reasons not mentioned in the survey. The majority of respondents had average confidence (70%), 26% had high trust, and only 4% did not trust the dentist.

The level of anxiety (categorized) measured by the MDAS scale showed that the majority of patients in the respondent group were people with moderate anxiety levels (68%), 25% with low and 7% with high levels of anxiety (phobia) (Fig. 1). The assessment of anxiety level measured by the DFS scale showed that in the study group, respondents with low anxiety levels accounted for 45%, with average anxiety 48%, and those with high anxiety

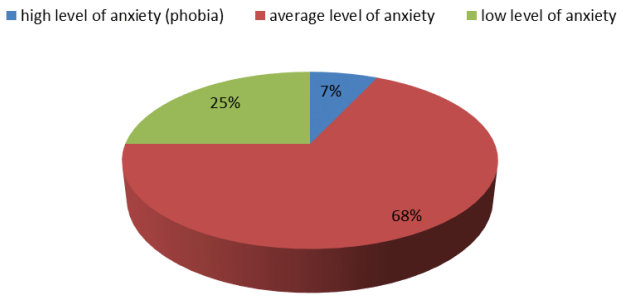

Fig. 1. The level of anxiety (categorized) measured by the MDAS

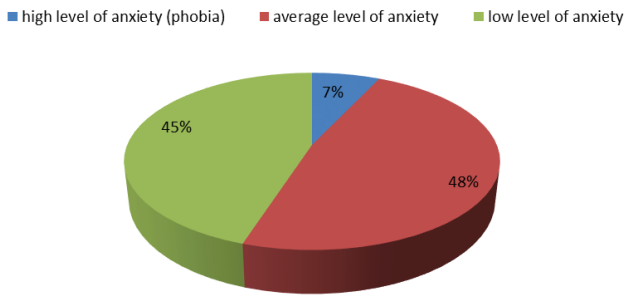

Fig. 2. The level of anxiety (categorized) measured by the DFS

(phobia) 7% (Fig. 2). Using the scales to assess MDAS and VAS anxiety, it was found that sex remained unaffected by the test parameter This is similar to the parameter of trusting a dentist as rated by the DBS scale. The intensity of anxiety was significantly higher in women based on the results of the DFS scale (Table 1). At the same time, it was shown that with increasing age, anxiety levels rose, but this dependency only concerned the comparison of people over the age of 60 with respondents under 30 years of age (MDAS and DFS questionnaires) or 51–60 vs 31–40 (VAS scale).

Age did not influence the aspect of trust in the dentist (Table 2). People with higher education showed significantly lower anxiety levels than those with primary, vocational or secondary education (MDAS, DFS and VAS scales). The type of education did not affect the confidence in the dentist measured by the DBS questionnaire. The type of procedure affected the severity of anxiety, with those seeking tooth extraction or those who could not give a reason for an appointment exhibiting a higher anxiety level compared to patients attending a general check-up, dental treatment, or hygienic treatment.

Table 1. Analysis of variables with regard to gender

Variables	Female (n = 158)	Male (n = 148)	Analysis		
	average	average	factor	p-value	type of test
mDAS	13.13 ±3.70	12.62 ±3.07	t = 1.309	0.191	test t-Studenta
DFS	45.61 ±13.82*	42.24 ±10.45	t = 2.393	< 0.05	
VAS	34.37 ±19.80	31.77 ±19.81	t = 1.146	0.253	
DBS	39.41 ±8.92	38.85 ±9.62	t = 0.535	0.593	

* p < 0.05

Table 2. Analysis of variables with regard to age

Variables	Age in year divided into groups							
	group 1	group 2	group 3	group 4	group 5	analysis		
	< 30 (n = 81)	31–40 (n = 56)	41–50 (n = 73)	51–60 (n = 43)	> 60 (n = 53)	factor	p-value	type of test
MDAS	12.21 ±3.72	12.36 ±3.10	12.92 ±3.47	13.56 ±2.94	13.89 ±3.30*	F = 2.909	<0.05	ANOVA
DFS	41.00 ±13.29	42.34 ±11.95	44.99 ±13.04	45.61 ±10.09	47.59 ±11.32*	F = 3.745	<0.05	
VAS	30.09 ±21.02	27.61 ±16.64	36.11 ±21.16	35.61 ±17.67*	37.38 ±19.39	F = 2.815	<0.05	
DBS	37.21 ±10.26	38.91 ±7.39	39.56 ±8.73	39.21 ±9.59	41.72 ±9.47	F = 1.982	0.097	

Groups:1/5; 2/4 * p < 0.05

There was a strong correlation between VAS scores and MDAS scores for dental anxiety (Spearman's r = 0.7616; p < 0.001). There was a strong correlation between VAS scores and DFS questionnaire scores for dental anxiety (Spearman's r = 0.7674; p < 0.001). There was a weak correlation between trust in the dentist assessed on the DBS scale and anxiety levels determined on the VAS scale (Spearman's r = 0.2780; p < 0.001). There was a strong correlation between MDAS and DFS dental anxiety scores (Spearman's r = 0.7686; p < 0.001). There was a weak correlation between the results of the dental anxiety MDAS scores and the trust in the dentist scores assessed on the DBS scale (Spearman's r = 0.2743; p < 0.001). There was an average correlation between DFS dental anxiety scores and trust in the dentist scores assessed on the DBS scale (Spearman's r = 0.11617; p < 0.001).

Discussion

Dental anxiety can, to a large extent, be "modeled" by environmental factors and prior experience. Significant factors are early and negative medical experiences, family impact, age and cause of the first visit to the dentist. Studies show that fear of dental treatment in adults can be acquired and learned in childhood. Considering the question of dental anxiety, we should consider the patient's trust in the doctor and the whole dental treatment process a trust built from early childhood. This is confirmed by, among others, the Olszewska study, which showed such a relationship; namely, patients declaring a high level of anxiety were characterized by low confidence in the dentist.[17] Results confirmed that the most important positive qualities of a physician for patients are competence and avoidance of pain, while the worst is awkwardness, roughness and lack of respect and haste.

Wilk-Sieczak and Gmyrek-Marciniak assessed the effect of family attitudes on children's behavior during their first visit to the dentist, declaring that the majority of surveyed mothers and caregivers declared high (61.4% and 58.6%, respectively) and average (27.2% and 35.8%) trust in the dentist.[15] At the same time, it was shown that a low level of trust in the dentist on the part of the mothers was significantly correlated with difficult behavior during the first visit to the dentist. The results of this study indicate

that sex, age, education and type of procedure remained virtually unaffected by the degree of patient confidence in the physician. However, there is a positive correlation between the results of the MDAS, DFS and VAS scores and the trust in the physician. Patients who trust a doctor show less aggravation and vice versa, while a distrustful person is characterized by a higher intensity of anxiety. Similar correlations have been observed by other authors, e.g. Kowalińska-Kania et al. confirmed (in children aged 10–15 years) a moderate correlation between anxiety levels measured on the NRS, CDAS and CFSS-DS numerical scales and the degree of confidence measured by the DBS questionnaire.[18] The cited authors also noted that with increased confidence in the dentist, the anxiety of the examined children decreases, which is also consistent with the results of other researchers studying similar relationships in a Lithuanian child population.[19]

There are many papers analyzing the impact of variables such as age, sex, education, socioeconomic status, or type of procedure on dental anxiety.[20] Olszewska et al. found that women exhibited a higher degree of anxiety than men, similar to those with primary education compared to patients with higher education.[21] The greatest anxiety was aroused in patients by such procedures as grinding teeth under the crown or prosthetic bridge and root canal treatment (both also considered the most painful), and the least by removal of tartar. Similar results were obtained by Firat et al. in a Turkish population.[22] On the MDAS scale, women in this study scored significantly higher than men, while DFS scores were negatively correlated with education (lower education – higher anxiety).[22] These results are consistent with our findings.

When analyzing the problem of dental anxiety, the most common source of anxiety in dentistry is fear of pain during the procedure.[23] In our study, the source of the most unpleasant experiences during a visit to a dental clinic was pain during the procedure (77%), waiting for surgery (12%), pain during anesthesia (5%), the wrong approach by the doctor (3%) and other reasons not mentioned in the survey (3%). Interestingly, further analysis has shown that the type of procedure also affects anxiety. So, those attending for tooth extraction, or those who could not give a reason for a visit exhibited a higher anxiety level compared to patients who had come for a general check-up or hygienic treatment.

Our results are partially consistent with the results of other authors, for example Walawender et al., who found that pain during surgery was the source of the most unpleasant sensations for 41% of respondents, anesthesia pain for 22%, incorrect treatment for 17%, prolonged waiting for surgery for 13%, and 7% indicated other causes.[7] Borowy et al., when analyzing the intensity of dental anxiety and attitudes toward the dentist (among university students in Kraków), also showed that the most unpleasant experience during the visit was pain during the procedure (48.9%) or a long wait for the visit (21.7%).[13] The remaining responses pointed to pain during anesthesia, incorrect approach by the doctor, and reasons described as "other".

In conclusion, in most studies, patients point to pain during the procedure as a source of unpleasant sensations during a dentist visit. In our study, using both MDAS and DFS scales, dentophobia was reported by about 7% of patients. Similar results (7.3%) were obtained by Nicolas et al.[24] (France), while the least frequent incidence of dentophobia occurred in Denmark, i.e. 4%.[25] Women and the elderly show a higher level of anxiety, which was also confirmed in our study. (Tables 1 and 2). Dentophobia was reported in 9.49% of women and only 4.05% of men (MDAS questionnaire, $\chi^2 = 3.537$; $p = 0.059$) or 11.39% of women and only 2.03% of men (DFS questionnaire $\chi^2 = 10.486$; $p < 0.05$) (results not graphically presented). The above observations coincide with the reports of other authors.[11]

Considering the importance of anxiety in dentistry, it is important to identify patients with very high (phobia) and high levels of dental anxiety, as this can have a positive effect on the final result. In our study, the VAS scale was derived from the pain assessment methodology, and 2 additional scales, MDAS and DFS, were used for dental patients only. The raw results of the MDAS and DFS questionnaires were categorized, which allowed the population to be divided into 3 groups, i.e. individuals with low, medium and high levels of anxiety. It was found that according to the MDAS scale, the majority of patients (68%) in the respondent group were characterized by average anxiety levels, 25% with low and 7% with high levels of anxiety (phobia). The anxiety level measured, in turn, with the DFS scale showed that 45% of the respondents were characterized by low anxiety levels, 48% with average, and 7% with high-anxiety (phobia).

Kaczmarek et al. assessed the aggravation of anxiety among students of medicine and dentistry (using the MDAS scale) and confirmed that, in the respondent group, the highest number of people exhibited an average level of anxiety, i.e. 60.6% (medical students), and 47.2% (dental students), while for the low anxiety level it was 18.2% (medical students) and 43.1% (dental students) and high levels of anxiety (phobia) were 21.2% and 9.7%, respectively.[9] The same authors also used the second scale of dental anxiety assessment, i.e. DAS, which is a modification of MDAS. In spite of the similarity between these scales, they obtained a slightly different profile for the severity of anxiety, but, as they state, the differences were not statistically significant. The above results are mostly consistent with the results of our study, i.e. the prevalence of patients with moderate anxiety. In our study, the distribution of MDAS and DFS respondents to the respective anxiety groups was different, but in this case the differences were statistically significant.

Since the DFS questionnaire contains many more questions than the MDAS questionnaire, it is characterized by a higher sensitivity,so despite the high correlation, these research tools slightly differentially graduated the severity

of dental disease in patients. Further studies have shown that there is a high correlation between VAS scores and the scales, which, as previously mentioned, are only used for dental anxiety assessment: MDAS and DFS.[26]

In the available literature, there is virtually no study that has addressed this problem. Only a handful of studies can be found in which the VAS scale (a "tool" taken from the methodology of assessing the severity of pain) has been used to measure anxiety in patients prior to a procedure. Thus, Millar et al. assessed the utility of VAS for anxiety assessment in a group of 44 preoperative patients, comparing the results obtained with the State-Trait Anxiety Inventory (STAI) and the results of the Hospital Anxiety and Depression Scale.[27] The obtained relationships have shown that the VAS scale can be regarded as a reliable "tool" for assessing anxiety, but there are some limitations, i.e. the patient's uncertainty as to the correct answer or the tendency to avoid stress evaluations is revealed. The authors termed this "the impact of the central tendency" on the results. Similar issues were also studied by Kindler et al., who in a much larger group of patients (734), immediately prior to a procedure and anesthesia, assessed anxiety with the use of the VAS scale and the STAI questionnaire.[28] These researchers also demonstrated a positive correlation between VAS and STAI scores.

Also, in the Polish literature you can find one publication from this range: Romanik et al. assessed the severity of anxiety in 38 patients awaiting a procedure using the STAI Inventory and the VAS scale.[29] They stated that those who declared that they were afraid of surgery indicated a length of 3.7 ±2.6 mm on the VAS scale, while those who were not afraid – 1.5 ±1.7 mm. The VAS scale has been used to evaluate anxiety in patients in a dental practice in only one publication, Bahammam and Hassan, by validating MDAS scale in the Arabic language. They recruited 486 patients, and after analysis they found that the Arabic version of MDAS is characterized by high reliability and accuracy.[30] By plotting the Receiver Operating Characteristic curve (ROC), the cutoff point for the presence of very high dental anxiety (phobia) is 16 points or more. On the other hand, the assessment of anxiety on the VAS scale showed that the recruited patients were characterized by an average anxiety level (55.74 ±17.46 mm) and the results corresponded very well to MDAS scores.

Meisel-Denes et al. used the VAS scale, which is in some sense analogous to the numerical scale (NRS), in their study to assess pain and anxiety in sedation with nitrous oxide.[31] Walawender et al. also evaluated dental anxiety in adult patients seeking dental surgery using the NRS scale and the results were compared to the STAI Inventory (general anxiety assessment) and CDAS questionnaire.[24] These authors showed a high correlation between NRS and CDAS and a moderate correlation with the L-state STAI scale. Similar findings have been made by other researchers using NRS and CDAS and CFSS-DS scales, assessing anxiety in children aged 10–15 years.[17]

In summary, clinical experience so far has shown that the currently-available scales for dental anxiety evaluation are rarely used under typical dental practice conditions. The results show that the VAS scale provides the opportunity for a quick and reliable assessment of the degree of anxiety in adult patients registered with a dental practice, and the unmatched benefits of this method are the short test time and simple interpretation of results.

Conclusions

Age, sex, education, and type of procedure have an impact on the severity of anxiety concerning dental treatment. A high degree of correlation was found between the results of the MDAS scale and DFS dental anxiety scores and VAS scale results. The VAS scale can be a simple and yet reliable tool for assessing anxiety in patients before dental surgery.

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Hand eczema among Lebanese dentists: An epidemiological study

Wyprysk rąk u libańskich lekarzy dentystów – badanie epidemiologiczne

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Abstract

Background. Dentists are at risk of developing hand eczema, as are most people who work in the health care field.

Objectives. The objective of this study was to investigate the prevalence of hand eczema and allergies among a sample of Lebanese dentists to understand their probable causes and propose solutions to reduce their occurrence.

Material and methods. A total of 314 Lebanese dentists, who practiced different specialties of dentistry, after giving verbal consent, completed an anonymous questionnaire that focused on occupational diseases. This study was approved by the ethics committee of Saint-Joseph University (USJ) of Beirut, Lebanon. The statistical analyses were performed using SPSS software for Windows. The alpha error was set to 0.05.

Results. The mean age of the participants was 39.2 (±11.66) years (58.6% male). The results showed that 15.3% (n = 48) of the surveyed dentists developed allergies to latex gloves, 2.5% (n = 8) developed allergies to resins, and 3.8% (n = 12) developed allergies to glutaraldehyde.

Conclusions. This study showed that a large number of Lebanese dentists suffer from hand eczema. It is important to note that not all skin reactions are related to gloves or natural rubber latex. Dentists should be aware of hand eczema symptoms, the common allergens contained in dental materials, the prevention and the appropriate treatment of occupational skin diseases.

Key words: latex, occupational disease, gloves, glutaraldehyde, methacrylate

Słowa kluczowe: lateks, choroba zawodowa, rękawice, aldehyd glutarowy, metakrylan

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Dermatitis, or eczematous dermatitis, is an inflammatory response of the skin to various extrinsic and intrinsic agents. Occupational hand dermatitis has been a particular problem for the worker in the medical field, including dentists. The 2 major forms of dermatitis are contact dermatitis and atopic dermatitis.[1] Dental materials used for dental care constitute a major risk of inducing allergic reactions in patients and dentists.[2] Allergic contact dermatitis (ACD) manifestations vary among individuals, and dental personnel is more likely to develop hand dermatitis, while patients with ACD caused by dental materials tend to develop stomatitis or cheilitis (type IV allergy) or contact urticaria (immediate – type I allergy).[3]

The adoption of universal precautions in response to concerns about the transmission of human immunodeficiency virus (HIV) and other viruses has led to an increase in hand eczema from gloves and an increase in the frequency of irritant contact dermatitis.[3,4] In their work during dental treatment, dentists also use several products and handle polymer resin materials, which are known to be skin irritant, causing contact allergies and/or irritation of the skin and mucous membranes.[5] Additionally, frequent hand washing and the use of protective gloves for many hours per day contribute to an unfavorable environment for the skin of the hands.[6] Furthermore, cosmetic dentistry is becoming more popular, exposing dental workers to resins, bleaches and adhesives, with such components as acrylic and methacrylic-based materials causing hand eczema.[3,5]

Nevertheless, little is known about the current prevalence of hand eczema among Lebanese dentists, and only a limited amount of published information is available, only 1 epidemiological study was realized in 2005.[7] Thus, the purpose of this study was to investigate the epidemiology of hand eczema symptoms and allergies among Lebanese dentists, to try to understand their probable causes and to propose solutions that would reduce their occurrence.

Material and methods

This was an observational cross-sectional study. This research and its consent procedure were approved by the ethics committee of the Saint-Joseph University (USJ) Beirut, Lebanon, in accordance with the World Medical Association Declaration of Helsinki. A questionnaire focused on hand eczema was prepared. The questionnaire was pretested and auto-administrated on a sample of 30 dentists arbitrarily chosen from the dental school of USJ. Improvements of this questionnaire were done according to this pilot study. Thereafter, the improved questionnaire was distributed to the general dental practitioners (GDPs) and specialists who attended the 3-day francophone symposium organized by USJ in 2014. This questionnaire was auto-administrated by each participant. The inclusion criteria were the Lebanese dentists from among the dentists who accepted to fulfill the questionnaire. The non-Lebanese dentists that were attending the dental symposium were excluded from the study. 1,100 Lebanese and non-Lebanese dentists were present during the 3-day francophone symposium (including the instructors). A sample of 350 Lebanese dentists was randomly selected using the random number table. The response rate was 90%, since 314 dentists accepted to participate in the study.

The outcome variable of the study was the presence of hand eczema (Yes/No) in dentists. The predictor variables of the study were: age, gender, years of dental practice, dental specialty, mean number of working days per week, number of patients treated per day, mean hours of wearing gloves per week, presence of a dental assistant (Yes/No), allergic predisposition (Yes/No), handling composite with fingers (Yes/No), type of X-rays used (normal/digital).

The statistical analyses were performed using statistical package software for social sciences (SPSS) for Windows (v. 18.0, Chicago, USA). The alpha error was set at 0.05. The normality distributions of the continuous variables were assessed with the Kolmogorov-Smirnov test. Univariate analyses were performed to assess the association of each predictor factor with hand eczema. The χ^2 square test and Fisher's exact test were used for categorical variables and the Student/Mann-Whitney tests were used for continuous variables. Logistic regression analysis was used with hand eczema as the dependent variable. Predictor variables that showed associations with $p < 0.250$ in univariate analyses were candidates for the multivariate model, according to the Enter method.[8] Collinearity among independent variables was also tested. Highly correlated independent variables were excluded.

Results

A total of 314 dentists (184 male and 130 female), aged 39.2 ±11.66 years, completed the questionnaire (Table 1).

The mean number of dental working years was 15.50 ±11.18 (range: 0–45 years), the mean working days per week was 4.68 ±1.11 (range: 1–7).

Our results showed that 10.2% (n = 32) of participants developed hand eczema, 71.9% (n = 23) of whom had contact dermatitis, 15.6% (n = 5) had atopic dermatitis, and 12.5% did not specify. On the other hand, 15.3% (n = 48) of the surveyed dentists developed allergies to latex gloves, 2.5% (n = 8) developed allergies to resins, and 3.8% (n = 12) developed allergies to glutaraldehyde. The results revealed that dentists wore gloves at a rate

Table 1. Sociodemographic characteristics of the participants. Percentage is more than 100% due to duplicate answers. Fisher's Exact test

Explicative varible	n	%
Marital status (n = 314)		
married	179	57.0
single	126	40.1
divorced	3	1.0
widowed	3	1.0
no answer	3	1.0
General practitioner (n = 314)		
yes	144	45.9
no	164	52.2
no answer	6	1.9
Specialty (n = 314)		
restorative and prosthetic dentistry	79	25.2
orthodontics	34	10.8
surgery	33	10.5
endodontics	32	10.2
periodontology	31	9.9
pediatric dentistry	24	7.6
oral pathology	5	1.6
oral radiology	1	0.3
no answer	86	27.4

Table 2. Continuous variables associated with hand eczema. Student's t-test or Mann-Whitney test

Explicative varible	Hand eczema	N	Mean	SD	p-value
Age	yes	30	37.97	10.614	0.584
	no	259	39.20	11.831	
Years of dental practice	yes	32	14.50	9.935	0.629
	no	258	15.52	11.386	
Working days per week	yes	31	4.84	1.098	0.432
	no	260	4.67	1.110	
Number of patients treated per day	yes	31	9.26	4.966	0.389
	no	259	8.34	5.673	
Hours of wearing gloves per week	yes	26	30.65	14.519	0.699
	no	238	29.51	14.267	
Years of wearing gloves	yes	25	13.80	7.874	0.697
	no	245	14.53	8.957	

of 29.54 ±14.24 hours per week (n = 267) for over 14.51 ±8.82 years (n = 274).

Concerning allergic predisposition, 5.1% (n = 16) complained of asthma and 10.2% (n = 32) of pollen allergies.

