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Spis treści

Prace kazuistyczne

New Members of the Editorial Board

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Akira Aoki, DDS, PhD

Dr. Akira Aoki received his DDS degree from Tokyo Medical and Dental University (TMDU), Japan, in 1989. He was awarded a PhD in 1996 from TMDU and currently serves as an Associate Professor at the Department of Periodontology, TMDU. From 2003 to 2004, he was a Visiting Assistant Professor at the Department of Preventive and Restorative Dental Sciences, University of California, San Francisco (UCSF), USA.

He has been engaged in Er:YAG laser research in the fields of periodontology and implant therapy since 1991. Dr. Aoki received the Best Presentation Award at the 3rd International Congress on Lasers in Dentistry, organized by the International Society for Lasers in Dentistry (ISLD), in 1992, and at the 7th Congress in 1998. In 2001 he received the T. H. Maiman Award from the Academy of Laser Dentistry (ALD), USA, for excellence in Er:YAG laser research in dentistry.

Dr. Aoki is an author of 6 international books' chapters and has published over 100 scientific articles.

His current research is focused on basic and clinical studies of the application of lasers/LEDs in the treatment of periodontal and peri-implant diseases, the development of biological diagnosis of periodontal disease using biomarkers and the bacterial analysis of periodontal disease.

He contributes to the following professional organizations: World Federation of Laser Dentistry (WFLD) (Asian Pacific Division Committee Member), Academy of Laser Dentistry (ALD), Japanese Society for Laser Dentistry (Councilor), Japanese Society for Laser Medicine and Surgery (Councilor), Japanese Society of Periodontology (Councilor), and Japanese Society for Conservative Dentistry (Councilor).

The effect of daily intake of green coffee bean extract as compared to Agiolax® on the alveolar bone of albino rats

Wpływ codziennego spożycia wyciągu z ziaren zielonej kawy w odniesieniu do preparatu Agiolax® na kość wyrostka zębodołowego szczurów albinosów

Marwa Magdy Saad Abbass[A–F], Dalia Abdel-Hameed El-Baz[A–F]

Faculty of Oral and Dental Medicine, Cairo University, Egypt

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. Obesity is a worldwide medical problem in which excess body fat is accumulated in the body. The use of weight loss supplements such as green coffee bean extract and Agiolax has become a common trend among people who want to lose weight in a fast and non-tiring way. As a result of their effect on fluid excretion, both of these products may be expected to have a damaging effect on the alveolar bone.

Objectives. The aim of the present study was to evaluate the histopathological effect of green coffee bean extract as compared to Agiolax on the alveolar bone of albino rats.

Material and methods. Twenty-seven adult male albino rats were randomly assigned to 3 groups. Nine received distilled water daily for 2 months by oral gavage (the control group); the other 2 groups received 1 mg/100 g. body weight green coffee bean extract or Agiolax 8 mg/100 g. body weight daily for 2 months by oral gavage (the GC and Ag groups, respectively). The alveolar bones were dissected and examined histologically, histomorphometrically and by western blotting.

Results. The bone area percentage and the calcium level in serum were significantly decreased in the GC and Ag groups, while the calcium level in urine was significantly increased in both the experimental groups as compared to the control group. On the other hand, RANKL expression was significantly increased only in the GC group, and the tissue calcium (Ca) level was significantly decreased only in the GC group as compared to the control group.

Conclusions. Long-term oral administration of green coffee bean extract and Agiolax might lead to alveolar bone loss. A greater deleterious effect was caused by green coffee bean extract, as it caused more RANKL expression, significantly reduced Ca level in the tissue and consequently decreased the bone area percentage.

Key words: obesity, RANKL, alveolar bone, Agiolax, green coffee bean extract

Słowa kluczowe: otyłość, RANKL, kość wyrostka zębodołowego, Agiolax, ekstrakt z ziaren zielonej kawy

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Obesity, defined as an abnormal or extensive fat accumulation, is an important health issue. It is a chronic medical condition requiring long-term therapy. It increases the likelihood of various diseases, particularly heart disease, type 2 diabetes, obstructive sleep apnea, certain types of cancer, and osteoarthritis. In addition, obesity can diminish one's quality of life.[1,2] Obesity is the 5th leading risk for global deaths, killing more people than underweight; at least 2.8 million adults die as a result of obesity each year.[3]

Weight loss reduces susceptibility to weight-related diseases, decreases pain, increases physical functions and improves the overall quality of life. Several options for weight loss exist, ranging from medications to exercise, dietary modification, and surgery.[4] Dietary supplements, which include vitamins, minerals, herbs, and amino acids, are widely used for weight loss, muscle building and sexual function.[5]

Green coffee bean extract (GCBE) is widely marketed as a dietary supplement aiding in weight control. It functions by blocking starch absorption by means of an α amylase inhibitor. Biologically, 3 major components of coffee are considered to contribute to its beneficial effects: cholorogenic acids, caffeine and the coffee diterpenes (cafestol and kahweol).[6,7]

Shimoda et al. reported that oral administration of GCBE for 13 days reduced visceral fat and body weight by inhibiting fat absorption and activating fat metabolism in the liver.[8] Vinson et al. also demonstrated the efficacy of GCBE in reducing body weight, body mass index and body fat percentage.[9]

Laxatives are usually used to speed up the digestion process, to avoid chronic constipation and also to regulate bowel movements.[10] Lately, laxatives are among the drugs that are frequently used among those looking to lose weight quickly. It has been estimated that more than 4% of the general population engages in laxative abuse.[11]

Agiolax is a combination of bulk and stimulant laxatives, as it contains natural dietary fiber from the seeds and husks of *Plantago ovata* (PO) combined with the herb senna.[12] Each sachet of 5 g contains 2.60 g seeds of *Plantago ovata* (PO), 0.62 g of tinnevelly senna pods and 0.11 g of ispaghula husk. The oral administration of senna to Dawley rats resulted in a slight reduction in the rats' body weight, increased water consumption and caused notable changes in electrolyte levels in serum and urine.[13] Romero et al. demonstrated the hypolipidemic effect of PO on male guinea pigs, whose plasma triglycerides and cholesterol LDL were significantly lowered, while the activity of cholesterol hydrolase was significantly increased.[14]

Objectives

Since green coffee bean extract and Agiolax are commonly used worldwide as weight loss and laxative dietary supplements, the aim of the present study was to investigate their histopathalogical effects on the alveolar bone of albino rats upon daily administration.

Material and methods

Experimental procedures

Twenty-seven adult male inbred Wistar albino rats, with an age range from 3 to 4 months and weight range from 150 to 200 g, were used in the study. The animals were housed in a sterile, controlled environment (temperature 25 ±2°C and 12 h dark/light cycles) and fed a standard pellet diet and tap water. All the experiment procedures were conducted in the animal house of the Faculty of Medicine, Cairo University (Egypt), in accordance with the recommendations and approval of the Institutional Animal Care and Use Committee (IACUC), Cairo University, Egypt (approval No: CU/III/F/18/18).

The rats were randomly distributed into 3 groups of 9 rats each. The control group received 5 mL of distilled water via oral gavage a daily for 60 days. The green coffee bean extract (GC) group received 1 mg/100 g. body weight of green coffee bean extract (standardized to contain 45% chlorogenic acid; Puritan's Pride, Oakdale, USA) in 5 mL of distilled water via oral gavage daily for 60 days. The Agiolax (Ag) group received 8 mg/100 g. body weight of Agiolax (granulated mixture of *Plantago ovata* seeds, tinnevelly senna pods and ispaghula husk; Madaus/CID, Giza, Egypt) in 5 mL of distilled water via oral gavage daily for 60 days.

The animals were sacrificed by ketamine overdose and the mandibles were dissected. The right side of each mandible was used for light microscopic examination and histomorphometric analysis. The left sides of the mandibles were used for detection of the calcium (Ca) level in the bone tissue and for assessment of RANKL expression using western blotting.

Light microscopic examination

The specimens were fixed in 10% neutral formalin for 48 h, washed, soaked in 10% ethylene diamine tetra-acetic acid (EDTA) for decalcification for 6 weeks and then rinsed in distilled water. The specimens were dehydrated in ascending grades of alcohol and embedded in paraffin.

Mesiodistal sectioning of the right side of the jaws was carried out. Histological sections (5 um thick) were prepared. The sections were subjected to hematoxylin and eosin (H&E) stain according to the conventional method. Histopathological examination was performed using a light microscope.

Histomorphometric analysis

A Leica Qwin 500 image analyzer computer system (Leica Micro Systems Ltd., Milton Keynes, UK) was used for the analysis. In the hematoxylin and eosin-stained sections, the bone volume, defined as the percentage of trabecular bone volume to tissue volume, was measured.[15]

The measurements were taken using an objective lens of magnification 10, that is, a total magnification of 100. Ten fields were measured from each group and the mean values were calculated.

Western blotting

The antibody used was the antigen affinity purified receptor activator of nuclear factor- κB ligand (RANKL) monoclonal antibody (Santa Cruz Biotechnology Inc., Dallas, USA). The Ready Prep™ protein extraction kit (Bio-Rad Inc., Hercules, USA) was used for protein extraction from the tissues. The Bradford Protein Assay Kit (Bio Basic Inc., Markham, Canada) was used for the quantitative protein analysis. Sample proteins were then separated on polyacrylamide gel (TGX Stain-Free FastCast Acrylamide Kit, Bio-Rad Inc.), loading 20 μg of total protein per each mini-gel well. The gel was then assembled in transfer sandwiches with polyvinylidene difluoride (PVDF) membranes. The blot was then run to allow protein bands to transfer from gel to membrane using BioRad Trans-Blot Turbo. The PVDF blots were incubated in 5% non-fat dry milk, Tris-HCL, 0.1% Tween 20 for 1 h. RANKL antibody was then added to the membrane containing the specimen samples and incubated at 4°C overnight. An appropriate secondary antibody was incubated for 2 h at room temperature. After the specimens were washed twice in 1 × TBS-T, a densitometric analysis of the immunoblots was performed to quantify the amounts of RANKL in all the samples against control sample beta actin (housekeeping protein) by protein normalization using the Chemi-Doc MP imaging system.

Biochemical analysis

After the completion of the experiment and before the animals were sacrificed, urine and blood (serum) samples were obtained from each group. Following the sacrifice of the animals, tissue samples from left mandibles were obtained from each group. The level of calcium was measured in all these samples.

Statistical analysis

Values were presented as mean and standard deviation (SD) values. The data was checked for normality using the Kolmogorov-Smirnov test. The results of the Kolmogorov-Smirnov test indicated that most of the data was normally distributed (parametric data), therefore a one-way analysis of variance (ANOVA) test was used between groups. When the ANOVA yielded a significant difference, it was followed by Tukey's post hoc test. The significance level was set at $p < 0.05$. The statistical analysis was performed using SPSS for Windows v. 18.0 (SPSS, Inc., Chicago, USA).

Results

Histological results

The alveolar bone of the control group showed regular shape and orientation. It consisted of interconnected bone trabeculae containing osteocytes in their lacunae with intervening red bone marrow spaces (Fig. 1A, B).

The histological sections of the mandibles from the green coffee bean extract group showed marked changes in the alveolar bone. The marrow spaces were extremely widened and interconnected, containing red marrow and multinucleated large cells (Fig. 2A). Some marrow spaces showed fatty bone marrow (Fig. 2B). Wide white spaces with irregular scalloped surfaces (reversal lines) representing resorbed areas of bone were observed (Fig. 2A–C). Osteocytes appeared with widened lacunae and shrunken nuclei. Few lacunae appeared empty (Fig. 2C).

The alveolar bone of Agiolax group revealed multiple medium sized irregular bone marrow spaces (Fig. 3A). A marked increase in lines of demarcation, cement lines and reversal lines gave the alveolar bone a mosaic pattern (Fig. 3B). The lines of demarcation separated newly formed bone surrounding the marrow spaces with uniform staining patterns, bone with exposed collagen fibers, extensive vacuolation and empty osteocyte lacunae (Fig. 3C).

Histomorphometric analyses

Significant differences in the area percentage occupied by alveolar bone trabeculae between specimens of all the study groups were noted. A significant decrease in bone area percentage was observed in the jaws of the 2 experimental groups (GC and Ag) as compared to the control group ($p = 0.000$). Moreover, a significant decrease in bone trabeculae area percentage in the GC group as compared to the Ag group was revealed ($p = 0.002$; Table 1).

RANKL expression

Significant differences in RANKL expression were found between all the groups. The highest mean value for RANKL expression was detected in the GC group, whereas the lowest mean value was recorded in the control group, with a significant difference between the 2 ($p = 0.000$). Moreover, a significant increase in RANKL expression was detected in the GC group as compared to the Ag group ($p = 0.001$), while a nonsignificant difference was revealed between the Ag group and the control group ($p = 0.534$; Table 1).

Biochemical results

Differences were noted in Ca levels between all the groups in serum, urine and bone tissue.

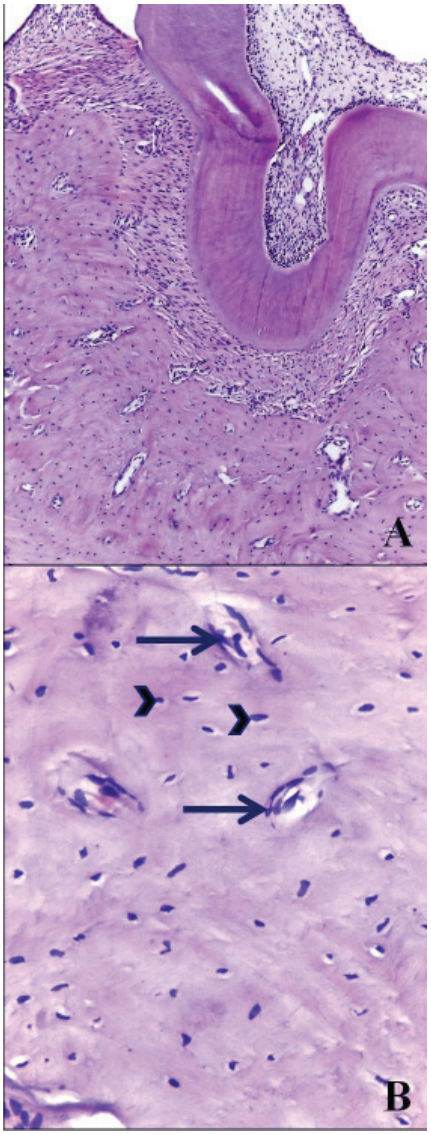

Fig. 1. A photomicrograph of an alveolar process from the control group

A – the normal structure of the alveolar bone; B – bone marrow spaces (arrows), bone trabeculae and osteocytes in their lacunae (arrowheads) (H&E, orig. mag. A: ×10, B: ×40)

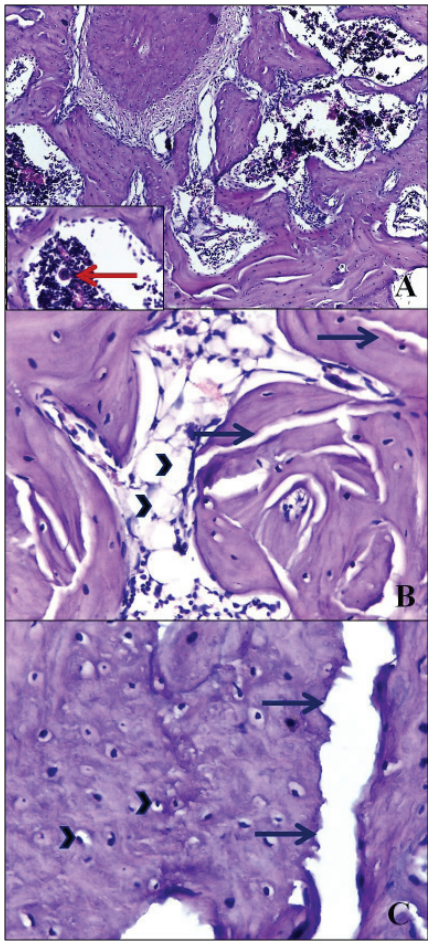

Fig. 2. A photomicrograph of an alveolar process from the GC group

A – wide interconnected marrow spaces enclosing bone trabeculae; inset showing a large multinucleated cell in a marrow space (arrow); B – multiple sequestrated bone trabeculae with scalloped borders (arrows) surrounded with fatty bone marrow (arrowheads); C – bone trabeculae with scalloped borders (arrows) as well as osteocytes with widened lacunae and shrunken nuclei (arrowheads). Few lacunae were empty (H&E, orig. mag. A: ×10, inset, B and C: ×40)

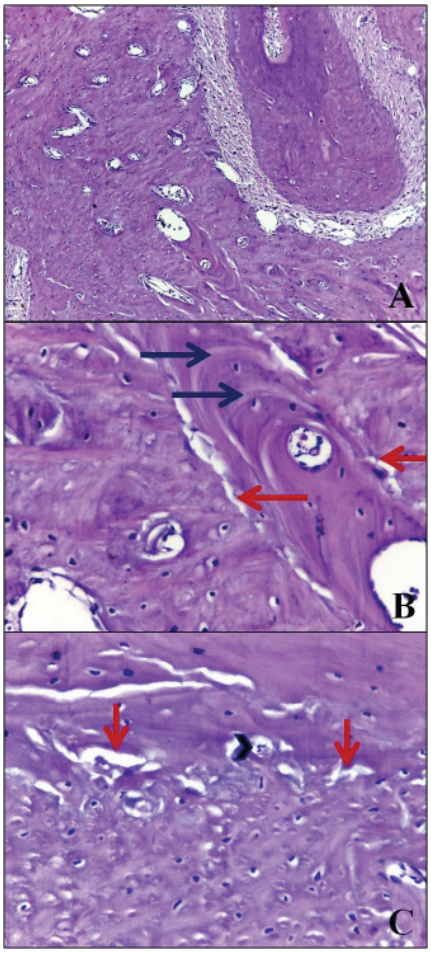

Fig. 3. A photomicrograph of a rat alveolar bone from the Ag group

A – multiple relatively wide marrow spaces; B – a higher magnification showing cone-shaped rest lines (arrows) surrounding marrow spaces, scalloped lines of demarcation (red arrows) giving the bone a mosaic pattern appearance; C – lines of demarcation (red arrows) that separate newly formed bone with uniform staining, osteocytes occupying their lacunae and bone with multiple vacuoles that represent empty, widened lacunae and exposed collagen fibers. Osteoclasts (arrowhead) were evident on this demarcation line (H&E, orig. mag. A: ×10, B and C: ×40)

In serum, a significant decrease in Ca level in the Ag group and the GC group as compared to the control group was revealed (p = 0.000). Despite the calcium level being lower in the Ag group than the GC group, the difference between them was not significant (p = 0.977; Table 1).

On the other hand, the calcium level in urine was significantly increased in the Ag group and the GC group as compared to the control group (p = 0.000). Although the calcium level in the urine of the Ag group was higher than in the GC group, there was no significant difference between them (p = 0. 275; Table 1).

Regarding Ca levels in the mandible, the highest mean value was detected in the control group, whereas the lowest mean value was recorded in the GC group, with a significant difference between the 2 groups (p = 0.006). No significant differences in tissue Ca levels were revealed between the GC group and the Ag group (p = 0.413) or between the Ag group and the control group (p = 0.102; Table 1).

Discussion

Over the last 20 years, obesity has become the most prevalent nutritional problem in the world, affecting not only adults but also children and adolescents. It is the key risk factor for many chronic and noncommunicable diseases.[16] Dietary supplements for weight loss encompass a wide variety of products. Herbs, dietary fiber, caffeine and minerals are common ingredients in these supplements.[17]

Table 1. Comparison of values of different parameters between groups (ANOVA test)

Measured items	Groups	Mean ±SD	95% confidence interval for mean		p-value
			lower	upper	
Bone area [%]	control	40.91[a] ±4.37	37.26	44.57	0.000*
	green coffee bean extract	22.01[c] ±2.23	20.15	23.87	
	Agiolax	30.18[b] ±4.98	26.01	34.34	
RANKL	control	2.95[b] ±0.20	2.78	3.11	0.000*
	green coffee bean extract	3.76[a] ±0.22	3.58	3.94	
	Agiolax	3.11[b] ±0.42	2.75	3.46	
Ca in serum [mg/dL]	control	13.16[a] ±1.97	11.5	14.8	0.000*
	green coffee bean extract	7.88[b] ±1.82	6.36	9.40	
	Agiolax	7.66[b] ±2.64	5.46	9.87	
Ca in urine [mg/mL]	control	119.65[b] ±9.14	112.0	127.3	0.000*
	green coffee bean extract	263.14[a] ±83.6	168.1	358.2	
	Agiolax	332.81[a] ±101.3	248.2	417.5	
Ca in tissue [mg/mg]	control	11.13[a] ±2.03	9.43	12.82	0.000*
	green coffee bean extract	8.13[b] ±1.25	7.08	9.17	
	Agiolax	9.25[a,b] ±1.83	7.72	10.78	

Significance level – $p < 0.05$; SD – standard deviation; * significant; values sharing the same superscript letter within the same comparison are not significantly different in Tukey's post-hoc test.

In the current study, oral administration of green coffee bean extract caused obvious changes in the alveolar bone of rats' mandibles. There were multiple huge marrow spaces and wide white spaces with irregular scalloped surfaces (reversal lines), representing resorbed areas of bone. These results coincide with Liu et al., who reported that caffeine effectively increased bone resorption activity via enhancement of the receptor activator of NF-κB ligand (RANKL).[18] Moreover, Tsuang et al. demonstrated that adding caffeine to the culture medium of osteoblasts significantly increased the intracellular prostaglandin PGE_2 content and PGE_2 secreted into the medium.[19] Prostaglandins (PGs) are local mediators that stimulate osteolysis in bone organ cultures, and when administrated systemically or locally in vivo, result in increased bone loss. The authors added that caffeine may induce osteoblast apoptosis, which then led to decreased bone cell viability.

Moreover, the histological results of the present study demonstrated osteocytes with shrunken nuclei and widened lacunae in the green coffee group. The latter finding is in accordance with Wysolmerski, who reported that osteocytes appeared with large sized lacunae due to perilacunar and pericanalicular matrix remodeling that occurred as a result of high levels of parathyroid hormone (PTH) in response to an increased systemic demand for calcium.[20]

In the current study, large multinucleated cells were observed in the bone marrow spaces in the GC group. These cells might be osteoclast precursor cells and their presence in large amounts could be attributed to the production of osteoclast-inducing cytokines such as RANKL, which play a major role in tissue destruction.[21]

Interestingly, both the biochemical results and the histomorphometric data of our study supported the histopathological results, as the measured Ca level in serum and in the alveolar bone tissue in the GC group was significantly decreased in comparison to the control group, but in the urine it was markedly increased. Furthermore, a decrease in the bone area percentage was found in the GC group as compared to the control group ($p = 0.000$). Moreover, the highest level of RANKL expression was reported in the GC group, indicating increased bone resorption activity. These findings are supported by Rapuri et al., who detected significant increased bone loss in the spine in a high caffeine consumption group compared with subjects with lower caffeine consumption.[22]

Lacerda et al. reported similar results when they investigated the effects of coffee on bone metabolism in male rats born of females treated daily with coffee and with coffee intake since birth.[23] The results showed significantly greater amounts of calcium in the plasma and urine and significantly less calcium in bone. Moreover, the significant decrease in the Ca level in the mandibular bone tissue in the GC group in the current work is consistent with Shapses and Riedt, who reported that decreased calcium absorption during caloric restriction for weight reduction led to high serum levels of PTH.[24] Parathyroid hormone is secreted in response to low blood Ca levels, and it indirectly stimulates osteoclast activity to release more calcium into the blood through RANKL expression.[25]

With regard to the Agiolax group, the results of the present study demonstrated a mosaic pattern of the alveolar bone with several demarcation and reversal lines, denoting bone remodeling. Irregular white spaces surrounded by reversal lines were seen, representing resorbed areas

of bone. Newly deposited bone was observed around the marrow spaces. The lines of demarcations separated newly formed bone (surrounding the marrow spaces with uniform staining patterns and many rest lines) and bone (with exposed collagen fibers, extensive vacuolation and empty osteocytes lacunae).

The histomorphometric results of the study confirmed the histological results, which showed a significant decrease in bone area percentage in the Ag group compared to that of the control group, and a significant increase in the bone area percentage in the Ag group compared to the GC group. However, the RANKL level was slightly increased in the Ag group compared to that of the control group; this difference did not reach the level of statistical significance. The biochemical findings denoted a significant increase in the Ca level in urine, a significant decrease in the Ca level in serum and a nonsignificant decrease in the Ca level in the mandible bone tissue in the Agiolax group as compared to the control group. Therefore, the exposed collagen fibers observed in the Ag group could be related to the negative effect of Agiolax on calcium retention, as long-term Agiolax abuse leads to severe electrolyte and water losses.[26]

The results for the Ag group in the present study are supported by Lin et al., who reported that the administration of senna (one of the main components of Agiolax) and rheum polysaccharides led to a significant decrease in free Ca^{+2} levels in rats' liver cells as compared to a control group ($p < 0.01$).[27] Moreover, Mitchell et al. reported that the oral administration of different doses of senna to Dawley rats increased potassium and chloride in serum and decreased sodium, potassium and chloride in urine.[13]

By comparing bone area percentage results, RANKL expression and the biochemical results of the green coffee group with the Agiolax group, we found that the bone area percentage was significantly decreased in the Agiolax group, while RANKL expression was significantly increased. No significant differences in Ca levels were reported between the 2 experimental groups. These outcomes support that green coffee (caffeine) has a direct effect on the viability of bone cells, as it induces osteoblast apoptosis and enhances osteoclast activity, which means bone repair in the GC group is reduced compared with that in the Ag group.

He et al. reported that apoptosis was induced by caffeine at a relatively low concentration in JB6 Cl41 cells, and that the percentage of apoptotic cells gradually increased as the caffeine concentration was increased.[28] Bode et al. investigated the effect of caffeine on cell cycle function.[29] At concentrations <1μM, caffeine has been reported to induce p53-dependent apoptosis associated with increased expression of pro-apoptotic Bax and caspase-3. At concentrations of 1–2μM, caffeine induced G1 arrest, whereas concentrations of 2–4μM appeared to block G1 arrest and induced apoptosis.

The bone repair that was observed in most of the specimens from the Ag group denoted that Ag acts as a diuretic, causing change in body electrolytes without affecting bone cell viability; the newly formed bone trabeculae surrounding the marrow spaces had uniform staining, while old bone stained differently and revealed exposed collagen fibers and vacuoles. This denoted that old bone became poorly calcified (less mineralized), which was supported by the significant increase of Ca in urine.

The empty and widened osteocyte lacunae detected in the Ag group in the current research could be explained by Sohn et al., who reported that the products of PO fermentation induced apoptosis in colorectal cancer cells by increasing expression of caspase activation, up-regulation of B-cell lymphoma protein 2 homologous antagonist killer (BAK) and death receptor (DR5).[30]

Conclusions

The overall results of the present study clearly evidenced that long-term oral administration of green coffee bean extract and Agiolax led to alveolar bone loss, which was demonstrated in the rats' mandibles using histopathological, histomorphometric, western blotting and biochemical analyses. A greater deleterious effect was caused by green coffee bean extract, as it caused more RANKL expression, lower Ca levels in the tissue and subsequently less bone area percentage. Further investigations are needed to clarify the mechanism of the action of Agiolax on bone cells.

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Effect of Er:YAG laser-activated irrigation on dentine debris removal from different parts of the root canal system: An in vitro study

Wpływ lasera Er:YAG aktywującego przepłukiwanie na usuwanie zębiny z różnych części kanału korzeniowego – badania in vitro

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Abstract

Background. There is insufficient information available in the literature about the efficacy of laser-activated irrigation (LAI) in removing dentine debris at different coronal-apical levels of the root canal system (RCS).

Objectives. To evaluate the efficacy of erbium (LAI) in removing dentine debris from different coronal-apical levels of the RCS when compared to passive ultrasonic irrigation (PUI) and conventional irrigation (CI).

Material and methods. Forty-five single-rooted human teeth were split longitudinally into halves. In each sample, a standardized groove was cut 2–6 mm from the apex along the canal wall of the 1st half, and another standardized groove was cut 10–14 mm from the apex along the canal wall of the 2nd half. Each groove was filled with dentine debris mixed with sodium hypochlorite (NaOCl) 5.25%. The samples were assigned to 3 experimental groups according to the irrigant activation techniques (n = 15); (a) CI group, (b) PUI group and (c) LAI group. The amount of the remaining dentine debris was identified and scored using a stereomicroscope.

Results. Laser-activated irrigation removed significantly more debris than PUI and CI systems. The efficacy of dentine debris removal was not affected by the root canal third within all groups.

Conclusions. Erbium LAI enhances dentine debris removal from the artificial irregularities in the RCS.

Key words: conventional irrigation, dentine debris removal, laser-activated irrigation, passive ultrasonic irrigation, root canal system

Słowa kluczowe: konwencjonalna irygacja, usuwanie zębiny, irygacja aktywowana wiązką laserową, pasywna irygacja za pomocą ultradźwięków, system kanału korzeniowego

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Chemo-mechanical preparation, including shaping and cleaning of the root canal system (RCS), is an essential step in successful endodontic treatment.[1] Cleaning depends on using an irrigant solution to chemically dissolve the tissues and mechanically flush organic/inorganic debris out of the RCS.[1] It has been suggested that the flushing action of the irrigant solution could be more critical than its dissolvent capability for complete debridement of the complex RCS.[2] Conventional irrigation (CI) depends simply on a syringe and a needle to supply an irrigant solution to the root canal. In this protocol, the flushing action is not sufficient to remove organic/inorganic debris due to its limited distribution within the complex RCS.[3,4] Therefore, several activation techniques have been suggested to increase the flushing action of irrigant solution and enhance its distribution within the root canal, including passive ultrasonic irrigation (PUI) and laser-activated irrigation (LAI).[5]

Passive ultrasonic irrigation depends on the acoustic streaming produced when an ultrasonically oscillating small file vibrates freely within the irrigant solution in the prepared root canal.[6] Moreover, cavitation can occur during PUI. However, this specifically occurs at the tip of the oscillating file, requiring a large apical preparation and a high energy setting.[7] Laser-activated irrigation improves the flushing action of the irrigant solution in the RCS, depending upon the cavitation effects, which includes the expansion and immediate implosion of the vapor bubble to induce a rapid movement of the intra-canal solution with profound shock waves and secondary cavitation bubbles.[8–10] It has been shown that erbium lasers, such as the erbium-doped yttrium aluminum garnet (Er:YAG) laser, exhibit the highest absorption in water, which promotes their use in the LAI technique.[11]

It has been suggested that erbium LAI may enhance debris removal from root canal irregularities.[12–14] Laser-activated irrigation is performed using a plain fiber tip inserted within the root canal 5 mm away from the apex which, in turn, may exhibit undesirable side effects such as carbonization, cracking[15] and apical extrusion.[15,16] Therefore, using the fiber tip in the pulp chamber instead of inserting it within the canal is advocated.[17–22] However, the use of the fiber tip in the pulp chamber without inserting it into the root canal may decrease the irrigant efficiency. Therefore, the objective of this study was to investigate the efficacy of LAI with a conical fiber tip (Xpulse® 400/14; Fotona, Ljubljana, Slovenia) in dentine debris removal from different root canal levels when held in the pulp chamber, in comparison with both PUI and CI. The 2 null hypotheses investigated in this study were that LAI exhibited a similar efficiency in dentine debris removal to that of PUI and CI, and that the efficacy of dentine debris removal was not affected by different root canal levels.

Material and methods

Sample preparation

Forty-five caries-free, single-rooted human teeth, extracted from patients aged 18–30 years, were collected. The teeth were radiographed to verify the presence of only 1 canal without any resorptions or calcifications. Then, they were stored in saline solution at room temperature until use. The teeth were accessed and the working length (WL) was determined by inserting a size 10 file into the canal until the tip of the file was just visible at the apical foramen, and then deducting 1 mm. Then, they were cut with a diamond disc under water coolant to standardize the working length at 19 mm.

The canals were shaped with Protaper® universal rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) up to F2 (size 25) and irrigated with 2 mL of 5.25% sodium hypochlorite (NaOCl) after each instrument was used. A diamond bur with a diameter of 2.3 mm was used to enlarge the coronal 3 mm of each tooth in order to simulate and standardize the pulp chamber.[12]

Each sample was partly embedded in a putty impression material (Zetaplus®; Zhermack, Badia Polesine, Italy) to obtain a matrix, allowing the reassembly of the tooth halves for irrigation test after splitting (Fig. 1A).[3]

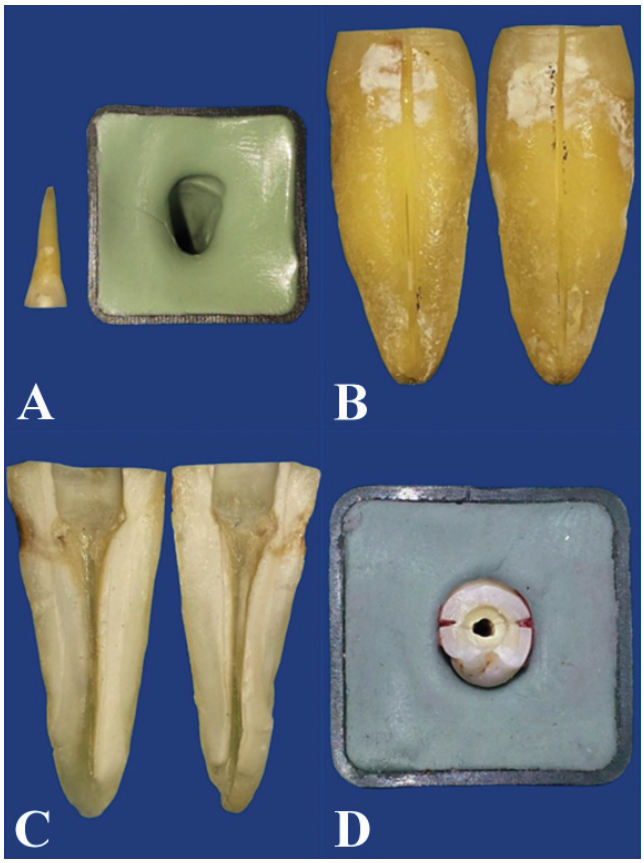

Fig. 1. A – a set matrix of putty impression material for tooth reassembling; B – grooves cut in the root surfaces; C – tooth was split into halves; D – split tooth reassembled for irrigation tests

Each tooth was grooved longitudinally with a diamond disc (Jota AG, Rüthi, Switzerland) along the outer surface of the root, avoiding penetration into the canal, to split it longitudinally into halves using a small chisel (Fig. 1B, 1C).

For each sample, a standardized groove (4 mm in length, 0.2 mm in width, 0.5 mm in depth) was cut 2–6 mm away from the apex on the canal wall of the 1st half and a similar groove was cut 10–14 mm away from the apex on the canal wall of the 2nd half (Fig. 2). This helps in stimulating the uninstrumented canal irregularities in the apical and coronal third, respectively.[4,23] The dentine of other split teeth was grounded by round bur to produce dentine debris. Each groove was filled with this debris after mixing it with 5.25% NaOCl 5 min before use. A digital baseline image for each half containing the groove was taken before the irrigation procedure using a digital camera (Nikon D80; Nikon Co, Tokyo, Japan) and a stereomicroscope (Meiji Techno D80; Saitama, Japan) at ×20 magnification. The halves of each sample were reassembled using sticky wax and putty impression material (Fig. 1D).