Univariate analyses showed that age, years of dental practice, number of working days per week, number of patient treated per day, number of hours and years of wearing gloves were not significantly associated with hand eczema in dentist ($p > 0.05$) (Table 2). Moreover, gender, specialty, presence of dental assistant and type of radiography used in dental practice were not significantly associated with hand eczema ($p > 0.05$) (Table 3).

Multivariate analyses revealed that dentists who manipulate the composite with their fingers were 10.3 times more at risk to develop hand eczema compared to dentists who do not manipulate composite with fingers (p-value = 0.008). Moreover, dentists who had developed allergy to resins, latex, aerosol and glutaraldehyde were 5.4 times more at risk to develop hand eczema than dentists who had not developed an allergy (p-value < 0.001). Asthma and allergy to pollen were not associated with hand eczema (p-value = 0.216) (Tables 4, 5).

Table 3. Categorical variables associated with hand eczema. χ^2 test or Fisher's exact test

Explicative varible	Hand eczema				p-value
	yes		no		
	n	%	n	%	
Gender					
male	23	71.9	154	57.5	0.117
female	9	28.1	114	42.5	
total	32	100.0	268	100.0	
GDP					
yes	12	37.5	128	48.7	0.232
no	20	62.5	135	51.3	
total	32	100.0	263	100.0	
Dental assistant					
yes	26	81.2	194	74.0	0.375
no	6	18.8	68	26.0	
total	32	100.0	262	100.0	
Allergy					
yes	17	58.6	47	20.9	<0.001
no	12	41.4	178	79.1	
total	29	100.0	225	100.0	
Handling composite with fingers					
yes	5	15.6	7	2.8	0.006
no	27	84.4	246	97.2	
total	32	100.0	253	100.0	
Type of X-rays used					
normal	12	38.7	101	39.3	0.133
digital	15	48.4	149	58.0	
any	4	12.9	5	1.9	
both	0	0.0	2	0.8	
total	31	100.0	257	100.0	

Table 4. Logistic regression model of the predictor variables associated with hand eczema

Explicative varible	B	Standard Error	Degree of freedom	Sig.	Exp (B)	95.0% CI for Exp (B)	
						lower	upper
Allergy	1.691	0.440	1	0.000	5.427	2.291	12.854
Gender	0.912	0.486	1	0.060	2.489	0.961	6.447
Composite/ fingers	2.336	0.874	1	0.008	10.340	1.866	57.307
X-Ray type	–0.076	0.193	1	0.696	0.927	0.635	1.354
Constant	–6.374	2.084	1	0.002	0.002		

B – beta coefficient; Sig. – significance or p-value; Exp (B) – odds ratio. Multivariate logistic regression model.

Table 5. Allergic predisposition to dental materials or others and hand eczema in dentists. χ^2 test and Fisher's exact test

Hand eczema	Hand eczema				p-value
	yes		no		
	n	%	n	%	
Allergy to					
latex (gloves)	10	34.5	31	13.8	
resins (methyl methacrylate)	2	6.9	2	0.9	
glutaraldehyde	3	10.3	4	1.8	
aerosols	0	0.0	1	0.4	
no allergy	12	41.4	178	79.1	<0.0001
others	0	0.0	5	2.2	
latex and resins	2	6.9	1	0.4	
latex and glutaraldehyde	0	0.0	2	0.9	
glutaraldehyde and aerosols	0	0.0	1	0.4	
total	29	100.0	225	100.0	
Allergic predisposition to					
pollen	2	6.5	31	13.5	
asthma	4	12.9	12	5.2	
no allergy predisposition	19	61.3	163	70.9	0.216
other	6	19.4	21	9.1	
pollen and asthma	0	0.0	3	1.3	
total	31	100.0	230	100.0	

Discussion

Our statistics revealed that 10.2% of the Lebanese dentists developed hand eczema, while a study realized in Sweden reported that 20% had hand dermatitis.[9] Extensive contact with water and soap caused by frequent hand washing after each patient, given that the average number of patients received per day, according to our statistics, was 8.43 ±5.57, is a well-known risk factor for irritant contact dermatitis.[10]

The prevalence of latex allergies among Lebanese dentists revealed that 15.3% of them had been medically diagnosed with latex allergies, while 2.1% in Queensland, Australia, have been diagnosed. This is due to the extensive use of latex gloves the medical field and domestically.[1] Furthermore, our study showed that Lebanese dentists used latex gloves for 14.51 ±8.82 years, and rubber latex gloves can cause delayed allergies (type IV), with a reaction usually occurring 24–96 hours after exposure, as well as immediate (type I) allergic reactions.[11–12]

Hand eczema caused by acrylates and methacrylates is considered to be one of the more common occupational diseases, affecting mainly dental care personel (dentists, dental assistants and prosthetics technicians).[13] Acrylic monomers are considered to be potent sensitizers and acrylic resins have the potential to induce cytotoxic, irritant and/or contact allergic reactions, whereas this capacity is absent or significantly reduced after polymerization, which is incomplete or at best 83%.[13–16] Methyl methacrylate, as a small molecular acrylate, can permeate thin protective disposable gloves; protective gloves are insufficient due to the permeability of natural rubber latex and vinyl gloves to these substances.[17–21] With the growing evolution of cosmetic dentistry, which exposes dental workers to resins, bleaches and adhesives, composed of acrylic- and methacrylic-based materials that can cause hand eczema, more dentists are exposed to methyl methacrylate.[3,5] Previous studies in Serbia[17] and in Valencia, Spain,[22] reported that 5–25% of dental personnel might be sensitized to methyl methacrylate, while our study revealed that 2.5% (n = 8) developed this type of allergy. Since most of the Lebanese dentists send acrylic work to prosthetics technicians (e.g., temporary crowns, dentures, etc.), they are less exposed to non-polymerized methyl methacrylate.

Glutaraldehyde is considered the disinfectant of choice for sterilizing medical and dental equipment; it fixes cell membranes, blocks the release of cellular components and therefore kills the micro-organisms.[23,24] Despite published case reports and patch testing results indicating its potential for sensitization and other toxic reactions, glutaraldehyde remains the sterilizing agent of choice in the cleaning of medical and dental equipment. This is due to its affordable cost, disponibility, disinfectant properties, stability, and the absence of any significant harmful effects on equipment.[25]

Unfortunately, glutaraldehyde has many toxic side effects, including the ability to induce hand eczema.[23] Hand eczema caused by glutaraldehyde is common in Lebanese dentists; 3.8% (n = 12) of Lebanese dentists developed allergies to glutaraldehyde, while 10.3% (n = 3) developed allergies to glutaraldehyde associated with hand eczema. Statistics from Kansas, USA, revealed that 4% of dentists developed allergies to glutaraldehyde, which was in accordance with our results.[26]

Understanding the causes of hand eczema in dental care workers is important for developing strategies for prevention. The recommended procedure to reduce the occurrence of hand eczema caused by latex gloves is to reduce the exposure of the dentist to natural rubber latex (NRL) protein. Avoidance is the only effective option, so the affected dentist should initially change to free-powdered, latex gloves to minimize the incidence of allergy to latex.[27] If this step is unsuccessful, they should change to non-latex gloves or should wear glove liners under their latex gloves.[28] Additionally, washing the hands frequently after the use of gloves could help remove irritants causing allergy.[27] Dentists with known NRL protein hypersensitivity should use only non-latex (nitrile) gloves and should undertake proper hand care in the form of topical moisturizers and corticosteroid- or antihistamine-containing ointments, which is why the usage of nitrile gloves is the most important preventive measure in the dental occupation.[17,28]

To prevent hand eczema caused by methyl methacrylates, it is important to develop no-touch techniques to avoid skin exposure to these chemicals.[29] Additionally, protection can be improved using nitrile rubber gloves or double gloving to prevent small molecular acrylates from permeating the gloves;in this manner, direct skin contact could be avoided.[17]

Despite the awareness that glutaraldehyde induces hand eczema, the rate of the allergy has appeared to increase constantly, which is why it is necessary for dentists exposed to glutaraldehyde to heighten occupational safety standards and improve the methods of barrier protection until a less sensitizing disinfectant is developed.[23]

In addition, hand eczema caused by commercial hand cleansers occurred more frequently than hand eczema caused by alcohol-based hand rubs (ABHRs), which why we recommend the use of ABHRs daily in dental clinics.[30]

Conclusion

This study showed that Lebanese dentists suffer from hand eczema. Within the limitations of this study, especially the limited number of participants, our study confirmed that hand eczema constitutes a health problem for dentists.

It is important to note that not all skin reactions are related to gloves or natural rubber latex. Dental professionals should be conscious of the chemical allergens used in their daily practice, the symptoms of hand eczema, and their correct treatment.

In addition, skin care advice should be incorporated into hand hygiene education. Dermatologists must be kept abreast of the newer allergenic materials and products used in dentistry to diagnose and treat hand eczema correctly.

Given that, hand eczema may have medical, social, occupational, and subsequently financial repercussions. It is important to note that this occupational health problem should be highlighted at all clinical and research symposia to achieve greater awareness.

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Root caries: A geriatric challenge

Próchnica korzenia – problem gerostomatologiczny

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Abstract

Root caries is an important problem of concern for the elderly population in many countries. Due to its rapidly progressing nature and occurrence in areas of limited visibility, these lesions often go unnoticed unless they become symptomatic. Multiple systemic diseases, poor oral hygiene coupled with reduced manual dexterity of this age group add to the severity of the challenge. Limitations of available biomaterials along with reduced accessibility and isolation make the restoration of such dental lesions a clinical challenge also for dentists. Routine dental checkups and regular monitoring of risk factors can significantly reduce the occurrence of such caries to a major extent.

This article reviews the contemporary literature concerning the clinical features, etiology, risk factors and prevention of root caries. The main topic of the work is the electronic search of literature related to root caries; it was carried out in MEDLINE PubMed database using MeSH terms "root caries", "etiology", "prevention".

Key words: risk factors, prevention, restoration, root caries

Słowa kluczowe: czynniki ryzyka, zapobieganie, odbudowa, próchnica korzeni

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Root caries is a multifactorial dynamic disease process that involves the interaction of the host, bacteria and nutrients, along with modifying or protective factors, resulting in the demineralization of a tooth. It was virtually the only form of caries seen in the aboriginal population in Papua-New Guinea.[1] An examination of ancient skulls has revealed that root caries was more common than enamel caries in ancient man (Egyptian, North American Indian, Early Anglo Saxon). Today, in primitive societies such as certain natives of New Guinea highlands and aborigines of India, has been observed as the major cause of tooth loss.[2]

These soft, rapidly progressing destructive lesions are either confined to the root surface or involve undermining the enamel at the cementoenamel junction. Often, it is seen close to or within 2 mm of the cementoenamel junction.[3] Root caries lesions that occur closely adjacent to or within 2 mm of the crest of gingiva are considered to be active, whereas lesions that occur farther from the gingival crest are more likely to be arrested.[4] These lesions usually have less well-defined margins, are u-shaped in the cross section, often asymptomatic and have rapid progression. They can occur in areas of abrasion, erosion, abfraction, or as primary root caries or recurrent caries.[5]

Root caries progresses at about twice the rate of coronal caries because the critical pH of dentin is 6.7. Cementum covering the root surface is extremely thin near the cementoenamel junction, so it provides less resistance to acid attack. Apatite crystals of dentin and cementum are smaller in size than the enamel, and so the reactive surface is bigger.[6] The loss of cementum increases the rate of penetrating the root by the lesion and also increases calcium and phosphate loss from the tooth surface.[7] Early root caries tends to be diffuse and track along the cementoenamel junction on the root surface. More advanced root lesions enlarge toward the pulp.[8]

Evidence suggests that either facial or interproximal surfaces are more affected by root caries.[9] The proximal root surface near the cementoenamel junction is often unattended by routine oral hygiene procedures because of the concave contours and occasional roughness at the termination of the enamel. These factors along with gingival recession lead to proximal root surface caries. Among the mandibular teeth, molars are more often affected, whereas in the case of maxillary teeth, the anteriors are more affected.[10]

In 1980, Root Caries Index (RCI) was introduced to overcome the limitations of DFS (Decayed, Filled Surface) index, since DFS index does not consider the number of tooth surfaces at risk of caries.[11] It is calculated using the formula below and is expressed as a percentage:

$$\text{Root Caries Index} = \frac{\text{number of root surfaces with root caries}}{\text{number of root surfaces with gingival recession}} \times 100\,.$$

The prevalence of root caries in the age group of 50–64 was found to be 3 times higher compared to 20–34 age group.[12] Initially, *Actinomyces* sp. was believed to be the pathogen responsible for initiating root caries.[2] Later, some studies suggested that *Lactobacillus casei/paracasei/rhamnosus* and *Psuedoramibacter alactolyticus* are associated with root caries.[13] With advancing age, as a result of reduced immunity and systemic problems, oral microflora changes. Proteolytic bacteria represent 40% of microbes in root caries lesions.[14] A recent study has found *Propionibacterium acidifaciens, Streptococcus mutans, Olsenella profusa, Prevotella multisaccharivorax* and *Lactobacillus crispatus* to be more associated with root caries.[15]

Classification of root caries

International Caries Detection and Assessment system (ICDAS) classifies and detects root caries based on the following criteria:

– color (light/dark brown/black);
– texture (smooth/rough);
– appearance (shiny/glossy, matte/non-glossy);
– perception on gentle probing (soft/leathery/hard);
– cavitation (loss of anatomic contour).[16]

In order to detect and classify root caries using ICDAS criteria a community periodontal index (CPI) probe should be used by the examiner. One score will be assigned per root surface. The facial/mesial/distal/lingual root surfaces of each tooth should be classified as follows:

Code O → Root surface does not exhibit any unusual discoloration or surface defect, has normal surface contour.

Code E → Root surface cannot be visualized directly or by gentle air-drying.

Code 1 → Clearly demarcated areas on root surface or at the cementoenamel junction that is discolored but no cavitation present (loss of anatomic contour <0.5 mm).

Code 2 → Clearly demarcated area on root surface or at cementoenamel junction that is discolored and has cavitation (≥0.5 mm).

Code 3 → Cavitated (>0.5 mm depth) carious root surface which is soft/leathery.

Code 4 → Cavitated (>0.5 mm depth) carious root surface which is hard/glossy indicating arrested/inactive caries.

Code 6 → Extensive caries involving at least half of the tooth surface and reaching the pulp.

Code 7 → Filled root with no caries.

Risk factors for root caries

Since root caries is a multifactorial disease, several intraoral, behavioral and population related factors may increase an individual's risk of developing root caries.

Some of these factors are modifiable, whereas others are uncontrollable.[17] Most studies have shown that the majority of root caries are primary lesions. This indicates that controlling/modifying risk factors can prevent caries.[18] Risk factors can be intraoral or extraoral. The most common intraoral risk factor for root caries in adults is increased gingival recession leading to exposed roots.[17] From clinical findings it can be assumed that an individual with a high risk of coronal caries has a higher chance of developing root caries, indicating that risk factors for both type of caries are more or less the same.

Xerostomia, resulting from chronic medication and radiation therapy, increases the risk of root caries. Drugs such as antipsychotics, sedatives, barbiturates, antihistamines reduce salivary flow and increase caries risk.[19] Some studies indicate that low buffering capacity, low salivary immunoglobulin A, low salivary calcium and phosphate may also be associated with increased risk of root caries. As we age, our immune system weakens and less antimicrobial immunoglobulin is produced and found in the saliva. The level of serum immunoglobulin IgG and IgM is significantly reduced in older individuals. This may contribute to the increased susceptibility of elderly individuals to oral diseases.[20]

A diet high in refined carbohydrates, poor general and dental health are also risk factors contributing to the development of root caries. Both the quantity and frequency of sugar consumption are crucial factors in the development of root caries, similarly as in the case of coronal caries. Other intraoral risk factors include periodontal disease, periodontal surgery, unrestored coronal caries, partial dentures associated with plaque accumulation and gingival recession on abutment teeth, overdenture abutments, removable partial dentures, malocclusion, cervical non-carious lesions, tipped teeth, which make certain areas of teeth inaccessible for cleaning.[21]

Cardiovascular diseases have also been associated with higher caries experience, particularly in individuals of 80 years or older. Older people with hypoalbuminemia are at considerable risk of root caries.[22] Diseases like Sjögren's syndrome, diabetes mellitus also increase caries risk status.[19.] Drugs used for managing these systemic conditions, unattended oral hygiene and altered oral flora may be the contributing factors for elevated root caries level in such individuals. Low indices of socioeconomic status have been associated with an increase in caries due to reduced access to care. Another behavioral risk factor is tobacco use. Smoking is associated with periodontal diseases and gingival recession, and chewing tobacco contains fermentable carbohydrates.[23] Other behavioral risk factors include consumption of alcohol/narcotics. Males are more often affected by root caries than females. Patients with physical disabilities or with limited manual dexterity for cleaning their teeth are also at a high risk of root caries. Traumatic tooth brushing habits render the retained dentition susceptible to root surface caries.[24]

Prevention of root caries

Measures to prevent root caries can be categorized into 3 levels – primary, secondary and tertiary prevention. Primary preventive measures help prevent the occurrence of the disease. This can be done at the population level or individual level. Measures at the population level include water fluoridation, whereas individual measures include reducing or removing risk factors and enhancing protective factors. Secondary preventive measures help slow down or arrest an ongoing disease process. In the case of root caries these measures include remineralization/minimal restoration of carious lesions. They help remineralize incipient lesions and prevent the development of new lesions. Tertiary preventive measures include placing extensive restorations so as to prevent further disease-related deterioration of the tooth and to return it to normal function. Preventive and restorative options based on the risk status of the individual are presented in Table 1.[21,25]

In clinical practice, primary preventive measures to prevent root caries are significant, since restorative treatment of such lesions is extremely challenging and may lead to tooth loss in most cases due to recurrent caries or the sensitivity of the restored tooth. Therefore, such measures should be taken immediately after the exposure of root surfaces, as root caries progresses faster due to low mineral content of the covering cementum.[26] Fluoride is a widely accepted preventive agent, since it can interfere with the physiochemical and microbiological proceses of root caries. High fluoride concentration may be necessary to prevent and control root caries compared to coronal caries.[27] Patient-level preventive measures include taking fluoride supplements regularly, fluoridated toothpaste, xylitol gums/mouthwash, chlorhexidine rinses, diamine silver chloride lozenges, altering dietary habits etc.

Table 1. Experimental groups

Risk level	Oral hygiene	Root caries	Preventive measures	Restorative material
Low	good	no caries in 3 years	reinforce prevention, annual recall	no restrictions
Medium	fair	1–2 lesions in 3 years	diet counseling, fluoride toothpaste, fluoride mouthwash, professional fluoride application, 6-month recall	resin composites, resin modified glass ionomers, compomers
High	poor	more than 3 lesions in past 3 years	monitor microorganisms, modify diet, high-fluoride toothpaste, sodium fluoride/APF gel daily and chlorhexidine rinse for 2–4 weeks, xylitol chewing gum, 3-month recall	fluoride releasing materials

Professional-level preventive measures include the application of topical fluoride gels/varnishes. The list of medications taken by the patient can be checked and less xerogenic drugs can be prescribed or their dosage can be reduced. Salivary stimulants such as pilocarpine can be prescribed.[28] For the primary prevention of root caries the recommended best choice is 38% silver diamine fluoride solution professionally applied manually; it is recommended as the most cost saving treatment for root caries prevention in high risk individuals.[29] If no professional application is possible, the best alternative is the use of self-applied amorphous calcium phosphate (ACP) and fluoride toothpaste daily.

Subjects with risk of root caries should be recommended to use fluoride toothpaste with a concentration between 1000 and 1500 ppm of fluoride as sodium fluoride, monofluoro phosphate or amino fluoride. The daily use of 1100 ppm dentifrice combined with APF (acidulated phosphate fluoride) gel application provides added protection.[30] Studies have shown that the use of fluoride toothpaste containing 1.5% arginine and insoluble calcium resulted in the formation of ammonia and increased pH level of the oral cavity, and thus prevented the development of root caries. Also, arginine helps maintain the normal oral flora and thereby derive the benefits of normal oral flora.[31] Mechanical plaque control methods may require good manual dexterity, which is compromised at old age. Moreover, hypersensitivity is a common problem for elderly people. Therefore, antimicrobial agents may complement mechanical plaque removal for preventing root caries. The use of automated toothbrushes and the daily use of water irrigation devices can also be suggested for root caries-prone patients. In high risk patients who wear dental prostheses avoid placing restoration margins apical to the surrounding tissue to prevent plaque accumulation.[28]

Cavitated root caries that is not easily accessible for cleaning may be restored by minimally invasive techniques.[32] Fast setting self-cure glass ionomers could be used for such minimal restorations. Regular use of dentifrices containing 5000 ppm fluoride and quarterly professional application of chlorhexidine or silver diamine fluoride varnishes have been found to be effective in decreasing the progression and initiation of root caries.[33] Silver nitrate and silver diamine fluoride are more effective in arresting active caries lesions and preventing new caries than fluoride varnish. It has antimicrobial activity against *Streptococcus mutans* and *Actinomyces naeslundii* found on dentin surfaces and slows down dentin demineralization.[34] Studies have shown that the use of 10% sodium hypochlorite removes organic materials and increases the permeability of fluoride ions, and thereby increases the potential of remineralization.[35] In a 15-month period study the daily intake of milk supplemented with fluoride and, or probiotic bacteria was found to reverse soft and leathery primary root caries lesions.[36]

Dentin biomodifiers are agents which interact with various extracellular matrix components of dentin and increase their mechanical properties, decrease the biodegradation rate and possibly promote mineral nucleation.[37] Dentin modifiers, such as 5% glutaraldehyde, 0.5% proanthocyanidin and 0.625% genipin, can modify dentin collagen and increase its resistance to enzymatic digestion by cariogenic organisms.[38] Grape seed extract contains proanthocyanidin which can be used instead of fluoride during minimally invasive the treatment of root caries. Proanthocyanidin-treated collagen matrices resisted enzyme digestion in vivo and in vitro. Also it increased collagen synthesis and accelerated the conversion of soluble collagen into insoluble collagen during development. Grape seed extract also induced cross-links in dentin collagen and increased the ultimate tensile strength of demineralized dentin.[39] The combined use of proanthocyanidin and casein phosphopeptide-amorphous calcium fluoride phosphate (CPP-ACFP) has synergistic effect on root caries remineralization and increases the hardness of root caries.[40]

Coating the root surface with resin-based materials that can release and recharge fluoride may be a simple and effective measure to protect it from physical, chemical and biologic insults. Surface prereacted glass ionomer (S-PRG) fillers incorporated into resinous material, which have the ability to release and recharge fluoride and other ions such as aluminum, boron and strontium, can be used to enhance remineralization and reduce acid attack by oral cariogenic bacteria. RG filler containing resins were found to inhibit bacteria induced pH drop and formed a hermetic seal on the exposed dentin surface.[41] Progression of root caries could be inhibited by the application of antibacterial adhesive system containing 12-methacryloyloxydodecylpyridinium bromide (MDPB). Unpolymerized MDPB in the primer solution penetrates deeply into the lesion to kill or inactivate the infecting bacteria. Also, it seals the lesion and prevents caries.[42]

A combination of casein phosphopeptide and amorphous calcium phosphate (CCP-ACP) and photo activated disinfection (PAD) proved to be very effective and holds great potential as a recommended treatment for stabilizing root surface caries in the clinical practice.[43] Healozone has been proposed as a method of reversing, arresting or slowing down the progression of dental caries. Ozone gas is applied to the carious lesion followed by the use of a remineralizing solution, immediately after the application of ozone.[44]

Carious lesions should be restored taking into consideration the patient's age, health status and symptoms associated with root caries. Before the teeth are restored, root caries must be controlled using preventive measures. The type of restorative material depends on the location, accessibility of margins of the lesion and oral hygiene. Restorative management is challenging due to difficulties in visibility, moisture control, access to carious lesions, proximity to pulp/gingival margin and high organic content of dentine.

Microleakage and poor marginal adaptation of the restoration or defective margins are the most common causes of failure. Restorative material with high potential for fluoride release as well as uptake should be considered.[45]

The root surface is cleaned with pumice, the excavation of carious tissue is done, and the restoration walls are prepared. Margins and restoration design depend on the restorative material used. Modified composite or resin modified glass ionomer are ideal for restorations in medium risk individuals. Root caries often may extend below the gingival margin, making it necessary to retract the gingiva with a clamp/pack to expose the cervical margin of the lesion or to utilize laser or electrosurgery to recontour the gingiva and obtain access to the lesion. A combined minor periodontal and restorative procedure is relatively simple and when done properly can provide excellent and affordable dentistry in the problematic areas.[46] The decision to use a particular method of retraction depends upon whether the apical extension of the lesion is located 2 mm above the height of the alveolar crest. Access can be gained by the use of a retraction cord and cervical clamp like 212, which displaces the soft tissue and exposes the lesion, or by creating a mini flap.[47] Coverage of a previously carious root with subepithelial connective tissue graft is a very predictable procedure, with results similar to those found in intact roots. This procedure may provide a definitive biological alternative for conventional treatment modalities for root caries. Moreover, the results are more esthetic, biologically acceptable and maintainable.[48] In search of other effective long-term preventive measures against caries, research is being conducted on developing caries vaccine. The main research target is the mechanism of adherence of *Streptococcus,* which can be affected by active/passive immunization and the use of DNA vaccines.[49]

Conclusions

With the development of newer technologies and oral hygiene measures, the incidence of dental caries has been reduced significantly. However, root caries continues to be a major challenge for both the patient and the dentist. It has been found to be a major factor which negatively affects the oral-health-related quality of life in the elderly population. In most cases, when these lesions are diagnosed, they are in the advanced stages, which necessitates the removal of the tooth. Regular dental visits and oral hygiene monitoring is essential in old age to meet this challenge.

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Current trends and clinical applications of optical coherence tomography in orthodontics: A literature review

Współczesne możliwości wykorzystania optycznej tomografii koherencyjnej w ortodoncji – przegląd piśmiennictwa

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Abstract

This paper presents an overview of the current knowledge about non-invasive investigations using optical coherence tomography (OCT) – structural imaging of oral tissues and biomaterials applied in vivo and in vitro – employed in the field of orthodontics. Optical coherence tomography is an emerging technology for producing high-resolution cross-sectional imagery. OCT provides cross-sections of tissues in a non-contact and non-invasive manner. The device measures the time delay and the intensity of light scattered or reflected off of biological tissues, which results in tomographic imaging of their internal structure. This is achieved by scanning tissues at a low resolution.

This paper aims to describe the application of OCT in the field of orthodontics, through previous studies investigating the development and disorders of natural tooth hard tissues; the paper also describes OCT studies on dental demineralisation and dental biomaterial characterisation. We explain the working principles of OCT and mention different types of OCT systems in use. Comparisons between OCT and other commonly used orthodontic diagnostic aids are also made and the possible future implications of OCT in orthodontics is discussed.

Key words: optical coherence tomography, non-invasive investigation, orthodontics

Słowa kluczowe: optyczna tomografia koherencyjna, badania nieinwazyjne, ortodoncja

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As in every other medical and dental specialisation, accurate diagnostic imaging is a key factor for orthodontic diagnosis and treatment planning. In addition, it is an essential tool that allows an orthodontist to closely monitor treatment progress and outcome. In 1896, the first intraoral radiograph was taken; since then, two-dimensional (2D) images have been the staple of orthodontic imaging. In recent times, numerous technological breakthroughs like computed tomography are emerging as the new face of imaging techniques in orthodontics. Current imaging modalities have limited resolution. As a result, they are not effective at detecting minute details in tooth tissues; smaller lesions such as tiny pre-caries and cracks always go undiagnosed. Dental radiography, including computed tomography, has limited imaging contrast. The contrast in radiographs arises from attenuation variation between different tissue composites. The human tooth – consisting of enamel, dentin, and pulp – does not exhibit good X-ray contrast. One of the initial indicators of dental decay is demineralisation of the enamel, and on radiographs its presentation might sometimes be overlooked by a professional. A thorough understanding of the tooth and its microstructures, the mineralisation process, and its dynamic mineral exchange processes can aid in gauging the health of the tooth. To study the microstructures of the tooth, studies using imaging modalities such as atomic force microscopy (AFM) and the transmission electron microscope have been used in previous studies. The latter modality needs to be performed ex vivo and cannot be used to assess healthy tissues or be performed in real time.

High-resolution and high-contrast images are some of the benefits that optical coherence tomography (OCT) imaging provides. Polarisation-sensitive OCT is a new improvement in OCT technology which provides better contrast when imaging tissues and their surrounding environment compared to the contrast of regular OCT imaging.

In 1991, Fujimoto et al. initially reported on the applications of optical coherence tomography (OCT).[1] Since then, copious clinical studies in diverse fields of ophthalmology,[2–4] dermatology,[5,6] gastroenterology,[7–9] and dentistry[10,11] have used OCT. OCT is a non-invasive, non-radiative optical diagnostic apparatus dependent on the principles of interferometers. With the use of a low-coherence, broadband near-infrared light source, a spatial resolution of ~20 μm and real-time images become a reality.[12,13] The initial applications of OCT were to visualise the human retina and atherosclerotic plaque.[1,14] This optical imaging approach facilitates the cross-sectional imaging of the microstructures of tissue in situ. Negating the need for excision and the processing of specimens, as in conventional biopsy and histopathology, is a fundamental advantage in using OCT. With the advent of improved optical specifications and system capabilities, OCT shows great potential in orthodontic research and clinical applications.

The latest developments in OCT technology have made it feasible to image non-transparent tissues, allowing the technology to be implemented in a wide range of medical specialisations.[15–18] There are restrictions in imaging depth due to optical attenuation from tissue scattering and absorption. Nevertheless, images up to a depth of 2–3 cm can be achieved in most tissues, as with conventional biopsy and histology. Although ultrasound can reach deeper tissues, the resolution in OCT images is far superior to standard clinical imaging. The excellent resolution of OCT makes it a treasured ally to study in vitro arterial pathology and plaque morphologies.[19]

In recent times, many functional OCT systems have evolved, like the Doppler OCT (DOCT),[20,21] polarisation-sensitive OCT (PS-OCT),[22–24] endoscopic OCT,[25,26] and acoustic OCT.[27,28] These functional systems provide structural images in conjunction with unique optical characteristics such as tissue orientation and blood flow velocity.

The use of OCT has been gaining popularity in the field of dental research. In 1998 the first in vitro images of dental hard and soft tissues in a porcine model were released.[29] Subsequently, the in vivo imaging of human dental tissue was developed.[30] Multitudinous studies have been conducted using OCT in orthodontics and information regarding the enamel surface, microleakage around the bracket base, and enamel demineralisation in relation to the bracket base has been revealed with the use of OCT.

Principles of OCT

OCT functions similarly to the technique of ultrasound imaging, but it works with the principle of light scattering instead of sound. Two-dimensional cross-sectional images of the sample structure are generated by measuring the variation in path length differences of the backscattered light from the different layers of the sample structure.[1] OCT uses the near-infrared region of the light spectrum as its source since infrared light has optimal penetration depth in biological tissue structures. The speed of light travelling through air is very fast, thus the backscattered signals cannot be measured directly and correlation or interferometry techniques are used for this purpose. The most widely used approach for measuring the time delay in backscattered light is with the low coherence interferometry technique. Earlier primary applications of low-coherence interferometry were utilised in the field of optics and optoelectronic devices.[31,32] By using a known light path as a reference, we can measure the time delay or the path length difference between the backscattered light path reflected back from the sample and back from the known reference path. These measured values show the structural difference between the sample and the reference objects. The most commonly used interferometry technique for OCT is the Michelson interferometer.

In a basic Michelson interferometer configuration, the light from a source is directed onto a prism or a beam splitter. Then, the two split beams of light are directed to a reference path with a known length and to the sample that is to be measured. The reference path is varied according to the sample structure so as to obtain a better visualisation of the image. The backscattered light from the sample and from the reference path is interfered using a prism or a beam splitter. The interfered light produces dark and bright fringes correlating to the sample structures and this final interference signal is detected by a photodetector at the interferometer output. The axial resolution in OCT is determined by the coherence length and the bandwidth of the light source. The lateral resolution is dependent on the wavelength used and the beam optics used. Hence, by using a broad-bandwidth source with low coherence and an appropriate beam optics setup, it is possible to achieve high-resolution cross-sectional images of the sample structure. Figure 1 is a graphical representation of the working principles of OCT.

Types of optical coherence tomography

Optical coherence tomography (OCT) can be broadly classified into time domain optical coherence tomography (TD-OCT) and Fourier domain optical coherence tomography (FD-OCT). TD-OCT produces tomographic images by moving the reference arm mirror a few millimetres in order to create interference for individual layers of the sample. This means the image acquisition time is relatively longer. With the introduction of the Fourier relation, depth scanning can be done without any moving parts in the reference setup. This was achieved by either encoding the optical frequency in time by using a spectrally scanned source, or by an array of detectors for parallel acquisition of all wavelengths of the broadband source utilised. This helped to achieve the real-time acquisition of OCT images at high speeds. With a hundredfold increase in the capture time, quicker three-dimensional imaging of samples became possible. The FD-OCT can be

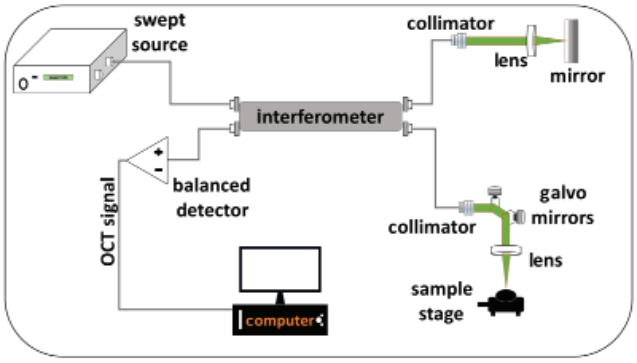

Fig. 1. Graphical representation of the working principle of optical coherence tomography

further classified into 2 types depending on the type of source and detector used. The first is spectral domain optical coherence tomography (SD-OCT); the other method is swept source optical coherence tomography (SS-OCT). Both OCT types share a common configuration for the fixed reference arm and the sample arm. SD-OCT uses a broad-bandwidth source and the detector part is comprised of a combination of a dispersive medium (grating/prism) followed by an array of detectors to simultaneously acquire the dispersed interference light. In the case of SS-OCT systems, the source bandwidth is spectrally scanned for individual wavelengths at high speed and the detector part is a single photodetector which individually acquires the interfered backscattered light signals one wavelength at a time. The SS-OCT has a higher depth sensitivity compared to SD-OCT but the acquisition time is slightly longer than for SD-OCT systems. By integrating the use of objective lenses and effectively utilising both coherence gating and confocal gating principles in OCT, it is possible to build optical coherence microscopy (OCM). By using high-magnification objective lenses and an expanded sampling beam waist, it is possible to attain a lateral resolution of 2 μm. The tradeoff is the limited depth of focus of OCM images.

Comparison with other dental diagnostic methods

Historically, newer imaging modalities replace existing technology to overcome their drawbacks. Computed tomography ushered in a new age of three-dimensional imaging with its appearance in the field of medical imaging, but its applications are limited due to its unnecessary exposure to ionising radiation and its inability to detect early lesions. Thus, the need arises to find a new, non-destructive technique that can be employed in the imaging of dental tissues. Currently, several innovative techniques are being developed for the diagnosis of dental diseases, such as a smart ultrasonic device,[33–35] LED-based dental optical probes,[36] and laser fluorescence.[37,38] Table 1 shows a comparison of dental OCT and other dental diagnostic modalities that are currently in practice. In short, OCT is a compelling diagnostic tool because it is a non-invasive, non-destructive, non-radiation-inducing, and real-time monitoring method with a high resolution and high contrast when compared to other imaging modalities.

Use of OCT in orthodontics

Formerly, the limitations of system size and light source manufacturing technology confined the applications of OCT in dentistry to studies involving visualisation of the morphology of dental hard and soft tissues. With the advent of well-engineered components, OCT applications

Table 1. Comparisons between optical coherence tomography and other diagnostic methods used in dental research

Methods	Advantages	Disadvantages
Radiography	low cost broad measurement range	radiative poor spatial resolution only 2D image
Dental-CT	broad measurement range 3D image reconstruction	no real-time image radiative poor spatial resolution
Intraoral Digital Cameras	low cost non-radiative	only surface information
Periodontal probe	low cost broad measurement range	low sensitivity no image invasive
OCT	high spatial resolution real-time image 3D image reconstruction is available	limited penetration depth and scanning range
Raman spectroscopy	high sensitivity responses to mineral and chemical concentrations	in vitro measurement expensive no image
Laser fluorescence spectrometer	real time detection responses to bacteria and chemical concentrations	lack of diagnostic consistency no image

have increased and have been used to visualise dental and periodontal diseases. OCT has grown beyond its initial use as an imaging apparatus and with the onset of its real-time imaging and its inherent high-resolution capabilities, it has kicked off a plethora of orthodontic research opportunities.

In the field of orthodontics, a number of studies have been done to evaluate the enamel surface in relation to bonding and de-bonding procedures. Filho et al., in 2013, evaluated the enamel surface after de-bonding with metal and ceramic brackets.[39] They studied the enamel fractures, adhesive remnants, and bracket fragments on enamel after de-bonding using OCT. In their study, the researchers were able to evaluate the damage caused to the enamel surface by different bracket systems and de-bonding procedures as well as to visualise and measure the adhesive remnant layer depth with the use of OCT.

Similarly, in 2015, Filho et al. studied the potential of OCT in evaluating the damage done to enamel by de-bonding and clean-up procedures by the use of metal and ceramic brackets.[40] With the help of OCT, the researchers evaluated the damage done to the enamel and remnants of fractured ceramic brackets during de-bonding procedures, along with the adhesive and bracket mesh remnants on the surface of the enamel.

Seeliger et al.[41] and Koprowski et al.[42] studied enamel thickness before and after orthodontic treatment using OCT and concluded that optical coherence tomography is an efficient aid in evaluating the surface and cross-sectional characteristics of enamel post-orthodontic treatment and it provides valuable information for deciding on the methodology and course of orthodontic treatment.

Nee et al. studied the use of cross-polarisation optical coherence tomography (CP-OCT) to longitudinally monitor demineralisation peripheral to orthodontic brackets.[43] The study was conducted over a 12-month period. Equipped with a high-speed CP-OCT the researchers extracted 3D images of the orthodontic bracket base. The images were analysed at intervals of 3 months in order to check for areas of demineralisation and remineralisation, and they also evaluated the use of a fluoride-releasing cement to check for remineralisation. They conferred the presence of and growth in the amount of demineralisation over time with the use of CP-OCT imaging. Additionally, the use of fluoride-releasing glass ionomer cement and conventional composite made no difference in the remineralisation of enamel around the bracket base.

Orthodontic adhesive materials can fail due to inherent voids between them and the bracket base, which can lead to bond failure and can delay orthodontic treatment progress. Though OCT cannot be used to quantify the bond strengths of orthodontic attachments, it can be applied to visualise and quantify the micro-damage at the junction of the bracket base and adhesive material. In the study done by Pithon et al., the researchers evaluated the in vitro effects of applying varnish containing casein phosphopeptide and amorphous calcium phosphate in the prevention of carious lesions around orthodontic brackets.[45] Equipped with OCT imaging, the researchers were able to evaluate the depth of caries penetration beneath the applied dental varnish. They reported that the use of CPP-ACP reigned superior to conventional varnish in the prevention of white spot lesions around the bracket base. The use of OCT, with its high resolution, allowed the researchers to analyse the microstructures of the enamel with high degrees of definition.

The occurrence and progression of periodontal disease play a crucial role in the success of orthodontic treatment. Studies have shown that advancement of periodontal disease can lead to orthodontic treatment failure, making

it vital for clinicians to observe, study, and monitor its progression. Many diagnostic modalities are available to clinically diagnose periodontal diseases. Recently, OCT has started to be used for that specific purpose. OCT renders high-resolution images that can be consistent and reproducible. With OCT the surface topography, pocket depths, their morphology, and attachment levels can be evaluated.[44] The progression of periodontal disease, including gingival morphology, the characterisation of the cementum surface, and the presence and propagation of sub-gingival calculus is possible in great detail with OCT imaging.[13] Colston et al. studied and evaluated OCT system efficiency to quantify gingival thickness along with alveolar crest morphology.[29] Being able to visualise the structures in detail and with precision greatly contributes to formulating a periodontal surgical treatment plan.

Marcauteanu et al. used optical coherence tomography to study the microstructural characterisation of the temporomandibular disc.[46] Temporomandibular joint discs were harvested from dead subjects and used in the study. Two different OCT systems were used. They compared the effectiveness of 2 OCT systems, one working at 1300 nm (time domain optical coherence tomography [TD-OCT]) and another at 840 nm (Fourier domain optical coherence tomography [FD-OCT]). The researchers scanned the harvested discs and evaluated them using the different OCT systems. Their results confirmed the OCT imaging technique to be the best for visualising the microstructural details of TMJ discs. They defined TD-OCT, due to its longer wavelength, to be particularly useful in the study of the homogenous microstructure of the thicker posterior pars. On the other hand, use of FD-OCT was faster. The researchers also advised that future studies with OCT be associated with arthroscopy, as OCT can be used to visualise the temporomandibular joint non-invasively and up to a sufficient depth.

Baek et al. determined the efficacy of OCT systems in determining tooth movement under light orthodontic forces.[47] Equipped with a TD-OCT, the researchers went about inducing orthodontic tooth movement in white rats. Post-induction of light orthodontic forces, structural

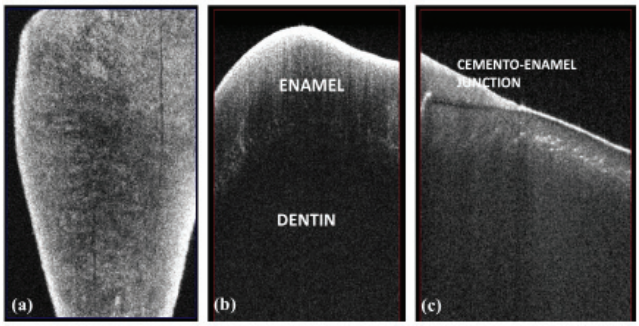

Fig. 2. OCT images of normal tooth hard tissues, from the orthodontic research archives. An image showing the tooth surface characterisation in different views, i.e., (a) the enamel surface, (b) a longitudinal section showing the enamel and dentinal layers of the tooth, and (c) the cementum – enamel junction of the tooth

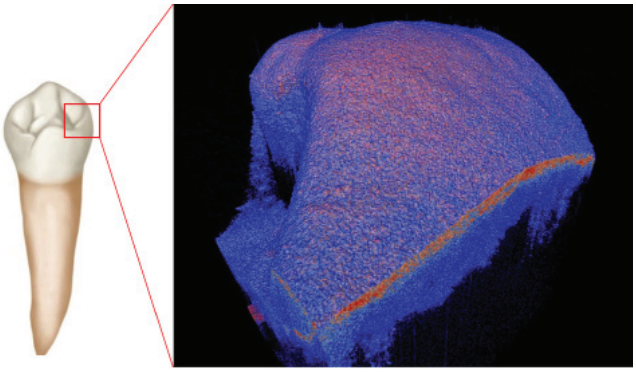

Fig. 3. 3D reconstruction of a premolar tooth, from the orthodontic research archives. The image depicts the 3D reconstruction of the scanned area using volume rendering software

variations in the periodontal ligament was studied using a digital radiography and TD-OCT system. With the use of OCT, they were able to successfully visualise the variations in the periodontal ligaments around the tooth, at different applications of force. In contrast, X-ray radiography could only confirm the presence of the PDL space and no discrimination of the variations within the PDL space as a reaction to orthodontic forces was possible. They concluded by suggesting that OCT can be used to predict tooth movement and can also be used to minimise the side effects associated with tooth movement by early detection.