Irrigation protocols

The specimens were randomly divided into 3 experimental groups (n = 15) according to the irrigant activation techniques; (a) CI group, (b) PUI group and (c) Er:YAG LAI group. The CI was performed with 5.25% NaOCl, delivered with a 10 mL syringe through a 30-gauge side-vented needle (NaviTip®; Ultradent Products Inc, South Jordan, USA) at a rate of 0.1 mL/s. The needle was inserted 1 mm coronal to the working length and moved slowly up and down over a distance of 4 mm in the apical third of the canal. The open side of the needle always faced the canal half with the apical groove.[3] A total of 6 mL of the solution was delivered over 60 s.

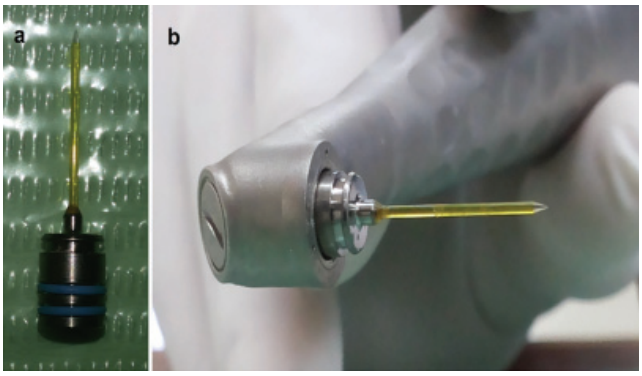

Fig. 3. A 14 mm long and conical 400 µm fiber tip (Xpulse 400/14; Fotona, Ljubljana, Slovenia) used in the study

Passive ultrasonic irrigation was conducted with a 15# K/21 mm file (Irri-Safe®; Satelec, Acteon Group, Norwich, UK) driven by an ultrasonic device (Satelec). After the root canal was filled with 5.25% NaOCl, the ultrasonically-activated file was inserted 1 mm coronal to the WL and the ultrasonic activation cycle was done for 20 s at a power setting of 25%. Then the canal was rinsed with 2 mL of 5.25% NaOCl using a syringe and a needle, and the irrigant solution underwent a 2nd ultrasonic activation cycle for 20 s. This sequence was repeated 3 times, resulting in a total irrigation volume of 6 mL and total activation time of 1 min.[24]

Laser-activated irrigation was carried out using an Er:YAG laser with a wavelength of 2.940 nm (LightWalker® AT; Fotona, Ljubljana, Slovenia). A 14 mm long and conical 400 µm fiber tip (Xpulse 400/14; Fotona, Ljubljana, Slovenia) was utilized (Fig. 3). The laser operating parameters were 40 mJ per pulse, 20 Hz and 50 µs pulse duration.[25] The water and air on the laser system were turned off. After the root canal was filled with

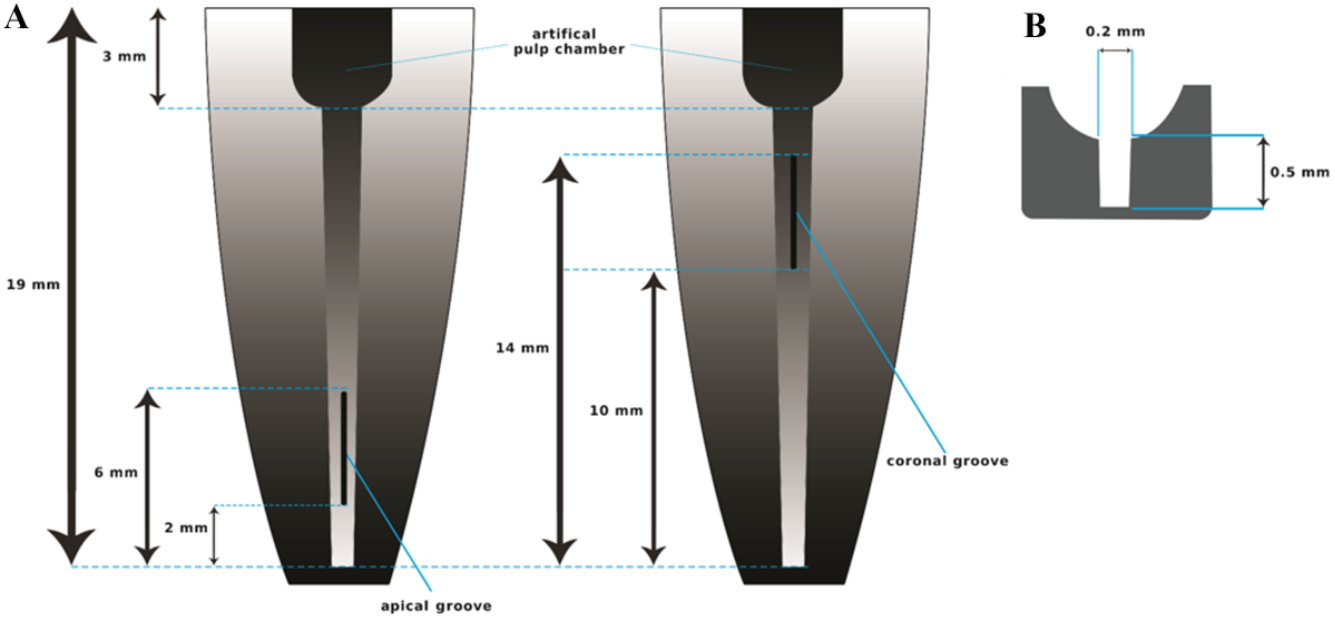

Fig. 2. Schematic representations of the "root canal-groove" model: A – the apical and coronal grooves; B – a cross section of the model

5.25% NaOCl, the fiber was placed into the artificial pulp chamber and a laser activation cycle was conducted for 30 s simultaneously with irrigation of 3 mL NaOCl through the pulp chamber. After 30 s of resting time, another activation cycle was performed for another 30 s, resulting in a total irrigation volume of 6 mL and total activation time of 1 min.[26]

Evaluation of dentine debris removal

The canal was carefully dried with paper points and the root halves of each sample were separated to evaluate dentine debris removal within the grooves. A 2nd digital image for each groove was taken at the same magnification as the baseline image. Two calibrated examiners, blinded to the experimental groups, assessed the presence/absence of dentine debris within the grooves. The reliability of the examiners was evaluated by repeating the assessment of the images after 1 week. A previously defined scoring system was used to evaluate the presence/absence of the dentine debris (Fig. 4): score 0 – the groove was empty; score 1 – less than half of the groove was filled with debris; score 2 – half or more of the groove was filled with debris; score 3 – the groove was completely filled with debris.[4]

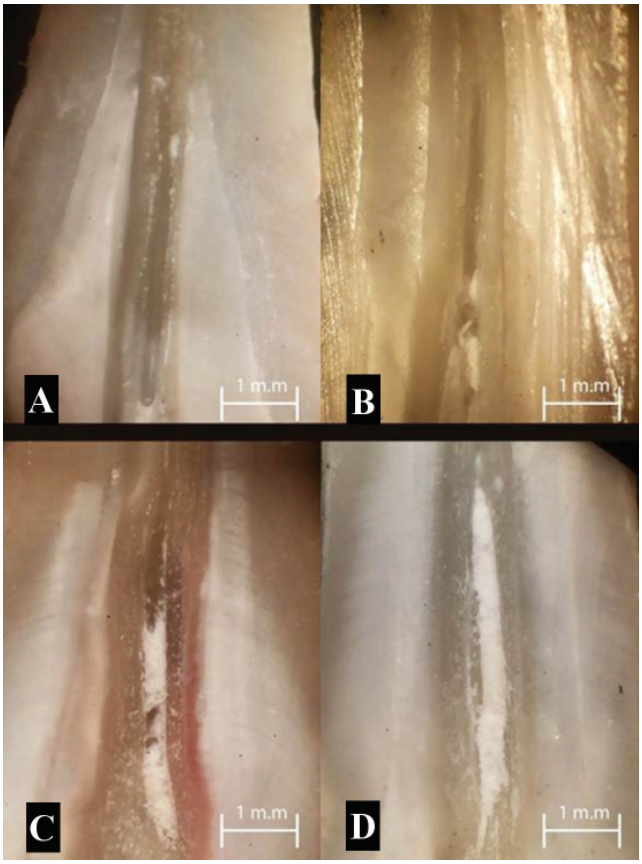

Fig. 4. Representative images of the grooves according to the dentine debris removal score: A) score 0 – the groove is empty; B) score 1 – less than half of the groove is filled with debris; C) score 2 – more than half of the groove is filled with debris; D) score 3 – the groove is completely filled with debris

Table 1. Distribution of dentine debris scores for each irrigation technique

Irrigation technique	Location of the groove	Debris score [%]				
		0	1	2	3	n
CI	coronal	0 (0)	1 (6.7)	7 (46.7)	7 (46.7)	15
	apical	0 (0)	5 (33.3)	6 (40.0)	4 (26.7)	
PUI	coronal	6 (40.0)	8 (53.5)	1(6.7)	0 (0)	15
	apical	6 (40.0)	7 (46.7)	2 (13.3)	0 (0)	
LAI	coronal	12 (80)	3 (20)	0 (0)	0 (0)	15
	apical	12 (80)	2 (13.3)	1 (6.7)	0 (0)	

Score 0 – the groove is empty. Score 1 – less than half of the groove is filled with debris. Score 2 – more than half of the groove is filled with debris. Score 3 – the groove is completely filled with debris.
LAI – laser-activated irrigation; n – number;
PUI – passive ultrasound irrigation; CI – conventional irrigation.

Statistical analysis

The intra-observer reproducibility and inter-observer agreement were tested using Cohen's kappa coefficient. Debris score data was analyzed using Kruskal-Wallis test and Mann-Whitney U test. The effect of the location of the groove on the debris removal was analyzed using the Mann-Whitney U test. All statistical analyses were performed at the 95% confidence level ($p = 0.05$) using SPSS Statistics 17 software (IBM, SPSS Inc., Chicago, USA).

Results

Kappa value for the inter-observer agreement was 0.921, and for the intra-observer reproducibility the Kappa values were 0.984 and 0.968 for the 1st and 2nd observer, respectively. Table 1 presents the debris score values according to the experimental groups in the coronal and apical grooves. A score of 3 was observed only within the CI group (7 grooves in the coronal group and 4 halves in the apical group). The highest values for score 0 were presented in the LAI group with 24 out of 30 halves.

There were significant differences between the 3 experimental groups in both apical and coronal grooves (Kruskal-Wallis test $p < 0.001$). Table 2 shows the results of the Mann-Whitney U test comparing debris scores

Table 2. Results of Mann-Whitney U test comparing debris scores between groups in both apical and coronal grooves. A p-value ≤0.05 was considered statistically significant

Location of the groove	Comparison	Mann-Whitney U test	p-value
Apical	LAI vs PUI	69.0	0.038*
	LAI vs CI	13.0	<0.001*
	PUI vs CI	33.5	0.001*
Coronal	LAI vs PUI	66.0	0.025*
	LAI vs CI	1.5	<0.001*
	PUI vs CI	8.5	<0.001*

* statistically significant values; LAI – laser-activated irrigation;
PUI – passive ultrasound irrigation; CI – conventional irrigation.

Table 3. Results of the Mann-Whitney U test comparing the debris scores between the apical and coronal grooves within each group. A p-value ≤0.05 was considered statistically significant

Comparison	Irrigation technique	Mann-Whitney U test	p-value
Apical vs coronal	LAI	111.0	0.929
	PUI	108.0	0.836
	CI	75.5	0.098

LAI – laser-activated irrigation; PUI – passive ultrasound irrigation; CI – conventional irrigation.

between groups. In the apical groove, LAI removed significantly more dentine debris than PUI ($p = 0.038$) and CI ($p < 0.001$). Passive ultrasonic irrigation removed significantly more dentine debris than CI ($p = 0.001$). In the coronal groove, LAI was significantly better than PUI ($p = 0.025$) and CI ($p < 0.001$) in removing dentine debris. Passive ultrasonic irrigation was more efficient than CI ($p < 0.001$) in removing dentine debris. The Mann-Whitney U test revealed that there was no significant difference on the debris removal score according to the location of the grooves within the same experimental irrigation group ($p > 0.05$) (Table 3).

Discussion

This study showed that CI was significantly less effective in dentine debris removal when compared to the LAI and PUI techniques, which is in accordance with previous studies.[23] Conventional irrigation exhibited a limited distribution and a weak stream action and therefore, its flushing action was not sufficient to remove organic and inorganic debris.[3,4] The findings of this study indicate that LAI was significantly more efficient in dentine debris removal in comparison to PUI, in agreement with the findings of the previous studies which used a plain fiber tip within the root canal.[12–14] In this study, however, a conical fiber tip was used in the pulp chamber without inserting it in the canal. This may be explained by the fact that the conical tip was able to transfer the laser energy along the root canal walls.[27]

The statistical analysis shows that LAI was significantly better than PUI at removing dentine debris from both apical and coronal grooves, which is compatible with the findings of a previous study that used a modified conical fiber tip – photon-initiated photoacoustic streaming (PIPS) tip – in the pulp chamber without inserting it within the root canal to remove dentine debris and antibiotic paste.[28,29] The stronger mechanical effect and better fluid movement of LAI resulting from the bubbles' impulsive nature induced by laser energy improve the dentine debris removal.[13,20,30] The term PIPS describes the interaction of laser energy with irrigant solutions when using a special laser fiber (the conical end and distal 3-mm without coating), which differs from the fiber used in the present study, a conical fiber tip (Xpulse; Fotona, Ljubljana, Slovenia). The use of this fiber design with a minimal ablative energy of 40 mJ permitted efficient dentine debris removal with consideration of the safety of the procedure.[25]

The findings concerning the efficacy of LAI in dentine debris removal according to the root canal thirds are compatible with a previous study evaluating the efficacy of LAI in removing antibiotic paste from artificial coronal and apical grooves.[29] However, Meire et al. claimed that the removal of the dentine debris was promoted when the fiber tip was held next to the apical groove rather than placed in the canal entrance or the pulp chamber.[25] In the present study, NaOCl was used as an irrigant solution, which may enhance the amount of secondary activation bubbles, improving the cleaning of the apical part, whilst Meire et al. used water as an irrigant solution.[25] In addition, the activation time was longer in this study (60 s), which may correlate with better dentine debris removal.

The root canal-groove model used in the present study ensures the standardization of the location and size of the grooves, making possible consistent evaluation with high reproducibility for the remaining debris.[4,23] However, this standardized groove method does not perfectly simulate an in vivo irregularity and the complex anatomy of the natural RCS, exhibiting a limitation of this study. Therefore, further studies are still required to evaluate the cleaning efficiency of LAI in vivo.

Conclusion

Laser-activated irrigation was significantly more efficient in dentine debris removal when compared to CI and PUI. Therefore, the 1st null hypothesis was rejected. The 2nd null hypothesis was accepted, as the efficacy of LAI in removing dentine debris was not affected by the root canal thirds. Thus, Er:YAG LAI enhances dentine debris removal from artificial irregularities in the root canal walls.

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Diagnostic value of cone beam computed tomography for recognition of oblique root fractures: An in vitro study

Wartość diagnostyczna tomografii komputerowej wiązki stożkowej w rozpoznawaniu skośnych złamań korzeni zębów – badania in vitro

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Abstract

Background. Diagnosis of tooth root fractures is based on radiographic examination, which is not reliable in the case of oblique root fractures.

Objectives. The aim of the study was to evaluate the efficacy of cone beam computed tomography (CBCT) imaging of oblique root fractures.

Material and methods. Twenty-four bovine incisors were used in the study. They were randomly divided into 2 groups: an experimental group with artificially created oblique root fractures and a control group without fractures. The teeth underwent a CBCT evaluation with a CS 9300 cone-beam scanner (Carestream, Rochester, USA) using a 5 × 5 cm field of view with the resolution up to 90 µm, and a dental radiography. The specimens were examined by 2 observers with different job experience.

Results. In the CBCT scans, fracture lines were detected in 95.8% of cases (the 1st observer made a proper diagnosis in 100% of cases and the 2nd in 91.7%). Fracture lines were identified on radiographs in 33.3% of roots (the 1st observer was able to see the lines in 41.7% of cases and the 2nd in 25%). The inter-observer agreement was very high (the kappa coefficient for CBCT scans was 1.00 and 0.88 for radiographs). The best diagnostic value was recorded for contiguous slices.

Conclusions. Cone beam computed tomography with a small field of view and high resolution significantly surpasses radiographs in effective imaging of oblique tooth root fractures and should be the method of choice in the diagnosis of these fractures.

Key words: cone beam computed tomography, dental root fracture, diagnosis

Słowa kluczowe: tomografia komputerowa wiązki stożkowej, skośne złamanie korzenia, diagnostyka

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In recent years, tooth trauma has been frequently a cause of patients reporting to the dental office.[1] Traumatic injuries to anterior teeth usually result in horizontal or oblique tooth root fractures.[2,3] Jayasudha et al. evaluated different dynamic forces acting on the tooth during the injury using a three dimensional (3D) experimental model.[4] Researchers stated that the greatest stresses in the dental and the alveolar bone tissues are induced by horizontal forces, leading to oblique fractures in the cervical or radicular region of the tooth. Another cause of oblique root fractures is repeated excessive pressure during the mastication of hard food,[5,6] which is usually observed in subjects above the age of 40 years and mostly affects lateral teeth, resulting from age-related changes in tooth elasticity and the presence of numerous and large fillings.[7]

There is a lack of data on the prevalence of oblique root fractures, because they are frequently recognized as horizontal ones. The diagnosis of tooth root fractures is predominantly based on radiological imaging, which is often unreliable in relation to oblique fractures. The central ray of the X-ray beam, despite taking images at different angles (3 or more projections), does not always pass through the fracture fissure running obliquely to the long axis of the tooth. In addition, the fracture, which is recognized in the cervical third of the root on an X-ray taken with the use of the right angle technique, is visible at a different height on an occlusal or oblique radiograph.[8]

Improper recognition of the course of the fracture fissure is a cause of frequent therapeutic failures. Therefore, the study on the diagnostic possibilities of CBCT in identifying oblique root fractures is justifiable.

The aim of the study was to evaluate the efficacy of imaging oblique root fractures of teeth by using cone beam computed tomography (CBCT).

Material and methods

Twenty-four bovine lateral incisors of the mandible (the animals aged up to 36 months) were obtained from a slaughterhouse. After extraction, the teeth were cleansed from periodontal tissues and stored in 0.5% thymol solution at room temperature for maximally 2 months. The teeth were assessed under a microscope in order to eliminate roots with cracks. The pulp was extirpated according to the guidelines of the International Organization for Standardization.[9]

After cutting off the crowns below the cemento-enamel junction, the roots were randomly divided into 2 groups, experimental (A) and control (B). In group A, an oblique fracture was generated in each root by using a universal testing machine Zwick/Roell Z020 (Zwick GmbH & Co. KG, Ulm, Germany), with 3-point flexure (Fig. 1). Two parts of each tooth were pieced together and tightly glued with a universal scotch gel. In this way, the fracture fissure width less than 0.1 mm was obtained in all fractures. The fissure width was evaluated with an electronic caliper (TESA Caliper IP67, 150 mm; TESA Technology, Renens, Switzerland) whose measurement accuracy was 0.01 mm, confirmed by the calibration certificate No. AP302.1/12. The certificate was issued by the Mikro Pomiar calibration laboratory accredited by the Polish Centre for Accreditation. The measurements were performed centrally to the long axis of the tooth in relation to 2 constant reference points. Group B (control) consisted of the roots without fractures. The investigations were carried out in the University Laboratory of Material Research of the Medical University of Lodz (Poland). The teeth of both groups underwent radiographic and CBCT examination.

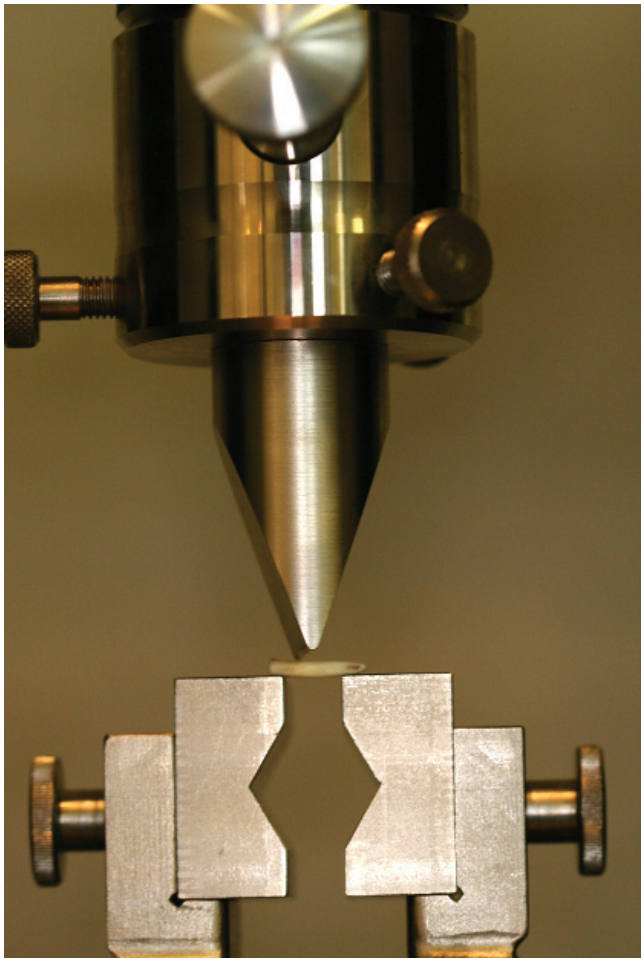

Fig. 1. Generating oblique fractures by using a universal testing machine Zwick/Roell Z020

Positioning of samples

The roots of the studied teeth were covered with a layer of wax to simulate the periodontal ligament space. Next, they were placed in the alveoli of the human mandible and tightly adhered to the alveolar walls (Fig. 2). The vestibular and lingual aspects of the mandibular body were covered with 3 layers of modelling wax, each one 1.6 mm thick, which simulated soft tissues.

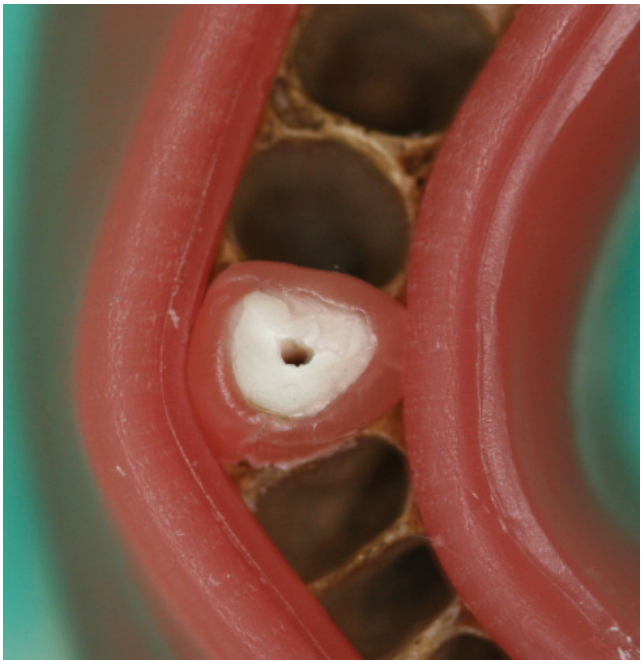

Fig. 2. A study model – human mandible with the dental root placed in the alveolus

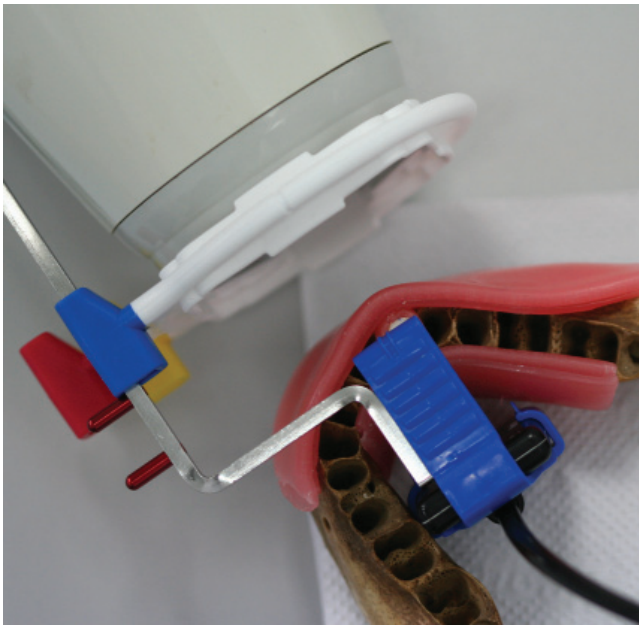

Fig. 3. Kodak 2200 Intraoral X-ray System with study model and the CCD sensor placed in the X-ray image positioner

Volumetric scanning

The samples were scanned with computed tomography CS 9300 Carestream® (Carestream, Rochester, USA) and a variable field of view. The mandible was placed in the center of the CT scan range, according to the X, Y, Z lines, which ensured repeatability of visualization conditions. The universal field of view (5 × 5 cm) with the 90 µm resolution was used in the study. Volumetric data was saved in the DICOM 3 format, and the images were analyzed using a compatible CS 3D Imaging Software (Carestream). The assessment was performed in axial, sagittal, frontal, transsectional and contiguous slices. Translucency was considered to be the fracture fissure when its borders did not exceed the outline of the tooth and were visible at least on 2 consecutive slices.[10]

Radiographs

Digital radiographs of both groups were taken with the Kodak 2200 Intraoral X-ray System + Kodak RVG 5100 Digital Radiography System (Carestream), which operates at a fixed distance of 25 cm between the radiation source and a detector. The CCD sensor was placed in the X-ray image positioner, which enabled the researchers to maintain exposure reproducibility (Fig. 3). The images were analyzed using the compatible Kodak Dental Imaging System Software. Translucency was considered to be a fracture fissure when its borders did not exceed the outline of the tooth.

Evaluation of radiographs

X-rays and CBCT scans were evaluated according to the 2-grade scale where: – was invisible fracture and + was visible fracture.

The evaluation was performed by 2 observers who differed in the time of professional work experience (observer I had been working as a dentist for 5 years and observer II for 30 years). They used a 19-inch LCD monitor (NEC MultiSync EA192M, USA; resolution 1280 × 1024). The time of evaluation was not limited. The inter-observer agreement was expressed by means of the kappa coefficient,[11] in which the value <0.10 shows a lack of agreement; 0.11–0.20 a very low level of agreement; 0.21–0.40 low; 0.41–0.60 moderate; 0.61–0.80 high; and 0.81–1.00 a very high level of agreement.

In the statistical analysis of the study results, the χ^2 test of independence and the Fisher's exact test (depending on the expected cell counts in the contingency tables) were used to compare the frequency of visualization of fracture fissures.[12] The following measures were used to evaluate the research methods: sensitivity, specificity, and accuracy. Sensitivity describes which percentage of fractured teeth is detected by means of a given method, specificity shows which percentage of teeth without fractures is properly diagnosed, and accuracy presents the probability of a correct diagnosis using a given method (the extent to which a researcher can be certain that the obtained result is true).

The level of significance for the applied tests was set at $\alpha = 0.05$. The statistical analysis was performed using STATISTICA v. 12 PL (StatSoft, Tulsa, USA).

The similar above-mentioned methodology was used in the author's previous publications.[13–15]

Results

Table 1 presents a comparison of the prevalence of fracture fissure identification by means of CBCT and radiographs in the teeth with and without fracture (control group) (Fig. 4, 5). The 1st observer established the correct diagnosis in all evaluated cases in the CBCT study, while the 2nd one in 91.7%. Fracture fissures in the teeth with generated oblique fractures were visible in 95.8% of the CBCT scans. Both observers correctly recognized the fracture fissure in 33.3% of the dental roots on the radiographs; the 1st researcher found fractures in 41.7% of the cases and the 2nd one in 25%. In the control group (B), both observers made the correct diagnoses in all examined cases, both in CBCT and radiographic examinations.

Table 1. Frequency of fracture fissure detection for CBCT scans and radiographs in the teeth with oblique fractures and in controls

Group	CBCT – correct diagnoses, n (%)	RTG – correct diagnoses, n (%)	p-value
A – oblique fractures (observer I)	12 (100)	5 (41.7)	0.016
A – oblique fractures (observer II)	11 (91.7)	3 (25)	0.008
A – total	23 (95.8)	8 (33.3)	0
B – control	12 (100)	12 (100)	1

CBCT – cone beam computed tomography.

As can be seen from the data in Table 1, the frequency of correct detection of oblique tooth root fractures for the CBCT scans was statistically significantly higher than for the radiographs ($p < 0.05$). This correlation denoted the presence of statistically significant differences in the sensitivity, specificity and accuracy used to describe the evaluated radiological methods in further analysis (Table 2). These differences can occur in all parameters or only in some of them.

The sensitivity, as described above, was 95.8% for CBCT scans and 33.3% for radiographs. The specificity reached the same 100% value in both diagnostic methods. The diagnostic accuracy for radiographs (66.7%) was lower than in the CBCT evaluation (97.9%) (Table 2).

Table 3 presents the diagnostic value of particular CBCT slices in the detection of the oblique root fractures. The data shows that the best diagnostic value was obtained for the contiguous slices.

The evaluation of the inter-observer agreement expressed by the kappa coefficient for the CBCT and radiographic evaluation is presented in Table 4. The kappa coefficient for the teeth with oblique fractures was 0.70 in the X-ray examination and 0.92 in relation to CBCT scans. The inter-observer agreement was, therefore, very high for the volumetric tomography studies and high for radiographs (Table 4).

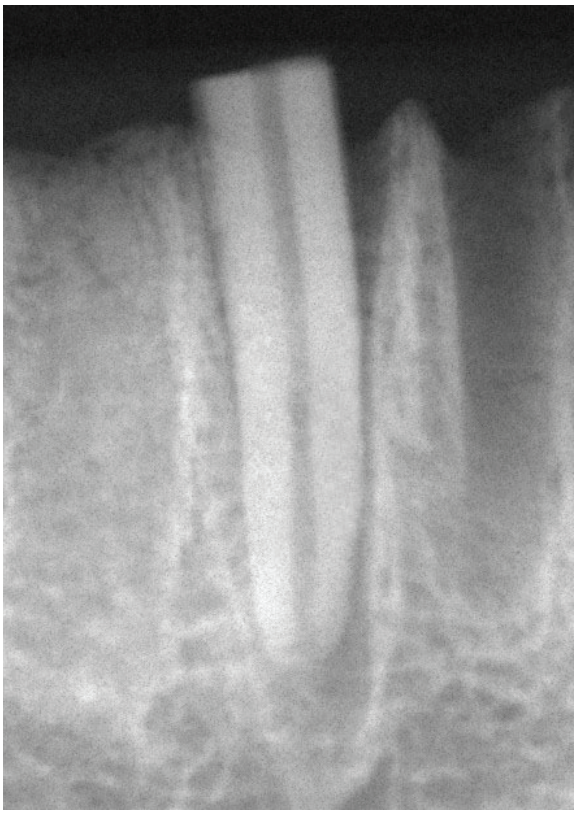

Fig. 4A. X-ray of tooth No. 2 – fracture not visible

Fig. 4B. Contiguous slice of tooth No. 2 – fracture visible

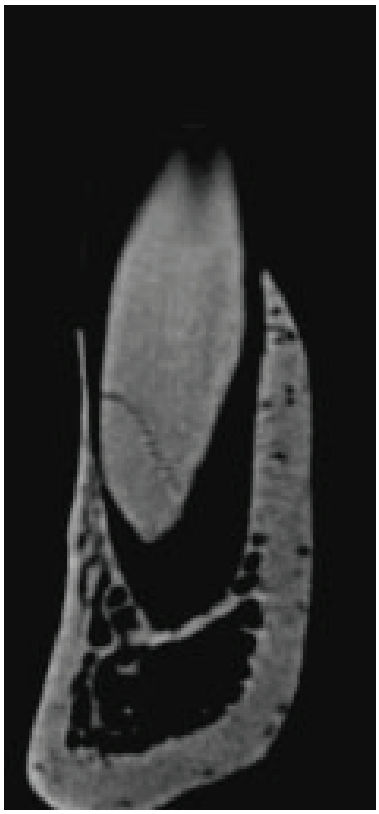

Fig. 4C. Transsectional slice of tooth No. 2 – fracture visible

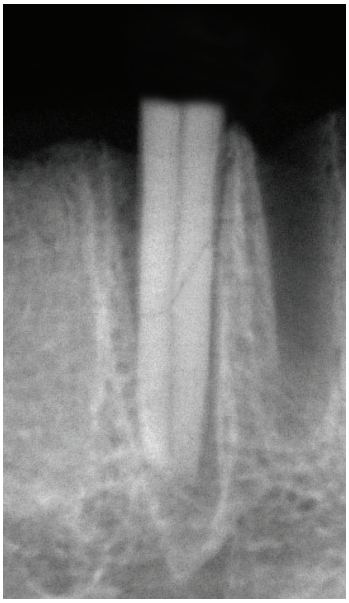

Fig. 5A. X-ray of tooth No. 12 – fracture visible

Fig. 5B. Sagittal slice of tooth No. 12 – fracture visible

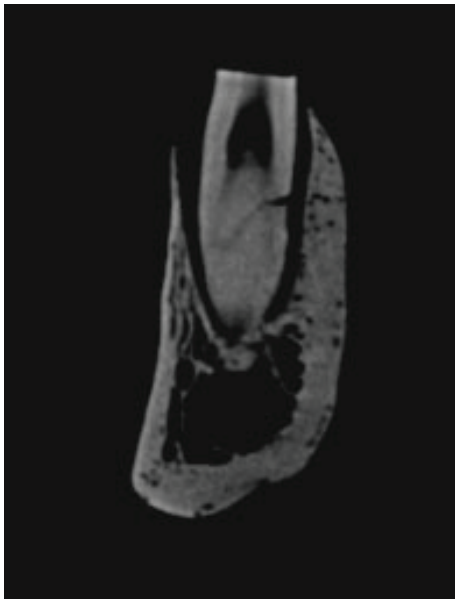

Fig. 5C. Transsectional slice of tooth No. 12 – fracture visible

Table 2. Sensitivity, specificity and accuracy for CBCT scans and radiographs in the detection of oblique root fractures according to the observer

Test	Total CBCT scans	CBCT 1	CBCT 2	Total radiographs	RTG 1	RTG 2
Sensitivity	95.80%	100.00%	91.70%	33.30%	41.70%	25.00%
Specificity	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Accuracy	97.90%	100.00%	95.80%	66.70%	70.80%	62.50%

CBCT – cone beam computed tomography.

Table 3. Diagnostic value of particular CBCT slices in the detection of oblique root fractures

Test	CBCT – total	Axial	Frontal	Sagittal	Transsectional	Contiguous
Sensitivity	95.80%	83.30%	91.70%	95.80%	91.70%	100.00%
Specificity	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Accuracy	97.90%	91.70%	95.80%	97.90%	95.80%	100.00%

CBCT – cone beam computed tomography.