Rashidifard et al. examined the ability of OCT, focusing primarily on structural OCT and PS-OCT, to identify and track early disease progression and its potential for the early diagnosis of osteoarthritis, rheumatoid arthritis, and rotator cuff repair.[48] This preliminary study was done to show that OCT technology can be used to visualise inflammatory arthritis. Study of the inflammatory markers is vital to understanding the disease as a whole and to aid in the future management of the disease. Here the high resolution of OCT can help assess musculoskeletal diseases at micron-scale resolutions.

Figures 2 and 3 are from the orthodontic research archives of the Department of Orthodontics, Kyungpook National University. Figure 2 shows the enamel surface characterisation in different views, i.e., (a) the enamel surface, (b) a longitudinal section showing the enamel and dentinal layers of the tooth, and (c) the cementum-enamel junction of the tooth are seen. Figure 3 shows the 3D reconstruction of the scanned area using volume rendering software.

Summary

OCT is an effective new imaging technique for non-invasive in vivo and in vitro investigations in the field of orthodontics. In orthodontics, OCT provides a non-invasive, non-radiative, high-resolution image that can be utilised in a broad spectrum of clinical studies, ranging from studies involving hard and soft tissues to the various biomaterials used.

For hard tissue imaging, OCT provides images in situ and in real time. Exposure to ionising radiation is a concern in modern-day clinical practice. OCT is an appropriate tool in this sense, as it is a non-invasive imaging modality that can provide images at a superficial level and also at considerable depth with high resolution and contrast for visualisation and analysis of dental hard tissue structures. OCT imaging allows early detection of demineralisation, which is commonly associated with the use of orthodontic brackets. A detailed visual analysis of remnants on the enamel surface after the de-bonding of orthodontic brackets can be created using OCT. The efficacy of various biomaterials that can influence the process of demineralisation can be visualised and analysed accurately with the help of OCT.

OCT allows for soft-tissue imaging, which is important in the treatment of periodontal diseases yet inaccessible to direct clinical assessment, and it offers great prospects for clinical studies involving tooth movement within the periodontal ligament. With the recent advances in OCT technology, it can be used to assess soft tissue lesions at a micron-scale resolution. The resolution might not be adequate for the study of single cells, but the architecture of the lesions can be studied. The measurements have no side effects and can be performed in real time.

Compared to other diagnostic methods used in orthodontics, the main advantage of using OCT lies in its higher resolution; OCT images display more detail and contrast than computed tomography and conventional radiography. There is the added advantage of being non-radiative. OCT imaging is also non-invasive, compared to other imaging techniques such as AFM and TEM, in which studies can only be performed ex vivo. Furthermore, the techniques are much simpler to perform than an MRI scan and much more detailed than ultrasound scans.

With the current system of OCT a number of images need to be analysed for investigation of an entire structure. In future, OCT systems with a higher depth penetration and with scanning heads purpose-built for orthodontic research can be made available. Various factors, including the components of the oral cavity and the degree of mineralisation of the teeth, impair the scattering and absorption of the light source; future developments may include an energy source of different wavelengths to target the specific components needed to investigate or to rule out the surrounding environmental noise. The entire process of scanning and acquisitioning the image is time-consuming, so developments in this area may see an even bigger jump in OCT in orthodontic research. Through the use of the diverse OCT techniques, for instance, polarisation-sensitive OCT, Doppler OCT, endoscopic OCT, optical coherence microscopy, and dual beam OCT, further research and advances in practical applications in the field of orthodontics need to be explored. By making the current OCT systems more robust and with scanning heads that are clinically applicable for orthodontic diagnosis, OCT can be utilised to its full potential.

OCT provides tissue sections in a non-contact and non-invasive manner and allows for real-time tissue imaging in situ, forgoing the need for biopsy, histological procedures, or the use of X-rays, so after solving the problems related to the availability and quality of equipment, it will be the method of choice in modern dental diagnostics. Increasing the number of clinical trials and the supplementary usage of OCT as an adjuvant in various studies is vital for OCT's growth in routine clinical practice and orthodontic research.

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Hearing and stomatognathic system: Searching for a link

Stan układu stomatognatycznego a proces słyszenia

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D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Acoustic vibrations reach the inner ear fluids in 3 integral ways: through the air, bone, and soft tissue. The final stimulation of the hearing receptor is recognized as the result of various interactions appearing between them. Air conduction is best described as the most efficient mode of auditory stimulation. Soft tissue and bone conduction (including dentaural hearing), being frequently underestimated in the complicated process of hearing, are still less examined. Clinical observations prove that dental health may have a direct influence on hearing. Additionally, hearing improvement after dental treatment is of a permanent nature.

This review presents a hypothesis and supporting literature review that dental disorders may contribute to disturbances in the excitation and/or the transmission of vibrations through the bone to the hearing receptor. Dissociation in the relationship between stimuli reaching the cochlea simultaneously in 3 modes may have a negative impact on hearing acuity.

Key words: bone conduction, acoustic stimulation, dentition

Słowa kluczowe: przewodnictwo kostne, stymulacja akustyczna, uzębienie

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Introduction

The entire human body is continuously affected by the sound fields. In the process of hearing, acoustic energy reaches the inner ear fluids in 3 integral ways: through the air, bone, and soft tissue. In spite of a few dissimilarities reported, the stimulation of hearing receptors (HR) does not depend onthe route through which the impulses reach the cochlea.[1–3]

Modes, pathways, and mechanisms of sound energy transmission

Air conduction (AC)

The conductive apparatus transmits sound through 2 pathways. The main one (ossicular) leads through the auricle, external auditory meatus (EAM), tympanic membrane (TM), ossicular chain, and the oval window to the fluids and other structures of the inner ear (IE). In the second, less effective pathway (acoustic), TM vibrations are transmitted to the surrounding air in the tympanic cavity, to membranes in cochlear windows, and further to the IE fluids. Differences in acoustic impedance between the air and IE fluids would cause only 0.1% of the initial acoustic energy to reach the HR. Elements of the outer and middle ear can, however, compensate for half of the acoustic energy loss. The large pinna of some animals is able to move in a desired direction, which can significantly increase hearing acuity. In the human EAM, the transmitted waves are amplified up to 20 dB at frequencies between 1–2.5 kHz. The TM and the ossicles act as a very efficient mechanical energy transformer. The sum of all their compensatory mechanisms result in an almost 44-fold amplification of acoustic energy.[4–6]

Bone conduction (BC)

In physiological conditions, the bone-hearing component is yet not considered to be significant. It is the result of large differences in acoustic impedance between the air and the solid structures of the skull. Additionally, the sound dampening properties of the soft tissues of the head cannot be ignored.[7,8] These limitations do not apply during fetal life, when a fetus is only able to register through BC sounds which reach amniotic fluids.[9] In indirect BC, acoustic waves in the surrounding air cause vibrations of the skull bone (SB) that are transmitted to the IE structures. The efficiency of HR stimulation depends on the energy of the acoustic wave and on the area of the skull that it reaches.[10] The acoustic stimulus is weakened here by about 50 dB. In direct BC, a tuning fork or vibrator directly contacts the head of the subject. The efficacy of stimulation depends on the place of the application and on the area of the transducer and applied static pressure.[11,12] The acoustic waves are weakened in this mechanism by about 30–40 dB. Each time, the vibrations may simultaneously go directly to both the bony labyrinth (cochlear pathway) and to the walls of the EAM, deforming them and producing sound in the ear canal and beyond as in the AC pathway (tympanic pathway). Tonndorf, in experiments on cats, described seven simultaneous mechanisms of BC stimulation of the HR.[13] Presently, 4 mechanisms of vibration transmission to the fluids of the IE are generally accepted and 1 still persists as disputable.

Compression of the cochlea

Skull vibrations alternately compress and decompress the bony labyrinth.[14] This mechanism relates especially to vibrations of high frequencies and is recognized as the most important contributor to HR stimulation above 4 kHz.[15,16]

Inertia of the cochlear fluids

In the vibrating cochlea, the fluid is also under the influence of inertial forces.[16] Fluid inertia is recognized as the second most valid mechanism in BC hearing. In a normal ear, it most convincingly explains the perception of sound from low frequencies to about 4 kHz.[17,18]

Inertia of the ossicles

The accepted basis of this mechanism resembles the activity of a mechanical spring when compared to the activity of the TM and the annular ligament with the attached ossicles.[16] It has been indicated that the inertia of the ossicles can have an important influence on BC perception from approximately 1.5 kHz to 3 kHz.[19]

Occlusion

During occlusion, the sound energy emitted by the motion of parts of the EAM is trapped and transmitted to the TM.[15] Sound pressure in the EAM generally increases from low frequencies to no more than 2 kHz.[20] When the EAM is opened, occlusion is acknowledged to be of limited importance in the complex process of hearing.[21]

Cerebrospinal fluid (CSF) pathway

SB vibrations induce vibrations in the underlying structures of the brain. Extensive studies have confirmed the transmission of sound pressures into the contents of the skull and directly through the fluid connections between CSF and the perilymph, from low frequencies up to about 3 kHz (Fig. 1).[11,22–24]

Soft tissue conduction (STC)

STC has seldom been examined and applied. One exception is the Lewis-Federici test, which depends primarily on comparing the duration of BC and "bone-cartilage conduction" (fork applied to the tragus). In normal hearing and

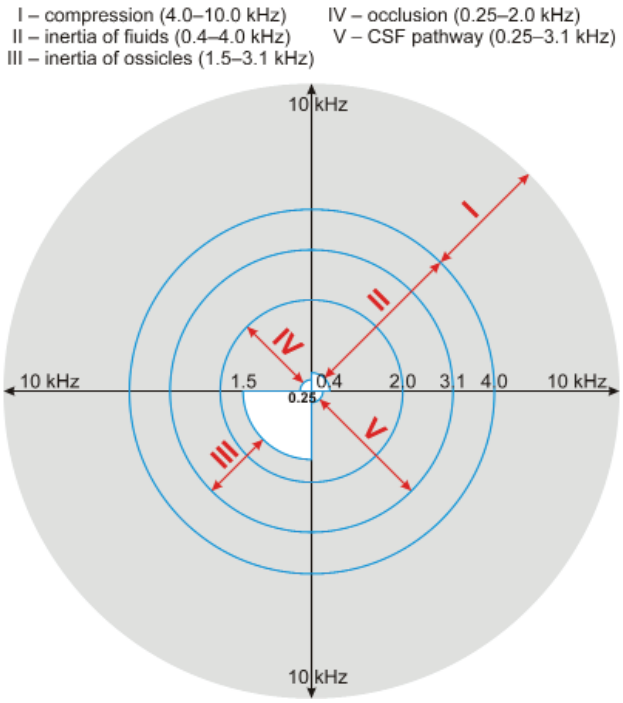

Fig. 1. Frequency ranges of hearing in the five mechanisms of transmission of skull vibrations

in sensorineural hearing loss (SNHL) – as opposed to CHL (conductive hearing loss) – the duration of the fork vibration is longer. In STC, the tuning fork may be applied to several sites, not only on the head but also on the neck and thorax of the subject.[3,25] Most likely, stimulation at such a distance from the SB and the vestibule cannot be effected by BC. Part of the vibrational energy induced in the soft tissue is also reflected in the boundary with bone.[11] Transmission of soft tissue vibration to the perilymph should follow along and from one to the other environment of similar acoustic impedance.

Ito et al. assessed thresholds in the frequency range of 0.25–4 kHz in response to stimulation at different sites on the human head.[26] An accelerometer measuring SB vibrations was attached to the teeth. BC thresholds measured with stimulation at the eye and forehead were higher, although strengths in acceleration at frequencies 2–4 kHz were equal to or larger than those with stimulation at the mastoid and temporal region. The authors concluded that there are different mechanisms of HR stimulation through vibrations of soft tissue and SB. Earlier, STC was also called non-osseous BC and frequently not separated from BC.[15,26] STC involves yet another singular mechanism and pathway, and may be recognized as entirely different from AC and BC modes of auditory stimulation.

The final complex stimulation of HR results from the total amount of energy as well as from the phases of vibratory forces. Because they reach the perilymph simultaneously, an interaction takes place between them. These vibrations can be amplified, suppressed, or even cancelled before the contribution of hearing cells.[3,24,27,28] Obrębowski even put forward the radical opinion that, under physiological circumstances, BC sounds are unwanted and, if at all possible, damped.[29] However, Beethoven is an example of making use of the "unappreciated" BC. This unusual musician, who was gradually losing his hearing, composed music while holding a bony stick in his teeth and resting it on his piano. The vibrations from the instrument, transmitted through the stick, could reach his IE. This was probably the first application of the variety of BC "dentaural hearing" (DH). We hope that a review of the modes, pathways, and mechanisms present in the complex process of hearing ought to simplify the detection of a possible connection between hearing acuity and dental condition (Fig. 2).

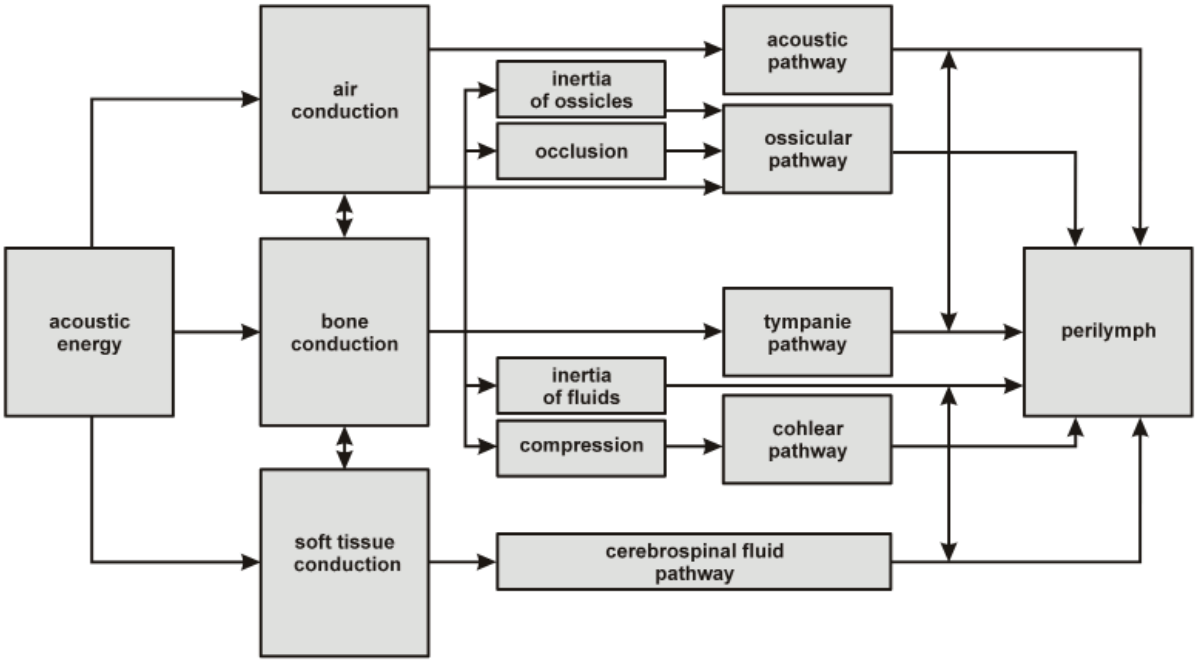

Fig. 2. Pathways and mechanisms of the hearing receptor stimulation through air, bone, and soft tissue (mutual relationships)

Mechanical properties of the skull

The uniqueness of each skull's vibrational characteristics is probably due to various geometrical variations and differences in the mechanical properties of 3-layered SB.[30,31]

However, some regularity can be observed here. Bekesy was of the opinion that – at low frequencies – the skull behaves like a rigid body, i.e. below 0.8 kHz it vibrates entirely.[32] At higher frequencies, some deformities might occur which result from the division of the skull into separate oscillating parts.[32] According to Huizing, the whole head, not only the skull itself, is assumed to be a system of separately vibrating segments with their mutual couplings.[17,33] On this point, Semczuk noted that not only the entire maxilla, but even its set of teeth, can constitute one of the oscillating elements.[34]

Presently, using the results of direct BC examination, it has been shown that, at frequencies ranging up to 10 kHz, a few types of skull vibration appear. At the lowest frequencies, e.g. below 0.3–0.4 kHz, the skull truly moves as whole and behaves like a rigid body.[8,16] At a frequency of about 1 kHz, the first global resonance appears.[35] From 0.3–0.4 kHz to 1 kHz, the skull vibrates as a mass-spring system. The large parts (temporal bone, maxilla) move in phase. Then, between 1 kHz and 2 kHz, the mass-spring behavior becomes affected by and – at higher frequencies – dominated by wave transmission.[15]

Generally, the transmission in direct BC is recognized as almost linear and proportional to the distance of the vibrator from the HR.[16,17] However, Sohmer et al. attributed lower hearing thresholds of stimulation at the temporal region containing thinner SB than stimulation at the thicker bone of the forehead.[23] According to the authors, vibrations can penetrate through to the cranial contents and excite the HR through the CSF pathway. Hoyer and Dorheide also postulated that the stimulated temporal bone surrounded by a frame-like structure may act almost like a membrane.[36] Therefore, the stimulation of HR in BC cannot be recognized simply as a result of vibratory energy transmission.

Dentaural hearing

The role of the teeth in the examination of BC, and likely their importance in the process of hearing, is exceptional. The teeth of the maxilla are part of the SB. The mandible then is loosely coupled to the SB by the temporomandibular joint (TMJ). In experiments on tooth stimulation, the importance of the CSF pathway and the participation of STC in the process of hearing has been examined and emphasised.[37] Though tuning forks were first constructed for musicians, they are presently also used for hearing assessment, especially to estimate the type of hearing loss.[38] The vibrating fork is usually placed against the mastoid process, pre-auricular region, forehead, skull apex, base of the nose, or mandibular symphysis. Under some circumstances, the results of the most popular Weber test may be inconclusive.[10,39] In such cases, it is recommended to press the fork against the teeth of the maxilla. BC is more intense there and the sensation associated with it is clearer. We have found a handful of studies confirming the high efficiency of stimulating HR through the "long" pathway from the teeth to the cochlea. One of the pioneers in this area was Semczuk.[34] He made a series of experiments on dried skulls and on volunteers with different dental conditions. The author used auscultation to evaluate the conduction of sounds from the skull vault and from the teeth to the temporal bone. He observed that the presence of natural or artificial teeth amplified conduction (0.5, 1, 1.5, and 2 kHz). Brown used DH to estimate bone-hearing thresholds in 2,000 subjects.[40] He noticed that maxilla teeth conduct sounds better than those of the mandible, and he believed that this was caused by the direct connection of the maxilla to the skull. Brown made audiograms for DH at 1, 2, and 3 kHz, and the results of his work consistently showed better hearing thresholds compared to conventional audiometric examinations.[40] Dahlin et al. presented the results of hearing tests between 0.25 and 4 kHz on 4 students.[41] The upper central incisors, canines and first molars were stimulated. The teeth were more sensitive than the forehead (5–15 dB) at all frequencies (except 4 kHz). Stenfelt and Hakansson conducted research on 9 patients with a complete set of their own teeth, who were examined in order to compare hearing thresholds by stimulating bone-anchored hearing aids (BAHA), the mastoid process, and the first 4 incisors of the maxilla. BC at each site was almost identically efficient at lower frequencies, and the titanium implants only started to gain an advantage at frequencies higher than 1 kHz.[42]

One way of passing acoustic energy from the teeth to the IE has not been precisely determined. This does not change the fact that the DH is very efficient at stimulating HR, and a few exciting applications have been made in this area. Dahlin et al., as early as 1971 at the University of California in Los Angeles, presented a wireless intraoral hearing aid.[41] Some research on using DH for audiological prostheses is still being conducted today. In 2009, a Californian company, Sonitus Medical, presented a system consisting of 2 devices: a microphone located in the EAM and an overlay device placed on the upper molars. The overlay wirelessly received acoustic stimuli and converted them into vibrations which were transmitted through the bone to the IE.[43] Over 90% of patients reported being satisfied with the results it provided in a long-term observation.[44] The main advantage over BAHA was that there was no need for any surgical procedures.[45] In 2007, the toy company Hasbro introduced a toothbrush (Tooth Tunes) that vibrated to create the sensation of listening to music inside one's head. It was marketed towards children to encourage them to brush their teeth longer and more thoroughly.[46]

Dental pathologies and hearing

The government of Peru recently launched an instructional campaign, "Always with a smile." The Ministry of Health in the country, where over 90% of the population suffers from dental problems, set a strategy to help people improve their dental health. A surprising secondary goal of this campaign is the possible beneficial impact on Peruvians' hearing.[47] Most researchers were in agreement about the harmful effect materials used in dental treatment can have on hearing.[34] In 2008, Rothvell and Boyd presented the results of hearing assessment in patients where the total amount and area of amalgam fillings were significantly related to increased hearing thresholds.[48] The correlation was strongest at 14 kHz and increased by 2.4 dB with every additional filling. The most convincing and unanimous implication seems to be the few publications so far where pathology is expressed as the number of lost teeth. Semczuk was investigating correlations between dental health and hearing in the 1960s and presented two large studies.[34] One was an analysis of 5,000 patients. Semczuk found that 51% of toothless patients demonstrated hearing loss. Severe hearing loss (whisper < 0.5 m) was observed in 40% of patients without teeth. Semczuk's second study focused on comparing the hearing thresholds and dental status in 600 otherwise healthy individuals.[34] Pure tone audiometry revealed normal hearing in 80% of the subjects with healthy teeth, while 50% of the patients with only half of their own teeth and only 15% of toothless subjects had normal hearing thresholds. Semczuk believed that this might be caused by malocclusion, TMJ pathologies, and Eustachian tube dysfunctions.[34] Schell et al. observed a significant increase in hearing thresholds among toothless patients in comparison to controls with full or almost full dentition (≥ 25 teeth).[49] They suggested that lower activity of the soft palate tensor resulted in Eustachian tube dysfunction. Lawrence et al. observed a 1.64-fold increase in hearing loss in subjects who had lost more than half of their teeth in comparison to those with less tooth loss.[50] They suggested that proper occlusion in the vertical dimension might be the most important protective factor. Correlations between dental defects and hearing disorders were investigated by Peeters et al.[51] Hearing thresholds were significantly higher at 0.125, 0.250, 4, and 8 kHz in subjects who had less than 17 teeth, compared to patients with a full set of teeth.