Table 4. The inter-observer agreement for the CBCT and radiographic study in the detection of oblique root fractures

Method	Sample	Kappa coefficient	Error	Test statistics	p-value
CBCT	oblique	0.92	0.08	4.51	0
Radiographs	oblique	0.7	0.19	3.61	0

CBCT – cone beam computed tomography.

Discussion

The subject of diagnosing oblique dental root fractures has been rarely undertaken in literature and concerned monitoring of post-traumatic tooth injuries.[16–18] In the literature, there is only one available in vitro study performed by Iikubo et al., in which the authors evaluated oblique root fractures using 2 types of dental radiographs (right angle and bisecting angle technique; apparatus DX-1, GC Co., Tokyo, Japan) and CBCT (CB Throne tomography, Hitachi Medical Corp., Tokyo, Japan, 10 × 10 cm field of view, with a resolution of 200 μm).[19] Human central incisors were used in the experiment. The roots were divided into 3 groups: in the 1st one, transverse fractures at an angle of 90° to the long axis of the tooth were generated, in the 2nd and 3rd one, fractures at 75° and 55° were induced. Roots were cut with abrasive discs of various thicknesses (0.15 mm, 0.25 mm, 0.35 mm) at appropriate angles until the root canal was reached. The roots were not broken and glued together as in our study, thus to compare the outcomes of both studies, we selected the group of roots with the smallest groove width of 0.15 mm, which was closest to the fissure width evaluated in our experiment. Iikubo et al. noticed that grooves performed at an angle of 75° were poorly visible on radiographs taken with the bisecting angle technique.[19] The same situation occurred on radiographs taken with the right angle technique, where radiographs taken at an angle of 55° were not

well visualized. According to the authors, the results clearly indicate difficulties in diagnosing such fractures using X-ray images.

In compliance with the studies of citied authors,[19] the sensitivity for CBCT scans in the detection of fractures at an angle of 75° was 94% as compared to 75% for radiographs taken with the paralleling technique and 12% for the Cieszynski's rule of isometry technique. For fractures induced at an angle of 55°, the volumetric evaluation showed a sensitivity of 96%, and a radiographic examination presented a sensitivity of 13% and 98%, respectively. The results from the mentioned data indicated that the cone beam CT appeared to be the most efficient modality for detecting the discussed fractures. Moreover, as regards radiographs, it should be added that the closer the angle of incidence of the radiation beam to the plane of fracture occurred, the better the fracture fissure was shown. This finding is in line with other literature reports.[20,21]

In the present study, the sensitivity of CBCT scans was 95.8%, whereas that of the radiographs taken in the right angle technique was 33.3%. Therefore, it can be concluded that the angle of incidence of the central ray in the paralleling technique while taking radiographs was close to the plane of the course of the fracture fissure only in 1/3 of the cases.

Specificity was a subsequent studied parameter. Iikubo et al. did not record any statistically significant differences in the values of this indicator for the evaluated radiological methods (100% CBCT, 96% right angle technique, 82% bisecting angle technique).[19] We did not observe differences in the specificity in our study either. In both methods used, the discussed parameter was 100%.

Among the slices used for the evaluation of fractures, the contiguous one appeared to be most efficient. There are no publications on this subject in the available literature; therefore, this parameter cannot be compared with the findings of other authors.

Iikubo et al. also presented the aspect of inter-observer agreement.[19] The evaluation was performed by 7 radiologists with more than 10-year professional work linked into pairs (21 pairs). After calculating the kappa coefficient for particular radiological methods, the highest value was found for volumetric tomography (0.83), followed by the paralleling technique (0.68) and the Cieszynski's rule of isometry (0.51). It can be observed that the results of our study are similar – 0.92 for CBCT and 0.70 for radiographs with the use of the right angle technique.

Clinical implications of the present study are worth emphasizing. As can be concluded from literature reports,[16–18] despite different projections of radiographs, oblique root fractures are frequently identified as horizontal ones. Bornstein et al. evaluated 44 cases of fractures, which were diagnosed on the basis of radiographs as horizontal root fractures.[18] The examination of volumetric scans demonstrated that 68.2% of them had an oblique course of the fracture fissure. Additionally, a fracture, which on a conventional radiograph was located in the middle or apical third of the root, on sagittal slices from palatal aspects is extended towards the tooth cervix.

Moreover, the authors noticed that the image of the horizontal fracture observable on the radiographs and CBCT scans from the vestibular aspect indicated a similar location of the fissure in 70.5% of the cases contrary to radiographs and scans taken from the palatal aspect, which confirmed the location of the fissure in only 31.8% of the cases.

In the clinical setting, artifacts may occur during the diagnosis of dental root fractures with the use of CBCT. They derive from radiopaque materials, such as gutta-percha and sealers used during root canal filling, metals from prosthetic appliances or are associated with the patient's movement during CBCT scanning. Image distortions in the form of star-shaped streaks imitating fracture gaps may affect the diagnostic value of CBCT examinations.[22–24]

However, it should be emphasized that the software in CBCT examinations allows dental practitioners to view teeth in at least 5 slices and different planes as well as from many angles. The fracture visible on 5, 4, 3 or even 2 slices of a particular scan enables clinicians to make a proper diagnosis.

The proper location of the fissure in the tooth with horizontal fracture allows dental practitioners to undertake adequate therapeutic management, i.e. root canal treatment or apicectomy. Idiopathic healing is also possible. Oblique root fracture is usually an indication that a tooth extraction is necessary. Treatment of such a fracture is always associated with failure, additionally leading to the loss of the alveolar bone, which makes further implant therapy more difficult.

Conclusions

The study indicated that CBCT is an effective method in diagnosing oblique dental root fractures. A contiguous slice appeared to be most effective in imaging oblique root fractures. The observer's experience did not play a significant role in the detection of oblique root fractures by means of CBCT.

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The reparative capacity of different bioactive dental materials for direct pulp capping

Zdolności reparacyjne bioaktywnych materiałów stosowanych w bezpośrednim pokryciu miazgi

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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. Maintaining pulp vitality is a major objective in restorative dentistry. Direct pulp capping (DPC) is considered a way to enhance pulp healing and induce reparative dentin. In the present study, 3 capping materials were used and compared in terms of promoting pulp tissue healing after mechanical exposure.

Objectives. The aim of the study was to evaluate the reparative capacity of Biodentine™ (BD), TheraCal® LC and TotalFill® as DPC materials and to assess dentin bridge formation.

Material and methods. The experiment required 3 groups (1-week group, 1-month group and 3-months group), each consisting of 24 fresh human premolars extracted for orthodontic reasons. A cavity was prepared on the buccal surface of each tooth and the pulp tissue was penetrated to a depth of approx. 1.0 mm. After exposure, hemostasis was obtained and the pulp-capping agents BD, TheraCal LC and TotalFill were applied. A final restoration with GC Fuji IX GP Fast (GC Corporation, Tokyo, Japan) was applied to each tooth to ensure an adequate coronal seal. Tissue samples were collected at 1 week, 1 month and 3 months. The samples were demineralized, sectioned, stained, and histologically graded.

Results. There was a statistically significant difference between TheraCal LC and both BD and TotalFill in terms of pulpal inflammation during the 3 capping periods, while BD and TotalFill showed comparable results, with no statistically significant difference between their results in the 3 capping periods.

Conclusions. TotalFill, a newly developed pulp-capping material, offers results comparable to BD in addition to its advantageous handling properties. Although TheraCal LC contains resin ingredients, given proper curing, it seems to be a successful material for DPC and offers superior handling properties.

Key words: pulp vitality, pulp capping, bioactive dental materials

Słowa kluczowe: żywotność miazgi, pokrycie miazgi, bioaktywne materiały stomatologiczne

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Maintaining pulp vitality is a major objective in restorative dentistry. Vital pulp therapy aims to maintain the viability of the dental pulp in addition to provoking the remaining pulpal tissue to regenerate the dental-pulp complex.[1] Direct pulp capping (DPC) is considered a way to enhance pulp healing and induce reparative dentin. Studies on capping materials have been undertaken by many clinicians and researchers, as selection of appropriate capping material is the key to a good treatment outcome.[2] Calcium hydroxide ($Ca(OH)_2$) has been considered the material of choice (the gold standard) for DPC for several decades, but many studies have reported that the strong alkaline nature of the material may induce necrosis of the pulp.[3] Therefore, mineral trioxide aggregate (MTA) has been used as an alternative to $Ca(OH)_2$ in dentistry.[4] The advantages of MTA over $Ca(OH)_2$ are its lower degradation potential, enhanced mechanical strength, better marginal adaptation, and sealing ability.[5] However, MTA still has some drawbacks, such as a prolonged setting time and a sandy consistency, which make the handling of this material difficult.[6] Recently, reports have been published about bioactive molecules like Biodentine™ (BD), inducing dentin bridge formation on exposed pulp tissues in experimental animals.[7] The main advantages of BD over MTA include its ease of handling, greater viscosity, faster setting time, and improved physical properties.[8] A new bioceramic material (TotalFill®) has recently been introduced on the market as a new hydraulic material with several applications as pulp capping.[9] However, unlike MTA, this material does not contain Portland cement, and hydraulic calcium zirconia is included as a radiopacifying agent.[10] The composition of this new bioceramic material seems promising in many aspects, such as its high mechanical bond strength, fast setting time and lack of discoloration; and since it is premixed, it could be a possible alternative to ordinary MTA.[11] It therefore seems worthwhile to investigate the reparative effects of these new bioactive dental materials as DPC agents over different observation periods (1 week, 1 month and 3 months), focusing on the dental pulp response and reparative dentin formation.

Material and methods

Sample preparation

A total of 72 fresh human premolars (extracted for orthodontic reasons) were used in this study after being examined clinically and radiographically to exclude teeth with caries and periapical pathologies. The teeth were washed under running tap water to remove blood and debris. The apical 3 mm of the tooth root was cut perpendicularly to the long axis of the tooth using a fissure burr with a high-speed hand-piece (W&H Impex Inc., Bürmoos, Australia). The teeth were then exposed to ultraviolet light for 20 min in a biological safety cabinet (SterilGARD III Advance; The Baker Co., Sanford, USA) to ensure decontamination.[12] The teeth were then transferred to 12-well cell culture plates (Falcon; Becton Dickinson, Franklin Lakes, USA), each tooth in a separate well containing Dulbecco's Modified Eagle Medium (DMEM) supplemented with 300 IU/mL penicillin, 300 µg/mL streptomycin and 0.75 µg/mL amphotericin per well, and stored for 2 h at 4°C to preserve pulp vitality.[13]

The design of the study

The samples were randomly divided into 3 main groups according to the capping duration (n = 24): group 1 (1 week), group 2 (1 month) and group 3 (3 months). Each main group was subdivided into 3 subgroups according to the capping material (n = 8): in subgroup A the exposed pulps were directly capped with BD, while in subgroups B and C the exposed pulps were directly capped with TheraCal® LC and TotalFill®, respectively.

Cavity preparation and mechanical pulp exposure

Standard class V cavities were prepared on the cervical third of the buccal surface of the teeth, approx. 1 mm coronally to the gingival margin, using a size 3 diamond round stone (MANI Inc., Utsunomiya, Japan) with a high-speed hand-piece (W&H Impex Inc., Bürmoos, Australia). A modified metal band with a central window was used to standardize the prepared cavities to 3 mm ±0.5 mm mesiodistally and 2 mm ±0.5 mm occlussogingivally. Copious amount of a coolant from the high-speed hand-piece was used to avoid overheating; each burr was used to prepare 4 cavities. The drilling was maintained until the pulp shadow appeared; this was assisted by means of ×4 magnifying eye loupes (Univet, Rezzato, Italy). A sterile sharp probe was then used to mechanically induce pulp exposure in the center of the cavity.[14] Diluted sodium hypochlorite (NaOCL) solution (1:1) was applied using a syringe to disinfect the area and to stop any hemorrhage that might have occurred; this was followed by drying with a dry sterile cotton pellet until physiological homeostasis occurred.[15]

Application of the pulp-capping material

All 3 of the experimental capping materials were mixed according to the manufacturers' instructions and applied to the teeth in the appropriate subgroups.

Application of the restorative material

Fuji II LC glass ionomer capsules (GC Corporation, Tokyo, Japan) were used for coronal restoration in this study. In accordance with the manufacturers' instructions, each capsule was first activated by depressing the button on the bottom, and then placed in a RotoMix™ high-speed amalgamator (3M ESPE Gulf, Dubai, UAE) at approx. 4,300 rpm for 10 s.[16] The mixed capsule was immediately removed from the amalgamator, placed in a glass ionomer applicator and injected into the cavity.

Hosting period

The crowns were fixed to a metallic wire with a sealant (Embrace®; Pulpdent, Watertown, USA). The wire was suspended on 2 adjacent plates. The apical part of each tooth was dipped in 4 mL of culture medium without touching the bottom of the culture wells in order to facilitate the diffusion of the medium through the apical part without any direct contact with the restorative material.[17] The culture medium was changed every day.

Histopathological evaluation

The histopathological evaluation was based on the International Organization for Standardization (ISO) 7405 criteria.[18] Inflammatory reactions were graded following the scoring system described in Table 1.[19]

Table 1. Inflammatory reaction scoring system

Scoring	Description
0	Normal tissue with no or few scattered inflammatory cells present in the pulp area corresponding to pulp exposure
1	Mild inflammatory cell infiltrate with polymorphonuclear or mononuclear leukocytes
2	Moderate inflammatory cell infiltrate involving the coronal pulp
3	Severe inflammatory cell infiltrate involving the coronal pulp or characterizing abscess

Statistical analysis

The statistical analysis was carried out using SPSS v. 17 software (SPSS Inc., Chicago, USA). A two-way analysis of variance (ANOVA) was used to test the effects of the materials, time intervals and their interactions on dentin thickness. A one-way ANOVA was used to test the effects of the time intervals for each material, as well as the effects of the materials within each time interval on dentin bridge thickness. A t-test was used to study the changes over time in each group. The significance level was set at $p \leq 0.05$.

Results

Effect of capping material on inflammatory score

The histological sections presenting the normal architecture of pulp tissue consisted of delicate and loose connective tissue. A single layer of peripheral odontoblasts lining the peripheral part of the pulp could be seen separating the loose connective tissue of the pulp from the predentin. This was followed by the cell-free zone and then the cell-rich zone with high densities of fibroblasts. Numerous blood capillaries with red blood cells were also detected (Fig. 1).

The results for group 1 (capping duration: 1 week; Fig. 2) showed that there was a statistically significant difference between the BD subgroup and the TheraCal LC subgroup. However, there was no statistically significant difference between the BD and TotalFill subgroups. In group 2 (capping duration: 1 month; Fig. 3), there was a statistically significant difference between the inflammatory scores of the BD subgroup and of the TheraCal LC subgroup. However, there was no statistically significant difference between the BD and TotalFill subgroups. In group 3 (capping duration: 3 months; Fig. 4) there was a statistically significant difference between the BD subgroup and the TheraCal LC subgroup. However, there was no statistically significant difference between the BD and TotalFill subgroups.

Effect of capping material on the dentin bridge thickness

The two-way ANOVA showed that both the capping material and the capping duration had statistically significant effects on the dentin bridge thickness. The interaction between the 2 independent variables (capping material and capping duration) had a statistically significant effect on the dentin bridge thickness (Table 2, Fig. 5).

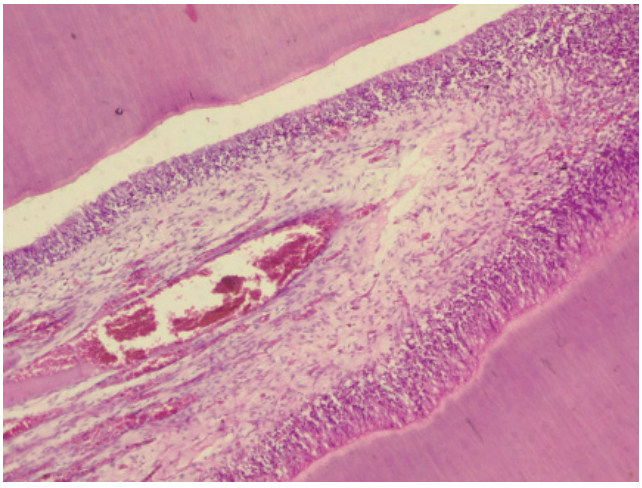

Fig. 1. A photomicrograph of normal pulp hematoxylin and eosin stain (H&E), (×40 magnification)

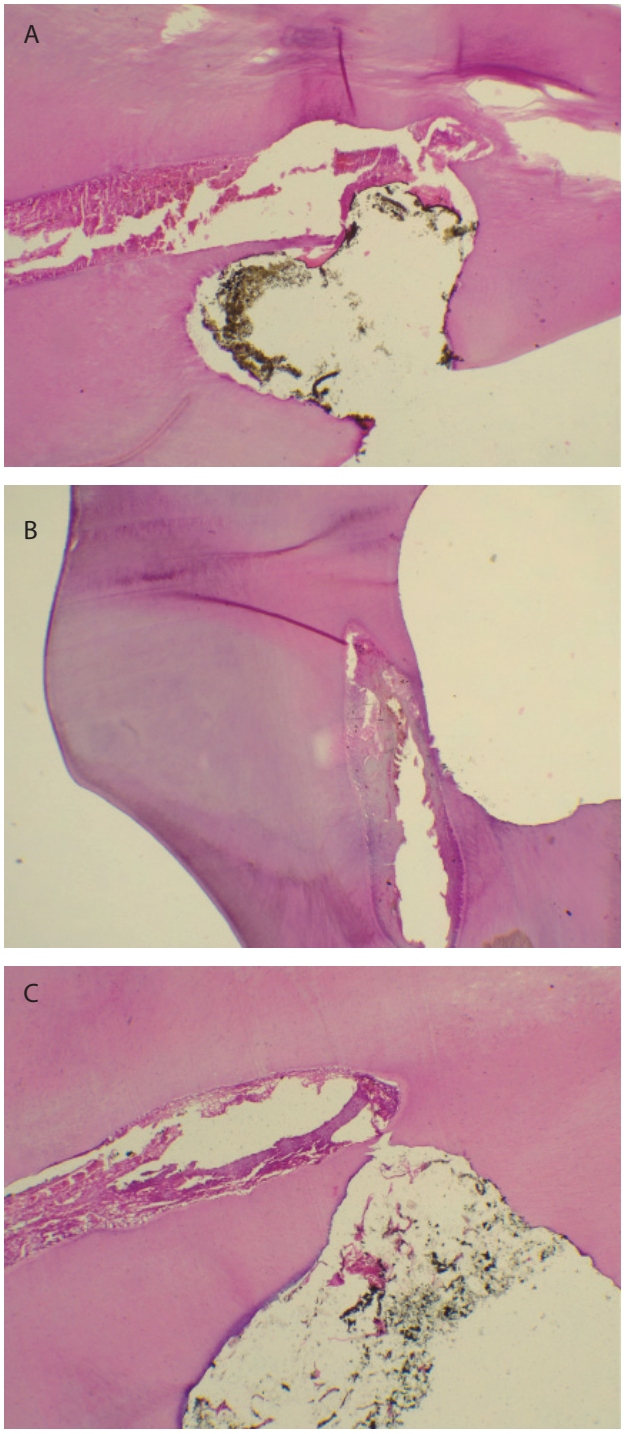

Fig. 2. A photomicrograph hematoxylin and eosin stain (H&E), (×40 magnification) after 1 week, showing mild inflammatory cells in the Biodentine™ (A) and TotalFill (C) subgroups, and moderate to severe inflammation in the TheraCal LC subgroup (B)

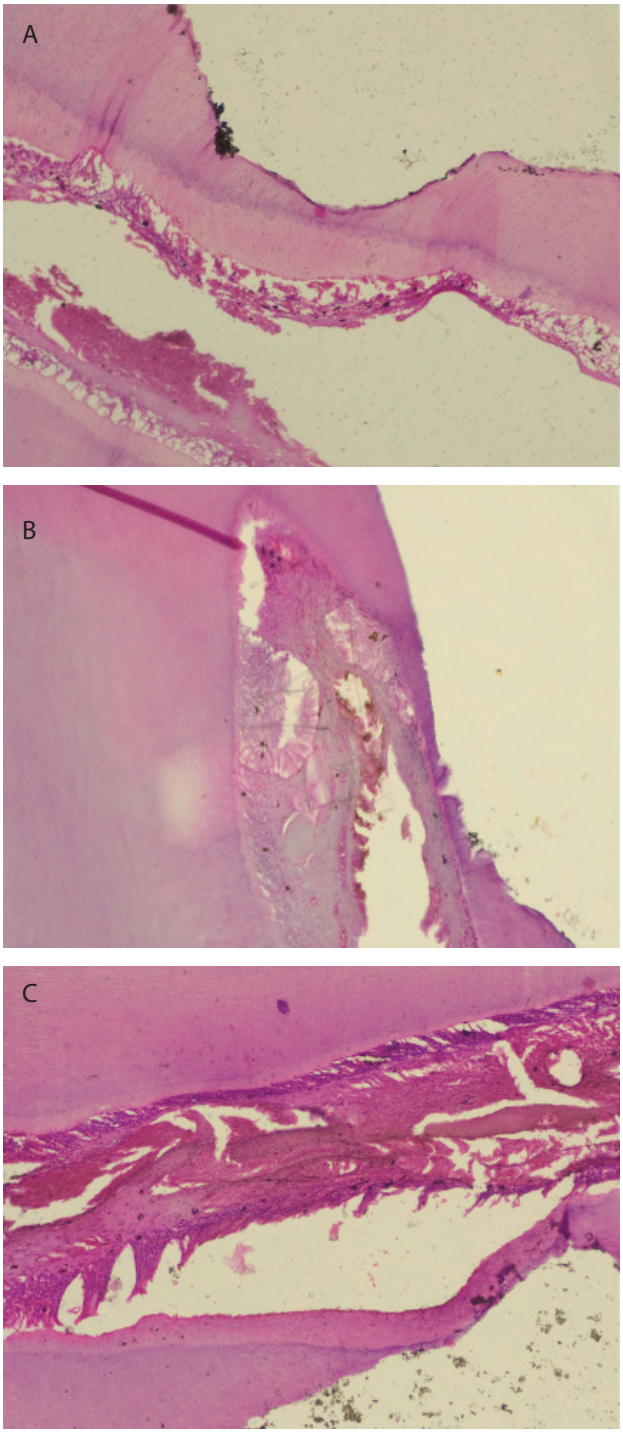

Fig. 3. A photomicrograph hematoxylin and eosin stain (H&E), (×100 magnification) after 1 month, showing a very thin bridge of dentin, and presenting osteodentin with osteocytes and evidence of newly calcified matrix formation in both the Biodentine™ and TotalFill subgroups (A & C). The TheraCal LC subgroup (B) shows a direct transition from a necrotic inflammatory odontoblastic layer to a multilayer of vital odontoblasts

Table 2. Descriptive statistics and test of significance for the effects of capping materials on dentin bridge thickness within the different capping durations

Material	1 week			1 month			3 months		
	mean	SD	DT	mean	SD	DT	mean	SD	DT
Biodentine™	0.00	0.00	a	0.180	0.204	a	0.520	0.294	a
TheraCal LC	0.00	0.00	ab	0.078	0.113	ab	0.159	0.207	ab
TotalFill	0.00	0.00	a	0.168	0.106	a	0.347	0.276	a

SD – standard deviation; DT – Duncan's multiple range test for the effect of time. Means with the same letter within each column and capping duration are not significantly different at p = 0.05.

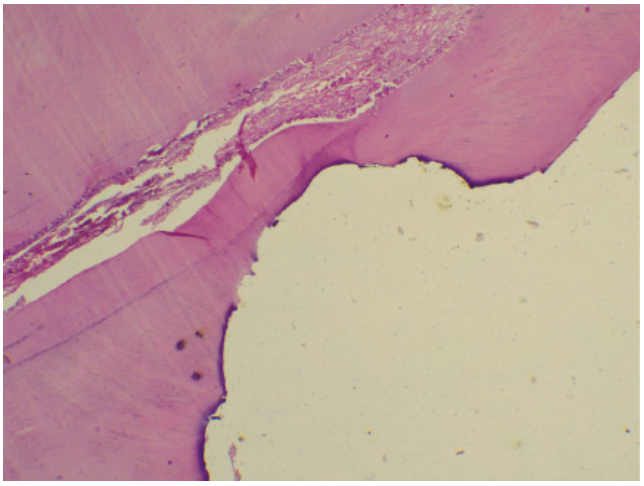

Fig. 4. A photomicrograph hematoxylin and eosin stain (H&E), (×40 magnification) after 3 months, showing dilated congested blood vessels and a bridge of hard tissue formation in both the Biodentine™ & TotalFill subgroups (A & C). The TheraCal LC subgroup (B) shows dilated congested blood vessels and a thin bridge of hard tissue formation

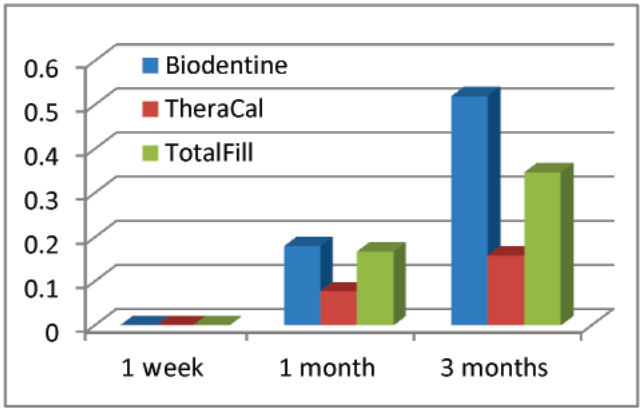

Fig. 5. Mean dentin bridge thickness for the 3 different materials within each capping duration

Discussion

Traumatized dental pulp cells possess the ability to differentiate into a specific cell lineage, forming tubular dentin in the absence of normal developmental conditions.[19] Pulp-capping techniques involve direct application of material over the exposed pulp for the immediate induction of cytological and functional odontoblast-like cell differentiation to initiate the formation of reparative dentin at the site of injury.[3] The entire tooth culture model provides a useful tool to predict the biocompatibility of dental materials. This model allows the early steps of dentine-pulp regeneration and pulp cell behavior to be investigated after applying pulp-capping materials. It reproduces the clinical situation for pulpal exposure in a whole-tooth environment, reducing the use of animal experiments before studies on humans.[13]

In our study, pulpal exposure was performed mechanically with a probe. Although it has been reported that this approach pushes dentin fragments into the pulp, it was found that these fragments seemed to induce an inflammatory pulpal response.[14] Three capping durations were selected. The 1-week period seemed to show the primary acute response of the tissues. In the 1-month period the cessation of the inflammatory phase and tissue organization was observed in some groups. The 3-month period was essential for a final assessment of the procedure.[20]

The histopathological results for the 1-week period for all 3 capping materials showed destruction of the odontoblastic layer with loss of the normal architecture of the connective tissue stroma, accompanied by inflammatory cells, dilated blood vessels and areas of edema. The general inflammatory pulpal response could be attributed to traumatic injury to the pulp tissue by the mechanical exposure and compression during the capping procedure. Mild to moderate chronic inflammation was found for all the DPC materials, except for TheraCal LC, with which 25% of the specimens showed severe inflammation. This was in agreement with other studies, which posited that the high percentage of severe inflammation reported with TheraCal LC may be caused by the fact that TheraCal LC contains resinous bisphenol A-glycidyl methacrylate, hydroxyethyl methacrylate and urethane dimethacrylate monomers.[21,22] If unpolymerized, the free monomers can diffuse through dentin and reach the underlying pulp, where they can exert their toxic effects. Chen and Suh, on the other hand, suggested that light curable resin modified calcium silicates, such as TheraCal LC, have less cytotoxicity and better or comparable clinical outcomes during the 1st week of DPC.[23]

For the 1-month capping period, there was no significant difference in the inflammatory score results between the BD and TotalFill subgroups. This may be attributed to the material properties: as TotalFill creates hydroxyapatite-like precipitates, an alkaline pH comparable to BD is produced, and Ca^{2+} is also released, which could be conducive to hard-tissue deposition. The histopathological results for the TheraCal LC subgroup for the 1-month period showed disorganization of the pulp tissue with multiple vacuolations. Moderate to massive inflammation around was seen, and the pulp tissue showed evidence of newly calcified matrix formation. A significant difference could be seen between this subgroup and both the BD and TotalFill subgroups. These findings coincided with those of Jeanneau et al.[24]

The histopathological results for the 3-month capping duration showed restoration of the normal architecture, dentin bridge sealing the exposure site and no to mild chronic inflammation in all 3 subgroups. There was no significant difference between the BD and TotalFill results, which coincided with those of Parirokh et al., who demonstrated a dentin bridge thickness of 0.25 mm and no inflammatory pulpal response.[25] This lack of significant difference could be due to multiple reasons; both materials are biocompatible, bioactive, similar in sealing ability, and have similar antibacterial efficacy.[9,26]

In addition, a significant difference may have been achieved if the evaluation period had been extended or if the sample size had been increased per group.

On the other hand, although TheraCal LC results showed dentin bridge formation with mild chronic inflammation, there was a significant difference between the TheraCal LC subgroup and both the BD and TotalFill subgroups in terms of dentin bridge thickness and inflammatory score, which may be attributed to the hydration properties of TheraCal LC. The hydration of TheraCal LC depends on the fluid uptake through the resin matrix from the environment. The high calcium ion release of TheraCal LC was demonstrated in vitro when the material was stored in a solution where the fluid uptake could occur unimpeded.[27] In the current study there was not enough moisture in the pulp-capping conditions to allow proper hydration of the tricalcium silicate in TheraCal LC, even when it was in contact with several milliliters of solution.

Conclusions

TotalFill, a newly developed pulp-capping material, offers results comparable to BD in addition to its advantageous handling properties. Although TheraCal LC contains resin ingredients, given proper curing, it seems to be a successful material for DPC and offers superior handling properties.

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Patient morbidity at the palatal donor site depending on gingival graft dimension

Ryzyko powikłań miejsca dawczego na podniebieniu w zależności od długości i grubości przeszczepu dziąsłowego

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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. Autogenous gingival grafts are considered the gold standard procedure with proven clinical success when it comes to gingival augmentation. Different graft harvesting procedures have been described in the literature. Understanding which factors might affect the level of discomfort (morbidity) that patients are likely to experience and oral health-related quality of life outcomes in general seems to be crucial.

Objectives. An evaluation of patients' morbidity depending on the free gingival graft (FGG) dimension.

Material and methods. Sixty patients were divided into 3 groups depending on the length of their graft (group L1: ≤10 mm, group L2: 10–20 mm, group L3: ≥20 mm) and into 2 groups depending on the thickness of the graft (group T1: ≤2 mm, group T2: >2 mm). Discomfort at the donor site was evaluated 1 week postoperatively, using a visual analog scale (VAS).

Results. With the length of the FGG, the mean VAS scores for pain, bleeding, eating and speaking disorders, stress and interference with social life increased. Analgesic consumption increased with the length of the graft. The thicker the grafts, the less discomfort and pain, and more problems with speaking, stress, daily and work routines occurred; however, without statistical significance.

Conclusions. No differences were demonstrated in the postoperative patients' morbidity between the examined groups; however, pain gradually increased with the FGG length and width.

Key words: visual analog scale, free gingival graft, patient comfort

Słowa kluczowe: wizualna skala analogowa, wolny przeszczep dziąsłowy, komfort pacjenta

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Autogenous gingival grafts are still considered the gold standard procedure with proven clinical success when it comes to gingival augmentation.[1] The palate is the most frequent donor site for grafts.[2] Different graft harvesting procedures have been described in the literature.[3–6] A whole free gingival graft (FGG) may be used at the recipient site or a graft may be deepithelialized after harvesting from the palate in order to get a subepithelial connective tissue graft (CTG).[7] Both can be used to increase tissue thickness, to cover gingival recession and/or to prevent the development and progression of gingival recession.[1]

There are numerous studies about the efficiency and predictability of different proposed surgical techniques on the recipient site as well as on the donor site.[1,2,5,8] Surgical techniques depend on several factors, such as the size of the recession defect, the width of keratinized tissue, the depth of the vestibule, and the quality of the tissue on the palate.[1,6,7,9,10] After FGG harvesting, the donor site becomes an open wound that may generate postoperative inconveniences for patients. Discomfort, pain and bleeding at the donor site after the FGG procedure are widely described in the literature.[2,5,11] However, there is limited information about patient-reported outcomes after surgical treatment depending on different thicknesses and lengths of the graft. In order to assess how a certain treatment affects patients' quality of life, the following components should be taken into account: 1. level of pain/discomfort; 2. ability to function (eating, chewing, speaking); 3. psychological well-being (stress); and 4. social well-being (socializing, eating/speaking in front of others). Without a doubt, it is of value to include patient-related outcomes in relation to quality of life measures after soft tissue grafts in clinical trials.[2,12]

The aim of this clinical study was to compare the postoperative morbidity at the donor site 1 week after the FGG procedure in reference to 3 different graft lengths and 2 different graft thicknesses.

Material and methods

Study population

The study included 60 Caucasian individuals of both genders (20 male and 40 female), aged 19–57 years, who were treated in the Department of Periodontology of the Medical University of Warsaw in Poland. The study protocol was planned in accordance with the ethical principles of the Declaration of Helsinki of 1975, as revisited in 2000, and approved by the Ethics Committee of the Medical University of Warsaw (KB/233/2014). The patients recruited had mucogingival problems qualifying them for surgery: thin biotype, a narrow zone of keratinized gingiva (≤1 mm) and multiple gingival recession on the facial aspect of the mandibular anterior area. All participants received oral hygiene instructions. Full-mouth plaque scores (FMPS)[13] and full-mouth bleeding scores (FMBS)[14] were recorded initially and after scaling and selective root planning of the tooth. Non-surgical therapy was performed until FMPS ≤ 20% and FMBS ≤ 20% were reached before surgery. All patients agreed to participate in the study and signed written informed consent. Exclusion criteria comprised smoking, age <18 years, presence of periodontal disease, conditions and/or medication that could interfere with periodontal tissue health or healing, pregnancy/lactating, or previous periodontal surgery on the involved sites. Two patients were excluded from the research due to delayed check-up appointments (after 10 days).

Study design

The participants of the study were divided into 3 group based on the length (mesial-distal dimension) of the graft: in group L1 the graft was ≤10 mm long (20 patients), in group L2 the graft was 10–20 mm long (20 patients) and in group L3 the graft was ≥20 mm long (20 patients). Based on the thickness of the graft, the patients were divided into 2 groups: in group T1 the graft was <2 mm thick (30 patients) and in group T2 the graft was ≥2 mm thick (30 patients). The length and the thickness of the FGG were evaluated immediately after being harvested. The measurements were made with a manual periodontal probe and rounded up to the nearest millimeter (PCP UNC 15; Hu-Friedy, Chicago, USA) (Fig. 1, 2). The height (apical-coronal dimension) of the FGG was the same in all cases, equal to 5 mm. All assessments were performed by the same experienced clinician (B.W.).