There are also a few publications reporting improved hearing after successful dental treatment. King et al. showed the results of audiometric examination in 2 subjects who had had all of their remaining teeth removed, and then underwent complete prosthetic treatment.[52] They observed lowered thresholds (AC and BC) and increased cochlear reserve after the treatment. Nagasaka et al. presented the results of the treatment of malocclusion followed by habitual unilateral chewing.[53] After stomatologic training, all 5 subjects presented improved air hearing thresholds for the full range of frequencies (0.25–8 kHz) on the affected side. Kempf et al. noticed diminished IE symptoms (hearing loss, tinnitus, and vertigo) in over half (56.5%) of patients after dental treatment.[54] Almost every time, the authors recommended a detailed dental assessment in patients with IE disorders of unknown etiology.

Some researchers proved that chewing simultaneously stimulated muscular activity, increased blood flow through the central nervous system, and increased neuronal activity.[55–57] Observations documenting the relationship between dental pathologies and aging, including the aging of the hearing organ, are not very surprising. It was suggested that poor dental health might contribute to the development of dementia in senility. However, many other conditions may contribute to dental defects, including poor dietary habits or chronic systemic conditions.[58] Tooth loss is also suggested to be a risk factor of Alzheimer's disease. Having no teeth, together with a lack of mental and physical activity, poor education, and previous head injuries, very greatly increases the probability of falling ill.[59] In these pathologies, hearing defects may likely be connected with poor results in speech audiometry.

Summary of findings

Auditory stimulation in AC, BC, and STC can interact with each other. Different vibrations of the SB and impaired BC could possibly influence the air-hearing threshold. Maxilla teeth are a very sensitive stimulating site of the HR in BC. Additionally, dental pathologies – especially the loss of teeth – and the results of dental treatment have a noticeable impact on hearing acuity. Hearing disorders, which interfere with dental health, are therefore the most probable at lower frequencies (from 0.3–0.4 kHz to 2 kHz), where the skull segments like the maxilla bone and teeth vibrate separately. In this range, the inertial mechanisms are currently recognized as the most valid in BC hearing.

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Denosumab-related osteonecrosis of the jaw: A literature review

Martwica kości szczęk wywołana denozumabem – przegląd piśmiennictwa

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Abstract

Osteonecrosis of the jaw (ONJ) is a rare treatment-related side effect of anti-resorptive drugs whose risk is increased by concomitant local and systemic factors. The number of cases of medication-related ONJ is constantly increasing as a result of the rising tide of molecular-targeted and immunological drugs used in cancer treatment. Denosumab-related ONJ presents peculiar pathophysiological, histopathological, clinical, and therapeutic features compared to that induced by bisphosphonates-related ONJ.

This study aimed to compare ONJ induced by denosumab to that caused by bisphosphonates. We have reviewed the literature of the last 5 years on denosumab-related ONJ, focusing on reviews and meta-analyses.

The physiopathology of ONJ is unclear. Denosumab acts on receptor activator of nuclear factor kappa-B ligand (RANKL) to inhibit the formation and activity of osteoclasts. The reduction of bone turnover seems to play an important role. Dentists and oral surgeons in the coming years will see an increasing number of patients who are receiving treatment potentially toxic to bone, but also require good dental care. Early recognition of ONJ is essential in the patient's treatment with denosumab, therefore a close collaboration between the dentist and oncologist is fundamental.

Key words: jaw, osteonecrosis, denosumab

Słowa kluczowe: szczęka, martwica kości, denosumab

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In 2003, for the first time Marx described 36 cases of osteonecrosis of the jaw (ONJ) induced by bisphosphonates in cancer patients.[1] Next year, Ruggiero described 63 cases. In the following years, the number of cases has rapidly increased, both as spontaneous reports to the various pharmacovigilance agencies, and as articles and case reports in medical journals.[2] Denosumab-related osteonecrosis of the jaw (DRONJ) was first reported in 2010 by Taylor.[3] Denosumab is a new antiresorptive drug, approved in June 2010 by the US Food and Drug Administration (FDA), under the name Prolia® (Amgen, Thousand Oaks, California, USA) for use in osteoporosis in postmenopausal women, and in November 2010 under the name Xgeva® (Amgen, Thousand Oaks, California, USA) for use in bone metastases cancers. The safety data sheet for this drug reads as follows: "(...) Rare cases of jaw bone necrosis have been reported in clinical trials in patients receiving denosumab; consideration should be given to conducting a dental examination before initiating treatment in patients with co-occurring risk factors; Patients undergoing treatment should avoid invasive dental procedures; during the treatment, special care should be taken during oral hygiene (...)".

This is a systematic critical review of the full-text papers focusing on reviews and meta-analyses published on the topic in the last 5 years in Medline-Pubmed, Google Scholar, Scopus, and Cochrane electronic databases, using the following key words: osteonecrosis of the jaw, denosumab, and metastatic bone cancer.

ONJ is a multifactorial disease characterized by necrotic exposed bone, intra-oral bone or extra-oral fistula in the maxillofacial area persistent for more than 8 weeks when radiotherapy or metastasis causes have been excluded, associated or not with pain and swelling of the soft tissues. Cases of spontaneous appearance have been observed, especially in patients with poor oral hygiene and dental or periodontal diseases, but the frequency is still unknown. In regard to drugs, ONJ was originally described in association with bisphosphonates, but recently their number has increased so much that in 2014 the American Association of Oral and Maxillofacial Surgeons (AAOMS) suggested renaming it "medication-related osteonecrosis of the jaw" (MRONJ). Bisphosphonates (BPs) and denosumab (DMab) are included among the antiresorptive drugs associated with ONJ. More recently, cases due to anti-angiogenic and immunological drugs have also been reported. ONJ's risk is increased by a set of local and systemic factors (Table 1).

ONJ can affect both the mandible and maxilla. Two thirds of cases affect the mandible, a third affect the maxilla and both in only 4% of cases. The physiopathology of ONJ is unclear. The special predisposition for the posterior region of the mandible is due to the increased density, poor blood supply and continuous masticatory stimulation there. Infections are an important factor, although it is not clear whether the infection precedes necrosis or it is rather a super infection of a necrotic base. However, the oral mucosa covering the jawbone is thin and the over 800 types of bacteria that form the dental plaque can pass into the underlying bone, especially in the presence of inflammation or mucosal injury. The presence of bacteria stimulates bone resorption through the production of cytokines which can contribute to bone necrosis. In ONJ lesions, vital bone is mixed irregularly with necrotic bone colonized by *Actinomyces* sp. colonies. The reduction of bone turnover seems to play an important

Table 1. Risk factors for ONJ

Local factors	Systemical factors
Tooth extraction	longer duration of antiresorptive therapy for metastatic neoplasia (breast, lung, prostate, rein and myeloma) or post-menopausal osteoporosis
Dent alveolar surgery	radiotherapy
Periodontal disease	chemotherapy
Trauma	antiangiogenic drugs: bevacizumab, sunitinib
Poor oral hygiene	immunotherapy: ipililumab
Local suppuration	glucocorticoid therapy
Denture use	erythropoietin therapy
	diabetes
	anemia
	hypertension
	hypothyroidism
	hyperparathyroidism
	renal failure and renal dyalisis
	osteoporosis
	smoking
	increasing age

Table 2. Classification of ONJ according to AAOMS 2009[4]

Pre-ONJ	No exposed/necrotic bone in patients who were treated with BPs
Stage 0	No clinical evidence of necrotic bone, but not specific symptoms or radiographic signs
Stage 1	Bone exposed/necrotic in asymptomatic patients who have no evidence of infection
Stage 2	Bone exposed/necrotic associated with infection as evidenced by bone pain and erythema in the exposure region with or without purulent drainage
Stage 3	Bone exposed/necrotic in patients with pain, infection, and one or more of the following conditions: pathologic fracture, extraoral fistula, osteolysis extension beyond the alveolar bone (eg. lower edge and mandibular branch; zygomatic process of the maxilla and maxillary sinus, nasal floor)

role, and this suggests the association of ONJ with antiresorptive drugs and a dose-related risk. However, there are other associated conditions with low bone turnover in which the ONJ problem does not arise. The BPs could act on ONJ through a reduction of the blood supply, thanks to their antiangiogenic properties. Conversely, DMab has no anti-VEGF action. In the last few years, cases of ONJ were reported in association with antiangiogenic agents, suggesting that angiogenesis suppression may play a role in ONJ's pathogenesis. Some experts suggest that there may be elements of a genetic predisposition, such as polymorphisms of farnesyl pyrophosphate synthase and cytochrome CYP450/CYP2C8.

ONJ clinically can be classified into 3 stages[4] (Table 2). Up to 30% of ONJ cases debut in stage 0, characterized by an absence of clinically exposed bone in patients presenting with nonspecific symptoms or radiographic findings, including alveolar bone depletion, trabecular alterations, lamina dura thickening, and narrowing of the alveolar duct. ONJ stage 0 has been described in the course of therapy with antiresorptive drugs, but the diagnosis is difficult and often delayed.

Bedogni et al. have proposed a new classification in 3 stages which includes CT imaging findings and eliminates stage 0 (Table 3).[5] Franco et al. in 2014 proposed a new dimensional staging system, classifying the lesions by size following imaging findings, with a view to making treatment decisions easier (Table 4).[6]

DMab is an antiresorptive drug indicated in post-menopausal osteoporosis and in some cancers with symptomatic bone metastases, hypercalcemia and prevention of skeletal-related events. In 2 phase III clinical trials comparing denosumab and zoledronic acid in patients with metastatic cancer, it appeared that the ONJ frequency is similar. A recent meta-analysis reports that the mean incidence of DRONJ in over 5700 cancer patients is 1.8% vs 1.3% in the zoledronic acid arm.[7] In contrast, during treatment of osteoporosis every 6 months with DMab, the occurrence of ONJ is very rare. In the FREEDOM study, no cases of ONJ occurred in 7000 women within 3 years of follow-up.[8] DMab is a human monoclonal immunoglobulin (IgG2) that binds the cytokine RANKL (receptor of activator of NF kB ligand) produced by osteoblasts, preventing the activation of the RANK receptor on the

Table 3. Classification of ONJ according to Bedogni et al.[5]

Classification of ONJ	
Stage 1	**Focal ONJ** Clinical signs and symptoms: bone exposure, sudden dental mobility, nonhealing postextraction socket, mucosal fistula, swelling, abscess formation, trismus and gross mandible deformity hypoesthesia/paraesthesia of the lips. CT signs: increased bone density limited to the alveolar bone region (trabecular thickening and focal osteosclerosis), with or without the following signs: markedly thickened and sclerotic lamina dura, persisting alveolar socket and cortical disruption
Stage 2	**Diffuse ONJ** Clinical signs and symptoms: same as stage 1. CT signs: increased bone density extended to the basal bone (diffuse osteosclerosis), with or without the following signs: prominence of the inferior alveolar nerve canal, periosteal reaction, sinusitis, sequestra formation and oro-antral fistula
Stage 3	**Complicated ONJ** Same as stage 2, with one or more of the following: Clinical signs and symptoms: extra-oral fistula, displaced mandibular stumps and nasal leakage of fluids. CT signs: osteosclerosis of adjacent bones (zygoma and hard palate), pathologic mandibular fracture and osteolysis extending to the sinus floor

Stage 1a: asymptomatic; stage 1b: symptomatic (pain and purulent discharge). Stage 2a: asymptomatic; stage 2b: symptomatic (pain and purulent discharge). CT: Computed tomography; ONJ: Osteonecrosis of the jaw.

Table 4. Classification of ONJ according to Franco et al.[6]

Classification of ONJ	
Stage 0	No exposed bone, with nonspecific radiographic findings such as osteosclerosis and periosteal hyperplasia, and nonspecific symptoms such as pain
Stage I	Exposed bone and/or radiographic evidence of necrotic bone*, or persistent socket space < 2 cm in greater diameter, with or without pain
Stage II	Exposed bone and/or radiographic evidence of necrotic bone*, between 2–4 cm in major diameter, with pain responsive to NSAIDs, and possible abscesses
Stage III	Exposed bone and/or radiographic evidence of necrotic bone*, > 4 cm in greater diameter, with intense pain that respons or does not respond to NSAIDs, abscesses, orocutaneous and/or maxillary sinus fistulization, with mandibular nerve involvement

* Radiographic evidence of necrotic bone: irregular areas of hypo- and hypercalcification and/or bone sequestration.

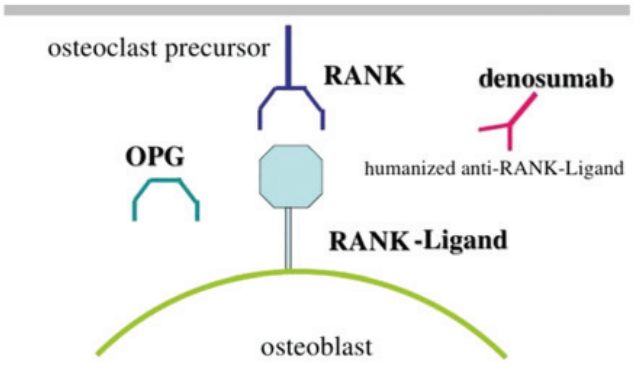

Fig. 1. Mechanism of action of denosumab

osteoclast and the precursor cell surface (Fig. 1). The reduction of the RANK/RANKL interaction inhibits osteoclast formation, its activity and survival. Additionally, bone resorption is reduced and bone mass is enhanced.[9,10]

Bone resorption is essential for the subsequent neoformation step and the correct sequence of resorption and bone formation is essential in the bone remodeling process. The inactivation of RANKL by denosumab also decreases macrophage mobility and chemotaxis. Macrophages are the first line of defense against invading microorganisms and the decrease of host defense mechanisms may predispose to the development and worsening of ONJ.[11] There are some differences between DRONJ and BRONJ (bisphosphonate-related ONJ). The slight prevalence of females in ONJ could be related to the many patients treated with BPs for osteoporosis and breast cancer. However, some authors deny gender differences. DRONJ can occur after a number of lower doses of the drug (8 to 15), compared to BRONJ, whose risk typically depends on the cumulative dose. DMab has a half-life of roughly 32 days and it seems that it does not induce the formation of neutralizing antibodies. After administration of the first dose, the inhibition of osteoclast activity occurs after just 6 hours, ending within 6 months after the last dose. Therefore, it is recommended to postpone any surgery until 4–6 months after termination of the DMab.[12] Unlike BPs, DMab does not accumulate at the bone level, whereby DRONJ is less intense that BRONJ, is rapidly reversible and responds better to conservative treatment. Also, the histopathological appearance of DRONJ is different: the viable bone around the sequestrum is characterized by a decreased number of morphologically immature osteoclasts as indicated by the presence of very few nuclei and this may reflect the inhibition of the formation and maturation of osteoclasts from monocyte cell lineage.

The particular incidence of DRONJ in cancer patients seems related to drug-dependent factors (dose used, duration of the treatment) and to the specific kind of malignancy. A recent meta-analysis suggested that patients with prostate cancer have 3 times higher risk compared to other types of cancer, probably linked to anemia and frequent use of corticosteroid.[7] In the case of breast cancer, concomitant use of drugs that reduce bone turnover (aromatase inhibitors) is an additional risk factor. In any case, the safety profile of DMab after long-term exposure is 19.1 months in breast cancer and 12 months in prostate cancer.[13] Finally, metastatic kidney cancer is a special case. This patient setting is particularly susceptible to ONJ due to the concomitant use of antiangiogenic drugs that block vascular endothelial growth factor (VEGF). In recent years, some cases of ONJ have been reported during treatment with bevacizumab[14,15] and sunitinib.[16] whereby it is possible that the potent antiangiogenic activity of VEGF-targeting agents may inhibit bone remodeling and promote ONJ development. Additionally, it is possible that these drugs may compromise the integrity of the bone and mucosal blood supply. Another group of drugs used in the treatment of these patients and of which one can hypothesize a co-factor role in the development of ONJ is mammalian target of rapamycin (mTOR) inhibitors,[17] such as temsirolimus. Inhibition of mTOR is accomplished through the binding of intracellular protein FKBP-12, which follows a lower expression of D-type cyclins, c-myc and ornithine decarboxylase, regulatory proteins of the cell cycle, which results in the stopping of the cell in G1. It also reduces the phosphorylation of proteins (4E-BP 1 and S6K) of the PI3 kinase/AKT, thus blocking cell division. However, it has the ability to inhibit the production of hypoxia-inducible factors (HIF-1 and HIF-2α) and vascular endothelial growth factor (VEGF), with consequent inhibition of tumoral angiogenesis. mTOR inhibition causes cell growth arrest and often immunosuppression, which explains the infection susceptibility of the treated patients.

Conclusions

ONJ is a rare condition associated with antiresorptive therapy. Denosumab-related ONJ and bisphosphonate-related ONJ have a similar frequency, but have different pathogenetic, clinical and histopathological features. The vast majority of cases (>90%) occurs in cancer patients, and simple preventive procedures are effective at reducing the risk. The growing association of drugs that can act as co-factors in favor of bone resorption, reducing blood supply and promoting infections should be avoided. A close collaboration between the oncologist and dentist is essential for its prevention, early diagnosis and treatment.

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Multifocal brown tumor of the maxilla and mandible in primary hyperparathyroidism – diagnostic challenges and literature review

Wieloogniskowy guz brunatny kości szczęki i żuchwy w przebiegu pierwotnej nadczynności przytarczyc (PNP) – trudności diagnostyczne i przegląd piśmiennictwa

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D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Multifocal brown tumors are a rare complication of primary hyperparathyroidism (PHPT). The reported prevalence of PHPT-related brown tumor is 3–4%. The tumor may histologically resemble any giant cell tumor of the jaws; hence, diagnostic errors or a delayed diagnosis of PHPT, when the lesion is the first clinical manifestation of this disease.

We present a 27-year-old patient at 17-week gestation, who was diagnosed with an expansile mass in the left maxilla. Diagnostic tests also revealed two osteolytic lesions in the mandible.

The patient underwent left maxillary segmental resection; the tumor was resected en bloc with teeth 25, 26. Histology confirmed the primary diagnosis of giant cell tumor. The observation was continued on an outpatient basis. Following delivery, progression of mandibular osteolytic lesions and maxillary tumor recurrence were found. Blood chemistry panel was ordered and the results raised a suspicion of primary hyperparathyroidism. Subsequent diagnostic tests revealed lower right parathyroid adenoma. Parathyroidectomy resulted in an almost complete regression of the mandibular lesions and a slight regression of the maxillary tumor.

The paper presents diagnostic challenges associated with brown tumors as well as clinical, radiological, biochemical and histological manifestations thereof. The effect of pregnancy on the course of primary hyperparathyroidism is discussed and a diagnostic/therapeutic scheme is proposed when giant cells are present in a biopsy specimen.

Key words: primary hyperparathyroidism, brown tumor of the maxilla/mandible, giant cell tumor of the maxilla/mandible, pregnancy epulides

Słowa kluczowe: pierwotna nadczynność przytarczyc, guz brunatny szczęki i żuchwy, guz olbrzymiokomórkowy szczęki i żuchwy, guzy ciążowe

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Primary hyperparathyroidism (PHPT) is an endocrine disorder (hypersecretion of parathyroid hormone) caused by parathyroid adenoma, hyperplasia or cancer. The disease is frequently associated with asymptomatic hypercalcemia, hypophosphatemia, hypercalciuria and increased bone resorption. Longstanding hypercalcemia and hypercalciuria may result in nephrolithiasis and heart rhythm abnormalities visible on ECG.[1,2] PHPT most often develops in women over the age of 50. The most common cause is a parathyroid adenoma (80–85%), although it can be difficult to distinguish between a normal and an abnormal gland, with multigland hyperplasia (15%) and carcinoma (1–2%) developing afterwards.[1,3–9]

Parathyroidectomy is the treatment of choice for symptomatic and progressive PHPT.[9–11]

Multifocal brown tumors are a rare complication of hyperparathyroidism. The reported prevalence of PHPT-related brown tumor is 3–4%.[12] Brown tumors develop in response to elevated serum levels of parathyroid hormone and can affect the long bones, clavicle, scapula, ribs, pelvic bones, mandible and other craniofacial bones, and the spine.[1,11] A microscopic examination shows multinucleated giant cells with hemosiderin imparting the brown color and hence the name of the tumor.[2,4,9,11,13] Bone manifestations are associated with elevated serum alkaline phosphatase. The brown tumor of hyperparathyroidism is histologically very similar to central giant cell lesions (CGCL), a heterogenous group of jaw lesions. Therefore, a histology report must be confronted with the results of the clinical examination, laboratory tests and diagnostic imaging. Otherwise, diagnostic errors or a delay in diagnosis may ensue.[8,10,12]

Objectives

Brown tumors of the maxilla and mandible may be the first clinical manifestation of PHPT. The aim of this report is to draw the attention of dentists, oral and maxillofacial surgeons to this entity and to emphasize the importance of calcium and phosphorus metabolism testing in patients with craniofacial bone pathologies.

Case report

A 27-year-old patient at 17-week gestation was referred to the Outpatient Clinic of Oral and Maxillofacial Surgery at the Provincial Specialist Hospital No 5 in Sosnowiec with expansile mass in the left maxilla. She gave a 12-month history of a slow painless growth of the tumor, which she first observed following the extraction of teeth 27 and 28. A physical examination revealed cardiac arrhythmia (1st degree atrioventricular block), mitral valve regurgitation, colloid nodule of the thyroid gland (confirmed on fine needle aspiration biopsy), nephrolithiasis (ultrasonography revealed calcium oxalate renal calculi) and pregnancy-related anemia (RBC 2.92 T/L; HGB 8.6 g/dL; HCT 26.0%). Four months before she had been hospitalized in an orthopedic department and underwent the excision of 1/2 of the lateral end of the right clavicle due to giant cell tumor confirmed on histology.

During her 1st appointment, a tumor biopsy was obtained for histological examination, which revealed a giant cell tumor.