Harvesting the graft

All surgical procedures were performed under local anesthesia with 2% lidocaine with 1:100,000 epinephrine by one of the authors (B.G.), according to the technique described by Sullivan and Atkins[3] and developed by Miller,[15] using microsurgical principles. In brief, a horizontal partial-thickness incision of the length of the FGG was traced

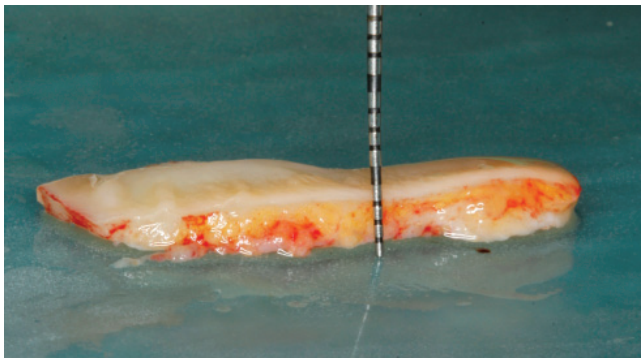

Fig. 1. Free gingival graft taken from the palate. The thickness of the FGG was evaluated with a periodontal probe immediately after being harvested

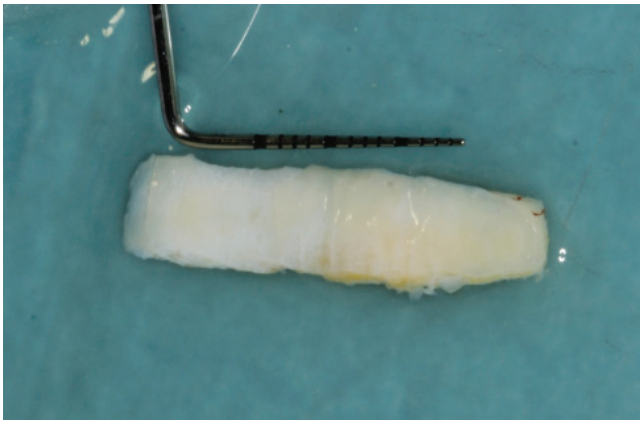

Fig. 2. Free gingival graft taken from the palate. The length of the FGG was evaluated with a periodontal probe immediately after being harvested

2 mm apically to the gingival margin of the upper teeth. Two vertical incisions of 5 mm length were performed to delimitate the height of the graft and a second horizontal incision was made. Subsequently, the blade was oriented almost parallelly to the superficial tissue along the coronal horizontal incision, once an adequate tissue thickness was obtained and the FGG was removed from the palate donor site. The palatal wound was protected with a hemostatic sponge (Equispon®; Equimedical, Zwanenburg, the Netherlands) maintained with polyamide sutures 5–0 (Seralon®; Serag Wiessner, Naila, Germany). A palatal stent was placed over the palatal area.

Postoperative care

Patients received 400 mg of ibuprofen at the beginning of the surgical procedure and 200 mg on its completion. Subsequent doses were taken only if required to control postoperative pain and edema. Patients were asked to record the quantity of analgesics taken. Chlorhexidine solution (0.2%) was administered 3 times a day for 1 min, and tooth brushing in the surgical areas was discontinued. The palatal stent was routinely used for the 1st postoperative week. The sutures were removed 10 days after surgery.

Discomfort assessments

One week after surgery, all patients were called for a check-up visit and requested to fill out a questionnaire. A visual analog scale (VAS) was used to measure the patients' postoperative discomfort. In the questionnaire, the respondents specified their level of 9 pre-selected issues by indicating a position along a continuous line between 2 end-points on a scale of 100 mm length.[16] Patients were asked about: 1. post-surgery discomfort; 2. post-surgery pain; 3. palate bleeding (at the donor site); 4. eating disruption; 5. speaking disruption; 6. stress/tension; 7. disruption of daily activities; 8. work disruption; and 9. social life disruption. Moreover, there was 1 question about the number of analgesics taken for pain relief.

Discomfort was defined as any disruption in daily functioning, summarizing all normal activities experienced by the patients during the 1st postoperative week due to the palatal wound. Bleeding was considered as prolonged (longer than on the surgery day) hemorrhaging from the palate during the postsurgical week. Eating disruption was described as discomfort, such as pain or changes in the taste of food, while eating due to the palatal wound. Stress was evaluated based on the level of apprehension or fear experienced by the patients due to the palatal wound. Daily routine, work and social life disruption were defined as lower activities than normal in these areas. Postoperative pain was controlled with ibuprofen as described above. Subsequent doses that were taken were recorded in the questionnaire.

Statistical analysis

Statistical analysis was computed using R 3.3.1.[17] To test the significance between 2 means (groups divided by the graft length and thickness), a univariate (one-way) analysis of variance (ANOVA) and Student's t-test were used, respectively. To compare a change in categorical variables in 2 groups, a χ^2 test was used. A p-value <0.05 was considered statistically significant.

Results

The participants of the study were divided into 3 groups based on the length of the graft: in group L1 the graft was ≤10 mm long, in group L2 the graft was 10–20 mm long and in group L3 the graft was ≥20 mm long. The results are presented in Table 1 and Fig. 3. There was no statistically significant difference between L1, L2 and L3 in terms of discomfort (25.1, 27.4 and 19.4, respectively, on the 0–100 VAS). Pain and bleeding gradually increased with a greater graft length, but neither parameter was statistically significant (19.6, 24.2 and 35.6, respectively, for pain, and 4.0, 4.2 and 14.2, respectively, for bleeding in L1, L2 and L3 on the 0–100 VAS). Similarly, eating was more constricted with greater graft length, but also without statistical significance (29.1, 45.4 and 48.7, respectively, in L1, L2 and L3 on the 0–100 VAS). The longer the graft, the more problems with speaking occurred (15.4, 19.5 and 23.5, respectively, in L1, L2 and L3 on the 0–100 VAS) and there were more patients with stress (17.8, 18.4 and 24.5, respectively, in L1, L2 and L3 on the 0–100 VAS) and problems in social life (10.5, 16.2 and 16.6, respectively, in L1, L2 and L3 on the 0–100 VAS). The level of disruption of daily routine (7.5, 12.3 and 11.5, respectively, in L1, L2 and L3 on the 0–100 VAS) and work (11.7, 10.6 and 15.0, respectively, in L1, L2 and L3 on the 0–100 VAS) did not seem to have any connection with the length of the graft.

Table 1. The comparison between the groups with regard to the graft length

Variable	L1	L2	L3	p-value
	mean (SD)	mean (SD)	amean (SD)	
Ibuprofen [mg]	146	100	400	0.022
Discomfort [VAS]	25.1 (25.5)	27.4 (23.9)	19.4 (20.3)	0.622
Pain [VAS]	19.6 (25.1)	24.2 (25.0)	35.6 (31.0)	0.389
Bleeding [VAS]	4.0 (9.7)	4.2 (11.3)	14.2 (21.7)	0.250
Eating [VAS]	29.1 (23.4)	45.4 (27.8)	48.7 (22.1)	0.119
Speaking [VAS]	15.4 (26.1)	19.5 (23.7)	23.5 (26.0)	0.754
Stress [VAS]	17.8 (19.0)	18.4 (26.2)	24.5 (25.0)	0.722
Daily routine [VAS]	7.5 (19.3)	12.3 (16.0)	11.5 (15.0)	0.798
Work [VAS]	11.7 (26.4)	10.6 (16.9)	15.0 (20.4)	0.831
Social life [VAS]	10.5 (18.6)	16.2 (24.3)	16.6 (22.5)	0.683

L1 – graft length ≤10 mm; L2 – graft length 10–20 mm; L3 – graft length ≥20 mm; SD – standard deviation; VAS – visual analog scale; except for the amount of ibuprofen, the means represent the positions along a continuous line between 2 end-points on a scale from 0 to 100, where 0 means no disruption and 100 means serious disruption; $p < 0.05$ considered statistically significant.

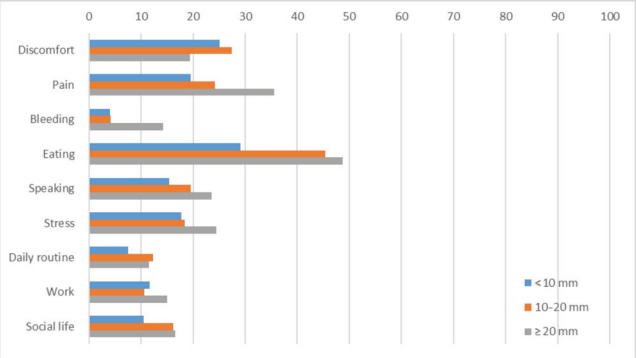

Fig. 3. The results for 9 pre-selected issues based on the length of the graft

L1 – graft length ≤10 mm; L2 – graft length 10–20 mm; L3 – graft length ≥20 mm; the patients estimated the position of the 9 issues along a continuous line between 2 end-points on a scale of 100 mm length (VAS – visual analog scale), presented above as a bar chart.

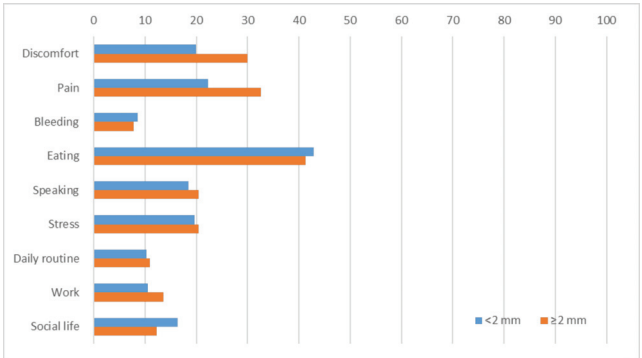

Fig. 4. The results for 9 pre-selected issues based on the thickness of the graft

T1 – graft thickness <2 mm; T2 – graft thickness ≥2 mm; the patients estimated the position of the 9 issues along a continuous line between 2 end-points on a scale of 100 mm length (VAS – visual analog scale), presented above as a bar chart.

Based on the thickness of the graft, the patients were divided into 2 groups: in group T1 the graft was <2 mm thick and in group T2 the graft was ≥2 mm thick. The results are presented in Table 2 and Fig. 4. There were no statistically significant differences between the groups. Discomfort (19.9 and 29.9, respectively, in T1 and T2 on the 0–100 VAS) and pain (22.3 and 32.6, respectively, in T1 and T2 on the 0–100 VAS) were lower with a thicker graft. Bleeding (8.6 and 7.8, respectively, in T1 and T2 on the 0–100 VAS), problems with eating (42.9 and 41.3, respectively, in T1 and T2 on the 0–100 VAS) and disruption of social life (16.4 and 12.3, respectively, in T1 and T2 on the 0–100 VAS) were slightly lesser when the graft was thicker. Moreover, eating (42.9 and 41.3, respectively, in T1 and T2 on the 0–100 VAS) was not more constricted with a thicker graft. The thicker the graft was, the more problems with speaking occurred (18.5 and 20.5, respectively, in T1 and T2 on the 0–100 VAS). Similarly, the level of stress (19.6 and 20.5, respectively, in T1 and T2 on the 0–100 VAS), disruption of daily routine (10.3 and 11.0, respectively, in T1 and T2 on the 0–100 VAS) and work (10.6 and 13.6, respectively, in T1 and T2 on the 0–100 VAS) were higher with an increased graft thickness.

Table 2. The comparison between the groups with regard to the graft thickness

Variable	T1	T2	p-value
	mean (SD)	mean (SD)	
Ibuprofen [mg]	200	200	–
Discomfort [VAS]	19.9 (19.7)	29.9 (26.2)	0.198
Pain [VAS]	22.3 (25.6)	32.6 (29.0)	0.252
Bleeding [VAS]	8.6 (17.2)	7.8 (16.2)	0.882
Eating [VAS]	42.9 (34.1)	41.3 (17.8)	0.858
Speaking [VAS]	18.5 (23.6)	20.5 (25.9)	0.802
Stress [VAS]	19.6 (21.5)	20.5 (24.1)	0.898
Daily routine [VAS]	10.3 (18.3)	11.0 (15.2)	0.892
Work [VAS]	10.6 (21.9)	13.6 (19.8)	0.663
Social life [VAS]	16.4 (24.5)	12.3 (18.8)	0.578

T1 – graft thickness <2 mm; T2 – graft thickness ≥2 mm; SD – standard deviation; VAS – visual analog scale; the means represent the positions along a continuous line between 2 end-points on a scale from 0 to 100, where 0 means no disruption and 100 means serious disruption; $p < 0.05$ considered statistically significant.

The mean painkiller consumption in group L1, L2 and L3 was 0.73 tablet, 0.5 tablet, 2 tablets, respectively. There was no statistically significant difference between group L1 and L2 ($p = 0.666$), and between group L1 and L3 ($p = 0.061$); however, there was one between group L2 and L3 ($p = 0.005$). Patients from group L3 received significantly more additional ibuprofen (on average 400 mg) compared to patients from group L1 (on average 146 mg) and patients from group L2 (on average 100 mg). The mean painkiller consumption in groups T1 and T2 was the same – 1 tablet.

Discussion

The palatal mucosa is commonly used as a graft donor site. Gingival grafts harvested with the epithelium can be used either directly as a FGG or as a subepithelial CTG after de-epithelialization outside the oral cavity. Soft tissue grafts can be used to increase the width of keratinized gingiva and tissue thickness.[2,4,6,18] The surgical wound on the palate heals by secondary intention within 2–4 weeks[3,5,7,11,19] (Fig. 5A–C). According to the literature, this procedure has been associated with discomfort for the patient due to postoperative pain and/or bleeding at the donor site.[2,5,19,20] Recently, patients' subjective assessment of medical procedures has gained in importance in healthcare, thus patients' expectations might be crucial in the selection of treatment measures. However, to the best of our knowledge, this is the first clinical study that has analyzed the patient's subjective morbidity at the donor site after FGG harvesting depending on the thickness and length of the FGG. We tried to evaluate how different components of patients' life quality were changing during the early healing phase after the FGG harvesting procedure. One week seems to be an adequate period to properly assess pre-selected subjective issues connected with the donor site, although healing lasts 2–4 weeks.[7,11,19] Since patient-reported outcomes are crucial to understand the effects of treatment on patients' quality of life during the early period of healing, they should be taken into consideration by clinicians while planning treatment.[2,12,19]

In our study, we evaluated all 4 components that constitute the well-being of patients. Although the differences mentioned were not statistically significant, they allowed for certain relationships to be observed. With an increased FGG length, patients reported greater pain, bleeding from the donor area and difficulty in eating and speaking. These aspects were reflected in the amount of analgesics administered (apart from 600 mg ibuprofen taken before and immediately after the procedure). Patients from group L3 received significantly more additional ibuprofen (on average 400 mg) compared to patients from group L1 (on average 146 mg) and group L2 (on average 100 mg). The length of the FGG was not reflected in the patients' reported general discomfort or impediments to daily routines or work. However, the level of general stress was higher in group L3, which was influenced by the above-mentioned difficulties in eating and speaking, which also translated into more problems in social contacts.

With regard to the thickness of the graft, the problems reported by patients were a little different. As the thickness of grafts increased (FGG ≥ 2 mm), general discomfort, speech disorders, stress levels, and difficulties in daily routines and work also increased. The FGG thickness did not affect the amount of administered painkillers, although the pain was greater in the group with thicker grafts. The variables were evaluated subjectively by indicating individualized responses of each patient, which further impeded their interpretation as well as comparison with reports from other researchers. In another study, the mean VAS pain scores 3 days and 3 weeks after the FGG surgery were 48 and 36, respectively.[21] Similarly, Zucchelli et al. compared the complaints reported by patients according to the size of prepared transplants.[22] In the "big graft group", the thickness of the FGG was ≥2 mm and the height was ≥4 mm, while in the "small graft group", the thickness was <2 mm, and the height was <4 mm. The authors did not take into account the length of the transplant. With the increase in the graft thickness and size, patients reported greater discomfort, palatine bleeding and difficulties while eating, which only in part coincided with the results of this work. The consumption of painkillers also increased (2520 mg of ibuprofen vs 1100 mg). The amount of nonsteroidal anti-inflammatory drugs (NSAIDs) taken was far greater than in our work, which might be related to the way in which the donor site was protected – for that purpose Zucchelli et al. used only equine-derived collagen without a palatal stent.[22]

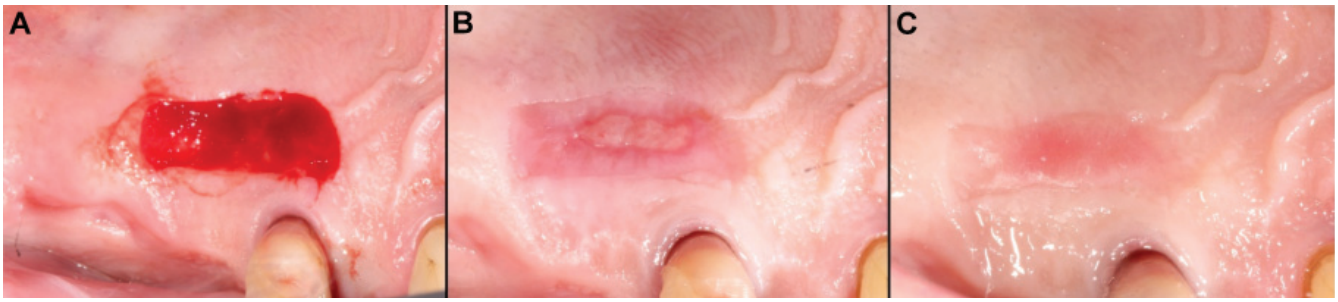

Fig. 5. A – the palatal wound after the graft has been harvested, the surgical wound on the palate heals by secondary intention; B – the palate condition after 3 weeks; C – the palate conditon after 4 weeks.

When it comes to patients' subjective assessment of the healing period after the FGG procedure, the type of covering method for the palate may be of utmost importance.[4,5,11,20,23] Eltas et al.compared the effects of a periodontal dressing, the Essix retainer, the modified Essix retainer, and modified Hawley retainer on pain, chewing, speaking, and appearance.[23] Using a periodontal dressing was associated with more pain and bleeding after 1 week post-surgery; however, the speaking and appearance VAS scores were lower. In light of the above, retainers might be the most appropriate in terms of pain and bleeding, but less ideal for speaking and appearance comfort. In other studies, hyaluronic-acid gels as well as platelet-rich fibrin (PRF) were applied at the donor site after FGG harvesting. Both PRF and hyaluronic-acid may provide significant benefits for wound healing parameters and reduce pain.[24,25] In our study, all patients were administered palatal stents. Thus complaints about the donor site (discomfort, pain, bleeding) might have decreased due to a reduction in pressure over the wound, independent of the graft length and thickness. However, it may also be the reason for impaired functions (eating, speaking), psychological well-being (stress) and social well-being (socializing, daily/work routines). In a study by Keceli et al., the application of medicinal plant extract (MPE) accelerated the healing rate of the donor site and decreased postoperative discomfort of the FGG-harvested patients.[11]

Apart from the method of protecting the palate wound, patients' postoperative sensations can also be influenced by the technique of graft collection itself and by the type of prepared grafts.[2,19,26,27] In their study, Zucchelli et al. compared patients' feelings depending on whether the transplant was obtained by the trap-door approach or from the deepithelialization of a FGG.[2] No differences were observed in the amount of painkillers taken, discomfort or postoperative bleeding. The trap-door transplantation was associated with lower patient's stress and better ability to chew. The pain grew together with an increasing height of the graft and with a reduced thickness of the soft tissue still covering the palatal bone. The height and depth of the withdrawal and not the type of palatal wound healing (primary vs secondary) influenced the postoperative pain. A possible explanation is that by inserting the blade into the depth of the palatal soft tissue and/or toward the palatal vault (the height of the withdrawal), the probability of severing a large-sized nerve/vessel increases, causing greater pain. Moreover, greater analgesic consumption was reported by patient's experiencing primary flap dehiscence/necrosis.[2] In our study, the height of all harvested FGGs reached 5 mm, hence the effects of the height of the withdrawal on patient's morbidity cannot be evaluated. Nevertheless, there was no statistically significant difference between L1, L2 and L3 in terms of overall discomfort in the questioned area as well as between T1 and T2. Generally, the thicker and the longer the graft, the more problems occurred in most assessed issues; however, the differences were small. This may implicate a helpful clinical hint during treatment planning when harvesting of a long and/or a thick graft is required.

Our study has some limitations that have to be addressed. An interpretation of the results of studies assessing the subjective feelings of patients should be very careful. The larger the studied population, the easier it is to analyze the results obtained. Our study included 60 patients divided into 3 groups, 20 patients in each group, depending on the FGG length (L1, L2 and L2) and 2 groups, 30 patients in each group, depending on the FGG thickness (T1 and T2). A lack of statistical significance between the groups evaluated does not mean that there exists equality between different graft lengths and thicknesses. Certainly, similar studies should be conducted on a larger sample of patients. In all patients, the palate treatment sites were secured with collagen sponges and individual palatine stents. This procedure also affects the patient's reported morbidity. The stents act as dressings, thereby reducing pain, discomfort and bleeding, but may impede speaking, eating and socializing.[4,5,11,20,23] It would be worthwhile to evaluate the feelings of patients in whom stents were not used, since the symptoms could be more associated with the geometry of the graft. Thirdly, in this study, grafts were prepared for soft tissue augmentation in patients with thin biotype, for widening the narrowed zone of the callused gingiva and for gingival recession coverage.[1,6,8] The method and extent of preparation of the donor site was different depending on the technique and treatment indications, which could also be reflected in the patients' reported reactions.[6,8–10,21] Nevertheless, the analyzed questions were explained to be related only to the treatment area on the palate, and the patients completed a questionnaire in the presence of a physician who provided assistance in case of interpretation difficulties.

Conclusions

Understanding which factors might affect the level of discomfort (morbidity) that patients are likely to experience and oral health-related quality of life outcomes in general is crucial. The majority of the parameters analyzed in our study were calculated with no statistical significance, which does not necessarily mean that there exists an equivalence between different graft dimensions. However, within the limitations of our study, it may be speculated that the correlations between postoperative morbidity and the graft size lose value when the palatal wound is covered by an individual stent. This implicates a valuable clinical conclusion in the case of treatment planning and while explaining the procedure to a patient in order to lower their anxiety before a procedure that requires harvesting of a long and/or a thick graft.

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Correlation between functional disorders of the masticatory system and speech sound disorders in children aged 7–10 years

Zależność pomiędzy zaburzeniami czynnościowymi narządu żucia a nieprawidłowościami wymowy u dzieci w wieku od 7 do 10 lat

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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. Masticatory system and speech sound disorders concur, have the same causes and similar consequences – both increase the risk of dental and periodontal diseases.

Objectives. The study was conducted to establish the correlation between functional disorders of the masticatory system and speech sound disorders.

Material and methods. Three hundred patients aged 7–10 years were examined to detect functional disorders of the masticatory system and speech sound disorders. Functional disorders were assessed in patients with and without speech sound disorders.

Results. According to the study results, functional disorders of the masticatory system concur more often with speech sound disorders than with correct articulation and lead to speech sound disorders. There is a strong correlation between:
– any dysfunction and errors in the /p/, /b/, /m/, /s/, /z/, /t͡s/, /d͡z/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds,
– mouth breathing and errors in the /p/, /b/, /m/, /s/, /z/, /t͡s/, /d͡z/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds,
– persistent tongue thrust and errors in the /s/, /z/, /t͡s/, /d͡z/, /ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds, and
– parafunctional sucking and errors in the /s/, /z/, /t͡s/, /d͡z/, /ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds.

Conclusions. To implement effective and early prevention and treatment, it is crucial to know the correlation between the masticatory system and speech sound disorders, as it reduces treatment duration and minimizes relapses of not only communication disorders, but also of concurrent masticatory system disorders.

Key words: prevention, malocclusion, speech sound disorders, dental care in children

Słowa kluczowe: profilaktyka, wada zgryzu, wady wymowy, opieka stomatologiczna dzieci

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Early orthodontic intervention and logopedic follow-up include all preventive, diagnostic, therapeutic, tutorial, and promoting steps aimed at preventing, limiting or eliminating speech sound and communication disorders, and attenuating their consequences. Orthodontic and logopedic prevention also includes the assessment of biological characteristics, defined as morphology and functioning appropriate for a given age.

Masticatory system and speech sound disorders concur, have common causes and similar consequences for the teeth, increasing the risk of dental and periodontal diseases. Both are featured together in many dental, orthodontic, laryngological, phoniatric, and logopedic studies. These studies cover various functional disorders, such as improper swallowing or oral breathing, and speech sound disorders.[1] However, there have been no studies simultaneously featuring the many parafunctional habits and dysfunctions of the masticatory system, in the broad meaning of the terms, and correlating them to respective speech sound disorders.[2,3] With such studies, dentists would be able to take part in the debate on the risk factors of speech sound disorders and on the impact of the latter on the oral cavity.

The aim of the present study was to define the correlations between functional disorders of the masticatory system and respective speech sound disorders in children aged 7–10 years.

Material and methods

Children aged 7–10 years attending primary schools in Warszawa, Poland, were qualified for the study. The inclusion criteria were as follows: children born between 2001 and 2004, with a written consent of their legal guardian to participate in the study. The exclusion criteria, aimed to increase the statistical significance of the results, included: cleft lip or palate, congenital anomalies with dysmorphic features within the facial bones of the skull, neurological disorders, mental diseases, intellectual disability, psychomotor retardation, delayed speech development, and hearing loss. Parents or legal guardians were informed verbally and in writing about the objective and scope of the study, techniques employed and data use, and were asked to sign a consent form regarding their child's participation. Children's caregivers were also given a medical interview questionnaire on dysfunctions and parafunctional habits. Dental and logopedic examination was performed between 2010 and 2012 by 1 dentist who was also a speech therapist. Examination was conducted at the school premises.

Dental and logopedic examination assessed the dysfunctions of the masticatory system, occlusal and non-occlusal parafunctional habits, dental and medical treatments underway, and potential logopedic treatment. Masticatory system examination encompassed:

- functional status of the masticatory system,
- dysfunctions such as oral breathing, persistent tongue thrust and lazy chewing,
- occlusal parafunctional habits (teeth grinding and clenching), and
- non-occlusal parafunctional habits (prolonged pacifier use, prolonged bottle feeding, sucking habits, nail biting, and lip or mucosa biting).

Logopedic examination assessed the articulation of Polish phonemes in 3 positions: initial, medial and final. All Polish phonemes were expressed according to the International Phonetic Alphabet.

Three hundred children participated in the study. Two groups were created after the logopedic examination:

1. treatment group – with speech sound disorders (161 patients, mean age ±8.26 years), and
2. control group – without speech sound disorders (139 patients, mean age ±8.89 years).

Statistical analysis was performed using SPSS v. 14.0 PL for Windows (IBM Corp., Armonk, USA). Pearson's χ^2 test compared the sample distribution of variables to their theoretical distribution. Cramér's V measured the correlation between 2 assessed nominal variables. Statistical significances were expressed quantitatively and set at $p \leq 0.05$.

Results

The prevalence of functional disorders was different in the treatment group (with speech sound disorders) and the control group (without speech sound disorders). Among the 10 functional disorders (6 parafunctional habits and 4 dysfunctions) assessed, the results referring to nail biting, prolonged bottle feeding, teeth clenching, and lazy chewing were found statistically insignificant. The remaining disorders occurred more often in the treatment group, and those results met the criteria for statistical significance.

The correlation between speech sound disorders and any parafunctional habits was weak, but statistically significant. It was slightly higher for occlusal than non-occlusal parafunctional habits.

The coexistence of occlusal parafunctional habits and speech sound disorders was also statistically significant. Occlusal parafunctional habits were exhibited 2 times more often in the treatment group than in the control group and their correlation with speech sound disorders was moderately strong.

A strong correlation exists between the prevalence of speech sound disorders and non-occlusal parafunctions: prolonged pacifier use, sucking habits and lip or mucosa biting. However, such a correlation was not observed for speech sound disorders and nail biting – their χ^2 test results indicated a considerable risk of being random.

The correlation between speech sound disorders and any type of dysfunction was much stronger than with any parafunctional habit (Cramér's V at 0.405 vs 0.188).

Oral breathing and persistent tongue thrust were common dysfunctions in the treatment group; persistent tongue thrust (Cramér's V at 0.387) and mouth breathing (Cramér's V at 0.378) had the strongest correlations with speech sound disorders.

Table 1 presents the prevalence of functional disorders and their correlation with speech sound disorders measured with Cramér's V.

The correlations between functional disorders and speech sound disorders, measured with Cramér's V, for persistent tongue thrust, oral breathing and sucking habits were strong. Lip or mucosa biting, prolonged pacifier use and tooth grinding ranked next according to the strength of their correlation with speech sound disorders.

The present study revealed 72 correlations between anatomical abnormalities and errors in the articulation of respective sound groups, of which 52 were statistically significant ($p \leq 0.05$) (Table 2).

There were strong correlations (Cramér's V 0.3–0.5) between the prevalence of:

1. Oral breathing and errors in /p/, /b/ and /m/ sounds;
2. Any dysfunction and errors in /p/, /b/ and /m/ sounds;
3. Persistent tongue thrust and errors in /s/, /z/, /t͡s/, and /d͡z/ sounds;
4. Oral breathing and errors in /s/, /z/, /t͡s/, and /d͡z/ sounds;
5. Any dysfunction and errors in /s/, /z/, /t͡s/, and /d͡z/sounds;
6. Sucking habits and errors in /s/, /z/, /t͡s/, and /d͡z/sounds;
7. Persistent tongue thrust and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds;
8. Sucking habits and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds;
9. Persistent tongue thrust and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds;
10. Oral breathing and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds;
11. Any dysfunction and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds; and
12. Sucking habits and errors in /ʂ/, /ʐ/, /t͡ʂ/, and /d͡ʐ/ sounds.

Discussion

There have been no comprehensive studies on parafunctional habits and dysfunctions of the masticatory system, and their correlation with speech sound disorders. Existing studies were focused on specific disorders of the masticatory system and their coexistence with speech sound disorders. They were also not aimed at assessing the strength of this relation in a quantitative manner. However, their results may be compared to partial findings of the present study.

In this study, occlusal parafunctional habits prevailed 2 times more often in the treatment group than in the control group and their correlation with speech sound disorders was moderately strong. The chi-squared test results confirmed that the correlation between occlusal parafunctional habits and errors in /t/, /d/ and /n/ sounds were statistically significant. Pizzolato et al. concluded that occlusal alterations concurred with errors of alveolar /s/, /z/, /t/, /d/, and /n/ and postalveolar /l/.[3]

Speech and sound disorders were observed more often in cases of prolonged pacifier use. Precisely 47% of children with speech sound disorders and 30% of those without speech sound disorders were found to have used the pacifier over longer periods of time. In a study on improp-

Table 1. Prevalence of functional disorders of the masticatory system and their correlation with speech sound disorders

Type of functional disorder (% in treatment and control group)	Prevalence – % of children in:		Correlation between the prevalence of parafunctional habits, dysfunctions and speech sound disorders (Cramér's V)
	group with articulation disorders (treatment group) n = 161	group without speech sound disorders (control group) n = 139	
Parafunctional habits in general	87.6	72.7	0.188
Occlusal parafunctional habits, including	46.0	23.7	0.231
teeth clenching*	15.5	7.2	0.129
teeth grinding	30.4	16.5	0.162
Non-occlusal parafunctional habits, including*	78.9	66.2	0.143
prolonged pacifier use	47.2	29.5	0.181
sucking habits	34.2	7.2	0.326
nail biting*	36.6	35.3	0.014
lip or mucosa biting	16.1	2.2	0.236
Dysfunctions in general	59.0	15.1	0.405
oral breathing	45.3	10.8	0.378
persistent tongue thrust	29.2	0.7	0.387
prolonged bottle feeding*	18.6	13.7	0.105
lazy chewing*	6.2	12.2	0.120

* result statistically insignificant ($p \leq 0.05$).

Table 2. Prevalence of incorrect pronunciation of groups of speech sounds and its correlation with given functional disorders of the masticatory system

Groups of speech sounds	Alveolar		Postalveolar		Pre-palatal		Bilabial	Labiodental
Type of functional disorder (number of patients in both treatment and control groups, Cramér's V)	/s/, /z/, /t͡s/, /d͡z/	/t/, /d/, /n/	/ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/	/r/, /l/	/ɲ/, /j/	/ɕ/, /ʑ/, /t͡ɕ/, /d͡ʑ/	/p/, /b/, /m/	/v/, /f/
Any parafunctional habit (parafunctional habits in general) n = 242	38.8% (0.165)	25.2% (0.176)	31.4% (0.187)	*	*	38.8% (0.179)	*	*
Teeth grinding n = 72	48.6% (0.160)	36.1% (0.197)	*	38.9% (0.165) (only /r/)	*	51.4% (0.197)	*	*
Prolonged pacifier use n = 117	51.3% (0.273)	33.3% (0.226)	37.6% (0.184)	*	*	48.7% (0.236)	*	2.7% (0.220)
Sucking habits n = 6	73.8% (0.428)	55.4% (0.430)	56.9% (0.349)	46.2% (0.242) (only /r/)	20% (0.167) (only /ɲ/)	67.5% (0.382)	18.5% (0.276)	10.8% (0.240)
Lip or mucosa biting n = 29	75.9% (0.280)	58.6% (0.293)	62.1% (0.255)	*	27.6% (0.185) (only /ɲ/)	69.0% (0.236)	*	*
Any type of dysfunction (dysfunctions in general) n = 116	60.3% (0.442)	42.2% (0.397)	44% (0.296)	36.2% (0.185) (only /r/)	17.2% (0.180)	58.6% (0.400)	15.5% (0.318)	6.9% (0.181)
Persistent tongue thrust n = 48	83.3% (0.442)	54.2% (0.344)	58.3% (0.304)	25% (0.239)	22.9% (0.180) (only /ɲ/)	77.1% (0.389)	18.8% (0.234)	*
Oral breathing n = 88	61.4% (0.356)	45.5% (0.372)	46.6% (0.278)	*	18.2% (0.176)	58.0% (0.315)	20.5% (0.392)	8% (0.187)

* result statistically insignificant ($p \leq 0.05$).

er function of the tongue, also in the context of speech, Straub established a statistically significant correlation between pacifier use and speech sound disorders.[4] However, a study by Shotts et al. did not suggest that there were significant differences in articulation related to prolonged pacifier use.[5]

Sucking habits (finger, thumb or lip) and speech sound disorders were strongly correlated. Van Norman and Tarvade et al. observed that children who persist in non-nutritive sucking of the thumb or finger beyond early childhood are more likely to develop speech difficulties.[6,7] It has been also confirmed that sucking habits are correlated with malocclusions, and malocclusions co-occur with speech sound disorders.[8–11] There were no studies on the correlation between sucking habits and specific speech sound disorders.