Due to the rapid growth of the tumor during pregnancy, a decision was made together with the attending obstetrician to hospitalize and operate on the patient in the Department of Oral and Maxillofacial Surgery. Prior to surgery, the patient underwent a cardiological examination and a craniofacial MRI with corT2, corT1, corSTIR, sagT1, sagT2, axT1, axT2, axSTIR and corMERGE sequences, but no contrast enhancement. An MRI was selected, as it posed the least danger to the fetus. The examination revealed a 32 × 26 × 18 mm mass (TR × AP × CC) adjacent to the distal surface of tooth 26, infiltrating the maxilla, bulging into the lumen of the left maxillary sinus and infiltrating the buccal soft tissues (Fig. 1). Also, 2 osteolytic lesions were visualized in the mandible; one sized 19 × 10 × 10 mm at teeth 41–34, causing disruption of the lower mandibular cortex and tooth 32 and 33 root resorption. The other, 11 mm in diameter, was located at the root of tooth 45; cortical thinning was also noted (Fig. 2). The maxillary tumor presented as exophytic nonpedun-

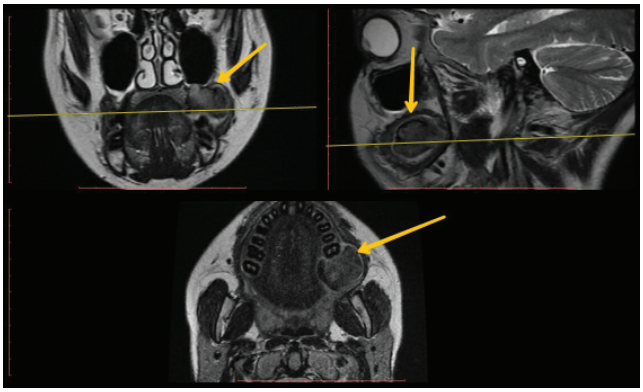

Fig. 1. Craniofacial MRI prior to surgery for maxillary tumor – axial, sagittal and coronal views (yellow arrows)

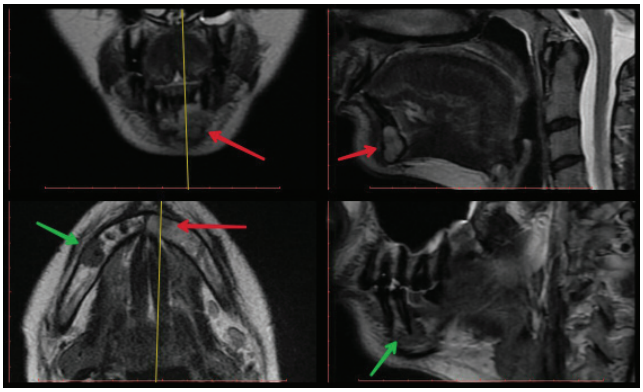

Fig. 2. Craniofacial MRI prior to surgery; 2 osteolytic foci in the mandible – at teeth 41–34 (red arrows) and at the root of tooth 45 (green arrows)

culated epulis-like lesion; teeth 25 and 26 were embedded in the tumor and showed pathologic mobility but no features of periodontal disease. The larger mandibular lesion was palpable as a painful elastic and soft mass in the mandibular vestibule covered with normal mucosa. The smaller lesion was symptomless. A physical examination revealed a late systolic murmur; ECG demonstrated PQ interval prolongation consistent with 1st degree atrioventricular block.

The patient was operated on at 24-week gestation under general anesthesia; a left maxillary segmental resection was performed; the tumor was resected en bloc with teeth 25, 26, alveolar recess of the maxillary sinus and safety margins. The defect was reconstructed using the neighboring tissues (Fig. 3). The patient made an uneventful convalescence and was discharged 7 days after surgery in good local and general condition. Histology confirmed the primary diagnosis of a giant cell tumor. All surgical margins were free of the tumor except for the hard palate margin (Fig. 4A, 4B).

The patient attended the Outpatient Clinic of Oral and Maxillofacial Surgery for follow-up appointments until delivery. Follow-up craniofacial computed tomography was performed at 5 months of surgery using a 16-row spiral CT scanner, a slice thickness of 2.5 and 1.25 mm and reconstruction interval of 0.6 mm, prior to and after contrast medium administration (Ultravist). The obtained scans revealed local recurrence of the maxillary tumor at the surgical site. A 15-mm mass infiltrated the alveolar process in the area of teeth 23 and 24, penetrated the nasal cavity and inferior nasal concha (Fig. 5). The examination also showed progression of the pathologic process within the mandible: the lesion located at teeth 41–34 was almost twice the size of the one visualized on MRI (25.6 × 8.4 × 17.2 mm vs 19 × 10 × 10 mm). The lesion situated at tooth 45 did not change (Fig. 6). A blood chemistry panel was ordered, whose results, along with those of imaging examinations, raised suspicion of primary hyperparathyroidism: Ca^{+2} – 1.8 mmol/L (reference range 0.98–1.21 mmol/L); parathyroid hormone – 653 pg/mL (reference range 10–62 pg/dL).

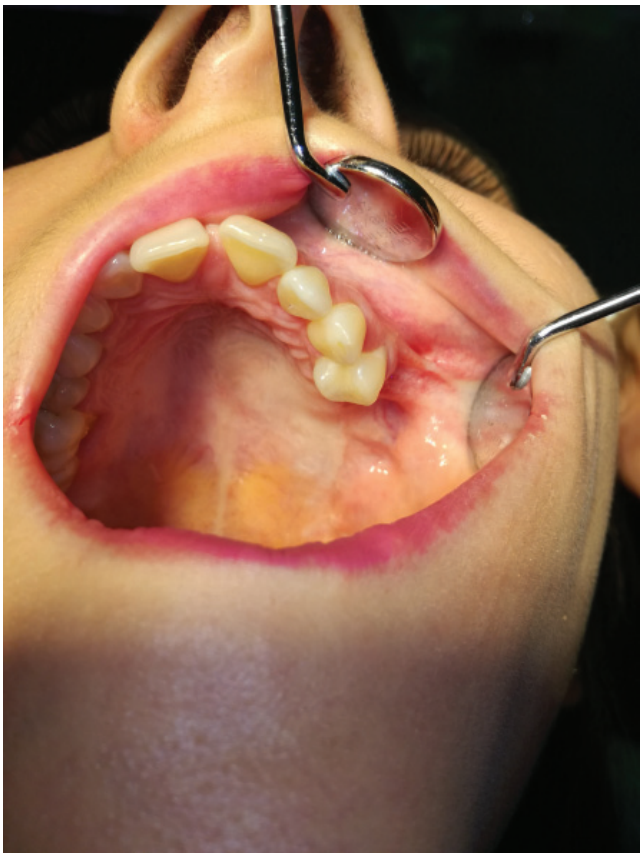

Fig. 3. Intraoral image – 8 weeks of left maxillary segmental resection en bloc with teeth 25 and 26

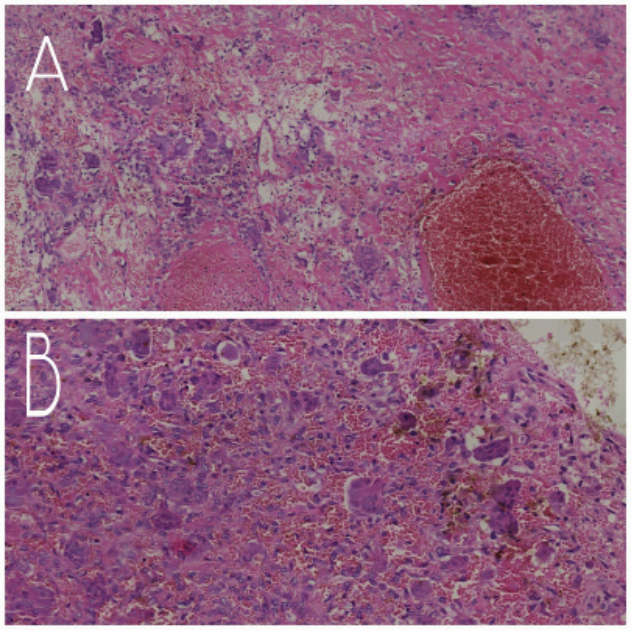

Fig. 4. Microscopic examination of the brown tumor. A. connective tissue with hemorrhage foci and aggregations of multinucleated giant cells (osteoclasts) (20 x magnification, H&E stain). B. aggregations of multinucleated giant cells (osteoclasts), hemorrhage foci and hemosiderin-laden macrophages (60 x magnification, H&E stain)

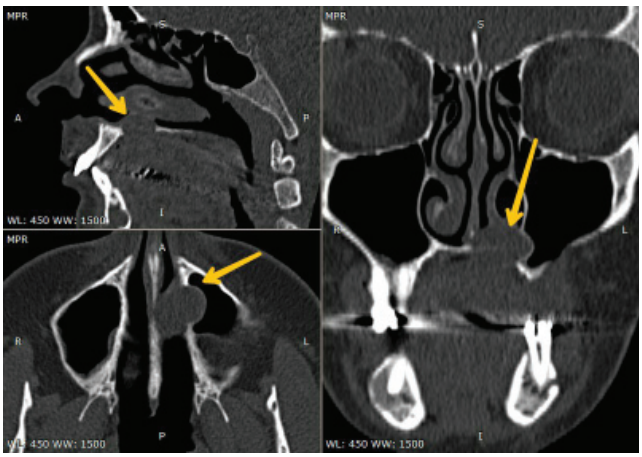

Fig. 5. Craniofacial CT – 5 months of left maxillary segmental resection; pathologic mass at the alveolar processes of teeth 23 and 24, penetrating the nasal cavity (yellow arrows)

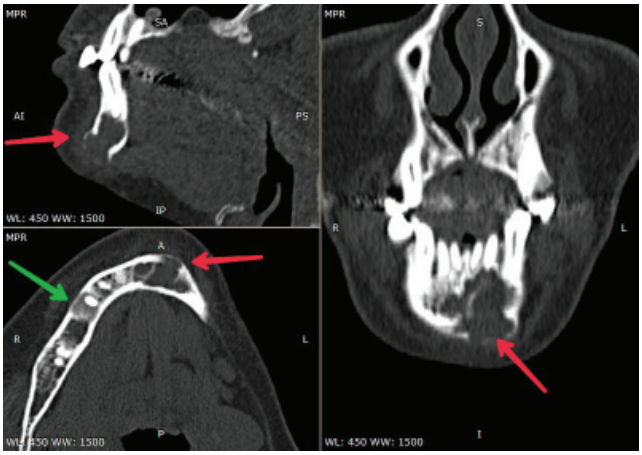

Fig. 6. Craniofacial CT – 5 months of left maxillary segmental resection; osteolytic lesions in the mandible – at teeth 41–34 causing disruption of the lower mandibular cortex (red arrows) and at the root of tooth 45 (green arrows)

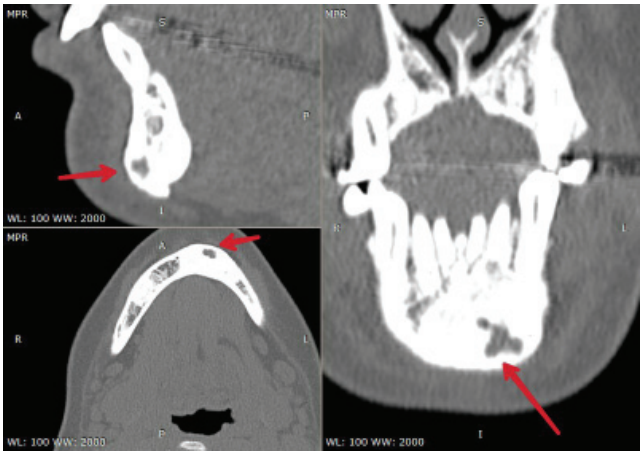

Fig. 8. Craniofacial CT – 12 months of parathyroidectomy; partial regression of mandibular lesion at teeth 41–34 (red arrows); complete regression of the osteolytic focus at tooth 45

The patient was referred to the Center of Oncology at Maria Sklodowska-Curie Memorial Institute, Gliwice, with suspected parathyroid cancer. In June 2016 (7 months of segmental resection of maxilla) she underwent right inferior parathyroidectomy in the Department of Oncologic and Reconstruction Surgery. Intraoperative PTH assay was performed; histology revealed a parathyroid adenoma.

The patient continued follow-up visits in the Outpatient Clinic of Oral and Maxillofacial Surgery. At 6 months after the parathyroidectomy, PTH and Ca^{+2} were within normal range; calcium replacement was not required. An orthopantomogram revealed higher density areas within the pathologic osteolytic lesions of the mandible, whereas the osteolytic lesion of the maxilla seen in the area of tooth 24 showed only slight regression (Fig. 7).

Follow-up craniofacial computed tomography performed at 12 months following the parathyroidectomy revealed further regression of mandibular lesions. The osteolytic focus at tooth 45 was no longer observed; the lesion at teeth 41–34 became reduced to 8 × 4 × 6 mm and extended between teeth 31 and 33 (Fig. 8). The osteolytic lesion of the maxilla still showed only slight regression (Fig. 9). The patient was referred for femur densitometry;

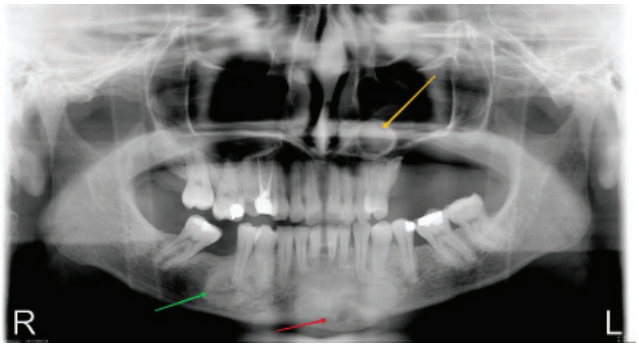

Fig. 7. Orthopantomogram – 6 months of parathyroidectomy; higher density of osteolytic foci at tooth 45 (green arrow) and teeth 41–34 (red arrow); slight regression of the osteolytic lesion within the maxilla (yellow arrow)

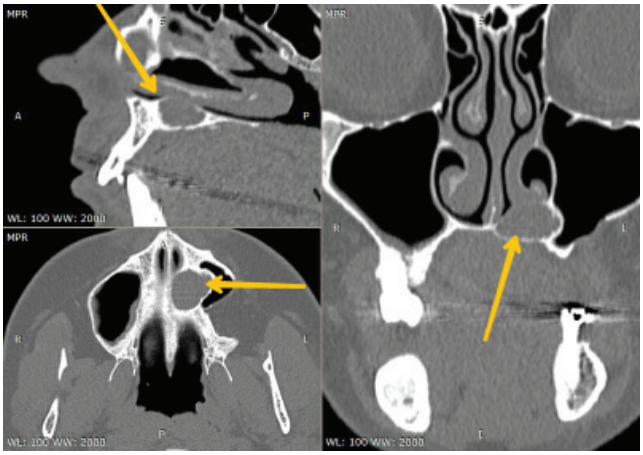

Fig. 9. Craniofacial CT – 12 months of parathyroidectomy; left maxillary tumor (yellow arrows)

the results were suggestive of osteopenia (T-score: –1.6; Z-score: –1.4; BMD: 0.809 g/cm^2). The attending endocrinologist instituted vitamin D3 supplementation.

Discussion

Brown tumor, a localized form of osteitis fibrosa cystica (fibrocystic osteitis), is a manifestation of hyperparatyroidism. At present, fibrocystic osteitis is rarely diagnosed in hyperparathyroidism as the disease is detected in its earlier stages than was the case in the past. Brown tumor usually affects the long bones; facial involvement is quite infrequent, especially in patients with multifocal lesions. It is more common in women in the 4th and 5th decades of life.[4,8-10,12,14] In younger people, brown tumor has been reported in multiple endocrine neoplasia syndromes (MEN1 and MEN2A).[4-6,14,15] Pregnancy has not been associated with brown tumor. Also, exophytic nonpedunculated lesions seen in our patient are rather uncommon. In pregnancy, clinical picture may be indicative of a pregnancy epulis or giant cell epulis.[14,16]

Histologically, brown tumors are identical to other central giant cell lesions of the jaws (CGCL) and are characterized by the presence of osteoclast-like multinucleated cells. Apart from brown tumors (brown tumors of primary, secondary and tertiary hyperparathyroidism), these lesions include central giant cell granuloma (CGCL), cherubism, aneurysmal bone cyst (ABC), giant cell tumor of bone also referred to as osteoclastoma, and others.[13] A histology report must therefore be confronted with the results of a clinical examination, laboratory tests and diagnostic imaging.[8,10,17]

Radiological findings tend to be noncharacteristic. Differential diagnosis includes other osteolytic lesions, most frequently solitary, with cortical thinning and tooth apex resorption, similar to odontogenic cysts and tumors.[4,8,12]

We believe the diagnosis of brown tumors is a complex process and should comprise the following:

- subjective and objective assessment with particular attention to symptoms characteristic of hyperparathyroidism (weakness, depression, bone and joint pain, polyuria, hypercalciuria, nephrolithiasis, loss of appetite, nausea, vomiting, constipation, gastric or duodenal ulcer, pancreatitis, cholelithiasis, hypertension, tachycardia, 1st degree atrioventricular block, decrease in muscle strength);
- physical examination including the thyroid;
- laboratory investigations: total and ionized calcium, vitamin D test, serum levels of parathyroid hormone and creatinine;
- diagnostic imaging: craniofacial CT, neck ultrasonography, Tc99m scintigraphy, bone densitometry (due to the risk of PHPT-related secondary osteoporosis);
- cytology and histology: fine needle aspiration biopsy, incisional biopsy/excisional biopsy/trepanobiopsy.[2,4,5,17,18]

The results of laboratory tests are virtually pathognomonic for HPTH. However, accessory investigations, such as neck ultrasonography or fine needle biopsy of the parathyroids, may leave some doubts, since parathyroid adenoma/hyperplasia might be misdiagnosed as a colloid goiter or follicular neoplasm of the thyroid gland, as was the case in our patient.[7]

The relationship between pregnancy and brown tumor progression has not been well documented in the literature, as brown tumors are extremely rare in pregnant women. Several researchers emphasize the increased demand for vitamin D3 (resulting in suboptimal circulating 25-hydroxyvitamin D) and calcium (total calcium increases while ionized calcium remains stable) as well as PTH-related protein secretion by the placenta, decidua and mammary glands. All these mechanisms may indirectly stimulate the bone resorption processes. No relationship has been found between pregnancy and PTH secretion.[14,16,19]

The management of brown tumors remains controversial, but the prevailing scheme includes parathyroidectomy, long-term monitoring of osteolytic lesions and, in the case of nonresponse and/or discomfort, the surgical removal of the tumor.[9,10,12] It has also been argued that expansive growth requires lesion resection followed by a parathyroidectomy.[4,8,17] Other authors described conservative treatment of central giant cell granulomas with intralesional injections of corticosteroids for 6 weeks.[20] Due to rapid maxillary tumor expansion in the 1st trimester of pregnancy, our patient underwent an en bloc maxillary resection including the tumor and teeth 25, 26. Osteolytic foci were left for observation. A follow-up CT performed at 12 months after the parathyroidectomy revealed an almost complete regression of mandibular lesions, while maxillary recurrence showed only a slight regression. Considering secondary hyperparathyroidism and low vitamin D3 levels, the patient remains under close clinical observation.

Primary hyperparathyroidism may also occur in the form of an inherited disorder referred to as hyperparathyroidism – jaw tumor syndrome (HPT-JT). There are no reports on brown tumors in HPT-JT patients, but they develop fibrous tumors of mesenchymal origin.[4,6,15,21]

Histologically confirmed CGCL justifies the implementation of our diagnostic and treatment algorithm (Fig. 10).

As already mentioned, numerous authors emphasize diagnostic challenges of primary hyperparathyroidism.[8,10,12] In our patient, the time interval between first symptoms, excision of a giant cell tumor of the clavicle and diagnosis of primary hyperparathyroidism was 24 and 12 months, respectively. Therefore, we conclude that a correct diagnosis of craniofacial brown tumors facilitates a timely diagnosis of primary hyperparathyroidism.

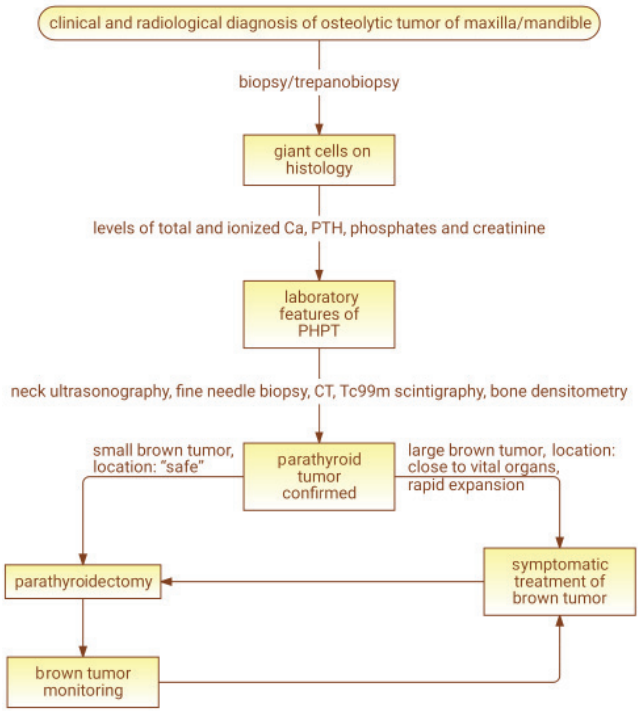

Fig. 10. Diagnostic/therapeutic scheme for brown tumor

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Difficulties in diagnosing and treating nasal rhinoscleroma: A case study

Trudności w diagnostyce i leczeniu twardzieli błony śluzowej nosa – opis przypadku

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Abstract

For many years scleroma was considered to be a neoplastic tumor. First findings of this disease came from the 4th century. In the 18th century it was also called the leprosy of the nose. In 1840, a Polish surgeon was the first in the world to describe rhinoscleroma as a "chronic nose cancer". In late 1877, Jan Mikulicz-Radecki classified this scleroma as rhinoscleroma, an inflammatory disease with the most common occurrence in the nasal cavity. Because of very rare cases of this disease reported nowadays (endemic), its treatment is challenging. The disease manifests itself as a symptomatic mass causing mostly an obstruction of nasal breathing or even local nose bleeds, and infiltrates the surrounding structures of the nose and sinuses. Difficult accurate clinical diagnosis of this disease seems to be the main problem in its early detection and treatment. Apart from a surgical excisional biopsy or more radical surgical approach, additional antibiotic treatment, along with routine checkups by an infectious diseases specialist, should be maintained.

A very rare and unusual case of a 75-year-old retired otolaryngologist diagnosed with a symptomatic mass in the nasal cavity, treated previously by unknown methods and without any success, will be presented. It is worth noticing that either the patient's economic status or his past job as an otolaryngologist might be related to the occurrence of rhinoscleroma as the possible route of infection.

Key words: rhinoscleroma, nasal cavity, diagnostic difficulties, treatment outcomes

Słowa kluczowe: twardziel błony śluzowej nosa, jama nosowa, trudności diagnostyczne,wyniki leczenia

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Rhinoscleroma can be found in many various anatomical parts of the entire respiratory tract. Because of civilizational and medical development, its occurrence in Europe is very rare today.[1] The WHO sources estimate its occurrence at about 6 cases between 2000 and 2004. Other reports rarely explain its occurrence in Europe.[1–3] The most common geographical occurrence sites for this disease are South America, India, south-eastern Asia and Africa. Most studies report an overall higher occurrence in women than in men, with the age ratio being about 15–35 years.[4] Lack of hygiene, poor economic conditions, malnutrition and prolonged contact with an infected person seem to be the most common epidemiologic factors for infection.[1,4] Rhinoscleroma (scleroma) is a very rare disease of the respiratory tract and is still considered to be incurable in some clinical stages.[5] In most cases it commonly manifests itself as a proliferative chronic inflammation caused by *Klebsiella rhinoscleromatis*, a Gram-negative rod bacillus, which is also called the Firsch bacillus.[3,6] Because of the rareness of this disease today, its accurate diagnosis might be troublesome and there may be many misdiagnoses. Excisional biopsy or ablative surgery followed by microbiological scrubs seems to be the treatment of choice.[4,7]

Rhinoscleroma (RS) is characteristic for its distinctive growth and has 3 clinical stages.[5,8] The 1st one, the atrophic stage, is characterized by a nonspecific rhinitis, which sometimes progresses into a purulent nasal secretion, while the 2nd one is the granulomatous stage. This one is characterized by the development of nodules and polyps in the nasal cavity. It is the time when the nose-wings begin to be asymmetrical. The final stage of RS is the sclerotic stage, characterized by the destruction of the nasal cartilage and nasal septum, the obstruction of the nasal cavity with granulation tissue and the obliteration of the pharyngeal opening of the auditory tube. In the most severe cases, the adhesion between the soft palate and the posterior pharyngeal wall is reported.[4,9,10]

Histopathological characteristics in RS include hard inflammatory infiltrations in the area of the anatomical recesses and openings of the respiratory tract. The infiltrations contain a large number of inflammatory cells (granulocytes, lymphocytes, plasmocytes, and histiocytes) and a characteristic formation of various granulation tissues, blood vessels or/and connective tissues. In these tumor masses, the characteristic Mikulicz cells are also found.[8,10] These foamy cells contain many vacuoles filled with numerous *Klebsiella rhinoscleromatis* bacilli, which are common and characteristic histopathologic findings confirming scleroma. Another feature is the presence of Russel bodies – cells containing hyaline.[3,7,11,12]

Differential diagnosis should include bacterial (actinomycosis, tuberculosis, syphilis, leprosy), fungal (histoplasmosis, blastomycosis, paracoccidioidomycosis, sporotrichosis) and even parasite infection (mucocutaneous leishmaniasis).[2,9,10] Rhinoscleroma can also have similar clinical manifestations as various inflammatory and neoplastic processes, such as basal cell carcinoma, nasopalatine duct cyst, sarcoidosis, verrucous carcinoma, wegener granulomatosis, central giant cell granuloma, histiocytosis X, lymphoma (lethal midline granuloma-FLMG or Hodgkins) or other neoplastic diseases, which also should be taken into consideration. Other findings should include: nasal polyposis, extranodal Rosai-Dorfman disease, vasculitis, paracoccidioidomycosis, cocaine-induced midline destructive erosions, foreign body granulomas, or others.[2,8]

In the cases of chronic growth, early stages of the disease are not clear and mostly underestimated or neglected. Slowly growing masses with progressive symptoms arising from the surrounding anatomical area of the respiratory tract should be carefully evaluated and never neglected. Another important issue concerning RS are inaccurate diagnostic methods and the lack of the ability to visualize clearly the pathology.[11]

Case report

A 75-year-old, generally healthy retired otolaryngologist without any previous medical history was referred to the department with a complete obstruction of the nasal cavity, anosmia, rhinophonia, pain in the naso-maxillary area of the incisive bone and floor of the nasal cavity. Additionally, breathing problems and swelling of lymph nodes were found. The first symptoms were related with maxillary incisor tooth pain and rhinitis. A diagnostic biopsy indicated foamy cells with *Klebsiella rhinoscleromatis* infection. Routine CT-examination revealed the presence of pathologic tissues within the nasal cavity and maxillary sinuses, manifesting as an obstruction with granulomatous tissue and bone destruction of surrounding structures, including vomer, nasal septum, and maxillary sinus with inferior and middle nasal conchae (Fig. 1). Laryngoscopy revealed widening of the vocal folds without any involvement of the epipharynx; however, a large amount of secretion due to the obstruction of the nasal cavity was

Fig. 1. Pre-operative compute tomography with visible tumor masses

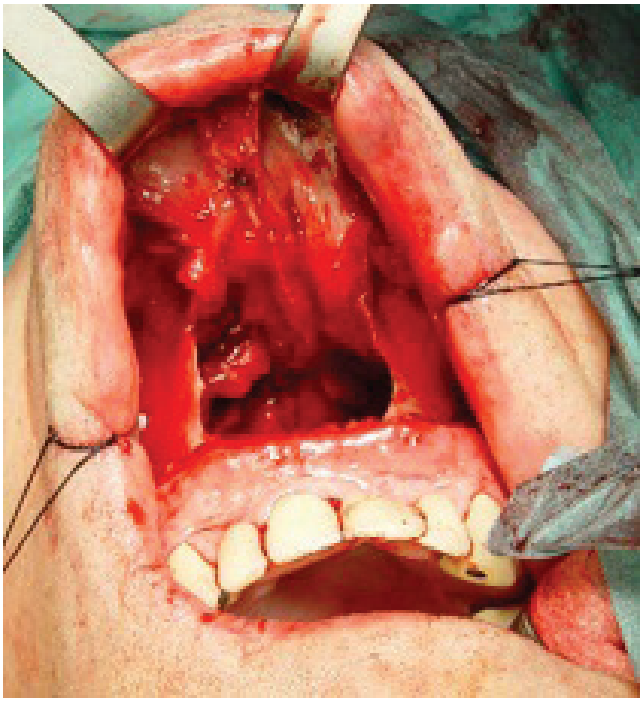

Fig. 2. Surgical deglovingapproach

found. Surgery included the dissection of swollen right lymph nodes-IB and part of nasal cavity from the degloving maxillary approach (Fig. 2). The entire content of the nasal cavity was removed along with the granulating tissue, inferior and middle nasal conchae, nasal septum and the additional nodule perforating to the epipharynx. Bone fragments were removed and an additional curettage of the resection site was made. Microbiological scrubs from deep inside the tumor mass along with tissues scheduled for a histopathological evaluation were sent for further investigation to 3 independent histopathological clinics in major university towns to confirm the diagnosis and exclude any possible misdiagnosis (Fig. 3, 4). Nasal packing with antibiotics (2% neomycin ointment – aminoglycoside) was applied around 2 silicone tubes to maintain adequate nasal breathing and enable the secure drainage

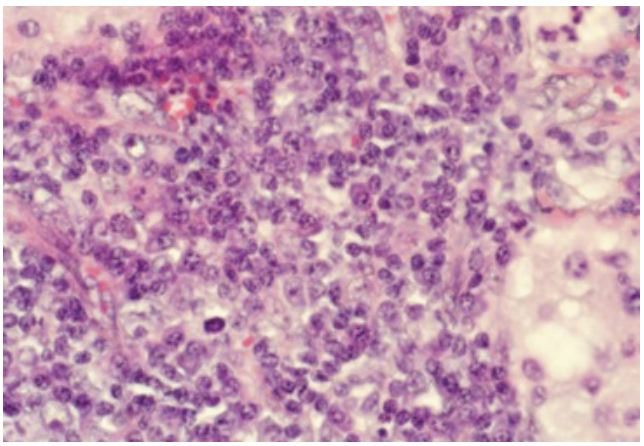

Fig. 3. Histopathological evaluation (H + E, staining 25×)

Fig. 4. Microscopic specimen

Fig. 5. Swollen lymph nodes (marked with blue circles)

Fig. 6. Excised swollen lymph nodes

of blood and other exudation for 48 h. The next step of the surgery was focused on the removal of 3 swollen nodes in the right submandibular area (IB) and right supraclavicular area (Fig. 5, 6). Histopathological evaluation described the main tumor as a massive inflammatory infiltration consisting of plasmatic cells, lymphocytes T and B with a huge amount of foamy cells, namely the Mikulicz cells. Additional immunohistochemistry revealed the presence of Bcl-2(+); CD20(+); CD3(+); MAC387(+); CD68(+) and Ki-67(–) antigens. Dissected swollen lymph nodes were also identified as rhinoscleroma.

The surgical period went without complications. The patient was treated with targeted antibiotic treatment Ciproxex® (fluoroquinolonum; 2 × 500 mg intravenously) and Doxycycline TZF® (tetracyclinum; 2 × 100 mg/mL intravenously), while in the department for 5 days, and then after discharge for additional 3 weeks. In a routine antibacterial swab from the operated area after 3 weeks, no bacterial or fungal infections were present. The 2nd part of treatment was scheduled at The Regional Infectious Diseases Centre with the same mentioned antibiotics. Control CT and nasopharynx endoscopy after 6 months revealed no signs of nasal obstruction or visible recurrence of RS and no tumor mass (Fig. 7). So far after two years, no disease recurrence was noticed.

Discussion

Rhinoscleroma of the sinonasal tract is rare in the European population.[4,12] When present, in most cases it is found in the upper respiratory tract, mimicking tumor-like hard inflammatory infiltrations.[13–16] In some cases, its growth is misdiagnosed with cancer occurrence.[3,10,16] In available data a large number of inflammatory cells which corresponds with the degree of destruction of the nasal cartilage and nasal septum were found.[15–17] A growing and proliferative tumor mass causes the obstruction of the nasal cavity with granulation tissue formation and the obliteration of the pharyngeal opening of the auditory tube.[18,19] Additional studies report the elevation of IL-10 and also other indirect inflammation markers levels.[13,19] This finding might be one of the positive markers for diagnostics of RS; however, additional levels of other inflammatory markers such as CRP (C-reactive protein) and procalcitonin levels might vary in the cases with or without a severe inflammation component.[11,13,14,20] It seems that a biopsy with microbiological scrubs are the most accurate factors for identifying RS.[2–4,19] A careful clinical examination should always be performed. In the most severe cases, tumor tissue mass adhesion to the soft palate and the posterior pharyngeal wall was reported.[6,7] In some rare cases, RS can mimic nasal polyposis or lead to the enlargement and asymmetry of the nasal septum.[14,15] The presented case shows how hard it was and how long it took to diagnose this disease. This worrisome fact corresponds to the small amount of RS occurrence in Europe.[16] It turns out that even in times when we have at our disposal state-of-the-art imaging techniques (such as computed tomography, magnetic resonance imaging, videofiberoscopy), pathomorphological tests (such as immunohistochemistry) and almost unlimited access to knowledge, the occurrence of rare or almost forgotten diseases in some geographical areas is troublesome.[18] Nevertheless, nasal and oral cavity endoscopy and scheduled computed tomography imaging still remain basic diagnostic approaches. Differential diagnosis should take into account many other nasal cavity diseases, especially infiltrative and inflammatory ones, whose exclusion or co-occurrence could improve the diagnosis.

Fig. 7. Six-month post-op computed tomography

The treatment of rhinoscleroma is challenging. When an excessive RS growth is present, a rhinosporidiosis progress might lead to a life-threatening obstruction or stenosis of the lower respiratory tract.[17,21] In those situations, bronchoscopic and/or endoscopic evaluation and treatment should be scheduled.[10,15,20,22] As scleroma was considered to be incurable, many patients must continue regular check-ups in a maxillofacial, laryngology, pulmonology and infectious diseases specialists. Nowadays, the most frequent method of treating scleroma is antibiotic therapy.[19] When streptomycin was added to the treatment, most symptoms decreased significantly. Currently, cases of scleroma are treated with fluoroquinolones, ex. rifampicin as well as with tetracycline and co-trimoxazole. In the authors' opinion, in some cases it is worth considering surgical treatment accompanied by pharmacological treatment.[21] Antibacterial treatment without a radical surgical excision is not recommended in cases of infiltration and destruction of nasal cavity walls. The presented case emphasizes that the surgical procedure stopped the disease from spreading, improved the quality of the patient's life and made it possible to diagnose the disease. Further pharmacological treatment sustained the therapeutic effect of the surgical treatment.[17,20,22]

Conclusions

The presented case underlines a possible etiological factor for the infection in components such as numerous contact with people diagnosed with ear, nose and throat diseases. The authors' study mentioned the etiological factors related with the patient's past job as a laryngologist. Radical surgery seems to be the treatment of choice in order to avoid the spread of the disease. On the other hand, the degloving approach seems to influence later proper nasal shape and function. If the patient is reporting an occurrence of a saddle nose, additional cosmetic surgery can be performed. The adequate time for it is estimated at 12 months from the previous surgery and when no recurrence of RS is noted.

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Different outcomes of managing severe intruded immature permanent incisors: A report of two cases

Zróżnicowane wyniki leczenia ciężkiej intruzji stałych zębów siecznych z niezakończonym rozwojem korzeni – opis dwóch przypadków

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Abstract

Intrusion is a very severe injury involving damage to the periodontal ligament, cementum, alveolar bone, and neurovascular pulp supply. Current management strategies include passive repositioning by waiting for the tooth to regain its preinjury position, and active repositioning, i.e., immediate surgical repositioning or repositioning with traction.

This report describes the interdisciplinary management of complete intrusions of the maxillary right central incisors with an immature open apex in 2 different patients of a similar age but with different outcomes. The most likely causes of these differences were: ankylosis; inflammatory root resorption; and the systemic condition of the 2nd patient. A number of preinjury and injury factors have a significant influence on the healing outcome. According to this report, prognosis after intrusive luxation appears to depend not only on the severity of the trauma, stage of root development and treatment method, but also probably on the patient's systemic condition. Therefore, the patient's current complex medical history should be taken into consideration as a factor significantly affecting the healing outcome and long-term prognosis.

Key words: corticotomy, intrusive luxation, permanent teeth, Wolfram syndrome

Słowa kluczowe: kortykotomia, zwichnięcie intruzyjne, zęby stałe, zespół Wolframa

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Intrusive luxations are characterized by tooth displacement into the alveolar bone. This injury is caused by an axially directed impact compressing the periodontal ligament with an accompanying fracture of the alveolar socket. It is a very severe injury involving damage to the periodontal ligament, cementum, alveolar bone, and neurovascular pulp supply; thereby it can compromise the vitality and ultimately affect tooth longevity. Intrusion frequency is relatively low and comprises 0.3–1.9% of all traumatic injuries to permanent dentition, but this type of trauma presents unique challenges to the clinician.[1,2]

Treatment decisions should take into consideration the clinical and radiographic signs and symptoms, such as occlusal misalignment, bleeding, and high-pitched metallic sound without sensitivity to percussion. Radiographic findings are useful in displaying partially or totally obliterated periodontal ligament spaces and differences in the position of the cemento-enamel junction relative to the bony crest between the traumatized tooth and its intact homolog.[3–5]

Intrusive luxation in permanent teeth has been associated with severe complications, such as pulp necrosis, pulp canal obliteration, inflammatory root resorption, dento-alveolar ankylosis, loss of marginal bone support, arrest of root development, and gingival retraction.[2]

The treatment strategy should be focused on eliminating, or at least reducing, post injury sequelae.[3] The contemporary state of knowledge concerning treatment options is mainly based on clinical case outcomes. There is no agreement in the literature regarding ideal treatment for permanent tooth intrusion after injury. Depending on the stage of development and severity of injury, waiting for spontaneous re-eruption and surgical or orthodontic repositioning are recommended.[2,3,6]

This report discusses the interdisciplinary management of severe traumatic intrusion of the maxillary central incisors in 2 different patients of a similar age but with different outcomes.

Case reports

Case 1

A 7.5-year-old boy presented to the Pediatric Dentistry Clinic of the Faculty of Dentistry, Medical University of Bialystok, Poland, 1 day after he had fallen at the swimming pool. His past medical history, neurological and extraoral examinations were unremarkable.

Intraoral examination revealed a submucosal hematoma in the area of the maxillary labial frenulum, an uncomplicated crown fracture with dentin involvement coupled with subluxation of the maxillary left central incisor, and a small incisal fracture of the maxillary left lateral incisor. The upper right central incisor had been axially intruded (> 7 mm, complete intrusion) as a result of the impact. In the clinical tests, both left incisors (21 and 22) did not respond to vitality tests and were not tender to percussion.

Radiographic examination confirmed a clinical diagnosis of complete intrusion of the maxillary right central incisor with an immature open apex and obliteration of the periodontal ligament space and lamina dura in relation to the intruded tooth (Fig. 1). Prior to the beginning of treatment, parental informed consent was obtained. Additionally, antibiotic therapy was prescribed for 7 days, with Augmentin® (375 mg 3 times per day), and a 14-day course of 0.12% chlorhexidine gluconate mouth rinse.

After 4 weeks, spontaneous re-eruption of the maxillary right central incisor could be identified (5.5 mm). The patient was referred to the orthodontist for orthodontic repositioning by extrusion. At 9 months after the trauma, clinical and radiographic examinations revealed further progress of extrusion for the upper right central incisor amounting to 9 mm and complete root development with closure of the apical foramen and apposition of the root dentin. Due to pulp vitality loss, endodontic therapy of

Fig. 1. Initial periapical radiograph revealing intrusion of tooth 11 and fracture of tooth 21

Fig. 2. Periapical radiograph after filling the root canal of tooth 11

Fig. 3. Periapical radiograph 4.5 years after trauma showing successful treatment of tooth 11

the intruded tooth was initiated. Finally, the root canal was filled with gutta-percha and epoxy resin-based sealer (Fig. 2). The tooth was restored with a light-cured resin composite and followed-up for 4.5 years. Eighteen months after the trauma, complete eruption under traction of the intruded tooth was achieved and orthodontic appliances were debonded. The tooth was clinically asymptomatic, with healthy surrounding periodontal tissue and no loss of marginal bone support. Radiographically, there was no evidence of root resorption or periapical lesions. The patient underwent a 4.5-year follow-up and showed no clinical or radiographic signs or symptoms (Fig. 3).

Case 2

A 7-year-old boy presented to the Pediatric Dentistry Clinic of the Faculty of Dentistry, Medical University of Bialystok, Poland, 2 days after he had fallen while riding his bicycle.

The neurological examination was unremarkable. Medical history revealed type 1 diabetes with good glycemic control.

Extraoral examination showed an abrasive injury to the chin and lower lip. The facial bones and TMJ were within normal limits. The right submental and submandibular lymph nodes were palpable, swollen and tender on palpation. Intraoral examination revealed a laceration and hematoma in the front central part of the maxillary alveolar mucosa.

The upper right central incisor appeared to be completely axially intruded as a result of the impact. No alterations were observed in the hard tissues of the maxillary left incisors (21, 22) and the maxillary right lateral incisor (12), but they did not respond to the cold test. Radiographic examination confirmed the clinical diagnosis of complete intrusion of the upper right central incisor and obliteration of the periodontal ligament space and lamina dura in relation to the intruded tooth (Fig. 4). Prior to the beginning of treatment, parental informed consent was obtained.

The patient received a 7-day course of Augmentin (375 mg 3 times per day) and a 14-day course of 0.12% chlorhexidine gluconate mouth rinse. He was instructed to maintain meticulous oral hygiene by brushing with a soft brush and prescribed a soft diet for 14 days. No re-eruption of the intruded tooth was observed. The appointments scheduled for 2, 3, and 4 weeks later demonstrated spontaneous re-eruption of the upper right central incisor by 1.5, 2.5 and 3.5 mm at each follow-up, respectively. After a further 4 weeks, clinical examination showed no improvement in re-eruption and the patient was referred for orthodontic repositioning by extrusion. After 6 months, as no progression in orthodontic extrusion was observed, clinical follow-up examination showed tooth immobility and infraposition, whereas an X-ray image showed the absence of the periodontal crevice around the root apex, which suggested replacement resorption (Fig. 5). A corticotomy procedure of the compact bone lamella of the maxillary alveolar process was performed around the intruded tooth, including intraoperative tooth luxation. Despite the decortication, orthodontic extrusion was proceeding slowly – 4 mm at 12 months following the trauma, and at 18 months 5 mm. During this period, the patient's general health status changed. Besides type 1 diabetes, the boy developed signs of optic atrophy and underwent diagnostic procedures with the suspicion of Wolfram syndrome. Wolfram syndrome (WS) is defined with the term Wolfram DIDMOAD syndrome (diabetes insipidus, diabetes mellitus, optic atrophy, deafness). Wolfram patients demonstrate non-inflammatory atrophic changes in the brain and pancreatic islets resulting in progressive diabetes, blindness, deafness, and other severe neurological defects. WS has been attributed to mutations in the WFS1 gene, which codes for a protein called wolframin. It appears to be important in the regulation of intracellular Ca^{+2} homeostasis.[7,8]

Fig. 4. Initial periapical radiograph revealing complete intrusion of tooth 11

Fig. 5. Radiograph before surgical procedure showing the disappearance of periodontal space around tooth 11

Fig. 6. Periapical radiograph 22 months following trauma showing inflammatory root resorption

Twenty-two months after the trauma, the right upper incisor was in slight infraocclusion (re-eruption of 7 mm) in relation to the homolog. Endodontic treatment was not begun during this time, because the patient failed to report for follow-up visits to the Department of Pedodontics. Also, a pink spot in the cervical area of the maxillary right central incisor appeared, which gave rise to the suspicion of inflammatory resorption. Radiographic examination confirmed the presence of severe inflammatory root resorption and the decision was made to debond the orthodontic appliances and extract the tooth (Fig. 6). The patient was provided with an orthodontic appliance which simultaneously replaced the missing upper right central incisor.