Nail biting was a statistically insignificant parafunctional habit. Only 1 more child bit its nails in the treatment group than in the control group. However, Straub came to completely different conclusions – he established that nail biting led to an improper function of the tongue, including speech sound disorders.[4]

The correlation between speech sound disorders and persistent tongue thrust was strong. Zadurska et al. established the same – 61% of children with persistent tongue thrust had speech sound disorders. In the present study, this percentage was much higher – 98%. Therefore, persistent tongue thrust seems to lead to speech sound disorders. Straub, Tarvade et al., Rehak et al., Hopkin and Mackiewicz confirmed this theory.[7,12–14]

Subtelny and Subtelny often observed, when assessing the impact of tongue thrust on speech sound disorders, adapted patients with malocclusions and normal speech; however, all patients with an improper function of the tongue had speech sound disorders.[15] In later studies, Subtelny first established that 72% of patients with normal swallowing and 40% of patients with tongue thrust did not have speech sound disorders, and then subsequently that 63% of patients with normal swallowing and 1% of patients with tongue thrust did not have speech sound disorders.[16]

Fieux (citing Szlachetko) published the results of cinematoradiographic studies on swallowing and speech.[17] Children with persistent tongue thrust touched their lower lip with the tip of their tongue when articulating most speech sounds, although it was not always audible, i.e., either the produced sound or the position of speech organs was improper. Rix and Cleall, who took cineradiographic images of the swallowing process, focused not only on improper tongue posture, but also on other structures, and came to similar conclusions.[18,19] Cleall established that persistent tongue thrust impacted the anatomy and motility of the stomatognathic system.[19] Horn et al., who studied improper swallowing with electromagnetic articulography, came to similar conclusions.[20]

In the present study, persistent tongue thrust concurred with errors in bilabial (/p/, /b/, /m/), alveolar (/t/, /d/, /n/, /s/, /z/, /t͡s/, /d͡z/), postalveolar (/ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/, /r/, /l/), and pre-palatal (/ɕ/, /ʑ/, /t͡ɕ/, /d͡ʑ/, /ɲ/) sounds. Straub, Subtelny as well as Clausnitzer and Clausnitzer described concurrent improper swallowing and errors in the /s/ sound.[4,16,21]

Oral breathing occurred 5 times more frequently in children with speech sound disorders than in children without speech sound disorders. This correlation was strong and statistically significant. Hitos et al. concluded that mouth breathing can affect speech development.[22] Zadurska et al. also established a correlation between mouth breathing and speech sound disorders.[11] However, the percentage of mouth breathing children with speech sound disorders was lower (59%) in the quoted studies than in the present study (82%).

The correlation between speech sound disorders and prolonged bottle feeding was statistically insignificant. Significance was much higher than 0.05 (0.246). This outcome is contrary to Straub's results, who established that artificial feeding (bottle with the wrong nipple) or prolonged bottle feeding in early childhood led to improper swallowing, improper tongue posture and speech sound disorders.[4] Subtelny obtained results similar to Straub's.[16] Also, Barbosa et al. suggested that extended use of bottle feeding and other sucking behaviors may have detrimental effects on speech.[23]

Conclusions

Functional disorders of the masticatory system, apart from teeth clenching, nail biting, prolonged bottle feeding, and lazy chewing, concur more often with speech sound disorders than with proper articulation, and are a material cause of speech sound disorders.

There is a strong correlation between: any type of dysfunction and errors in /p/, /b/, /m/, /s/, /z/, /t͡s/, /d͡z/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds; oral breathing and errors in /p/, /b/, /m/, /s/, /z/, /t͡s/, /d͡z/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds; persistent tongue thrust and errors in /s/, /z/, /t͡s/, /d͡z/, /ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds; and sucking habits and errors in /s/, /z/, /t͡s/, /d͡z/, /ʂ/, /ʐ/, /t͡ʂ/, /d͡ʐ/, /ɕ/, /ʑ/, /t͡ɕ/, and /d͡ʑ/ sounds.

Knowledge on functional correlations between the masticatory system and speech sound disorders makes it possible to introduce effective prevention and treatment at the right moment. Dentists and speech therapists could work together, understanding the correlation between the structure and the function of the stomatognathic system, and focusing on the causes of speech sound disorders and concurrent dental disorders. It could shorten treatment duration and minimize the risk of relapse after the treatment's conclusion.

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Spectrophotometric evaluation of 5-layer acrylic teeth hyperpigmentation caused by selected food colors: In vitro study

Spektrofotometryczna ocena przebarwień wywołanych wybranymi barwnikami spożywczymi na 5-warstwowych zębach akrylowych – badanie in vitro

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Abstract

Background. Prosthetic treatment restores proper chewing function and facial aesthetics, and enhances the quality of life. The overall aesthetic result of the use of removable prostheses is correlated with the type of artificial teeth used and with the maintenance of aesthetic effect and color stability.

Objectives. The aim of the study was to evaluate the formation and intensity of discoloration caused by the dyes present in selected 5-layer acrylic teeth.

Material and methods. The study material was a group of 90 5-layer acrylic teeth. Samples were immersed in black tea and dry red wine for 6 months. The control group was immersed in distilled water and consisted of 30 samples. The teeth were subjected to spectrophotometric examination at the start of the study, after 24 h, 7 days, 14 days, 1 month, 4 months, and 6 months.

Results. Among the teeth examined, in about 85% of the samples the color corresponded with the order. Teeth immersed in black tea became darker. From the 7th day to the 6th month, none of the samples changed their brightness. The teeth had the same degree of brightness. The teeth did not change tone during the experiment. Teeth immersed in dry red wine changed their shade to A starting on the 14th day, and by the 4th month all samples had changed shade to A or C. The 5-layer teeth had quite high shade stability until the 14th day of observation. In the control group, the teeth did not change tone and individual brightness changed more in the direction of brighter shades and less in the darker direction. In the study group, 93% of the samples did not change their brightness.

Conclusions. Both black tea and dry red wine cause tooth discoloration, more intensely in the case of the 2nd fluid. Acrylic teeth with a 5-layer structure ensure good color stability over time. It improves the quality and aesthetics of the restorations used.

Key words: spectrophotometry, acrylic resins, artificial teeth

Słowa kluczowe: spektrofotometria, tworzywa akrylowe, sztuczne zęby

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Prosthetic treatment restores the proper function of the masticatory system and facial aesthetics, and also affects the improvement of the quality of life. The main aim of the dentist is to combine science and art to achieve the optimal functionality and aesthetic effect, which allows the natural look and feel of attractiveness to be restored. Four basic determinants affect the aesthetics of the prosthetic restoration: position, contour, texture, and color of the teeth. Although color is not an important factor affecting denture function, from the physiological point of view, it can have a decisive influence on the process of acceptance. Aesthetics in clinical dentistry offers almost unlimited and exciting challenges for practitioners. In our society, it is believed that appearance significantly affects professional and personal success. It is increasingly expected from the dentists to improve also the smile and appearance of the patient. Knowledge of the concept of color and understanding the nature of light, perception and interpretation of the image is crucial to achieve therapeutic success. Of the many different elements that influence the perception of image, color is considered the most important factor.[1–13]

The overall aesthetic result in treatment with the use of removable dentures is significantly correlated with the type of artificial teeth used and their color stability. Color stability, i.e., retaining color in a specific environment, is an important property of many materials used in dentistry. The use of artificial teeth made of acrylic resin is common due to their beneficial properties, good binding to the prosthesis, low weight, and low fracture rate. Conventional acrylic teeth also have a number of disadvantages, such as poor aesthetic effect, higher wear and susceptibility to discoloration. In order to overcome these problems, manufacturers have introduced numerous modifications that result in the improvement of the quality of acrylic teeth.[14,15]

Discoloration of acrylic resins can be caused by many factors. Internal factors, such as the degree of conversion and amount of residual monomer, can affect the color stability. Another possible source of color change is porosity. The color stability of acrylic teeth is associated with eating habits. It has been reported that some beverages, such as coffee, tea and wine, and the effects of cleaning agents, tobacco, saliva composition, and hygiene habits, can cause discoloration. Changing the color of the resin can lead to aesthetic problems. In order to minimize the color change, it is necessary to choose the right materials from which the artificial teeth are made.[15,16]

The aim of the study was to assess the formation and intensity of discolorations of acrylic 5-layer teeth induced by the dyes present in selected food products.

Material and methods

The research material consisted of a group of 90 ready-made 5-layer acrylic teeth (medial upper incisors) in B3 color (according to information provided by the manufacturer) (Ivoclar Vivadent AG, Liechtenstein). The research material was divided into 3 equal groups:

– group 1 – samples immersed in distilled water as a control group (30 samples),
– group 2 – samples immersed in black tea (30 samples),
– group 3 – samples immersed in dry red wine (30 samples).

Each specimen was marked individually by engraving a number from 1 to 30 in each test group on the side of the acrylic tooth, which allowed fully repeatable measurements.

The teeth from the 1st group, constituting the control group, were immersed in distilled water. Teeth from the 2nd group were immersed in black tea. The tea solution was obtained by immersing 5 pre-packaged black tea bags weighing 2 g each in 1000 mL of boiling distilled water for 10 min. After cooling to 37°C, the experimental solution was filtered through a filter paper.[17] The 3rd group of samples was immersed in dry red wine.

The material was immersed for 6 months in the fluids in closed containers and stored at room temperature (22–24°C) in the absence of light.

The spectrophotometer SpectroShade Micro® (MHT Optic Research, Niederhasli, Switzerland) was used for the objective assessment of the degree of discoloration, which allowed analysis with reference to a standard determined according to the Vita colorant VITAPAN® Classical (Vita Zahnfabrik, Bad Säckingen, Germany).

The spectrophotometer calibration was 2-stage and included the positioning of the handle for white and green tiles. The system analyzed 3 basic components of color: brightness, saturation and color. The following aspects were also analyzed: transparency and transluminescence, base color and component color. A full color map of each tooth was also performed. Using a special scanner (SpectroShade Micro; MHT Optic Research, Niederhasli, Switzerland), a picture of the selected tooth was obtained. The device made it possible to obtain reproducible results by placing the analyzed tooth in a specific position on the device display. The measurement of each sample at the time of testing was performed 3 times on a matte black background, using intraoral attachments provided by the manufacturer. This procedure made it possible to create conditions similar to those in the clinical situation.

The individual color determinations were assigned numbers from 1 to 16, according to the decreasing brightness determined using the colorant. In total, 7 measurements were made: at the beginning of the study, after 24 h, after 7 days, after 14 days, after 1 month, after 4 months, and after 6 months. The analysis of the results was performed using STATISTICA PL software v. 12 (StatSoft, Tulsa, USA). Descriptive statistics and non-parametric tests, i.e., Pearson's χ^2 test and χ^2 NW were used to analyze the qualitative data. For quantitative data analysis, parametric t-tests and a Tukey's honest significant difference test were conducted. Normal distribution of variables was tested using Shapiro-Wilk test and Levene's test. The significance level was set at $p = 0.05$.

Results

Change in the color of the teeth subjected to the influence of particular liquids

Color change of teeth in distilled water

At the beginning of the experiment, the control group of 5-layer teeth was found to be in the B3 color given by the manufacturer in 94.44% of cases. A statistically significant change in color occurred after 14 days ($p = 0.044869$) and after 1 month. In the remaining stages of the experiment, the color changed to a slightly lighter one, but these changes were not statistically significant. At all stages, the 5-layered teeth were in the B3 (87.78–98.89%) and B4 (1.11–12.22%) colors. None of the samples changed the color tone. The change of sample brightness in distilled water during the experiment is shown in Table 1.

Table 1. Number of samples that changed brightness in distilled water during the experiment

Time	No change	Brighter	Darker
24 h	88	2	0
7 days	85	4	1
14 days	86	4	0
1 month	86	4	0
4 months	84	4	2
6 months	84	4	2

Color change of teeth in black tea

At the beginning of the experiment, in the group of teeth immersed in black tea, the B3 color given by the manufacturer was noted in 84.44% of cases. The rest of the group was in the B4 color (15.56%). After 24 h, none of the samples changed color. After 7 days of the experiment, all samples reached the B4 color and did not change it later. The color from the initial period point compared to the other stages differed significantly ($p = 0.0000$). The change in sample brightness in black tea during the experiment is shown in Table 2.

Table 2. Number of samples that changed brightness in black tea during the experiment

Time	No change	Brighter	Darker
24 h	90	0	0
7 days	14	0	76
14 days	14	0	76
1 month	14	0	76
4 months	14	0	76
6 months	14	0	76

Color change of teeth in dry red wine

At the beginning of the experiment, the B3 color given by the manufacturer was reported in 76.56% of cases. The rest of the group was in the B4 color (24.44%). After 24 h, the percentage of samples in the B3 color dropped significantly (62.22%) ($p < 0.05$). After 7 days, the group entirely turned into the B4 color. After 14 days, the percentage of the B4 color (86.87%) decreased, but new colors, A3.5 and A4, appeared (each color 6.67%). After 1 month, the percentage of samples with the B4 color decreased (47.78%), while the A3.5 (22.22%) and A4 (30%) colors increased their share. After 4 months, the B tone disappeared and there were only 2 colors, A4 (88.89%) and C4 (11.11%). After 6 months, there were still only 2 colors, A4 (74.44%) and C4 (25.56%). At each of the examined stages, statistically significant changes occurred compared to the previous stages ($p < 0.05$). The change in brightness of samples immersed in dry red wine during the experiment is shown in Table 3. The percentage distribution of shades in the test group immersed in dry red wine over the duration of the experiment is shown in Fig. 1.

Table 3. Number of samples that changed brightness in dry red wine during the experiment

Time	No change	Brighter	Darker
24 h	78	0	12
7 days	22	0	68
14 days	22	0	68
1 month	20	0	70
4 months	0	0	90
6 months	0	0	90

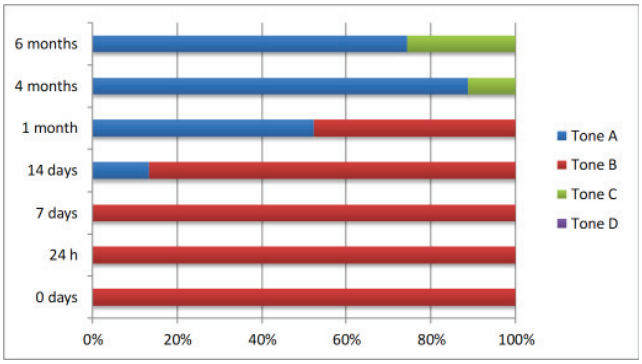

Fig. 1. Percentage distribution of shades in the group immersed in dry red wine during the experiment

Comparison of the ability of the tested fluids to cause discoloration

At the beginning of the experiment, the teeth differed statistically significantly in terms of the degree of color between the distilled water group and the wine group ($p < 0.05$).

At the 24 h stage, the effect of the wine was significantly stronger than the influence of tea or distilled water on teeth color ($p < 0.05$), and the influence of tea and the effect of distilled water on the color of teeth was similar ($p > 0.05$). After 7 and 14 days, the influence of distilled water was the smallest ($p < 0.05$). In the remaining stages, the influences of individual factors were significantly different ($p < 0.05$); the smallest in case of distilled water, the largest in case of dry red wine. The percentage distribution of average values of the degree of brightness for particular solutions during the experiment is presented in Fig. 2.

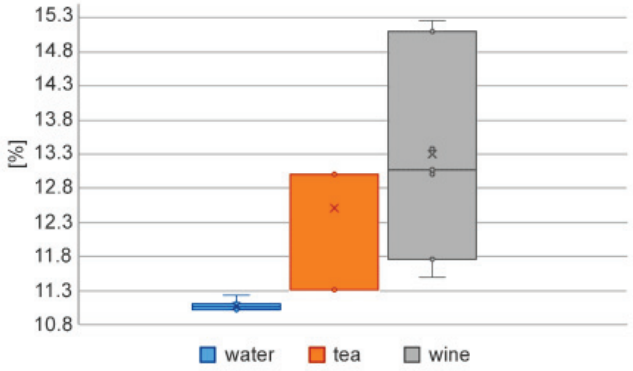

Fig. 2. Average brightness values depending on the solution used

Discussion

The color and appearance of teeth is a complex phenomenon depending on many factors, such as: transparency, lighting conditions, smoke, light scattering, and gloss. The human eye and brain also affect the overall perception of tooth color. Visual perception can be disturbed by various factors, such as: lighting conditions, gingival color and the closest surroundings, as well as by the type and shape of the used colorant and its position relative to the tooth.[1,6,7,12] Discoloration of dental materials, including acrylic teeth used in removable dentures, can be assessed visually or by means of spectrophotometric analysis.

Five-layer teeth, according to the manufacturer, are made of 5 layers of different translucency, without the use of additional fillers, thanks to which they give a metameric effect, causing them to be perceived as natural teeth. The use of 5-layer acrylic teeth allows a highly-valued so-called chameleon effect to be obtained. They are characterized by very high durability, wear resistance and biocompatibility. If there is not enough space in the bite, when the dental technician has to make a correction, the 5-layer teeth still retain their color and translucency. These teeth are characterized by a 40% lower absorption (absorption of moisture by acrylic), with 56% less discoloration caused by food and liquids. They have a higher wear resistance compared to the average values of other acrylic teeth.

The study material was a group of 90 5-layer acrylic teeth. The samples were immersed in food liquids, i.e., black tea (30 samples) and dry red wine (30 samples), for 6 months. The control group immersed in distilled water also consisted of 30 samples of 5-layer acrylic teeth.

Among the examined 5-layer teeth, in approx. 85% of the samples the color of the delivered teeth corresponded with the color of the order. Five-layer teeth immersed in black tea mostly became darker. From the 7th day and up to the 6th month, none of the samples changed their brightness. The teeth had the same degree of brightness and did not change their tone during the experiment. Five-layer acrylic teeth immersed in dry red wine changed shade to A starting on the 14th day, and by the 4th month all samples had changed their shade to A or C. Five-layer teeth showed fairly high shade stability up to the 14th day of observation (Fig. 1). The teeth did not change tone in the control group; in this group, there were individual changes in brightness towards lighter shades and slightly weaker towards darker ones. In the above study group, 93% of the samples did not change brightness (Table 1).

The research shows that both black tea and dry red wine cause the discoloration of acrylic teeth, which is more intense in the case of the 2nd liquid. These results are consistent with other studies performed in vitro.[18,19] Black tea has the ability to induce yellow discoloration and red wine changes the color of the teeth to a cyanotic shade.[18] This phenomenon is also confirmed by our own results. Dark brown, easy to remove sediment appeared on the samples immersed in black tea. The combination of dietary chromogens found mainly in tea can cause surface precipitation reactions without the formation of metal sulfides. Both the concentration of the colorant and the exposure time can affect the degree of discoloration of acrylic resin.[20–25] The surface structure also determines the amount and direction of light reflection. With a smoother surface, the tooth appears brighter. The dyeing of acrylic resins is also dependent on the contact angle and water sorption. The higher the contact angle and lower the water sorption, the lower the tendency to become discolored. These parameters are related to the smoothness of the surface and the porosity. A lower porosity of the surface also reduces the degree of sorption of food dyes. Greater smoothness has a positive effect on increasing the contact angle.[20]

In conclusion, this research confirmed that both black tea and dry red wine cause the discoloration of acrylic teeth, which is more intense in the case of the 2nd liquid. Acrylic teeth with a 5-layer structure provide good color stability over time. This has a positive effect on the quality and aesthetics of the prosthetic restorations used.

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Factors associated with insufficient removable partial denture design instructions

Czynniki warunkujące niepełny przepływ informacji między lekarzem stomatologiem a technikiem podczas projektowania ruchomych częściowych uzupełnień protetycznych

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Abstract

Background. The design of removable partial denture (RPD) has an important role in the health of dental and periodontal tissues. Dentists are responsible for the design since designing it requires mechanical and biological considerations. There is lack of literature focusing on the behavior of dentists in Turkey concerning the design of RPDs.

Objectives. This study aimed to assess the capability of dentists to transfer RPD design information to dental laboratories, and to determine the factors playing a role in the designing or transferring the design information.

Material and methods. A questionnaire was distributed to 25 dental laboratories in all geographical regions of Turkey. Design instructions of RPD provided by dentists using a prescription form, phone call and internet were examined. Clinic type, communication method, way of showing design information, and specialization in prosthodontics were recorded to investigate their association with design information. The data was analyzed with descriptive statistics and χ^2 test.

Results. Approximately 2/3 of the dentists did not mention any design information in the instructions. Laboratory prescription form was the most frequently used communication method. Design features were mostly indicated in diagrams. The ratio of indicating design information was higher among prosthodontists. Over a half of the dentists who mentioned design information in their instructions were from private dental clinics. The dentists who preferred both writing and drawing for showing design specifications had the highest ratio of showing rest type, clasp location and rest location in their instructions.

Conclusions. The majority of dentists do not mention any design information. Expertise in prosthodontics and type of dental institution affect the content of the design information. Showing design features in more than 1 way seems to increase the amount of design items. Training dentists in aspects of RPD design and evaluating the circumstances of clinics is essential.

Key words: removable partial denture, denture design, dental laboratory

Słowa kluczowe: ruchome częściowe uzupełnienie protetyczne, projekt protezy, laboratorium dentystyczne

Removable partial denture (RPD) is a comparatively economical and noninvasive option for prosthetic rehabilitation of partial edentulism.[1] The design of RPD has an important role in the health of dental and periodontal tissues and the stability of the denture.[2–4] Designing an RPD necessitates mechanical and biological considerations, and requires clinical examination. Because of this concern, dentists are responsible for the RPD design as an ethical obligation.[5–8] A proper transfer of design information to the dental laboratory provides increased professional quality assurance in an RPD service.[5]

Successful transfer of information regarding the details of prostheses to the dental technician plays an essential role in maintaining high quality of the prostheses.[1,5] Methods of communication between dentist and technician are: authorization form,[8–10] telephone call,[8,9] e-mail,[9] web-based communication,[10,11] and text messaging.[9] A growing body of literature has examined communication between the dentist and laboratory for fixed partial dentures and RPDs. Most of these studies have focused on the choice of impression trays and materials[1,7,12–14] as well as quality of the written prescriptions.[1,7,8,12–20] The studies that investigated the quality of the written prescriptions considered the following items: personal data of the patients,[17–20] submission and completion date,[16–18,20] fee,[20] shade of teeth,[16–20] material selection for prostheses,[16–18] design information,[7,8,13,16,17,19,20] and quality of the prescription (assessed as clear, a guide, poor, or none).[1,7,12–17]

According to the results of these investigations, the quality of the written prescriptions was often reported as poor[1,7,13,14,17,19] and design of the prostheses was often delegated to the technician.[1,7,8,13–17,19,20]

Most studies about the communication concerned the quality of prescriptions. However, there is still a need for discussion on probable factors that may be responsible for delegating the design to the technician. Also, there is a lack of research addressing information on RPD design given by dentists in Turkey.

The first aim of this study was to investigate to what extent dentists in Turkey provide the dental technicians with adequate design information. The second aim was to determine whether there is a correlation between some conditions (professional training, type of dental institution, communication method, way of indicating design features) and adequacy of design information. A structured questionnaire on RPD design was developed for this study.

Material and methods

The target population of the study was identified as all members of dental technician unions or associations located in the 5 most populous cities in each of 7 geographical regions of Turkey (Aegean, Black Sea, Central Anatolia, Eastern Anatolia, Marmara, Mediterranean, and Southeastern Anatolia). In Turkey, the dental technician associations and unions are independent institutions located in different cities. However, not all cities have such an institution. The laboratories located in the cities which do not have such an institution as well as the laboratories who did not fabricate RPDs were excluded from the study. Finally, the number of laboratories included in the study was 1 in the Aegean region, 2 in the Black Sea region, 3 in Central Anatolia, 1 in Eastern Anatolia, 2 in the Marmara region, and 2 in the Mediterranean region.

A pilot questionnaire was developed by the author to determine the adequacy of communication between dentists and dental laboratories in Turkey for RPD design and to examine probable factors affecting the adequacy of such communication. The pilot questionnaire was delivered to 7 dental laboratories, each located in a different geographical region, via e-mail. One-hundred seventeen pilot questionnaires were returned. A 6-item final questionnaire was designed to clarify the quantity and quality of design instructions from various categories of dentists and delivered to the target population with an invitation letter (Fig. 1).

Item No.	Please answer the questions below for each cast removable partial denture case
1	Where did you receive the instructions from? dental office ( ) private dental clinic ( ) state dental clinic ( )
2	Who did send the instructions? general dentist ( ) prosthodontist ( )
3	Was there any design information? yes ( ) no ( )
If the answer is "no", terminate the questionnaire.	
4	How did you receive the instructions? phone call ( ) internet (mail/web site) ( ) laboratory prescription form ( )
If the answer is "phone call", terminate the questionnaire.	
5	What was the format of design information written ( ) drawing (cast/paper) ( ) written and drawing ( ) diagram ( )
6	Which one(s) of the following were indicated? type of major connector ( ) type of clasps ( ) location of clasps ( ) type of rests ( ) location of rests ( )

Fig. 1. Questionnaire

Communication methods between dentists and dental technicians, including prescription forms, phone calls and internet messages, were examined. However, instructions from the dentist to the technician by phone call is not a reliable way of communicating, because oral instructions are liable to be subjectively interpreted. Consequently, such instructions were regarded as "no instructions" in the statistical analyses.

The survey was carried out within a time window of 2 months. The collected data was analyzed with descriptive statistics and then with χ^2 test (SPSS v. 20 software; IBM Corp., Armonk, USA). Values of $p < 0.05$ were considered statistically significant.

Results

Eleven laboratories refused to participate in the study. Inconsistent responses from 2 laboratories were excluded. A total of 747 questionnaires were received from 25 laboratories from 8 cities (response rate = 66%). Distribution of responses according to cities and geographical regions is shown in Table 1.

The majority of RPD orders were from state dental clinics (60.8%) and general dentists (83%). Only 37.5% of the dentists gave design instructions to the dental technicians as they were sending a master model or impression to the laboratory for RPD metal substructure casting. Filling a prescription form (85.7%) was the most frequently preferred communication method to communicate with the technician and a diagram was the most preferred choice to indicate the design features (47.1%). The type of clasp was the most common specification among design details (67.8%) (Table 2).

Whereas 57.5% of the prosthodontists specified design information, only 33.4% of the general practitioners did so (Fig. 1). This difference was statistically significant ($p < 0.001$).

Dentists from private dental clinics (56.9%) were more likely to send RPD design information to a dental laboratory compared to dentists from dental offices (34.9%) and state dental clinics (36.3%) ($p = 0.006$) (Fig. 2).

Table 1. Distribution of survey responses

Geographical region	City	Number of responses	Number of laboratories
Aegean	İzmir	65	4
Black Sea	Ordu	78	3
	Zonguldak	282	5
Central Anatolia	Ankara	229	6
	Eskişehir	18	1
Eastern Anatolia	Elazığ	33	2
Marmara	Istanbul	22	2
Mediterranean	Mersin	20	2
Total		747	25

Table 2. Distribution of answers to the questionnaire

Questions	Answers	n	%
Institution	dental office	235	31.5
	private dental clinic	58	7.8
	state dental clinic	454	60.8
Dental practitioner	general dentist	620	83
	prosthodontist	127	17
Design information	available	280	37.5
	not available	467	62.5
Communication method	phone call	25	8.9
	internet (mail/web site)	15	5.4
	prescription form	240	85.7
Format of design information	written	53	20.8
	drawing	47	18.4
	written and drawing	35	13.7
	diagram	120	47.1
Design specifications	type of major connector	120	52.9
	type of clasps	173	67.8
	location of clasps	94	36.9
	type of rests	42	16.5
	location of rests	96	37.6

n – number of responses.

No significant correlation was identified between the method of providing design information and specification of the major connector ($p = 0.174$) and clasp type ($p = 0.124$). The correlation between the method of providing design information and specifying rest type, clasp location and rest location was statistically significant ($p < 0.001$ for rest type; $p = 0.002$ for clasp location;

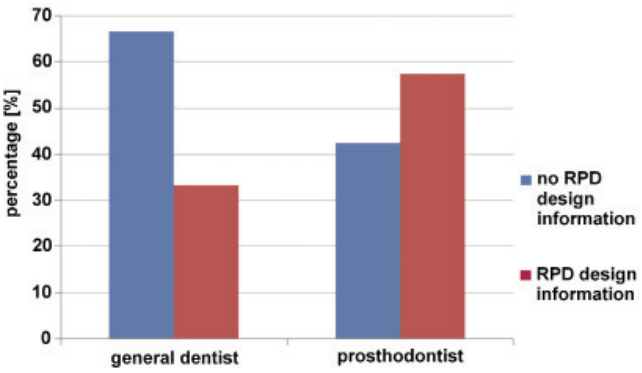

Fig. 1. Relationship between RPD design information and expertise

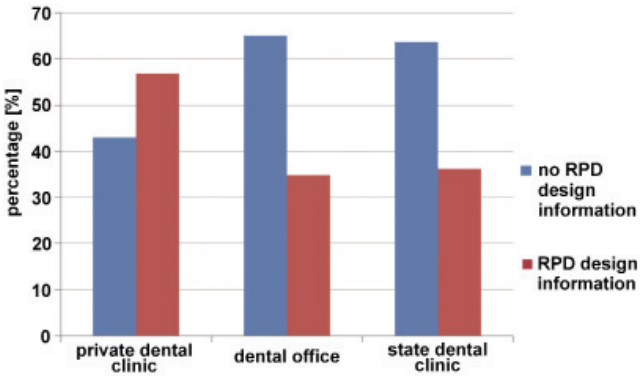

Fig. 2. Relationship between RPD design information and the type of clinic

$p < 0.001$ for rest location). The prescription forms which included both written statements and drawn instructions had a higher ratio of data about rest type (48.6%), clasp position (62.9%) and rest position (71.4%).

Discussion

Clear communication between the dentist and dental laboratory is an essential component of proper and high-quality prosthetic rehabilitation.[5] The present results indicate that the most common communication method between the dentist and the dental technician was a laboratory prescription form (85.7%). This result is similar to the findings by Haj-Ali et al. in the United Arab Emirates.[8] The role of RPD design in the success of the denture is an accepted fact.[2,21,22] The results of this study showed that 62.5% of the dentists offered no design information when they sent a master model or impression to the laboratory for RPD fabrication. This result is higher than the findings of Kilfeather et al. (54%, England, Ireland and Wales), Radhi et al. (57%, Bahrain) and Pun et al. (42%, Wisconsin, USA).[1,13,23] In contrast, Haj-Ali et al. reported that 89.5% of laboratory prescriptions in the United Arab Emirates rarely or never provided design information.[8] Lynch and Allen attributed inadequate design instructions to deficiencies in the vocational training of dentists.[7] A similar conclusion may be drawn as a result of this study because of the positive correlation found between specialization in prosthodontics and design instructions. Higher professional education seems to have positive effects on dentists' awareness of the importance of RPD design information sent to the dental technicians. In view of the fact that the percentage of prosthodontists was only 17%, the ratio of providing design information would be higher if more prosthodontists had contributed to the survey.

Most studies have determined the quality of RPD design instructions according to the scores given by technicians as "clear, a guide, poor, none".[1,7,12–17] This kind of scoring may lead the technician to decide in a subjective manner. In the current study, to reduce the subjectivity of the technician, a question about RPD design elements was included. Details regarding type of the major connector was found in 52.9% of the instructions, which is lower than reported by Kilfeather et al. (62%) and Sui et al. (88%).[1,19] In this study, detailed information about type of clasp was present in 67.8% of the instructions and location of clasp was found in 36.9%. Sui et al. reported that 90% of the instructions included clasp design.[19] Kilfeather et al. reported that 39% of direct retainers were described in the prescriptions.[1] In this study, only 16.5% of the instructions showed type of rest and 37.6% of the instructions showed location of rest. Radhi et al. found that the percentage of the prescriptions regarding denture base, clasp design, rest design, and connector was 43% with 4 variables, 43% with 3 variables, 14% with 2 variables, and 43% with 1 variable.[13]

Dentists who work in private dental clinics more frequently gave design specifications than dentists who work in dental offices and state dental clinics. Further data collection is required to determine exactly how the type of clinic affects such information. One explanation why the design was not communicated to the dental technician might be excessive workload, causing the dentist to refrain from taking the necessary time to do so. Conditions of dental institutions may also lead lower percentages of details regarding major connector and clasp than similar studies mentioned above.

The ways dentists convey the design information to dental technicians was another issue examined in this research. The annotation document, which included both written statements and drawn instructions, had a higher ratio of data about rest type, clasp position and rest position. This could be attributed to the fact that more than 1 way of communicating was used, which might have motivated the dentist to give more details. However, in these documents, lack of specification of other RPD design features is still questionable. The results regarding the effect of the type of clinic and the way the design information was conveyed raises the question whether the problem is incompetence in designing the RPD or inadequacy in transferring design information. Further studies are needed to recognize the difference between the incapability of the dentist of making an appropriate RPD design and his/her incapability of transferring the design information to a laboratory even when he/she has adequate knowledge.

In this study, the results from the 8 cities were not analyzed separately. Further research may be undertaken including analyses of data for each city and comparison of the results among different localizations. However, dentists who work in a village/city lacking an RPD producing laboratory may post casts and instructions to other cities. This might influence the results.

Since a laboratory prescription form was the preferred communication method (85.7%), the relevance between quantity of design specifications provided by dentists and the contents of present laboratory prescription forms can be researched in another study. Elaborating the contents of the form may encourage dentists to give more details about RPD design. Also, a diagram was the preferred choice to indicate the design features (47.1%). Improved diagrams with more details may enable dentists to show more design features.

Conclusions

This study evaluated instructions for 747 RPDs made at 25 dental laboratories in 8 cities located in different regions of Turkey. More than a half of the dentists did not provide any design information. More prosthodontists than general dentists provided design information. The type of dental institution where the dentist works seems to have an effect on providing design information to the

laboratory. Written and drawn design information is associated with better design specifications. This research can serve as a basis for future studies examining the determinants of poor RPD design information.

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Use of the Explicit Health Guarantee of Oral Health Care for Pregnant Women at a Family Health Center, Concepción, Chile, 2014–2015

Zastosowanie Programu Gwarancji dla Zdrowia Jamy Ustnej w Opiece nad Kobietą w Ciąży w Rodzinnym Centrum Zdrowia w Concepción, Chile, w latach 2014–2015

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Abstract

Background. Oral health plays a crucial role in general health, quality of life and well-being of pregnant women and their newborns. In Chile, pregnant women have dental care guaranteed by law. However, due to the lack of previous epidemiological studies on the benefits of this guarantee, it is necessary to describe this situation and evaluate the need to change the methods of providing dental services.

Objectives. The objective of this study was to describe the pattern of providing dental benefits resulting from the Explicit Health Guarantee – Integral Oral Health in Pregnant Women (GES-SOIE) program to pregnant women attending the Juan Soto Fernández Family Health Center, Concepción, Chile, in 2014–2015.

Material and methods. A cross-sectional study of the electronic dental records of patients admitted to GES-SOIE was conducted. The variables studied were sociodemographic data, dental chair hours, non-attendance, treatment completion, and the type of referral to secondary healthcare (SHC).

Results. Of 233 pregnant women, 65.2% were registered for non-attendance, 21.2% required referral to SHC and 76.4% completed their treatment. When performing logistic regression, it was found that for each non-attendance the chance of not completing the treatment increased 1.4 times.

Conclusions. The level of non-attendance and opting out of the treatment in pregnant women is high, which hinders the proper functioning and effectiveness of GES-SOIE.

Key words: pregnant women, dental care, dental health services

Słowa kluczowe: kobiety w ciąży, opieka dentystyczna, świadczenia dentystyczne

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Oral health plays a crucial role in general health, quality of life and well-being of pregnant women and their newborns.[1–2] It is known that the oral cavity is affected by the multiple changes that occur during pregnancy, increasing the predisposition to periodontal diseases, induced by bacterial plaque and exacerbated by the release of steroid hormones.[3–7] In addition, a decrease in salivary pH and the buffer effect, together with diet changes, lead to an increase of cariogenic risk.[8–10]

The association between periodontal disease and premature birth, low birth weight and preeclampsia has been established. On the other hand, active caries in pregnant women is a risk factor for the development of early childhood caries in their future children. Thus, proper oral healthcare of pregnant women is essential, with the intention of reducing both these adverse effects during pregnancy and the transmission of cariogenic bacteria to the infant.[1] This is why the state of pregnant women's oral health is considered a public health problem.

Given the above, in Chile in 2010, the Integral Oral Health in Pregnant Women program (GES-SOIE) was introduced within the Explicit Health Guarantees (GES).[11] GES is a Chilean health public policy that constitutes a set of benefits guaranteed by law for people affiliated with the National Health Fund (FONASA), a public body with state funding, and the Health Insurance Institutions (ISAPRE), which from a private health insurance system. Users receive appropriate treatments, with financial support, for health problems that fall within the GES scope, with certified quality and in terms guaranteed by law.[12] Specifically, GES-SOIE provides dental care aimed at educating, preventing, recovering, and rehabilitating oral health, thus contributing to the formation of a healthy environment that promotes and protects oral health.[11]

For FONASA affiliates, GES-SOIE is comprised of free primary oral healthcare, including preventive and restorative treatment, performed by general dentists at Public Family Health Centers (CESFAMs), and secondary oral healthcare, which includes specialty treatment and is generally performed in referral centers by specialty dentists.[11,12] Unfortunately, according to the findings of Núñez et al., only 31% of pregnant women were receiving dental care, which shows the underutilization of GES.[13]

Due to the lack of previous epidemiological studies on the delivery of the benefits of GES, it is necessary to describe this situation and evaluate the need to change the approach in providing dental services. Therefore, the objective of this study was to describe the pattern of providing of the dental benefits of GES-SOIE to pregnant women attending the Juan Soto Fernández CESFAM, Concepción, Chile, in 2014–2015.

Material and methods

A cross-sectional study was carried out based on the dental electronic records of pregnant women admitted to GES-SOIE. Approval was obtained from the Commission of Research and Bioethics of the Faculty of Dentistry of the University of Concepción, Chile, and the Scientific Ethics Committee of the Concepción Health Service.

The population of interest was composed with the use of dental electronic records of the entire group of pregnant women, belonging to Juan Soto Fernández CESFAM, between 2014 and 2015 (237 records). Four incomplete electronic records, and those of patients who at the time of data collection were still during treatment, were excluded. The variables studied were sociodemographic data, number of dental appointments undergone, non-attendance, treatment completion, referral to secondary healthcare (SHC), and the type of referral. Data collection was performed by 2 researchers between May and June 2016, and the data was registered in Microsoft Excel v. 2013 (Microsoft, Redmond, USA).

A univariate analysis was carried out, using frequency tables, summary measures (central tendency and dispersion) and relevant graphs. Then, a bivariate analysis was performed with summary measures, contingency tables and grouped bar charts. Finally, to study the relationship between qualitative variables, Spearman's correlation test was applied. Furthermore, logistic regression and an analysis of maximum sensitivity and specificity were carried out. The analysis of the data was performed with the InfoStat v. 2014 software (InfoStat, Córdoba, Argentine). This is a census study, thus no statistical significance was calculated.

Results

From a total of 233 records analyzed, the largest amount of admissions was in 2015 (59%), with an average patient age of 26.5 years. From the total number of pregnant women, 65.2% had at least 1 non-attendance with a maximum of 12 non-attendances registered. Of the patients referred to SHC, 78.8% required only 1 specialty treatment. Within the referrals, the specialties of endodontics and surgery comprised 85.7% of total referrals (Table 1).

Between 2014 and 2015, 1,293 dental appointments were requested, of which 34.8% resulted in non-attendances. From a total of 843 appointments executed in pregnant women covered by the GES-SOIE plan, 74.9% were in the case of patients who completed their dental treatment (Table 2).

Pregnant women referred to SHC required an average of 5.7 appointments to complete their dental treatment, and those not referred to SHC required an average of 3.1 appointments. No correlation was found between the age of the patients, and the number of appointments executed and the number of absences (Spearman's correlation coefficient –0.09 and –0.12, respectively).

Table 1. Characterization of pregnant women admitted to GES-SOIE, 2014–2015

Pregnant women		15–24 years old (%)	25–34 years old (%)	35–44 years old (%)	Total (%)
Year of admission	2014	45 (46.4)	39 (40.2)	13 (13.4)	97 (100)
	2015	60 (44.1)	53 (39.0)	23 (16.9)	136 (100)
At least 1 non-attendance		77 (73.3)	56 (60.9)	19 (52.8)	152 (65.2)
Dental treatment completion		79 (75.2)	72 (78.3)	27 (75.0)	178 (76.4)
SHC referral		22 (21.4)	17 (18.5)	10 (27.8)	49 (21.2)
Type of referral	endodontics	16 (15.2)	11 (12)	8 (22.2)	35 (15.0)
	surgery	8 (7.6)	4 (4.3)	1 (4,3)	13 (5.6)
	removable prosthesis	0 (0)	3 (3.3)	4 (11.1)	7 (3.0)
	periodontics	0 (0)	0 (0)	1 (2.8)	1 (0.4)
Dental appointments requested per pregnant woman*	1–5 appointments	58 (55.8)	51 (55.4)	24 (66.7)	133 (57.3)
	6–10 appointments	31 (29.8)	30 (32.6)	8 (22.2)	69 (29.7)
	>10 appointments	15 (14.4)	11 (12.0)	4 (11.1)	30 (12.9)

GES-SOIE – Explicit Health Guarantee – Integral Oral Health in Pregnant Women; SHC – secondary healthcare; * attendance + non-attendance.

Table 2. Distribution of appointments requested by pregnant women admitted to GES-SOIE, 2014–2015

Appointments	Age range			Total
	15–24	25–34	35–44	
Appointments undergone* (average number of appointments per pregnant woman)	396 (3.8)	327 (3.6)	120 (3.3)	843 (3.6)
Appointments undergone per dental treatment completion** (average number of appointments per pregnant woman)	308 (3.9)	249 (3.5)	83 (3.1)	640 (3.6)
Number of non-attendances*** (average number of appointments per pregnant woman)	216 (2.8)	185 (3.3)	49 (2.6)	450 (3.0)

GES-SOIE – Explicit Health Guarantee – Integral Oral Health in Pregnant Women; * total number of appointments undergone with and without dental treatment completion; ** total number of appointments undergone per pregnant woman that completed her dental treatment; *** total number of non-attendances with and without dental treatment completion.

When performing logistic regression with the event "completing the dental treatment" and the number of non-attendances as a predictor, it was found that for each absence, the chance of not completing the dental treatment increased 1.4 times. This did not change when controls for the age variable were applied. When carrying out an analysis of maximum sensitivity and specificity for the outcome of the event "not completing the dental treatment", we found a cut-off value close to 3 absences (receiver operating characteristic (ROC) curve area = 0.663 ±0.047; p = 0.0003) (Fig. 1).

Discussion

Regarding the data obtained in this study, approx. a quarter of pregnant women admitted to GES-SOIE did not complete their treatment. In addition, more than half of this population had repeated absences. This situation unnecessarily extends treatment time, since, according to the results obtained, around the 4th appointment, the pregnant patient should have had her treatment completed, with only a small percentage of patients requiring referral to a specialist.

A similar scenario was reported by Núñez et al., who showed that 69% of Chilean pregnant women did not receive dental care, which is in contrast to the observations by Fuentes-Fernández, who reported that 98% of pregnant women believed that it was necessary to consult the dentist during pregnancy.[13,14] This is a worrisome situation because, according to national data, the oral health status of Chilean pregnant women is poor, with 38.1% of women between 17 and 24 years of age being partially edentulous, increasing to 65.5% in the case of women 25–44 years old.[11]

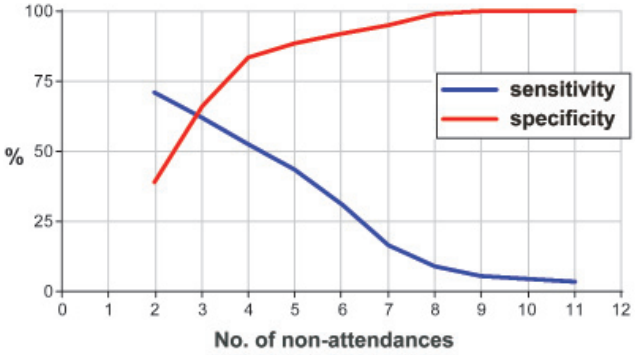

Fig. 1. Maximum analysis of sensitivity and specificity for dental treatment completion

Regarding the referrals, unlike in the report by Norambuena-Suazo and Palma-Cárdenas where 7 pregnant women required referral to periodontal treatment, in our study only 1 pregnant woman required such referral.[7] This difference may be due to our study design, using a secondary data source, in addition to the non-registration of a periodontal examination, in contrast with the Norambuena-Suazo and Palma-Cárdenas's study, where a primary data source was used and the data was, collected by calibrated examiners using the Community Periodontal Index of Treatment Needs (CPTIN).[7]

Every time a pregnant woman misses her dental appointment, the risk of not completing the dental treatment increases, which is why it is recommended that local interventions be carried out (rescue, phone calls, motivating, etc.) regarding the patients who already have 2 non-attendances.

It should be pointed out that each dental appointment on the premises of CESFAM lasts 20 min; therefore, the 1,293 sessions delivered to pregnant patients correspond to 48 working days, that is, 2 months and 1 week. When calculating the number of absences into working days, they correspond to 23 8-hour workdays, time during which 1 of the 2 dental offices of CESFAM is not providing dental care to the rest of the community, because the appointment vacancies are filled by these patients who do not show up for their dental appointment.

The delivery pattern of GES-SOIE involves multiple variables. In this study, using a database made it possible to perform calculations and estimates regarding the use of GES, but it did not allow us to identify the reasons for non-attendance and treatment dropouts.

Since a similar scenario is present internationally, where most pregnant women do not request dental care, many studies have tried to identify the possible causes of this behavior.[15–19] As reported in Malaysia and Mexico, the main reasons why pregnant women do not request dental care are long waiting times in the clinics, lack of immediate dental care and economic factors.[15,16] However, although these problems would be resolved by GES, there is an underutilization of GES. It should be remembered that primary healthcare (PHC) in Chile is free and, as this is a health problem covered by GES, it categorizes pregnant women as a priority when requesting dental care, because they are included in the healthcare goals that must be met year after year in every CESFAM.[11]

Other possible causes of this underutilization could be the ignorance of the harmlessness of dental treatment during pregnancy, low oral health literacy, ignorance of the effect of oral health in pregnancy, and dental anxiety.[16–19] However, as Cantarutti et al. mention, international literature does not necessarily apply to Chilean reality, due to cultural differences and the characteristics of its health system.[20] We suggest performing prospective national studies with a larger sample size, in different health centers and with the incorporation of other variables, considering both quantitative and qualitative approaches, in order to recognize the barriers that are responsible for this pattern. Such information would be useful for an early identification of pregnant women at risk of absenteeism and GES-SOIE dropouts, as well as for designing strategies aimed at removing these barriers and improving care. This would allow for the improvement of oral health in pregnant woman, optimizing the limited resources of the public service.

Among the limitations of this study is the use of a secondary database, in which 4 incomplete records were noticed, and that the database could present other unperceived typing errors. In addition, the variability existing among professionals while completing of the electronic clinical records and the lack of standardization of the registry must be considered, as they made it impossible to analyze more variables, such as the Chronic Obstructive Pulmonary Disease (COPD) index and number of pregnancies, among others. Another limitation of this study is the representativeness of the population, with a restricted sample size, which represented only pregnant women who requested GES, and that the data was limited to a single CESFAM.

Dental care covered by GES-SOIE consists mainly of PHC services, with few referrals to SHC, so it could be inferred that it is possible to provide the majority of dental treatments in CESFAMs; however, the level of non-attendance and treatment dropouts is high, which hinders the proper functioning and effectiveness of GES.

In Chile, pregnant women have comprehensive dental care guaranteed by law. However, there are no records of the pattern of delivery of these dental benefits, regarding the number of absences and dropouts of the treatment. In the present study it was possible to quantify that 65.2% of the studied pregnant women presented absences and 23.6% did not complete their dental treatment. Identifying this underutilization highlights the need to design strategies aimed at optimizing the limited resources of the public service. It is also necessary to identify the causes of this underutilization and, from there, implement strategies to improve adherence to dental treatment.

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Patterns of dental visits and their predictors among male adolescents

Częstotliwość i czynniki prognostyczne wizyt w gabinecie stomatologicznym wśród nastolatków płci męskiej

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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. Improved oral health outcomes, including better quality of life, are associated with dental attendance. Visiting a dental office is an important mode of behavior, especially among adolescents; however, the factors that influence the patterns of dental visits are not fully understood.

Objectives. The objective of this study was to investigate the frequency of visiting a dental office and its predictors among male adolescents.

Material and methods. This cross-sectional study involved a sample of 376 male adolescents (13–14 years old). Multi-stage random sampling was used to recruit participants from public schools in Dammam, Saudi Arabia. World Health Organization (WHO) oral health questionnaire for children was used for data collection. The χ^2 test and multiple logistic regression analyses were performed to investigate the predictors of dental attendance.

Results. Fifty-one percent of studied adolescents (n = 192) visited the dentist during the last 12 months. Pain was the most common reason for the dental visit (22.9%), followed by a treatment or a follow-up (16.2%), and a routine dental check-up (9.3%). The participants with pain were 16.29 times more likely to visit a dental office than those without pain. Similarly, adolescents who had routine dental check-ups (odds ratio (OR) = 7.54, 95% confidence interval (CI) = 3.75, 15.15) and treatment or follow-ups had significantly higher odds (OR = 15.21, 95% CI = 7.22, 32.04) of making a dental visit than those without check-ups and treatment. In addition, the perception of good health of gums (OR = 2.49, 95% CI = 1.33, 4.66) and difficulty in chewing (OR = 2.00, 95% CI = 1.02, 3.92) were associated with dental attendance.

Conclusions. Visiting a dental office was common among male adolescents. Pain was the most important reason and a predictor for dental attendance, and a small proportion of adolescents made dental visits for routine dental check-ups. Oral health literacy should be improved through awareness programs in schools. Adolescents should be encouraged to regularly visit the dentist to maintain optimal oral health.

Key words: adolescents, dental pain, dental visits, dental check-up

Słowa kluczowe: młodzież, ból zębów, wizyty u stomatologa, kontrola dentystyczna

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Visiting a dental office is associated with improved oral health (reduced caries experience and tooth loss) and better quality of life.[1,2] It has been found that regular dental visits in children can result in positive oral health outcomes in adulthood.[3] The prevalence of untreated caries in at least 1 permanent molar was 20% in children aged 12–19 years.[4] Data from the third National Health and Nutrition Examination Survey (NHANES III) showed that the prevalence of untreated caries in at least 1 permanent molar was 20% in children aged 12–19 years in the USA. In addition, the cost of dental treatment in children (5–17 years old) was approx. $20 billion in 2009 in the USA.[5] Teenagers were reported to have the highest unmet oral care needs and they had the least annual dental visits in addition to reduced dental service utilization.[6,7] Moreover, it has been shown that 32% of adolescents did not have a dental examination during the last 12 months in the USA.[8]

The majority of adolescents avoid seeking healthcare advice on the conditions that could cause disability or even death among them, despite the presence of risky behaviors, systemic diseases and poor health during adolescence.[9] It was found that 1/3 of adolescents (13–17 years old) made no preventive visits during the 4 years of enrollment in a healthcare plan.[10] Preventive dental visits are effective in reducing the burden of oral disease, however, the utilization of oral care was low, as only 14.2% of children received topical fluoride and/or dental sealants.[4] It was observed that preventive dental visits in children were related to family income, the educational level of the head of the family and the type of insurance.[5,11] Gender, smoking behavior and parental dental visiting patterns were also associated with dental attendance in adolescents.[12] Furthermore, an individual's income level and the degree of pain experienced determine visiting a dental office.[13]

The concept of "dental home" was promoted to provide preventive oral care to children according to the values of family.[14] There has been a lot of emphasis on dental attendance in preschool children, as an early dental visit is suggested for the prevention of oral diseases before their occurrence and should be made when a child is 1 year of age.[5] Although a significant burden of oral disease exists in adolescents, in addition to poor oral and systemic health as well as their risky health-related behaviors, little is known about the pattern of dental visits among them. Similarly, there is a high prevalence of oral diseases among adolescents in Saudi Arabia and evidence is scant about dental attendance in Saudi schoolchildren.[15] The objective of the study, therefore, is to assess the pattern of dental visits and associated factors among male Saudi schoolchildren.

Material and methods

This cross-sectional study employed an estimated sample of 430 male schoolchildren aged 13–15 years. The sample calculation was based on the approximate population size of male students in Dammam, Saudi Arabia, 5% confidence limit, hypothesized frequency of outcome factor in the population, and design effect (Sample size $n = [DEFF*Np(1 - p)]/[(d^2/Z^2_{1-\alpha/2}*(N - 1) + p*(1 - p)])$. The students were recruited using multi-stage sampling technique from public schools in Dammam, Al-Khobar and Dhahran, Saudi Arabia. World Health Organization (WHO) oral health questionnaire for children was used for data collection.[16] The self-completed questionnaire was translated into Arabic. The study was explained to the participants and informed consent was obtained from them before the administration of the research tool. The right to voluntarily participate in the study was also discussed with the respondents. They were ensured about preserving the anonymity of their responses. Ethical guidelines were followed during the data collection, reporting and the publication of information.

The respondents were asked to provide information about the frequency and reasons for their dental visits, oral hygiene practices, including the use of fluoridated toothpaste, the experience of oral problems during the past 12 months, and educational attainment of parents. The data was collected as a part of an internship research project at the College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia, and partial data was analyzed to report the patterns of dental attendance among adolescents.

The descriptive and inferential statistics were calculated using SPSS Statistics for Windows, v. 22.0 (IBM Corp., Armonk, USA). The students' responses were dichotomized to calculate odds ratio (OR). Pearson's χ^2 test was performed to calculate unadjusted ORs of the education of parents, reasons for visiting a dental office, difficulty in biting and chewing, use of toothpaste, and perceived health of gums and teeth, with visiting the dentist. Binary logistic regression was performed to observe the association between different variables of the study and dental attendance after controlling for other factors. A stepwise forward selection method was used for building the final logistic regression "best" model. A 95% confidence interval (CI) and a p-value <0.05 were used for determining statistical significance.

Results

Out of the 430 questionnaires distributed, 376 were entered in the statistical analysis. The mean age of the participants was 14.3 years ± standard deviation (SD) 0.051. The majority of the students had parents with secondary school education or higher. More than 2/3

of the students perceived the health of their gums and teeth as good. Half of the members of the sample (51.1%) visited the dentist during the last 12 months. Eighty-six respondents (22.9%) indicated that they had visited a dental office during the last 12 months due to pain or problems with teeth or gums, and this was the most common reason for dental attendance. The second most common reason was dental treatment or a follow-up (16.2%, n = 61), followed by a routine dental check-up (9.3%, n = 35). The majority of respondents (88.3%) said they used toothpaste to clean their teeth; however, only 18.1% were aware of using fluoridated toothpaste. More students had difficulty in chewing (18.1%) than problems with biting the food (9.8%), although these percentages were low. Considerable proportions of mothers and fathers had secondary school education (Table 1).

Table 1. Distribution of responses of study participants

Variables	Percentage (95% CI)
Prevalence of visiting the dentist	51.1 (46, 56.1)
Reasons of dental visits	
pain or trouble with teeth, gums or mouth	22.9 (18.9, 27.4)
treatment/follow-up	16.2 (12.8, 20.3)
routine check-up	9.3 (6.8, 12.7)
Mother's education ≥secondary school education ≤primary school education	 65.4 (60, 70) 34.6 (29.9, 39.5)
Father's education ≥secondary school education ≤primary school education	 76.9 (72, 81) 23.1 (19, 27.6)
Difficulty in biting food	9.8 (7.2, 13.3)
Difficulty in chewing food	18.1 (14.5, 22.3)
Cleaning teeth	89.4 (85.8, 92.1)
Use of fluoridated toothpaste	18.1 (14.5, 22.3)
Use of toothpaste	88.3 (84.7, 91.2)
Dissatisfaction with appearance	48.9 (43.9, 54)
Perceived health of gums	78.7 (74.3, 82.6)
Perceived health of teeth	84 (80.3, 87.7)

CI – confidence interval.

Figure 1 shows the frequency of dental visits among the respondents during the last 12 months. It can be seen that a small percentage (16.2%) visited the dentist once a year. Thirty-eight percent of the respondents either did not visit a dental office during the last 12 months or had never received dental care/visited the dentist.

Unadjusted ORs were calculated to observe the association between different variables of the study and visiting the dentist. The participants who had difficulty in chewing and were aware that they used fluoridated toothpaste were more likely to visit the dentist than those with no difficulty in chewing or who were unaware of using fluoridated toothpaste. Similarly, dental pain, treatment/follow-up, routine dental check-up and perceived good health of gums were significantly associated with visiting the dentist. After controlling for other variables of the study, dental pain (0.001), treatment/follow-up (0.001), routine dental check-up (0.001), use of fluoridated toothpaste (0.023), and self-perceived good health of gums (0.001) remained significant predictors of a dental visit (Table 2).

With the best predictive power, final logistic regression model using a forward method revealed that the participants with dental pain were 16.29 times more likely (0.001) to visit the dentist than those without pain. Similarly, the respondents who needed dental treatment or had a follow-up visit had higher odds (OR = 15.21, 0.001) of visiting the dentist than those who did not require treatment or follow-up. Other significant predictors of dental visits included routine dental check-up (OR = 7.54, 0.001), perceived good health of gums (OR = 2.49, 0.022) and difficulty in chewing (OR = 2.00, 0.042) (Table 3).

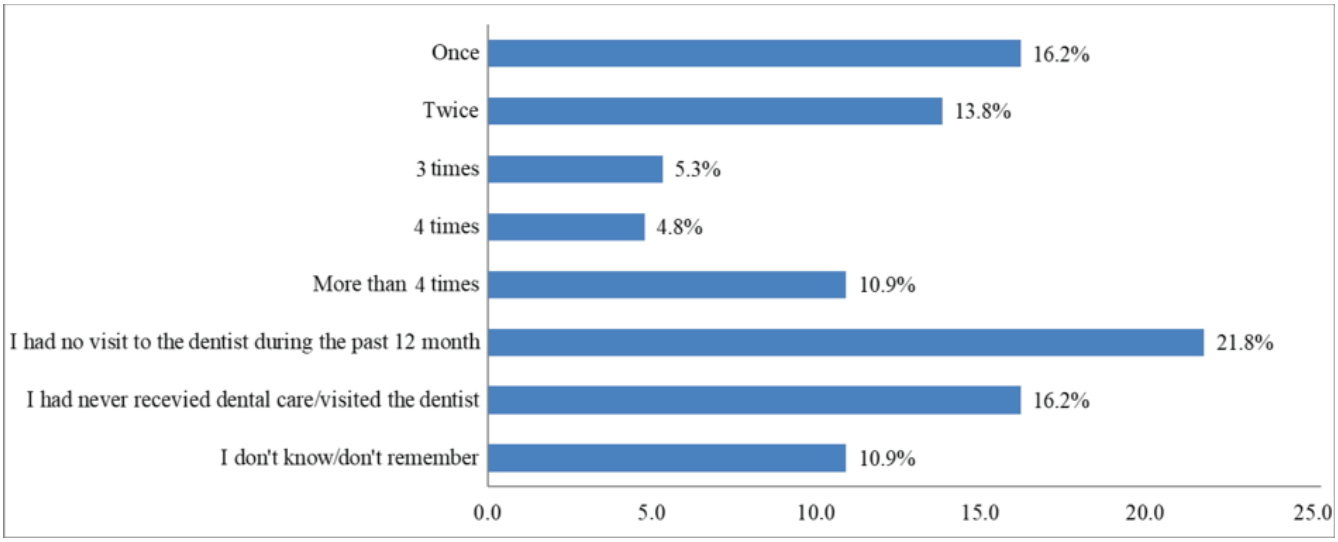

Fig. 1. Frequency of dental visits among adolescents during the past 12 months

Table 2. Factors associated with visiting the dentist among adolescents

Variables	Unadjusted OR		Adjusted OR	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Mother's education ≥secondary school education vs ≤primary school education	1.25 (0.83, 1.88)	0.83	1.11 (0.59, 2.09)	0.60
Father's education ≥secondary school education vs ≤ primary school education	1.173 (0.76, 1.80)	0.90	0.52 (0.25, 1.0)	0.08
Difficulty in biting food	1.80 (0.92, 3.81)	0.08	1.15 (0.39, 3.35)	0.97
Difficulty in chewing food	1.98 (1.14, 3.42)*	0.016*	1.71 (0.77, 3.78)	0.11
Never cleaned teeth	0.95 (0.49, 1.83)	1.00	1.47 (0.48, 4.53)	0.65
Use of fluoridated toothpaste	1.83 (1.07, 3.15)*	0.03*	2.17 (1.09, 4.32)*	0.02*
Use of toothpaste	1.03 (0.54, 1.97)	1.00	0.90 (0.30, 2.69)	0.87
Dissatisfaction with appearance	0.88 (0.59, 1.32)	0.61	0.87 (0.52, 1.47)	0.37
Dental pain	6.61 (3.61, 12.09)*	0.001*	17.88 (8.84, 36.15)*	0.001*
Routine dental check-ups	2.42 (1.31, 4.47)*	0.005*	8.59 (4.11, 17.98)*	0.001*
Dental treatment/follow-up	4.91 (2.51, 9.59)*	0.001*	17.95 (8.24, 39.07)*	0.001*
Perceived health of gums	2.15 (1.29, 3.59)*	0.004*	2.46 (1.30, 4.66)*	0.001*
Perceived health of teeth	0.972 (0.56, 1.68)	1.00	0.78 (0.17, 1.37)	0.12

OR – odds ratio; CI – confidence interval; * statistically significant $p < 0.05$.

Table 3. Final logistic regression model: factors associated with visiting the dentist among adolescents

Variables	Adjusted OR	
	OR (95% CI)	p-value
Difficulty in chewing food	2.00 (1.02, 3.92)*	0.04*
Dental pain	16.29 (8.24, 32.21)*	0.001*
Routine dental check-ups	7.54 (3.75, 15.15)*	0.001*
Dental treatment/follow-up	15.21(7.22, 32.04)*	0.001*
Perceived health of gums	2.49 (1.33, 4.66)*	0.02*

OR – odds ratio; CI – confidence interval; * statistically significant $p < 0.05$.

Discussion

The present study documented that pain was the most common reason (22.9%) for dental attendance and the strongest predictor (OR = 16.2) of dental visits among teenagers. These findings are in accordance with the available body of evidence. Zhu et al. observed that 29% of Chinese teenagers (12 years old) visited the dentist because of pain or dental caries.[17] A study of 12-year-old children in Kuwait reported that 53% of the participants visited a dental office due to pain or problems with teeth or gums.[18] Similarly, a nationwide survey of Jordanian schoolchildren (6–12 years old) found 83% of them visiting the dentist because of symptoms.[19] However, children expressed esthetics/appearance as the major cause of dental visits in the USA.[20] A high prevalence of dental caries (decayed, missing and filled teeth [DMFT] index = 3.34) in permanent dentition of children aged 6–18 years in the Saudi Arabia could be a possible reason for dental pain or problems, and subsequent visits to the dentist.[17,21]

In Saudi Arabia, a previous study conducted in 1998 reported that 45% of children (6–12 years old) performed an annual dental visit in the city of Madina, while 51.1% children in the present study attended a dental office during the past 12 months in Dammam.[22] It seems that over a period of 18 years, no comprehensive oral health awareness program for children has been successfully established and run in the country. In contrast, the patterns of dental visits among teenagers appear different in developed countries. The majority of children aged 11–15 years (57.8%) made a dental visit and 20.8% availed themselves of preventive dental care in the USA.[5] In a survey of Australian teenagers (12–17 years old), 81.8% visited the dentist during the last year.[23] Similarly, 79.9% and 84% of adolescents made dental visits during the past 12 months in New Zealand and Canada, respectively.[24,25]

The present study showed that 49% of Saudi children had never visited a dental office, which is close to the results of a study by Zhu et al., who found that 52.2% of Chinese children (12–18 years old) had never saw a dentist.[17] On the other hand, a study of Nigerian children showed that 80% had never visited the dentist.[26] However, data from National Longitudinal Study of Adolescent Health in the USA showed that 2% of adolescents had never had a dental examination.[8] It is known that access to oral healthcare is related to social, economic and cultural dynamics in addition to the geographic distribution of populations and healthcare resources. However, many obstacles associated with these factors can be minimized by increasing oral health literacy, improving training of the dental workforce, and creating avenues and developing a policy framework for the provision of optimal oral care.[27]

Routine dental check-up was performed by 9.3% of the members of the sample in the present study, and they were 7.5 times more likely to visit the dentist than those who did not have regular check-ups during the last 12 months. These results are in agreement with the data shown by Davoglio et al., who reported that preventive treatment

was the reason for visiting the dentist in 11.25% of Brazilian adolescents.[28] Similarly, a small proportion (11%) of Jordanian children visited the dentist for regular dental check-ups.[19] One-third of Chinese children (35.2%) made a dental visit for preventive dental check-ups during the last 2 years.[17] However, the prevalence of dental visits for check-ups was 85.9% among teenagers (12–17 years old) in Australia.[23] Sixty-two percent of adolescents in Britain made dental visits for examination without any symptoms.[7] The most plausible explanation of the high prevalence of not receiving dental care and low percentage of children visiting the dentist for a check-up could be that there is lack of awareness about oral health, including the importance of visiting the dentist, among children and their parents in Saudi Arabia. There should be a national oral health awareness program to improve oral health of children through preventive measures, including emphasis on regular dental visits.

Low education of parents was associated with reduced dental visits, a decreased utilization of preventive services and a high prevalence of untreated dental caries among adolescents.[4,5,29] It was found that the use of preventive medical care was related to parental education; however, annual dental visits had no association with the educational attainment of parents.[30] Similar to those results, in the present study, both univariate and multivariate analyses revealed no significant association between parental education and dental attendance.

Our data analysis showed that children with perceived good health of gums were twice more likely to visit the dentist than those with poor gingival health. This result confirms the estimate reported by Lopez and Baelum, who observed that adolescents with poor oral health were twice more unlikely (OR = 2.0) to make a dental visit during the last 12 months.[29] Likewise, it was found that schoolchildren with a high prevalence of caries did not visit the dentist.[26] This shows that there is a high prevalence of dental attendance among teenagers with improved oral health, and low self-esteem, shyness or embarrassment due to poor oral health could be the reason of low attendance to oral care, in addition to the presence of unmet dental care needs in our study.[29,31] The use of fluoridated toothpaste is essential to maintaining optimal oral health, as it can help improve oral hygiene and prevent dental caries and periodontal disease.[32] The children who were aware that they used fluoridated toothpaste were 2.5 times more likely to make a dental visit than those who did not know if they were using fluoride-containing toothpaste. Again, like in the case improved self-perceived well-being of gingival health, dentally aware children might frequently visit the dentist to maintain good oral health.

There is limited information available about the patterns of dental attendance among adolescents. Hence, our study provided valuable information about the frequency, reasons and predictors of dental visits. Healthcare policy makers and educators can utilize the findings of the study to improve the oral health of children. However, our study had a few weaknesses. Though it was anticipated that the inclusion of male students is not representative of teenagers in Dammam, data collection from female schools by male researchers was difficult due to culture norms in Saudi Arabia. Therefore, the data was unclear about the frequency and types of dental attendance among female adolescents. In addition, self-reported data can have some limitations; however, adolescents' responses have been shown to be valid.[33] A future study should include a large sample of male and female students from public and private schools in urban and rural areas of the eastern province of Saudi Arabia. Given the importance of oral health and improving the access to oral care, particularly in children, conducting a national oral health survey should be the top priority of healthcare decision makers in the country.

Conclusions

In conclusion, this study showed that visiting the dentist was common among male schoolchildren in Saudi Arabia. Furthermore, pain was the most important reason for and the predictor of dental attendance, and a small proportion of schoolchildren visited the dentist for a routine dental check-up. The perception of healthy gums and the awareness of the use of fluoridated toothpaste were associated with increased chances of making dental visits. The findings of the study suggest that there is a high prevalence of oral diseases and low oral health literacy among teenagers. Developing policies, creating dental human resources with education and training, putting greater emphasis on prevention, establishing oral health awareness programs, and conducting national oral health survey will help improve the access to dental care and reduce the burden of oral disease. The importance of routine dental check-ups should be emphasized, and adolescents in particular should be encouraged to regularly visit the dentist to maintain optimal oral health.

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The effect of social determinants on oral health knowledge and patient's bill of rights

Wpływ determinant socjalnych na wiedzę dotyczącą zdrowia jamy ustnej oraz uprawnienia pacjenta

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Abstract

Background. Health knowledge is a requirement in healthcare and having a higher level of health knowledge helps to promote a satisfactory health status. Also, patients have specific rights within the healthcare system, but sometimes they are not aware of their rights. These issues are highly affected by social determinants.

Objectives. The goal of this study was to assess the social determinants of oral health knowledge and the awareness of patient's rights.

Material and methods. This was a cross-sectional study conducted on patients referred to private offices and dental clinics in Tabriz, Iran. The study sample consisted of 500 patients and was selected by random sampling. A researcher-made questionnaire was used to collect data.

Results. The highest number of the patients (31.9%) were 25–34 years old; 62.2% of the participants were female and 37.8% were male. Regarding religion, on a 1–10 scale, the majority of the respondents (26.6%) had scored themselves 8. As for oral health knowledge, 84.8% believed that reducing sugar consumption prevents tooth decay and 96.9% declared that stopping smoking is effective in reducing oral diseases. Regarding patients' awareness of the right to access their medical records, only 40% stated that they have such right and 34.2% declared "I don't know", while 25.8% believed they have no right to access their medical records.

Conclusions. Education level plays a critical role in improving the oral health knowledge level and awareness of patient's rights. Educational programs by the mass media and healthcare centers can help patients achieve a higher level of oral health knowledge and awareness of their rights.

Key words: oral health, patient's rights, health knowledge, attitudes, practice

Słowa kluczowe: zdrowie jamy ustnej, prawa pacjenta, wiedza o zdrowiu, nastawienie, praktyka

Health knowledge is a fundamental prerequisite in healthcare.[1] People's health as individuals and as a community has a great impact on the development of society. Tooth decay and oral diseases are common even in developed countries and have a profound impact on the individual's health and, consequently, on the health of the society.[2] Within this context, studies have shown that there is a correlation between having broader knowledge and improved health.[3] Also, everyone has specific rights within the healthcare system, which have to be respected by the health staff and patients should be aware of these rights if high quality healthcare services are to be delivered.[4] During the last few decades, major reforms have been conducted in providing healthcare services. For years, healthcare staff believed that they can make the best decisions regarding patients without paying attention to their rights.[5]

As for health-related behaviors, different factors such as economic and social are considered. As an example, the education level has an influence on health-related behaviors. Those behaviors, e.g., brushing twice a day and applying fluoride-containing tooth paste and reducing sugar intake, were more common among senior students compared to junior.[6] Having basic information about oral health, followed by preventive actions, is essential in improving self-care behaviors. Although there is an emphasis on proper knowledge and information in the mentioned fields, in Italy, for example, there is not enough information about health behavior pertaining to oral health among people.[7] Studies have shown that there is a strong correlation between individuals' quality of life and health status. A study conducted by Watt demonstrated that individuals who have a lower income and education level, have a lower health status as well.[8] Another study, performed by Petersen, showed that demographic factors have an influence on behavioral factors and, consequently, affect the health status.[9] Few studies were carried out on the effect of social factors on oral health.