Discussion

Intrusive luxation in permanent teeth is one of the most severe dental traumas. The main etiological factors include bicycle accidents, sports, recreational activities, or falls.[4,5,9] A longitudinal clinical and radiographic evaluation of intruded teeth in a pediatric population, undertaken by Siebra Moreira Neto et al., demonstrated that tooth intrusion was twice as frequent in males and the maxillary central incisors were the most commonly affected teeth (93.3%), which is related to their anatomic position in the dental arch.[10] The cases reported here also confirmed these findings. Both our patients were males with traumatically intruded permanent upper right central incisors.

Treatment options for traumatically intruded teeth are still widely discussed in the literature. Although there is a paucity of evidence-based data from randomized control trials to evaluate the most effective treatment for traumatically intruded teeth, according to the International Association of Dental Traumatology (IADT), the stages in root development and intrusion level are the determining factors in choosing the most appropriate treatment methods.[11] Current management strategies include passive repositioning by waiting for the tooth to regain its preinjury position, and active repositioning, i.e., immediate surgical repositioning or repositioning with traction.[12] Waiting for spontaneous re-eruption is indicated for immature permanent teeth, because of their high potential for eruption and pulp/periodontal repair.[13]

In the present report, the intruded teeth were immature and revealed complete intrusion (tooth dislodgement >7 mm). In cases such as ours, treatment guidelines recommend orthodontic extrusion if passive re-eruption fails to occur within several weeks after injury, which we applied in both our patients. In case report 1, orthodontic extrusion was initiated 4 weeks after the trauma, while in case report 2 after 8 weeks. The variations in the initiation of orthodontic treatment were determined by differences in the progress of spontaneous re-eruption, which allowed for incisal edge exposure sufficient to apply orthodontic brackets.

In case 1 presentation, orthodontic treatment was completed after 1.5 years, achieving normal positioning for the maxillary right central incisor. The 9-month delay in endodontic therapy provided for continued root development and root dentin apposition. Umesan et al. applied an almost comparable procedure and obtained tooth orthodontic replacement 7 months after injury.[9] It can be assumed that orthodontic repositioning in the aforementioned report progressed more rapidly than in our case due to an earlier stage of root development. However, the authors did not carry out root canal treatment because the pulp responded to the vitality test, while post-treatment review 1 year later revealed that the entire pulp canal appeared partially obliterated. It has been shown that immature teeth present a better prognosis than do those with complete root formation.[3,6,9,14]

Despite the implementation of an identical procedure in case report 2, eruption under traction proceeded unsatisfactorily and radiological examination revealed ankylosis. Therefore, a corticotomy and luxation were administered as supportive treatment to hasten re-eruption. Corticotomy is a procedure where only the cortical bone is cut, perforated, or mechanically altered in a controlled surgical manner, and thus it is defined as the osteotomy of the cortical bone. In light of some reports, this procedure helps orthodontic tooth movement by accelerated bone metabolism due to controlled surgical damage, so it is called corticotomy-assisted orthodontics.[15,16] According to Bhattacharya et al., corticotomy techniques reduce the time taken for re-eruption when compared with conventional orthodontic treatment by 30–50%.[16] In case 2 presentation, despite decortication and luxation, orthodontic extrusion was unsatisfactory and ankylosis was observed. The incidence of replacement root resorption after intrusions ranges from 25% to 50%. This occurs more often with incisors that have been severely intruded and those that have been repositioned with traction forces.[17] Early radiological diagnosis is difficult because initial changes are usually found on the labial or lingual root surface.

Takahashi et al. suggest the use of orthodontic force after luxation to prevent ankylosis, although other authors have noted that in many cases it had not brought positive results.[18,19] Furthermore, in case 2, we noticed that the intruded tooth exhibited severe inflammatory internal root resorption, which is known to be a frequent complication of extensive tooth intrusion.[20] This was confirmed in the study by Wigen et al.[5]

The 2 cases described of severe tooth intrusions in patients of a similar age showed varied outcomes. The most likely causes of these differences were: ankylosis; inflammatory root resorption; and the 2nd patient's systemic condition. Besides suffering from type 1 diabetes, the boy developed signs of optical atrophy and was referred for diagnosis with suspected Wolfram syndrome.

Conclusions

A number of preinjury and injury factors have a significant effect on treatment outcome. According to this report, prognosis after intrusive luxation appears to depend not only on the severity of the trauma, stage of root development and treatment method, but probably also on the patient's systemic condition.

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Facial talon cusp on a permanent mandibular canine: A rare case report

Dodatkowy guzek talon na powierzchni wargowej kła żuchwy – opis rzadkiego przypadku

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Abstract

Talon cusp is an unusual abnormality characterized by a cusp-like projection that occurs due to the evagination of enamel and dentin with a variable amount of pulp tissue before calcification, usually present on the cingulum area on the palatal and lingual surface of the anterior teeth. The maxillary lateral incisors are most often affected, followed by the maxillary central incisors in both primary and permanent dentition. The etiology is unknown. This developmental anomaly is rare on the facial surfaces of mandibular canines and very few cases have been reported. When it occurs on the facial surface, it usually affects the esthetics and functioning.

The present case report describes an unusual case of a facial talon cusp on a permanent mandibular left canine in a 12-year-old girl. To date, only 1 such case has been reported to our knowledge and it requires careful dental and radiographic examination of the affected patient since the findings can be of clinical significance.

Key words: developmental abnormality, mandibular, canine

Słowa kluczowe: zaburzenie rozwojowe, żuchwa, kieł

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Talon cusp is a developmental abnormality which is characterized by a prominent cusp on the palatal surface of maxillary and mandibular teeth.[1] The prevalence of talon cusp ranges from less than 1% to 8% of the Indian population. Studies show a prevalence rate of about 7.7% in the North Indian population and 19.35% in the South Indian population. It exhibits a higher incidence in males than females at a ratio of 16 : 9.[2] It is most commonly seen in maxillary teeth (94%) with maxillary lateral incisors being most commonly affected (55%) followed by maxillary central incisors (33%) and canines (9%).[3] This developmental anomaly may have multiple clinical implications such as esthetic and occlusal problems, caries and displacement of the affected tooth and irritation of the tongue during mastication and speech. The occurrence of talon cusp on mandibular teeth has been found to be extremely rare. In the literature, only 1 case report has been presented, by Chinni et al., on a permanent mandibular canine.[4] Thus, this case report adds 1 more case to the present literature on the labial aspect of a permanent mandibular canine, which is a very atypical condition.

Case report

A 12-year-old girl accompanied by her parents reported to the Department of Paedodontics and Preventive Dentistry with the chief complaint of pain and food lodgment in her upper front tooth for the past week. The pain was intermittent in nature and aggravated on having cold food. This was her first dental visit and the patient did not present any significant medical history. Intraoral examination showed that the lower left canine was structurally dissimilar to its antimere, having a convexity on the buccal surface (Fig. 1). The discovery of the anomaly was accidental and had nothing to do with the pain experienced by the patient. The patient did not report any problem while biting. All other teeth did not show any developmental abnormalities. The parents had no knowledge of similar anomalies in the dentitions of any other family members.

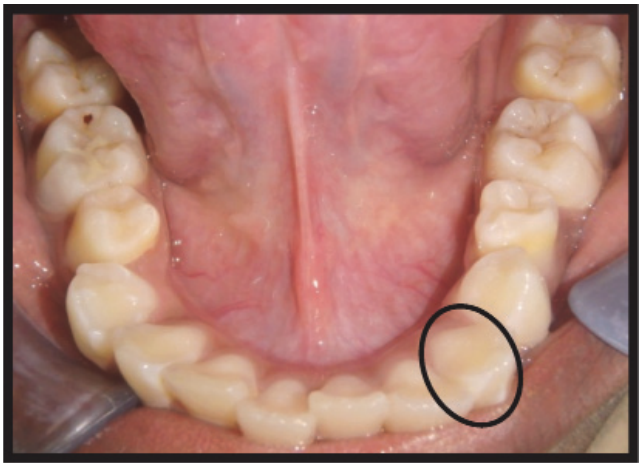

Fig. 1. Occlusal view of mandibular arch

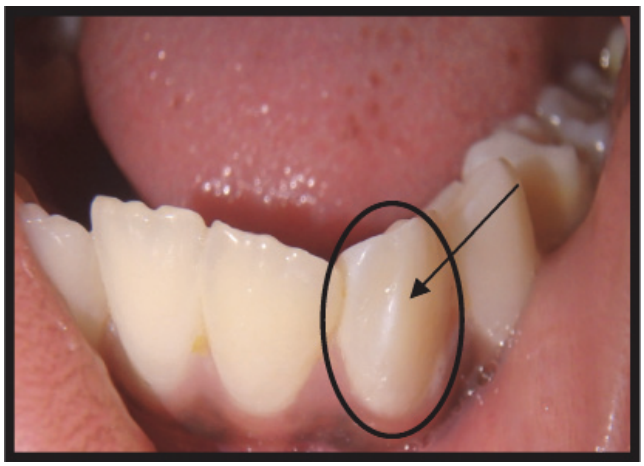

Fig. 2. Labial view of 33 showing talon cusp

Plaque and deep fissures were present in relation to the upper and lower first permanent molars.

A provisional diagnosis of talon cusp was made as the tooth with talon cusp is commonly thicker faciolingually and wider mesiodistally than the normal contralateral tooth (Fig. 2). An intraoral periapical radiograph of tooth 33 revealed a V-shaped structure with greater radiopacity in the crown, which confirmed the diagnosis of talon cusp (Fig. 3).

The management of talons cusp depends upon the case. It has been reported that just the mere existence of talon cusp is not an indication for dental treatment unless it causes clinical problems.[5] In this case, the talon cusp was asymptomatic and not interfering with the occlusion, therefore no treatment was done.

Fig. 3. IOPA of 33 showing radioopaque V- shaped structure

Discussion

In the year 1892, William Mitchell reported the first case of talon cusp in a permanent incisor, which presented an extra cusp-like structure, protruding lingually from the cingulum.[acc. 6] Mellor and Ripa coined the term in 1970 because of its distinctive similarity to an eagle's talon.[acc. 7] An archeological report belonging to the age of ca. 9500 BP in the Republic of Niger reported a facial talon cusp on the mandibular canine of an adult male, which was the only case report on a mandibular canine.[8] Thus, this case presents a very rare form of labial talon cusp on a permanent mandibular canine.

The exact etiology of talon cusp is unknown, however it is considered to originate at some point in the morphodifferentiation stage of odontogenesis because of the hyperproductivity of the dental lamina or outfolding of the enamel organ.[9]

Facial talon cusp had been categorized into 3 stages by Mayes in 2007.[10]

Stage 1: The mildest form, which consists of a slightly raised triangle on the facial surface of an incisor that extends the length of the crown but reaches neither the incisal edge nor the cementoenamel junction (CEJ).

Stage 2: The moderate form, which consists of a raised triangle on the facial surface of an incisor that extends the length of the crown and reaches the incisal edge but not the CEJ and can be observed and palpated easily.

Stage 3: The most extreme form, consisting of a free-form cusp on the facial aspect of an incisor that extends from the CEJ to the incisal edge.

The appearance of talon cusp may vary in shape and size and depends on the angle at which the X-ray is taken.[11] It can cause additional complications like unpleasant esthetics, a predilection for caries and occlusal interferences. The occlusal interferences can be confirmed by the attrition present on the talon cusp tip. Other problems such as accidental cusp fracture, misinterpretations of radiographs, further attrition resulting in pulp exposure, damage to periodontium because of increased occlusal forces and displacement of opposing teeth have also been reported.[12]

Depending on the accessory cusp location, shape, size and the tooth affected, the treatment of talon cusp can be conservative or radical. The management depends upon the case. Usually no treatment is recommended for a small asymptomatic talon cusp.[5] Sealing the interface of the talon and the palatal surface of the tooth concerned using a fissure sealant should be done as a preventive measure towards caries. Cusp reduction should be performed at periodic spans to promote the development of reparative dentin in cases of occlusal disturbances and unpleasant esthetics. Radiographically, if pulp extends into the talon cusp, while reducing the cusp, the clinician should be cautious to avoid accidental pulp exposure.

Conclusions

The present case report describes a rare case of talon cusp on the labial surface of a permanent mandibular canine and emphasizes that treatment is not mandatory for a talon cusp if it is asymptomatic, and treatment plans differ from case to case. Clinicians should be alert in diagnosing this unique entity, which can help in early treatment of the condition and thereby prevent any potential complications.

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Impact Factor Listing for Journals on Dentistry (2016)

First part: Journals on General Dentistry (40 titles with IF: 0.448–4.755)

Journal title	Abbreviation	Country of the publisher	Frequency in a year	IF (change vs 2015)
Journal of Dental Research	J Dent Res	USA	12	4.755 (+0.15)
Dental Materials	Dent Mater	Great Britain	12	4.07 (+0.14)
International Journal of Oral Science	Int J Oral Sci	China	4	3.93 (+1.34)
Journal of Dentistry	J Dent	USA	12	3.456 (+0.35)
Molecular Oral Microbiology	Mol Oral Microbiol	USA	6	2.908 (–0.16)
Journal of Oral & Facial Pain and Headache	J Oral & Fac Pain	Canada	4	2.76 (–0.06)
Journal of Evidence-Based Dental Practice	J Evid Bas Dent Pract	USA	4	2.477 (+1.00)
Clinical Oral Investigations	Clin Oral Invest	Germany	9	2.308 (+0.1)
Community Dentistry and Oral Epidemiology	Commun Dent Oral Epidemiol	New Zealand	6	2.302 (–0.03)
Journal of the American Dental Association	JADA	USA	12	2.15 (+0.39)
Odontology	Odontol	Japan	4	1.91 (+0.38)
Archives of Oral Biology	Arch Oral Biol	Great Britain	12	1.748 (+0.01)
Gerodontology	Gerodontol	Canada	4	1.681 (+0.29)
Australian Dental Journal	Aust J Dent	Australia	6	1.643 (+0.37)
European Journal of Oral Sciences	Eur J Oral Sci	Denmark	6	1.54 (–0.06)
BMC Oral Health	BMC Oral Health	Great Britain	open access	1.481 (+0.27)
International Journal of Computerized Dentistry*	Int J Comp Dent	Germany	3	1.436
Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics	Oral Surg Oral Med Oral Pathol Oral Radiol Endod	USA	12	1.416 (+0.15)
Dental Traumatology	Dent Traumatol	Australia	6	1.413 (+0.09)
Journal of Public Health Dentistry	J Public Health Dent	USA	4	1.378 (+0.19)
Head & Face Medicine	Head Face Med	Germany	open access	1.37 (+0.45)
International Dental Journal	Int Dent J	Israel	6	1.362 (+0.4)
International Journal of Dental Hygiene	Int J Dent Hyg	Sweden	4	1.358 (+0.56)
Journal of Applied Oral Science	J Appl Oral Sci	Brazil	4	1.342 (+0.23)
Brazilian Oral Research	Braz Oral Res	Brazil	4	1.331 (+0.48)
Journal of Esthetic and Restorative Dentistry	J Esth Restorative Dent	USA	6	1.273 (+0.04)
Acta Odontologica Scandinavica	Acta Odontol Scand	Norway	8	1.232 (+0.06)
International Journal of Periodontics & Restorative Dentistry	Int J Periodontics Restorative Dent	USA	6	1.113 (+0.08)
Dental Materials Journal	Dent Mater J	Japan	2	1.073 (–0.01)
British Dental Journal	Brit Dent J	Great Britain	24	1.009 (+0.01)
Quintessence International	Quintes Int	USA	10	0.995 (+0.17)
Journal of Craniomandibular Practice & Sleep Practice	Cranio	USA	6	0.877(+0.14)
Journal of Oral Science	J Oral Sci	Japan	4	0.876 (+0.07)
Dentistry*	Dent	Japan	open access	0.83
Community Dental Health	Community Dent Health	Great Britain	4	0.816 (+0.05)
American Journal of Dentistry	Am J Dent	USA	6	0.76 (–0.43)
Oral Health and Preventive Dentistry	Oral Health Prev Dent	Switzerland	6	0.657 (–0.04)
Swedish Dental Journal	Swed Dent J	Sweden	4	0.581 (+0.2)
Journal of the Canadian Dental Association	JCDA	Canada	11	0.514 (+0.23)
Journal of Dental Sciences	J Dent Sci	China	4	0.488 (–0.31)

*Journal has entered the list in 2016.

Second part: Journals on Specialist Dentistry (50 titles with IF: 0.023–4.794)

Journal title	Abbreviation	Country of the publisher	Frequency in a year	IF (change vs 2015)
Oral Surgery and Maxillofacial Surgery (7 titles)				
Oral Oncology	Oral Oncol	USA	12	4.794 (+0.51)
International Journal of Oral and Maxillofacial Surgery	Int J Oral Max Surg	Great Britain	6	1.918 (+0.35)
Journal of Oral and Maxillofacial Surgery	J Oral Max Surg	USA	12	1.916 (+0.28)
Journal of Cranio-Maxillofacial Surgery	J Craniofac Surg	Germany	12	1.583 (–0.01)
Oral and Maxillofacial Surgery Clinics of North America	Oral Max Surg Clin North Am	USA	4	1.478 (+0.8)
British Journal of Oral & Maxillofacial Surgery	Brit J Oral Max Surg	Great Britain	6	1.218 (–0.02)
Cleft Palate-Craniofacial Journal	Cleft Pal-Craniofac J	USA	6	1.133 (+0.08)
Dental Radiology (2 titles)				
Dentomaxillofacial Radiology	Dentomaxillofac Rad	Germany	9	1.583 (–0.33)
Oral Radiology	Oral Radiol	Japan	3	0.554 (+0.1)
Periodontology and Oral Pathology (8 titles)				
Periodontology 2000	Periodontol 2000	USA	3	4.072 (–0.87)
Journal of Clinical Periodontology	J Clin Periodontol	Great Britain	12	3.477 (–0.44)
Journal of Periodontology	J Periodontol	USA	12	3.03 (+0.19)
Journal of Periodontal Research	J Periodontal Res	Japan	6	2.662 (+0.19)
Journal of Oral Pathology & Medicine	J Oral Pathol Med	Great Britain	10	2.043 (+0.19)
Oral Diseases	Oral Dis	USA	8	2.011 (+0.01)
Journal of Periodontal & Implant Science	JPIS	Korea	6	1.23 (+0.13)
Medicina Oral Patologia Oral y Cirugia Bucal	Med Oral Pat Oral Cir Bucal	Spain	open access	1.156 (+0.07)
Implant Dentistry (7 titles)				
Clinical Oral Implants Research	Clin Oral Impl Res	Australia	12	3.624 (+0.16)
European Journal of Implantology	Eur J Implant	Great Britain	6	3.567 (+1.24)
Clinical Implant Dentistry and Related Research	Clin Impl Dent Res	USA	6	2.939 (–1.22)
International Journal of Oral & Maxillofacial Implants	Int J Oral Max Impl	USA	6	2.263 (+0.41)
Journal of Oral Implantology	J Oral Implant	USA	6	1.184 (–0.25)
Implant Dentistry	Impl Dent	USA	6	1.107 (+0.08)
Implantologie	Implant	Germany	4	0.034 (–0.02)
Cariology and Endodontics (6 titles)				
International Endodontic Journal	Int Endod J	Great Britain	12	3.015 (+0.17)
Operative Dentistry	Oper Dent	USA	6	2.893 (+0.08)
Journal of Endodontics	J Endod	USA	12	2.807 (–0.1)
Journal of Adhesive Dentistry	J Adhesiv Dent	Germany	6	2.008 (+0.41)
Caries Research	Caries Res	Switzerland	6	1.811 (–0.54)
Australian Endodontic Journal	Austr Endod J	Australia	3	0.838 (–0.05)
Orthodontics (8 titles)				
European Journal of Orthodontics	Eur J Orthod	Finland	6	1.622 (+0.18)
American Journal of Orthodontics and Dentofacial Orthopedics	AJO-DO	USA	12	1.472 (–0.22)
Angle Orthodontist	Angle	USA	6	1.366 (–0.21)
Korean Journal of Orthodontics	Kor J Orthod	Korea	6	1.182 (+0.02)
Orthodontics & Craniofacial Research	Orthod Craniofac Res	Netherlands	4	1.115 (–0.53)
Journal of Orofacial Orthopedics	J Orofac Orthod	Germany	open access	0.753 (–0.04)
Australian Orthodontic Journal	Austr Orthod J	Australia	3	0.423 (–0.03)
Seminars in Orthodontics	Sem Orthod	USA	open access	0.404 (+0.06)

Pediatric Dentistry (4 titles)				
Pediatric Dentistry	Pediatr Dent	USA	6	1.947 (+1.07)
International Journal of Paediatric Dentistry	Int J Paediatr Dent	Great Britain	6	1.532 (+0.23)
Journal of Clinical Pediatric Dentistry	JOCPD	Great Britain	6	0.775 (+0.21)
European Journal of Paediatric Dentistry	Eur J Paediatr Dent	Italy	4	0.683 (+0.26)
Prosthetic Dentistry (6 titles)				
Journal of Prosthodontic Research	J Prosthodont Res	Japan	4	2.561 (+0.87)
Journal of Oral Rehabilitation	J Oral Rehabil	Denmark	12	2.098 (+0.17)
Journal of Prosthetic Dentistry	J Prosthet Dent	USA	12	2.095 (+0.58)
Journal of Prosthodontics	J Prosthodont	USA	8	1.452 (+0.32)
International Journal of Prosthodontics	Int J Prosthodont	Canada	6	1.386 (–0.1)
Journal of Advanced Prosthodontics	J Adv Prosthodont	Korea	6	1.027 (+0.18)
Dental Education (2 titles)				
European Journal of Dental Education	Eur J Dent Educ	Great Britain	4	1.053 (+0.27)
Journal of Dental Education	J Dent Educ	USA	12	0.927 (+0.09)

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