The aim of this study was to assess the effect of social determinants on the oral health knowledge and on awareness of the patient's rights.

Material and methods

This is a descriptive, cross-sectional study conducted on patients referred to dentistry clinics and dental office in Tabriz, Iran. The study sample consisted of 500 patients selected by simple random sampling. A researcher-made questionnaire was used to collect data. The reliability of the questionnaire was verified by 10 members of a panel of dentists and its validity was confirmed by Cronbach's alpha 0.88 and 0.812, respectively. Tabriz city is divided into 10 districts. A total number of 600 clinics and dental offices were identified. In each district, according to the number of clinics and offices, 20% of them were chosen randomly. Within each clinic and office, 5 samples were selected randomly.[10]

To collect data, the aim of the study was explained to the participants clearly and if they intended to participate, the questionnaire was given to them and was collected after it had been completed.

The questionnaire consisted of 4 parts:

1) demographic information;
2) knowledge about oral health;
3) social determinants; and
4) patient's rights.

Religion factor was measured as a self-report on a 1–10 scale.

The correlation between variables was analyzed using SPSS software package v. 23.0 for Windows (IBM Corp., Armonk, USA) and the Pearson's χ^2 test was applied. A p-value <0.05 was considered significant.

Inclusion criteria consisted of min 18 years of age, literacy and consent to participate in the study. This study was approved by the ethical committee of Tabriz University of Medical Sciences, Iran, with the following ethical code: IR.TBZMED.REC.1395.50.

Results

The statistical analyses were conducted on the collected data. The highest number of participants (31.9%) were 25–34 years old, 23.8% of them were 35–44 years old, 22.5% were 45–59 years old, 12.5% were 18–24 years old, and 9.4% were above 60 years of age. Regarding gender, 62% of the participants were female and the rest (38%) were male. As for marital status, 73% were married and only 27% were single. The majority of the participants (38.2%) had bachelor's degree; the holders of a high school and "some school" diploma consisted of 29.4% and 13.7% of the study group, respectively (Table 1).

Regarding religion, on a 1–10 scale, the highest number of the respondents (26.6%) scored themselves 8, while 24.3% chose a score of 6. The lowest score was 5 and was chosen by 7.9% of the participants.

One of the signs of a health-centered culture in a family can be encouraging children to take care of oral health, especially by brushing the teeth. Therefore, the participants were asked if their parents encouraged them to brush their teeth since their childhood. A little more than half of the respondents (54.4%) declared that their parents were encouraging them to brush their teeth since childhood; but, on the other hand, 1/3 of the participants (33.5%) stated that their parents had no role in encouraging them to brush their teeth. Pertaining to financial issues in regard to seeking treatment, 22.4% stated that financial difficulties prevented them to treat oral diseases, while 22% responded they had no such problems and 55.6% chose "no comment".

Table 1. Demographic characteristics of the study participants

Characteristics		Frequency	Percentage
Age	18–24	60	12.5
	25–34	153	31.9
	35–44	114	23.8
	45–59	108	22.5
	>60	45	9.4
Gender	male	182	37.8
	female	299	62.2
Marital status	single	130	27.0
	married	352	73.0
Education	some school	65	13.7
	high school	140	29.4
	some college	39	8.2
	bachelor's degree	182	38.2
	master's degree	35	7.4
	PhD	15	3.2

Knowledge and awareness

In the knowledge and awareness section, 84.8% of the participants believed that reducing sugar consumption prevents tooth decay. Also, 80.5% thought that consuming fruit and vegetables is effective in preventing oral diseases and 13.3% declared that they "don't know". Regarding the effect of smoking, 96.9% declared that stopping smoking is beneficial in the reduction of oral diseases. Furthermore, 62.2% believed that gum diseases trigger losing teeth, but 31.6% held no such an opinion. In addition, 97.1% mentioned that having pretty teeth improves their self-confidence and 95.1% thought that it is an indicator of social prestige (Table 2).

Patient's rights

As for the awareness of patient's rights, 94.8% of the participants believed that dentists must explain to the patients the quality of the treatment and treatment methods before and after treatment. Regarding the right to access their medical records, only 40% stated that they have such right, 34.2% declared "I don't know" and 25.8% believed they have no right to access their medical records. Participants were asked if they have the right to consult other dentists and withdraw from treatment; 66% of them answered "yes", 18.4% answered "I don't know" and 15.7% chose "no". Regarding harm or injuries to teeth by dentist during treatment, participants were asked if they have the right to file a complaint against a dentist and the majority (93.9%) believed they have such right (Table 3).

To assess the correlations between the education level/marital status, reducing of sugar consumption and tooth decay, the Pearson's χ^2 test was applied. All (100%) of the holders of "some college" diploma and a PhD degree believed in the effect of reducing sugar consuming on tooth decay, while 97.2% of the holders of a bachelor's degree, 85.3% of the holders of master's degree, 72.7% of the holders of high school diploma, and 67.2% of the holders of "some school" diploma answered "yes" to that question ($p = 0.016$). As for the marital status, the majority of single participants (96.1%) believed that reducing sugar consumption is effective in preventing tooth decay; the result was 80.4% among married participants ($p = 0.031$).

Table 2. Knowledge and awareness of the study participants regarding the factors affecting oral health and the social impact of having attractive teeth

Question	Answer	Frequency	Percentage
Does reducing sugar consumption prevent tooth decay?	no	48	10.0
	yes	408	84.8
	I don't know	25	5.2
Is consuming fruit and vegetables effective in preventing oral diseases?	no	30	6.2
	yes	387	80.5
	I don't know	64	13.3
Is stopping smoking effective in the reduction of oral diseases?	no	2	0.4
	yes	463	96.9
	I don't know	13	2.7
Does gum diseases cause tooth loss?	no	30	6.2
	yes	299	62.2
	I don't know	152	31.6
Does having attractive teeth improve your self-confidence?	no	4	0.8
	yes	461	97.1
	I don't know	10	2.1
Are attractive teeth an indicator of social prestige?	no	13	2.8
	yes	447	95.1
	I don't know	10	2.1

Table 3. Knowledge and awareness of the study participants regarding patient's rights

Question	Answer	Frequency	Percentage
Should dentist explain the quality and the treatment method to the patients before and after treating?	no	3	0.6
	yes	455	94.8
	I don't know	22	4.6
Do you have the right to access your medical records?	no	124	25.8
	yes	192	40.0
	I don't know	164	34.2
Do have the right to consult other dentists and withdraw from the treatment?	no	75	15.7
	yes	316	66.0
	I don't know	88	18.4
Do you have the right to complain if the dentist causes harm or injuries to your teeth during treatment?	no	30	6.2
	yes	299	62.2
	I don't know	152	31.6
Does having attractive teeth improve your self-confidence?	no	3	0.6
	yes	447	93.9
	I don't know	26	5.5

Regarding the correlation of religion scale score and the effect of reducing sugar consumption in preventing tooth decay, the majority of the participants (74.3% of the patients who scored themselves 8 and above, 81.1% of those who chose 6 or 7 and 77.6% of those who chose 5) believed that reducing sugar consumption is effective in preventing tooth decay ($p = 0.081$).

As for the correlation between education and access to medical records, 85.7% of the holders of a master's degree, 71.4% of PhD holders, 46.7% of the holders of bachelor's degree, 39.9% of high school diploma holders, and 26.3% of the holders of "some college" diploma answered "yes". The highest number of participants who answered "no" were the holders of "some school" diploma with a 92.92% score.

As for the correlation between gender and awareness of the right to access the medical records, 41.4% of the females believed that they have the right to access their medical records, while the result was 38% among males ($p = 0.62$).

Discussion

This study was conducted to assess the effect of social determinants on the oral health of dental patients. The results of this study showed that the majority of the patients were familiar with patient's rights. No previous study in Iran was performed on the dental patients' awareness of their rights. However, research performed by Bazmi et al. in 2015 on the patients' awareness of their rights reported that the level of awareness was 80%.[11] The results of the current study demonstrated that education level has a significant impact on the level of awareness of patient's rights. Most of the contributors who held university degrees believed that they have the right to access their medical records; meanwhile, most of the patients with low education levels believed they had no such right. These results revealed the profound effect of education level on the patients' awareness of their rights. This shows that if people are encouraged to continue education on higher levels, as patients they will be more aware of their rights. A higher level of education enables and empowers people to receive more information regarding health-related issues, such as patient's rights. They also get training to use different sources of information such as digital sources, which can help them obtain widespread types of information, as well as communicate and consult with others easily. The results of this study proved that there is a significant correlation between education level and awareness of the right to have access to medical records; they are in line with a study conducted by Zülfikar and Ulusoy in Turkey.[12] Furthermore, research conducted by Mastaneh and Mouseli concluded that there is a strong correlation between education level and the patients awareness of their right to access their medical records. One possible explanation of this conclusion is that education helps people make informed decisions pertaining to health issues.[13] In addition, the correlation between education and health-improving behaviors was observed in studies such as the one conducted by Abuladze et al.[14] The reason might be the ability to use new types of sources of information about health improvement. Better-educated people might also have more interest in staying up-to-date with health-related issues. Although other studies, such as the one conducted by Rajesh et al., showed that there is a correlation between being religious and oral health-related behaviors, the current study showed no significant correlation.[15] A possible explanation of this is that most Iranians are religious.

In the current study, there was no significant correlation between gender and awareness of patient's rights. Today, because of equality in achieving education, with both men and women benefiting, gender does not constitute an effective factor in the awareness of patient's rights. Both men and women in most of the countries have access to the same level of education and the highest levels of education are available for both men and women. These results are in line with the results of the study carried out by Mastaneh and Mouseli.[13] The results of the study performed by Ansari et al. confirm the results of the present study.[16]

In the health knowledge field, those who have a higher level of education have a higher level of health knowledge as well. The results of the study carried out by Macek et al. showed the significant correlation between education level and health knowledge.[17] This significant correlation can be understood in the following way: those who have a higher level of education are able to use different sources and also want to obtain information about health. People who have a higher level of education know more about the importance of health promotion and the effect of health knowledge on health quality. In the current study, a significant correlation was observed between the education level and health knowledge, which is in line with the studies conducted by Yaghobian et al. and Wirth et al., which revealed that those who have a higher level of education, had broader knowledge about health as well.[18,19]

Regarding the correlation between marital status, health knowledge and awareness of patient's rights, married people had higher levels of such knowledge compared to single people, which is in line with research conducted by Yuan et al.[20] One possible explanation of this is that couples share their knowledge and spend time together discussing health-related issues.

Conclusions

This study showed that the education level is significantly correlated with the level of knowledge about oral health and with awareness of patient's rights. Financial issues are a barrier in seeking treatment and insurance poli-

cies should cover oral and dental diseases. Policy makers need to encourage the public to obtain higher education. It is also recommended to inform the public on their rights and proper nutrition and to help them in quitting smoking, using mass media and healthcare centers.

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Methods of accelerating orthodontic tooth movement: A review of contemporary literature

Metody przyspieszania ortodontycznego przesuwania zębów – przegląd współczesnego piśmiennictwa

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Abstract

Technological progress and the introduction of modern therapeutic methods are constantly changing contemporary orthodontics. More and more orthodontic patients are working adults, who expect satisfactory therapeutic effects as soon as possible, increasing the importance of methods accelerating tooth movement. The aim of this study was to review the current literature regarding methods of accelerating tooth movement and reducing the duration of the active phase of therapy. The literature was collected from the PubMed and EBSCO databases using "accelerated orthodontic tooth movement" as the search key words. The methods described were categorized as conservative and surgical. The pharmacological agents used in conservative treatment, such as growth hormone, parathyroid hormone, thyroxine, and vitamin D, are especially worth mentioning. They stimulate osteoclasts to increase resorption through a variety of mechanisms. Effective methods also include physical stimuli, e.g., vibrations or photobiomodulation. Most studies describing the effects of pharmacological agents were based on animal subjects and they may therefore lack clinical relevancy. Corticotomy and its modifications based on the regional acceleratory phenomenon (RAP) might prove to be a useful augmentation of orthodontic treatment, especially in adults, including patients with periodontal disease.

Key words: orthodontics, corticotomy, accelerated tooth movement

Słowa kluczowe: ortodoncja, kortykotomia, przyspieszone przesuwanie zębów

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The dream of a beautiful smile is currently not difficult to fulfill, as interdisciplinary treatment involving prosthetic, surgical, periodontal, and orthodontic procedures makes successful esthetic effects possible in the majority of cases. Among these methods, orthodontics have a fundamental disadvantage: prolonged therapy time. Depending on the kind and severity of the defect, as well as the general condition of the patient, comprehensive treatment lasts on average close to 2 years.[1] This has a negative impact on the patient's compliance with braces requiring strict control of meals consumed, special attention to hygiene, and regular appointments at the orthodontist's office. On the clinical level, long-term therapy may lead to iatrogenic complications, including demineralization of enamel, tooth decay, inflammation and recession of gums, damage to the periodontium, or root resorption.[2] In light of contemporary literature, using increased force to accelerate the movement of teeth is discouraged due to possible hyalinization of the periodontal fibers and undermining resorption, leading to delayed movement.[3] It is therefore necessary to affect the surroundings of the tooth that ensure its stable position in the neutral zone – the alveolar bone. Tooth movement takes place with the simultaneous cooperation of osteoclasts in the pressure zone (which leads to resorption) and osteoblasts in the pulling zone (the apposition process). An important role is also played by periodontal ligaments, which, while acting as a "force absorber", also play the role of specific receptors associated with the sympathetic system.[3] Methods of accelerating tooth movement are based on stimulating biological tissue response, i.e., enhanced metabolism and accelerated bone remodeling. On the basis of the level of invasiveness, the methods encountered in the scientific literature can be divided into conservative methods and those based on surgical intervention.

Conservative methods

The application of pharmacological agents

At the cellular level, the predominance of osteoclast activity over osteoblasts is responsible for bone resorption. It occurs as a result of the intensification of the inflammatory process in the periodontal and connective tissue of the gum. Mature osteoclasts can be stimulated by pro-inflammatory signals coming from periopathogens (LPS Gram-negative bacteria), fibroblasts (MMP-1, MMP-2, MMP-3), macrophages (IL-1β, IL-6, TNFα, PGE2), or Th lymphocytes (IL-6, IL-11, IL-17). Another pathway of bone resorption is based on the mechanism of osteoblast and cell-precursor differentiation towards osteoclasts. This is an effect of the nuclear factor kappa B receptor (RANK) system and the receptor activator of nuclear factor kappa-B ligand (RANKL) competing with osteoprotegerin (OPG).[4]

Growth hormone

Growth hormone (GH), also called somatotropin, is secreted by the anterior lobe of the pituitary gland. It has a stimulating effect on bone growth and remodeling, and a deficiency results in pituitary dwarfism. The action of GH is based directly on increases in the proliferation and differentiation of osteoblasts, as well as on induction of protein synthesis and mineralization.[5] Ribeiro et al. assessed the modifying effect of growth hormone on the pace of tooth movement during experimental orthodontic treatment in rats.[6] In their study, individuals from the experimental group were administered daily subcutaneous doses of growth hormone of ≈ 0.033 mg/kg, analogous to the dose used in humans. A day after the 1st dose was administered, a nickel-titanium spring was fixed between the incisor and the right 1st molar, exerting a force of 30 g. Growth hormone accelerated bone resorption (in the experimental group the highest number of osteoclasts was recorded as early as on the 3rd day, which was twice as high as in the control group on day 7), but it also delayed angiogenesis. This suggested that the activation of a device should be less frequent after GH administration. There are even recommendations to begin orthodontic therapy 12–24 months after GH administration, because only then will somatotropin stimulate the process of bone formation.[7] As GH reduces the synchronization between resorption and bone apposition, this is not a method of high potential clinical relevancy.

Parathormone

Parathormone (PTH) is a compound secreted by the parathyroid gland which binds to receptors on osteoblasts, activating them and leading to the expression of insulin-like growth factor 1 (IGF-1; somatomedin). This results in the proliferation of osteoblasts and, with the participation of the RANK ligand, osteoclast activation.[8] Depending on the frequency of administration, PTH may stimulate bone formation (intermittent therapy) or its resorption (exposure longer than 1–2 years).[9] Two 12-day studies in rats confirmed that intermittent administration of PTH accelerated the mesialization of the 1st molar 1.6 times after administration of a dose of 0.25 μg/100 g b.w. into the subperiosteal area and 1.4 times as a result of subcutaneous administration of 4 μg/100 g m.c.[10,11] However, another study by the same authors does not confirm the efficacy of intermittent therapy.[12] Long-term research on the superiority of this method over other protocols is needed, as well as clinical trials. Nevertheless, it is important to consider chronic PTH intake when planning orthodontic treatment, e.g., in cases of severe osteoporosis.[9,13]

Vitamin D

Another agent that may affect tooth movement is vitamin D. 1,25-dihydroxycholecalciferol is the most active metabolite of this vitamin. It mainly has an anabolic effect on the bone tissue (to a small extent also catabolic).[14] Similarly to PTH, sub-periosteal administration of vitamin D enhances the activity and proliferation of osteoblasts.[15] These properties prompted researchers to design animal experiments attempting to modify the course of orthodontic treatment. Collins et al. used calcitriol dissolved in DMSO (dimethylsulfoxide) – a compound that readily penetrates cell membranes, as well as has a high solubility coefficient for vitamin D) – administered daily into the periosteum.[16,17] After 3 weeks, the retraction range of the canines was 60% higher compared to the control group. Other researchers came to similar conclusions, this time testing the action of this vitamin on rats. They noticed an increased number of both osteoclasts and osteoblasts.[18–20] Kawakami and Takano-Yamamoto emphasized the continuation of intensified remodeling during the retention period as well.[19] In turn, Kale et al. observed that distalization of the maxillary incisors increased by 23%.[20] In a few clinical trials, acceleration of orthodontic tooth movement was also demonstrated.[21] After a daily oral dose of 0.25 μg of vitamin D, the mean difference in the retraction movement between the experimental group and the control group (who underwent orthodontic therapy without supplementation) was 1 mm/60 days. However, the use of a very low dose of the supplement in the study appears to be questionable (10 IU vs the daily recommendations of 1000–2000 IU).

Thyroxine

Thyroxine administration is a recommended form of hypothyroidism treatment. It increases bone remodeling and stimulates resorption, which contributes to a decrease in bone density. This is probably due to the increased concentration of interleukin 1 (IL-1), which stimulates the formation of osteoclasts and the resorption process.[14] Animal studies confirm accelerated tooth movement after administration of this substance.[22–24] Seifi et al. observed 0.45 mm of movement after 21 days in their experimental group, compared to 0.23 mm in the control group.[22] Additionally, they detected cumulative effects of concomitant administration of thyroxine and prostaglandine E2 (0.74 mm of movement). However, Shirazi et al. noticed much less root resorption after thyroxine-assisted orthodontic treatment.[23] Despite the lack of clinical trials, the presence of metabolic diseases related to the thyroid gland should be taken into consideration when planning orthodontic treatment. In cases of hypothyroidism it is recommended to activate the device less frequently, whereas for patients with hyperthyroidism, a longer retention period is recommended.[24]

Beta 2-adrenergic agonist

There is a very specific periodontal microenvironment between the tooth and the bone that requires further description. It consists of collagen fibers, cells and tissue fluid acting as a force absorber. The ligaments are strongly innervated: they contribute to the transmission of pain, modification of the immune response and bone remodeling.[25] During orthodontic treatment mechanical force acting on the tooth is transmitted to these ligaments. Periodontal cells stimulate the biological response (e.g., by increasing the amount of Y-neuropeptide-containing fiber, substance P or calcitonin gene-related peptide).[26] This is confirmed by the impossibility of moving ankylotic teeth, which are deprived of periodontal fibers due to direct connection with the bone. Periodontal ligaments are formed from the cranial neural crest differentiating in embryonic stem cells.[27] Due to their origins, they express β2-adrenergic receptors and, through the RANK receptor system, stimulate osteoblasts to undergo osteoclastogenesis.[28]

The available studies involving β2-adrenergic agonists are based on direct evidence (stimulation of receptors with agonists, e.g., isoproterenol) or indirect observations (similar inhibition of the sympathetic system after using propranolol). Takeda et al., using isoproterenol, induced an osteoclastogenic response in mice.[29] According to Kondo et al., by inhibiting the sympathetic system with the butaxamine, bone loss was limited and tooth movement slowed down.[30] Kondo et al. also made intraperitoneal injections of propranolol, isoproterenol or (in the control group) saline solution, and blockages or stimulations confirmed their thesis.[30] More invasive tests on rats were performed by Cao et al.[31] After performing ganglionectomies of the upper cervical ganglion, they noted a decrease in osteoclast differentiation and limited tooth movement. Yamashiro et al., in an animal model of experimental tooth movement, noted a lack of significant changes in bone remodeling after transection of the lower alveolar nerve.[26]

In conclusion, despite the presence of many experiments related to β2-adrenomimetics, one cannot overlook the fact that there are no clinical trials that provide significant scientific evidence.

Physical stimuli

Studies on the acceleration of teeth movement describing stimuli which increase the metabolism of tissues were investigated. The mechanisms of the most of them are not fully understood, but there is considerable evidence of their beneficial effects.

Electromagnetic fields

Electromagnetic fields have a proven effect on cell membrane permeability.[3] They can be divided into static magnetic fields (SMF) and pulsed electromagnetic fields (PEMF). Both types have been used in general medicine for many years. A SMF can contribute to the healing process after an osteotomy, can stimulate bone remodeling, or prevent bone volume decrease after surgical intervention or implantation.[32–34] In the field of orthodontics, it has been used for many years as an element supporting active therapy or even as an independent procedure. It may be of certain clinical benefit during space closure, intrusion, forced extrusion of impacted teeth, and palatal expansion.[35–38] An analysis of the few available animal studies concludes that in order to accelerate tooth movement, a field with a flux density of 460 mT should be used.[39,40] Sakata et al. came to this conclusion analyzing the previous experiment of Tengku et al., who, while using the intensity of 10 mT, did not observe clinically satisfactory results.[39,40] A PEMF, by stimulating osteoblasts to proliferate and differentiate, as well as increasing the production of alkaline phosphatase and regulating calcium metabolism, can improve the treatment of bone fractures, osteonecrosis and osteoporosis, among other things.[32,41–45] According to Bassett's research, therapeutic application of magnetic fields results in the creation of cellular tension similar to that which is induced during mechanical deformation of the bone (e.g., during the movement of the teeth).[46] Studies on a rat model have shown that the support of active orthodontic elements operating with a force of about 20 g, both using a PEMF of 1.8 mT (or 1.5 mT) and a Nd-Fe-B magnet (neodymium), increases the distance a tooth can be moved.[47,48] Stark and Sinclair and Showkatbakhsh et al. also confirmed the accelerating action of PEMF.[32,49] The clinical trial by Showkatbakhsh et al., assessed the distalization of the canine after 1st premolar extraction, using a removable PEMF-generating device with an intensity of 0.5 mT and a frequency of 1 Hz.[49] After 6 months, the difference in movements between the test and control groups was 1.57 ±0.83 mm. Dogru et al. performed an experiment on rats comparing a PEMF to a sinusoidal field.[48] In both cases, they observed positive effects. However, the authors pointed out that due to differences in size and physiology, predicted results on the human body should be extrapolated with caution. Information regarding the lag phase in orthodontic tooth movement (the phase of clearing hyalinized fibers from the pressure zone) is also important. It can be hypothesized that electromagnetic field therapy can shorten the lag phase (due, among other things, to earlier formation and removal of hyalinized tissue).[39,40,47]

Vibrations

Rubin et al. have proven that vibrations increase the remodeling rate and the overall reconstruction of the long bones – a phenomenon used in the prevention of osteoporosis.[50] In addition, by comparing the effects of cyclic and static forces in experiments on animal models (cranial sutures and the periosteum of the long bones), an improvement in bone formation and an increase in orthodontic tooth movement was observed.[51–53] Initial clinical trials have shown promising results. Dubravko et al. used the AcceleDent device (OrthoAccel Technologies, Inc., Bellaire, USA) to generate a vibration of 0.25 N and a frequency of 30 Hz.[54] It was possible to accelerate the distalization of canines with skeletal anchorage by 48.1% compared to the control group (1.16 mm vs 0.79 mm/month). Other reports have also confirmed the accelerating effect of vibrations.[55] This time, the source of the stimuli was electric toothbrush massage for 15 min a day (a frequency of 125 Hz). Within 3 months, a 2.85 mm distal axial movement of the canines was obtained (37.7% greater than in the control group). Those authors additionally investigated the concentration of IL-1β in fluid collected from the gingival pocket, which, as a factor stimulating the expression of RANKL, can be a good indicator of the effectiveness of orthodontic movement.[56,57] On the pressure side, the concentration of the cytokine in the study group was on average more than 6 times higher than in the fluid collected from the control group. Contrary to expectations, acceleration was not confirmed by studies in mice in which orthodontic forces were applied to the 1st molars and low frequency vibrations (5, 10 and 20 Hz) were used.[58] Furthermore, the latest randomized clinical trials call into question the chances of significantly shortening the time of orthodontic treatment by administering vibrations.[59,60]

Photobiomodulation

This technique can be characterized by a very limited invasiveness. It involves the exposure of tissues to the effects of red light of a therapeutic wavelength (600–1200 nm).[61] These wavelengths reduce absorption of the light by hemoglobin and water and allow it to reach the deeper soft tissue and the alveolar bone.[62] The resulting stimulation may have potentially positive effects on the production of adenosine triphosphate (ATP).[63] On the other hand, increasing the activity of cells leads to increased bone metabolism in situ, which creates favorable conditions for the movement of teeth.[64] Therapy with light can be divided into 2 basic types: low-intensity lasers (LIL), producing coherent light, and light-emitting diodes (LED), which are sources of incoherent light.[65] There are no publications regarding the superiority of one above the other. What is more, most authors agree that the cellular response depends primarily on the wavelength and

the dose of light, not on its source.[66] Only Fujita et al. noted more favorable results in LIL therapy, and Vinck et al. found that an LED source creates more favorable conditions for cell growth in green light.[67,68] Numerous studies on this subject can be found in the literature, on both animal and clinical models. Most of them indicate a significant increase in the speed of tooth movement. In these studies gallium-aluminum-arsenide (Ga-Al-As) lasers were used, and the length of light wave was on average 820 nm. The challenge was to determine the optimal energy dose.[61,70,72,75] Goulart et al. achieved acceleration as a result of a combined dose of 5.25 J/cm^2, but noted that increasing it to 35 J/cm^2 could have the opposite effect.[69] This thesis was confirmed by several researchers, including some studies applying irradiations of 100 mW.[61–70] Animal studies have adopted a methodology focusing on determining remodeling efficiency, the RANK/RANKL system, and the expression of fibronectin and type I collagen.[67,71,72] In addition to standard tooth movements, Saito and Shimizu were able to accelerate bone regeneration after suture opening during expansion of the palate in rats.[73] Youssef et al., after 6 months of research on a group of 15 adults, achieved an almost 2-fold acceleration of canine retraction.[70] Nahas et al. investigated the effects of the OrthoPulse device (Biolux Research Ltd., Vancouver, Canada) in patients with Little's irregularity index in the range of 2–10 mm.[61] Satisfactory results were obtained in the research group after an average of 68.3 days (compared with 87.8 days in the control group), which shortened the treatment time by 22%. Acceleration has also been reported in a few randomized clinical trials.[74–76] Nevertheless, Marquezan et al., during an experiment on an animal model, despite an increased number of osteoclasts on the pressure zone side, did not notice an increased dental shift macroscopically.[77] Chung et al. came to a similar conclusion after observing 11 patients for 3 months.[79] To sum up, due to the differences in the protocols of the experiments conducted, further research is needed, focusing, among other things, on harmonizing the radiation dose.

Clear aligners and self-ligating brackets

In the literature, only a few studies can be found analyzing the acceleration of the movement of teeth using clear aligners and self-ligating brackets. It should also be noted that research based on histological evidence is lacking. Conclusions can be drawn based only on the differences in therapy duration and cases assessed using various indices, such as the peer assessment rating (PAR) or the objective grading system (OGS).[79,80] Gu et al. found the Invisalign system (Align Technology Inc., San Jose, USA) to be advantageous in correcting minor orthodontic defects; the duration of treatment with the same effects was 30% (5.7 months) shorter compared to fixed braces.[79] Buschang et al. reached similar conclusions: in a study of 150 patients with incisor crowding under 5 mm (the study group), they noted that the duration of therapy was reduced by 5.5 months.[81] However, despite shorter treatment and less frequent visits, they point out that aligner therapy is much more expensive and requires more experience. On the other hand, Hennessy et al. did not notice a difference between the length of the treatment of mandible incisor crowding with the Invisalign system and with a fixed labial appliance.[82] In summary, the use of clear thermoplastic aligners, despite their presence and growing popularity in orthodontic clinics, requires further research in terms of accelerating the movement of teeth.

Self-ligating brackets are also worth mentioning. The 1st brackets of this type were created by Stolzenberg over 70 years ago.[83] The aim was to reduce the friction between the arch and the bracket, which is increased by ligatures (both elastic and metallic). According to some researchers, reducing it improved the effectiveness of the "sliding mechanism" used during tooth rotation, correction of angulation and closing spaces.[84] It does not affect bone remodeling, but only changes the distribution of forces that the orthodontist uses during treatment. In addition, despite manufacturers' assurances of shorter treatment times, numerous studies have reported the opposite, detecting no significant differences between the duration of active therapy with the use of conventional and self-ligating devices.[85,86]

Surgical methods

Surgical methods are more invasive, but also significantly broaden the scope of therapeutic options. They are used primarily when the remaining methods are insufficient, i.e., mainly after the period of growth is finished. They are characterized by surgical intervention to the bone tissue, which is more susceptible to the action of orthodontic forces while undergoing remodeling after traumatization.

Corticotomy

The aim of corticotomy is to cut the cortical layer of alveolar bone in order to induce local temporary osteopenia. Over the last several decades, it has undergone numerous modifications. The origins of the method date back to the end of the 19th century; however, Köle, who discussed the procedure in 1959, is considered the pioneer of corticotomy.[87,88] According to his claims, cortical bone is the main obstacle to the orthodontic movement of teeth. This theory, referring to osteotomy, was to a certain extent rejected in 1983, when Frost discovered the regional acceleratory phenomenon (RAP), and in 1994 Yaffe et al. introduced this concept to periodontal lit-

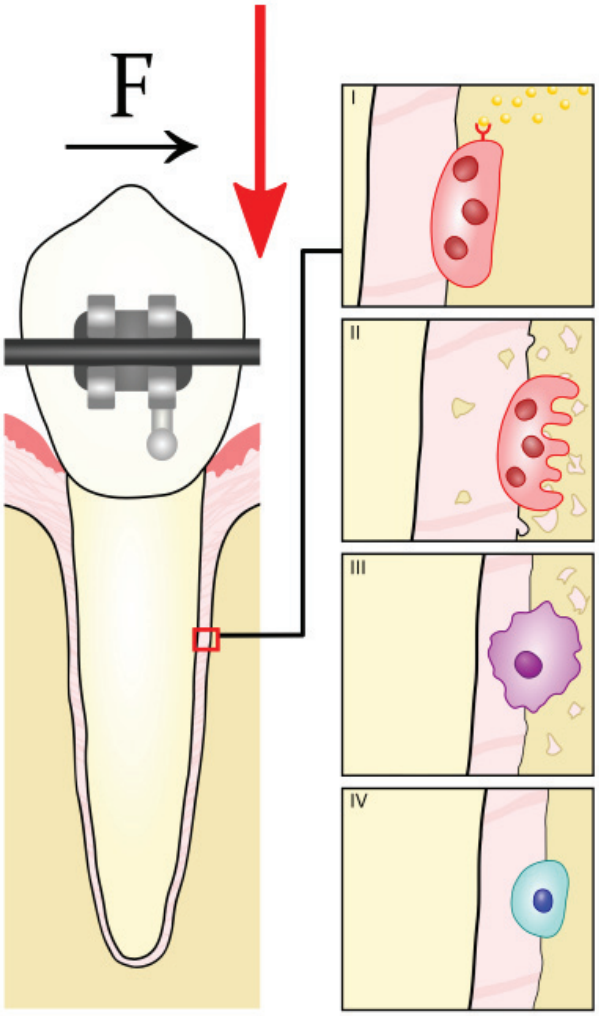

Fig. 1. The regional acceleratory phenomenon (RAP) – a phenomenon described by H. Frost in 1983, involving the temporary reduction of bone density as a result of harmful stimulus. I – The release of pro-inflammatory cytokines activating osteoclast progenitor cells as a result of harmful stimuli. II – Bone resorption caused by the action of mature osteoclasts. Bone density decreases by 10–50 times, making tissue much more susceptible to the action of orthodontic forces. III – Arrangement of the resorbed tissue by macrophages. IV – The inflow of osteoblasts. Bone remineralization with teeth in new positions after 4 months

erature (Fig. 1).[89,90] Small harmful stimuli (such as shallow bone incisions) activate the RANK/RANKL system. In "weakened" bone tissue, 10–50 times faster remodeling is expected. This effect lasts for about 4 months (though it can last up to 6–24 months), with peak efficiency reached 1 or 2 months after surgery.[91] Due to the nature of the surgery, which involves a high risk of infection, antibiotic protection is vital. Only local anesthesia is required. The field of the procedure depends on the defect: vertical incisions are made between the roots of the teeth, horizontally, 2–3 mm above the apices, in order not to damage the bundles. The advantage of the method lies in the creation of a more stable anchorage, not involving teeth/arches in the procedure. The brackets of the fixed appliance are bonded before the surgery. The cuts, after earlier retraction of the muco-periosteal flap, can be made with traditional rotational tools or a piezoelectric knife. Dibart et al. recommend the use of the latter, due to limited traumatization of tissues, greater precision of execution, and more extensive bone demineralization, which induces prolonged RAP.[92] To avoid interfering with the bone remodeling process, non-steroidal anti-inflammatory drugs (NSAIDs) should not be administered. Initially (in the first 3–7 days) the pain can severely affect the patient's well-being. Tooth brushing should be neglected for a week. An alternative is to rinse the mouth with an antiseptic solution (e.g., chlorhexidine). After this period, the 1st activation of the braces can be performed. It is important that during the demineralization of the bones, the patient appears regularly for frequent visits.[92]

Periodontally accelerated osteogenic orthodontics

Described by Wilcko et al. in 2001, the technique referred to as periodontally accelerated osteogenic orthodontics (PAOO) or accelerated osteogenic orthodontics (AOO) is a combination of conventional corticotomy with the implantation of bone graft material.[93] After analyzing high-resolution computed tomography (CT) scans, Wilcko et al. observed the process of remodeling remineralization and demineralization of the bone and demonstrated its relationship with the RAP, as described earlier.[93] After retraction of the muco-periosteal flap and incisions in selected areas, allogenic frozen and dried material is placed in the scars. It is very important that it is fully biocompatible. Otherwise, only the extension of the epithelial attachment can be observed, leading to the accumulation of bacteria, which in turn may result in abscess formation and bone loss.[94] Insertion of the material allows bone density and mass to increase. This is particularly important in adults, who have much lower regenerative bone capacity than children. The main goal is to surround the teeth on each side, while eliminating fenestration and bone dehiscence. This increases the possible range of tooth movement, the apical base and the arch envelope, and minimizes gum recessions, relapses and the need for extraction.[95] One indication is the presence of shortened roots, which could become shorter during traditional treatment.[96] Wilcko et al. presented many cases demonstrating the effectiveness of the method in accelerating the movement of teeth while improving the condition of periodontal tissues.[97,98]

Piezocision

To initiate the RAP phenomenon, one needs to perform a cut to the cortical layer of bone. In the traditional technique, this stage is preceded by the detachment of the muco-periosteal flap. This increases the risk of discomfort and postoperative pain. Park et al. and Kim et al. proposed

performing the procedure without the flap retraction, but directly through the gum.[99,100] An alternative combining limited invasiveness, enhanced precision and treatment of periodontal problems is piezosurgery (the piezocision technique), described in 2009 by Dibart et al.[101] It combines cuts in the bone through the gingiva with a piezoelectric knife to create of submucosal tunnels for bone-substitute material. The orientation incisions are made with a scalpel, then a piezoelectric knife is used with a marker indicating the working depth (according to the author, it is necessary to go through the entire cortical layer and reach the cancellous bone to stimulate RAP). Particular caution should be exercised in the area of interdental papillae and between roots located close to each other. Tunneling can be performed in areas of gingival recession, dehiscences or fenestrations. In the anterior part of the mandible, due to the small width of the teeth, incisions between the lateral and central incisors can be omitted. Active elements of the device are activated every 2 weeks, starting 2 weeks after the procedure.

Micro-osteoperforations

This is another treatment modality based on the RAP.[102] The goal is to further minimize soft tissue damage. Perforations are made in the bone through the mucous membrane, with the aim of accelerating orthodontic movement. Micro-osteoperforations can also be combined with standard corticotomy or the PAOO technique. The device used during the treatment was designed by Propel Orthodontics (Ossing, USA).[103] It is intended for single use only. It perforates both the attached gingiva and the mucous membrane. Clinically, the use of micro-osteoperforations significantly increases the expression of cytokines, which leads to a 60% shorter treatment time compared to a control group, and 2.3 times faster retraction of canines.[102] The procedure itself is described as effective, convenient, and less invasive than standard corticotomy.[104]

Corticotomy and other attempts at surgical acceleration of tooth movement are documented in a large number of scientific publications. Despite the different levels of invasiveness, they have similar effectiveness, which was confirmed in a comparative study by Librizzi et al.[105] It can be assumed that this is the effect of the same mechanism of action (inducing the RAP). Experiments conducted on an animal model show both a shorter therapy time and increased remodeling occurring within the cancellous bone.[106–108] Similar results were obtained during the treatment of mild crowding (a study on 24 patients resulted in a 47% shorter treatment time), orthodontic extrusion of palatally impacted canines (6 patients) and retroinclination of upper incisors with sufficient bone support.[109–111] Al-Naoum et al., in a group of 30 patients, obtained an average speed of 0.74 mm/week (compared to 0.2 mm/week on the control side) during retraction of canines.[112] The potential usefulness of corticotomy in the treatment of post-traumatic ankylosis is also worth considering. Małyszko et al. published a case of post-traumatic intrusion of tooth 11 complicated with ankylosis and resistant to other methods of traditional orthodontic treatment.[113] The application of bone incisions with the intraocular luxation resulted in a positive effect, i.e., tooth extrusion. The role of corticotomy in clinical orthodontics seems to be constantly growing and is currently one of the most frequently used methods to shorten the time of orthodontic treatment.

Combined methods

Considering the different mechanisms of action of conservative and surgical methods, the question arises: Would the combination of both prove even more efficient? Referring to this hypothesis, Kim et al. conducted a study combining cortical bone incision (also referred to as corticision) and radiation.[114] The experiment involved 12 dogs divided into 4 groups: a control group (only orthodontic force was used), a group undergoing photobiostimulation, a group undergoing surgical treatment, and a group in which both of these methods were implemented. In the groups involving the surgical procedure, incisions were made near the 2nd maxillary premolars (for the purpose of their mesialization after the extraction of the 1st premolars). A diode laser with a wavelength of 808 nm was used as the source of photobiostimulation. Contrary to expectations, the group covered by both treatment methods showed less acceleration than the groups undergoing each treatment separately. Moreover, within 8 weeks after the procedure, the dental movement in the group exposed to both methods was comparable to the control group (in which only orthodontic forces were used). Considering the regenerative effect of light irradiation, it can be assumed that the laser significantly accelerated bone healing and thus led to the elimination of the RAP. The available literature also describes 2 cases in which corticotomy and Smiletech polyvinyl overlays (Ortodontica Italia, Rome, Italy) were used. Cassetta et al. described the therapy of 2 patients with moderate crowding (the 1st with class I, the 2nd with class II).[115,116] The treatment was completed with a satisfactory effect after 2 months (in the class I patient) and after 8 months (in the class II patient). However, attention should be paid to the low power of scientific evidence (no control group; only a case report) and the possible bias of the conducted study.

Conclusions

The contemporary literature presents many methods of accelerating tooth movement during orthodontic treatment, but a significant number of them, especially those using pharmacological agents, are supported by rather limited

scientific evidence due to the fact that randomized clinical trials are rarely encountered. The methods using physical stimuli, in spite of the larger number of published trials, can prove difficult to apply in everyday practice due to the use of expensive and specialized equipment and the need for regular and repeated administration of specific agents. Surgical methods are currently the most soundly evidenced, and could be described as methods of documented efficacy. Unfortunately, they are associated with significant (though constantly diminishing) invasiveness, exposing the patient to additional stress and postoperative pain.

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Porcelain veneers: An update

Licówki porcelanowe – uaktualnienie wiedzy

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Abstract

New glass-ceramic restorative materials have been developed over the last few years, with enhanced strength characteristics along with desirable optical properties that make them ideal for the fabrication of esthetic crowns and veneers. The purpose of this paper was to provide an overview of the current state of the art of porcelain veneers as a viable option for the esthetic treatment of anterior teeth, and to illustrate the potential of the newly-developed glass-ceramics. Some historical background about the development of the porcelain veneer concept is provided. A list of indications and contraindications for porcelain veneers is followed by their preparation designs, with emphasis on the importance of maintaining the preparation boundaries within the enamel. Impression-taking procedures, provisional restoration fabrication, the choice of porcelain materials and their intaglio surface treatment are all discussed. A case where veneers made with a lithium-disilicate glass-ceramic were used to improve the appearance of maxillary anterior teeth is included. Several studies reporting on the longevity of porcelain veneers up to 12 years are discussed.

Key words: glass-ceramic, update, dental porcelain, longevity

Słowa kluczowe: tworzywo szklano-ceramiczne, uaktualnienie wiedzy, ceramika dentystyczna, trwałość

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Porcelain veneers are thin-bonded ceramic prosthetics that restore the facial surface and part of the proximal surfaces of anterior teeth that require esthetic treatment.[1] They typically consist of thin shells of porcelain, the fitted surface of which has been etched with hydrofluoric acid and coated with a silane coupling agent. Using a resin-based cement, the veneer is bonded to enamel that has been prepared with a phosphoric acid etchant.[2] Due to their high esthetic appeal, as well as their proven biocompatibility and long-term predictability, porcelain veneers have become a reliable restorative procedure for the treatment of teeth in the front area of the mouth.[3,4]

Porcelain veneers were introduced to the profession by John Calamia of New York University, USA, in the early 1980s.[5,6] Their development was one of several innovations and outcomes that followed the discovery of acid-etching and bonding to enamel that was first reported by Michael Buonocore in the 1950s.[7] Resin composite formulations based on bisphenol A-glycidyl methacrylate (Bis-GMA) were introduced to the profession by Rafael Bowen in the early 1960s.[8] These resulted in composite restorations with superior physical and mechanical properties, leading to enhanced clinical performance. Following the success of these resin-based restorative composites, resin cements based on Bis-GMA resin were introduced to the profession in the late 1970s. This meant that 3 crucial elements for the development of the porcelain veneer technique had been realized: the ability to acid-etch enamel to produce a microscopically rough surface that is receptive to bonding; the ability to acid-etch the fitted surface of a feldspathic porcelain veneer with hydrofluoric acid to create a microscopically rough surface that is also receptive to bonding to the resin; and the availability of a resin cement that can be used for cementing porcelain veneers to enamel.[9]

Indications and contraindications for porcelain veneers

Porcelain veneers are ideal for the treatment of discolored vital anterior teeth that do not respond well to bleaching. This includes moderate discoloration caused by tetracycline staining, excessive fluoride uptake, aging, and amelogenesis imperfecta.[10] Enamel hypocalcification and fractures can also be corrected with porcelain veneers.[5,6,11] They are also useful for closing moderate spacing between anterior teeth and to treat congenital tooth malformation.[12] When there is a need to lengthen or reshape maxillary anterior teeth, porcelain veneers provide a conservative treatment option.[13,14]

In contrast, endodontically-treated anterior teeth that are structurally compromised are not suitable candidates for porcelain veneers, as they need the bracing provided by full-coverage crowns to maintain their integrity. Heavily-restored teeth with inadequate enamel are not good candidates either, as enamel is the main source of retention for porcelain veneers. Other precluding conditions are dentition lacking posterior support, poor oral hygiene and existing parafunctional activity, such as bruxism.[15,16] Magne et al. reported that success rates for porcelain veneers drop to 60% in patients with bruxism activity; however, this percentage was similar to that obtained for metal-ceramic crowns used in the same situation.[17]

Preparation

Porcelain veneer preparation is characterized by minimal removal of the tooth structure. Ideally, porcelain veneer preparation should be confined to enamel in terms of the periphery and depth. For maxillary anterior teeth, typical preparation involves the whole facial (labial) surface to a depth of approx. 0.3 mm. In some cases, when there is a need to lengthen the teeth or close interproximal spaces, an incisal and/or proximal wrap-around is indicated. However, the key for proper retention of porcelain veneers is to keep the preparation within the enamel structure. This will ensure superior bonding and will allow avoiding the potential for postoperative sensitivity, which may happen if the dentin is involved in the preparation. The finish line of the preparation is typically of the feather-edge type, considering the minimal amount of enamel removed. Gingivally, it terminates at the gingival margin. An incisal overlap is performed only when needed. It can either be extended as a palatal chamfer or merely as a horizontal incisal reduction (a butt joint).

Porcelain veneer preparations have the advantage of being significantly more conservative than full-coverage crowns, and can address some of the limitations of metal-ceramic full-coverage crowns.[18] The advantages include superior optical reflectance due to the elimination of the metallic core; the ability to place margins supragingivally; and improved gingival tissue response as compared to that caused by by some elements in base metal alloys.[19]

Impression-taking for porcelain veneers

A vinyl poly-siloxane-based impression material is typically used in a custom or stock tray for veneer impression preparation. The retraction cord is positioned to expose the finish line. For computer-aided-designed and computer-aided-manufactured (CAD-CAM) veneers, a digital impression is made with an appropriate scanner.

The temporization of tooth preparation for porcelain laminate veneers is advocated in order to maintain the patient's appearance unchanged and for the overall success of the restoration.[20] However, in some cases, providing provisional restorations may be optional. Since the preparations involve enamel only, the risk of postop-

erative sensitivity is non-existent, and since contacts between the teeth are not always broken during the preparation, the risk of tooth shifting is remote. However, when a case dictates the use of provisional restorations, these should be made as one piece, with no attempt to separate individual provisional veneers. This ensures better retention by engaging the interproximal areas, and at the same time maintains the strength of the restorations, which are rather thin and delicate. One technique for cementing temporary porcelain veneers involves spot-etching at the center of the facial surface, followed by applying a bonding resin at the etched point only and using a small amount of a resin cement for attachment. The use of ordinary temporary cements, which are naturally opaque, adversely affects the final esthetic outcome of temporary veneers due to their ultra-thin nature, which allows the cement opacity to show through.

Types of porcelain used for porcelain veneer fabrication

Traditionally, veneers are fabricated using the manual layering technique from feldspathic porcelain. This necessitates the use of refractory dyes to support the condensed layers of the porcelain slurry.[11] This technique permits the use of layers with multiple levels of opacity, resulting in optimum esthetics. However, the process is technique-sensitive, and manual mixing and layering of the porcelain may result in the incorporation of small voids.[21] These voids may cause crack lines or even a fracture to occur over time.

Alternatively, pressed porcelain has been used for the fabrication of veneers.[22] The main advantages of pressed porcelain are that the resulting veneers have a high level of accuracy and minimal internal structural defects.[23]

Recently, CAD-CAM veneers from glass-ceramic blocks have become available, and their utilization is on the rise. While such veneers are significantly stronger than feldspathic porcelain ones, the color of many of the blocks available is of single opacity.[24] However, multi-opacity blocks are becoming available and can help to overcome this limitation. Figure 1 shows 6 maxillary incisors with discoloration and gingival recession. The right lateral incisor had previously been restored with a ceramo-metal crown. Figure 2 shows a postoperative view with 1 crown and 5 veneers made with milled e.Max® (Ivoclar Vivadent AG, Schaan, Liechtenstein) lithium disilicate glass-ceramic and cemented into place with a resin cement.

Fig. 1. Maxillary anterior teeth with gingival recession and discoloration

Fig. 2. Five lithium disilicate glass-ceramic e.Max® veneers and 1 crown were made according to a diagnostic mock-up approved by the patient. These were cemented with a light-polymerized resin cement

Surface treatment and cementation

Acid etching of the fitted surface with hydrofluoric acid has become the standard procedure to render the fitted surface microscopically rough.[25–27] A silane coupling agent is applied to the etched surface to enhance bonding to the resin cement.[28] For an optimal ceramic–cement bond, sandblasting the ceramic surfaces with aluminum oxide particles prior to acid-etching with hydrofluoric acid is recommended.[29]

Silane facilitates the adhesion between the inorganic substrate (porcelain) and the organic polymers (resin cement) by increasing porcelain wettability and interlocking.[30] Moreover, silane is a bifunctional molecule that chemically bonds to the hydrolyzed silicon dioxide of the ceramic surface on one side and to the methacrylate group of the resin cement on the other side.[31]

The attachment of porcelain veneers to the teeth depends on bonding to enamel. An appropriate resin cement is used to achieve this, and to help seal the margins of the veneers, reinforcing the ceramic structure and providing an opportunity to modify the color of the restoration if needed.[32,33] A light-polymerized resin cement is the only type of resin cement that can be used with porcelain veneers. This is because self-polymerized and dual-polymerized resin cements can darken with time, leading to undesirable changes in the color of the veneer.

As porcelain veneers are very thin, they must be handled carefully during the try-in and subsequent cementation. Excessive finger pressure may cause the veneer to fracture, particularly when a high-viscosity resin cement is used. Low film thickness is desirable for optimum adaptation to the tooth substrate.[32,33] Seating the restorations with ultrasonic energy has been recommended.[34] The vibrations, based on the oscillation principles of the ultrasonic device, are helpful in altering the viscosity of the cement, which settles the restoration into place, spreading the luting agent under the restoration and minimizing the potential for future leakage.[35–37]

An important key to success is proper occlusal adjustment after the porcelain veneers are cemented. Occlusion should first be checked in the centric position, and any contacts on the lingual aspects of the newly-cemented veneers must be removed. Similarly, occlusion must be checked in the protrusive mandibular excursion, and any contacts on the lingual aspects of the veneers must be removed. This will ensure that the veneers will be subjected to minimal compressive/shear forces, which is important for their longevity.

Gingival tissue response to porcelain veneers

Porcelain veneers are typically associated with favorable gingival tissue response due to the location of their gingival margin, which is typically at the gumline or slightly supragingival to the tissues. A proper emergence profile contributes to lowering the incidence of plaque retention, thus helping in the maintenance of periodontal health.[38] The periodontal response to porcelain veneers reported in the literature varies from clinically acceptable to excellent.[39]

Longevity of porcelain veneers

The long-term success of porcelain veneers depends on careful case selection, the design of tooth preparation, the material, the laboratory fabrication, and the insertion procedure. Several studies reporting on the longevity of porcelain veneers have been published. Fradeani et al. stated that feldspathic porcelain and glass-infiltrated ceramic veneers presented survival rates ranging from 96% to 98% at a 5-year evaluation.[40] Similarly, Della Bona and Kelly reported overall failure rates for ceramic veneers of less than 5% at 5 years.[41]

D'Arcangelo et al. reported that 119 porcelain veneers had a survival rate of 97.5% at a 7-year evaluation.[42] In a retrospective study by Gurel et al., evaluating 580 porcelain veneers with various preparation designs for a 12-year period, an overall survival rate of 86% was observed.[43] The most frequently observed type of failure was a veneer fracture. Preparations with margins on dentin were 10 times more likely to lead to failure than those with margins on enamel.

Beier et al. stated that porcelain veneers offer predictable and successful restoration with an estimated survival rate of more than 10 years.[44] Layton and Walton reported the longevity of feldspathic porcelain veneers as up to 12 years; at 5 years, the survival rate was 96%, dropping to 93% at 10 years and to 91% at 12 years.[45] A cumulative success rate of approx. 93% was reported after a 15-year retrospective clinical observation.[46] In a 10-year prospective clinical trial that involved 87 porcelain veneers, none of the veneers were lost. At 5 years, 92% remained in use without the need for clinical intervention; however, at 10 years, the percentage dropped to 64%.[47] Large marginal defects were the main failure mode (20%), particularly when the veneer ended on an existing composite restoration; a porcelain fracture (11%) was the next most frequent failure. Only 4% of the veneers needed to be replaced at the 10-year mark.

In a recent systematic review by Morimoto et al., 899 studies were identified, but only 13 were analyzed.[48] An overall survival rate of 89% at 9 years was reported; the survival of glass-ceramic veneers (94%) was higher than that of feldspathic porcelain veneers (87%). Failure modes included debonding (2%), a fracture (4%), caries (1%), and discoloration (2%). Figure 3 shows a case of a fractured porcelain veneer on a canine.

Calamia and Calamia enumerated keys to success for porcelain veneers that may lead to their survival for up to 25 years.[49] These included proper treatment planning, preparations terminating in enamel, proper selection of the ceramic to be used, and proper cementation.

In conclusion, porcelain veneers have been used in the profession for more than 30 years. They are characterized by a conservative preparation design with minimal enamel reduction. Proper case selection is key for their success. Several studies have indicated a high survival rate over the long term. When failure occurs, it frequently involves a veneer fracture. The introduction of milled glass-ceramic materials is expected to overcome the fracture issue due to the enhanced strength of this material as compared to the original feldspathic formulations.

Fig. 3. Maxillary left canine with a vertical fracture of a feldspathic porcelain veneer that took place several years after cementation

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Ankyloglossia as an oral functional problem and its surgical management

Zrost języka z dnem jamy ustnej jako wada czynnościowa i jej leczenie chirurgiczne

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Abstract

Tongue-tie or ankyloglossia is a developmental anomaly of the tongue characterized by an abnormally short, thick lingual frenulum resulting in limited tongue movement. Ankyloglossia can affect feeding, speech and oral hygiene, as well as have mechanical and social effects. Diagnosis of tongue-tie is based on a clinical examination. Tongue mobility and appearance associated with the insertion, as well as the attachment and the shortness of the lingual frenulum should be evaluated. Ankyloglossia management should be considered at any age considering the risk-benefit evaluation and because of the highest vascularization and mobility of tongue; lingual frenectomy should be performed with less traumatic events to avoid postoperative complications.

The aim of this article is to report 2 cases of ankyloglossia in young patients who were referred to the Department of Oral Surgery of the Faculty of Dentistry at the Mohamed V University of Rabat, Morocco. According to Kotlow's classification, both patients were diagnosed with Class II and treated with surgical frenectomy, followed by speech therapy for an immediate rehabilitation. A marked improvement in the movement of the tongue was observed at a follow-up visits in the treated cases.

Key words: ankyloglossia, tongue-tie, lingual frenectomy

Słowa kluczowe: zrost języka, skrócenie wędzidełka języka, wycięcie wędzidełka

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Ankyloglossia, also known as tongue-tie, is a congenital oral anomaly characterized by an abnormally short lingual frenulum, in which the tip of the tongue cannot protrude beyond the lower incisor teeth.[1] This anatomic condition may have an impact on tongue function and it can also interfere with the shape of the dental arches and their consequent occlusion.[2] In the literature, such a condition occurs in 0.02–10.7% of neonates, and males seem to be more affected than female patients in a proportion ranging from 4:1 to 1.7:1.[3] Tongue-tie is often an isolated anomaly, but its association with other craniofacial abnormalities might be possible.[1]

There is a continuous controversy over the diagnostic criteria and treatment of ankyloglossia.[2,3] Diagnostic criteria established by several studies are based on the length of the lingual frenulum, amplitude of tongue movement, heart-shaped look when the tongue is protruded, and thickness of the fibrous membrane.[4,5] In children, ankyloglossia can lead to difficulty in breastfeeding, pronunciation disorders, unsatisfactory oral hygiene, bullying during childhood and adolescence, as well as difficulties in sucking or ice-cream licking, kissing and playing wind musical instruments.[2,6]

The aim of the present article is to describe 2 clinical cases of ankyloglossia and their successful surgical management with lingual frenectomy, followed by speech therapy for an immediate rehabilitation of the lingual muscles; also, a short literature review is presented.

Case reports

Case 1

A healthy 15-year-old girl was referred to the Department of Oral Surgery by her orthodontist to undergo a frenectomy due to the restriction of tongue movements and functions. The patient followed her treatment in the orthodontic department for hyperdivergent Class III malocclusion (Kotlow's classification). Results of general physical examination were normal. The intraoral examination revealed that she could protrude the tongue only to the lower lip and not beyond. The ankyloglossia was classified as Class II using Kotlow's classification (Fig. 1A).

Case 2

A healthy 13-year-old boy reported a complaint of restricted tongue movement and speech difficulties; he was neither able to utter letter sounds "l," "t," "d," "n," "s," and "th" distinctly nor to protrude his tongue over the vermillion border of lower and upper lip. The patient followed his orthodontic management of a Class III malocclusion and was referred to the surgery department for a lingual frenectomy to optimize the pursuit of treatment. Clinical intraoral examination showed the presence of a Kotlow's Class II ankyloglossia and there was neither a malocclusion nor a recession present in lingual of the mandibular incisors (Fig. 1B).

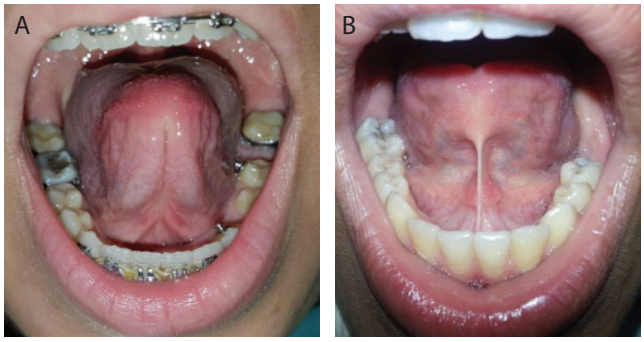

Fig. 1. Preoperative view showing ankyloglossia (A – case 1, B – case 2)

Surgical procedure

After a general assessment of both patients, informed consent from their legal guardians was obtained and lingual frenectomy was indicated.

The frenectomy was performed with a scalpel using blade No. 15. Local anesthesia infiltration was deposited bilaterally at the base of the tongue, floor of the mouth and toward the genial tubercle on the lingual aspect of the mandible. The frenulum was maintained with a curved hemostat by inserting the convex curve at the depth of the vestibule, and then clamped into position, followed by 2 incisions at the superior and inferior aspect of the hemostat. The frenulum was then removed, leaving a diamond-shaped wound (Fig. 2). Fiber remnants were excised and a blunt dissection was performed to achieve a good tension-free closure of the wound edges, and 4-0 non-absorbable silk sutures were placed over the wound (Fig. 3).

The postoperative period was uneventful with no hemorrhage complications. Sutures were removed after 1 week with no scar tissue formation and the patients were sent to speech therapy sessions. Both patients had a 3-months postoperative follow-up in which no recurrence nor difficulties in lingual functions were reported, which suggests an excellent prognosis for the 2 cases (Fig. 4, 5).

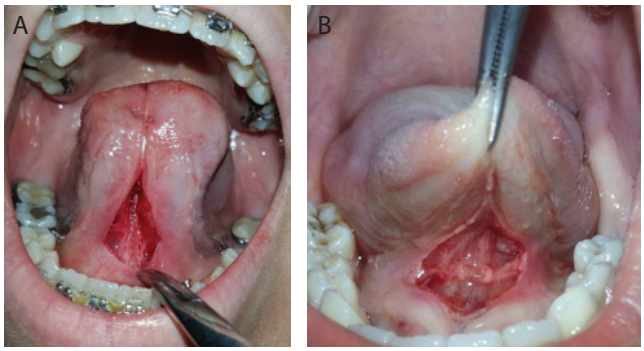

Fig. 2. Incision of the frenulum (A – case 1, B – case 2). The excised triangular tissue was held with the hemostats and excision of fiber remnants

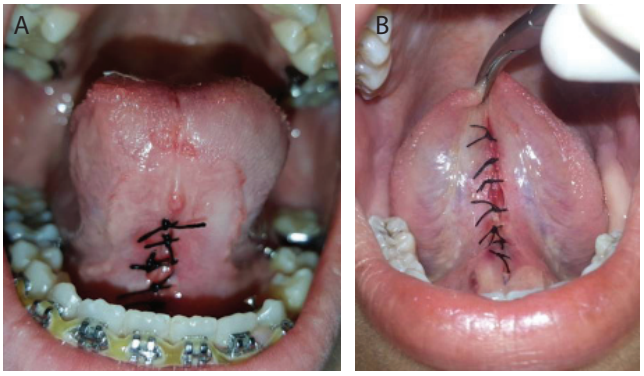

Fig. 3. Silk sutures placed over the wound (A – case 1, B – case 2)

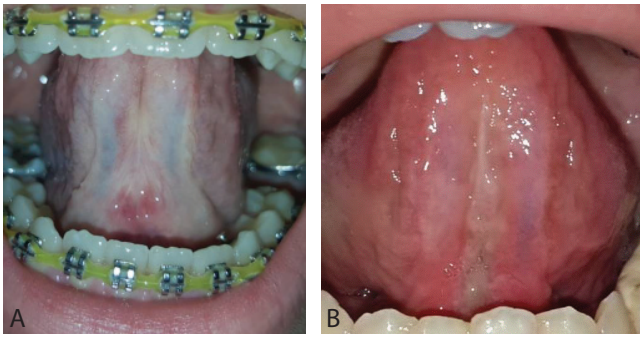

Fig. 4. Postoperative view 3 months after the surgery (A – case 1, B – case 2)

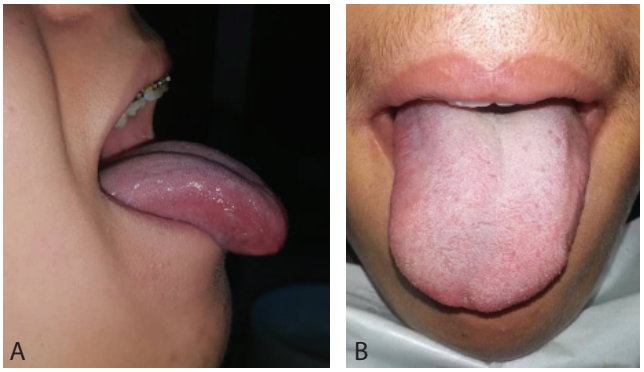

Fig. 5. Postoperative view at 3 months showing easy lingual propulsion (A – case 1, B – case 2)

Discussion

Ankyloglossia is a Greek term which means "agkilos" for curved and "glossa" for tongue and is more commonly called "tongue-tie". It is a congenital anatomical variation characterized by a short lingual frenulum, which may result in the restriction of tongue movement and can thus impact oral functions.[3,4]

During the 4th week of gestation, the tongue's origin is from the 1st, 2nd and 3rd pharyngeal arches. In this period, grooves are formed laterally to the structure and it can move freely, except for the region adhered by the lingual frenulum, initially at the apex of the tongue. As the development occurs, the frenulum cells undergo apoptosis and they tend to migrate distally to the medial region of the lingual dorsum, which explains the possible interferences in cell control and the incomplete migration, or even its non-occurrence resulting in an ankyloglossia.[7] In most cases, ankyloglossia is seen as an isolated finding in children. However, several syndromes are associated with this physical finding, including Ehlers-Danlos syndrome, Beckwith-Wiedemann syndrome, Simosa syndrome, X-linked cleft palate, and orofaciodigital syndrome.[1,3,6]

Ankyloglossia might be a result of a possible manifestation of mutations in T-box genes or of exposure to teratogenic substances during pregnancy.[2,3] Diagnosis is based on a clinical examination. Tongue mobility and appearance associated with the insertion, as well as the attachment and the shortness of the lingual frenulum, should be evaluated. Furthermore, instances of speech difficulty resulting from the limited tongue movements can be checked by vocalizing some letters and words (sounds such as "t", "d", "r", "n", and "l", and words like "ta", "te", time, water, cat, etc.).[3,6]

Kotlow classified the ankyloglossia into 4 classes:

- Class I: mild ankyloglossia (12–16 mm);
- Class II: moderate ankyloglossia (8–11 mm);
- Class III: severe ankyloglossia (3–7 mm);
- Class IV: complete ankyloglossia (less than 3 mm).[8]

Several publications have investigated the influence of the tongue and lingual frenulum on maxillofacial anomalies such as mandibular prognathism, maxillary protrusion and anterior open bite. Yoon et al. showed in their recent cross-sectional cohort study that the restriction of tongue mobility was associated with the narrowing of the maxillary arch and the elongation of the soft palate, which may affect maxillofacial development.[9] Generally, in the majority of published articles, this hypothesis is mainly based on single observation and speculative interpretations, and there is still limited evidence that tongue-tie represents a cofactor in the development of malocclusions, especially Class III malocclusion.[7,9,10]

Clinicians may strive with the management of ankyloglossia after diagnosis of the condition, since there is no consensus about the optimal timing, indication and type of surgical intervention for ankyloglossia. Correct diagnosis of ankyloglossia and early intervention are imperative, since several consequences ranging from restriction of tongue movement to impairment of mandibular growth may occur.[3,10]

Several management options exist for the treatment of tongue-tie. They include observation, speech therapy, otolaryngotherapy; frenotomy, frenectomy, Z-plasty, and laser frenectomy, and they have the capacity to deliver satisfactory results, often in a shorter time than expected. If the intervention of a speech therapist and otolaryngotherapist fails to resolve speech and tongue related problems, then it may be necessary to consider surgical protocol. Surgical interventions are absolutely safe at any age, including infants and adults, but strictly require postsurgical tongue reeducation and speech therapy to achieve satisfactory results.[6]

Surgical management of tongue-tie can be classified into 3 techniques:

– frenotomy defined as simple cutting of the frenulum;
– frenectomy defined as complete excision, i.e., removal of the whole frenulum;
– frenuloplasty that includes various methods to release the tongue-tie and correct the anatomic situation.

There is no sufficient evidence in the literature concerning surgical treatment options for ankyloglossia to favor any of the 3 main techniques.[6,11]

In these clinical cases, our 2 patients with tongue-tie were subjected to surgical correction by frenectomy procedure, which is more invasive and difficult to be performed in young children, although the results are more predictable, decreasing the recurrence rate.[12] On the other hand, the use of lasers as an alternative technique in the treatment of ankyloglossia is considered safe and minimally invasive. It has an advantage over conventional treatment as it is bactericidal; it also provides a bloodless operating field and does not require sutures or anesthesia. Recurrent ankyloglossia can occur with scarring at the site of the division and the clinical manifestation is less intense than before the 1st treatment; also, recurrent ankyloglossia responds effectively to revision surgery.[3,4]

Late postoperative complications after ankyloglossia management are rare. Various complications include bleeding, blockage of Wharton's duct while suturing on the ventral surface of the tongue leading to retention cyst, and damage to the lingual nerve causing numbness of the tongue tip.[13] A recent systematic review conducted by Bin-Nun et al. mentioned that the yearly number of ankyloglossia-related articles has increased dramatically in the past few years without bringing interesting evidence.[14] If this trend continues, much more solid evidence (randomized controlled trials and systematic reviews) should accumulate about diagnosis and management of tongue-tie, as it relates to breastfeeding and other outcomes.

Conclusions

Tongue-tie, or ankyloglossia, is a serious oral problem that affects quite a large number of infants and children. A careful clinical examination is essential for an early diagnosis of a lingual dysfunction and in order to choose optimal management, including surgical intervention or laser therapy, followed by proper tongue exercises, which leads to satisfactory results in a short time.

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Saethre-Chotzen syndrome: Case report and literature review

Zespół Saethrego-Chotzena – opis przypadku i przegląd piśmiennictwa

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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

Saethre-Chotzen syndrome (SCS) belongs to a group of rare congenital disorders connected with craniosynostosis and syndactyly. The purpose of this paper is to provide a review of the literature, to collect all reported symptoms and to describe the case of an 11-year-old female with SCS. The electronic databases PubMed and Scopus were searched to gain all symptoms of SCS described in the literature. The most common features of SCS described in the literature are synostosis of the coronal suture, syndactyly, facial asymmetry, low hairline, prominent ear crus, prominent nasal bridge, eyelid ptosis, and ocular hypertelorism. Less common symptoms include hearing loss, renal abnormalities and cardiac defects. Intraoral manifestations of SCS include maxillary hypoplasia, mandibular prognathism and high arched palate. Moreover, in some patients mental disability is observed, which may be connected with the size of the deletion in the *TWIST* gene. There are no pathognomonic symptoms of SCS, which would indicate a diagnostic problem. Our patient displayed small dysmorphic changes within the skull and limbs and proper intellectual development. On the basis of an intraoral, extraoral examination and X-rays, she was diagnosed with relative mandibular prognathism. Currently, she is treated with a removable appliance. This report emphasizes a considerable variability of symptoms in SCS and highlights the most common features.

Key words: craniosynostosis, Saethre-Chotzen syndrome, acrocephalosyndactyly, acrocephalosyndactyly type 3

Słowa kluczowe: kraniosynostoza, zespół Saethrego-Chotzena, akrocefalosyndaktylia, akrocefalosyndaktylia typu III

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Introduction

Saethre-Chotzen syndrome (SCS) (MIM 101400) belongs to a group of rare genetic disorders known as acrocephalosyndactyly, which is characterized by syndactyly and craniosynostosis – the premature fusion of certain cranial sutures.[1,2] Craniosynostosis can be a part of a genetic syndrome (e.g., Apert, Crouzon, Pfeiffer, SCS) but more often it is an isolated defect – approx. 85% of all craniosynostosis cases are nonsyndromic.[2]

Saethre-Chotzen syndrome is one of the most common craniosynostosis syndromes and was first described independently by 2 psychiatrists: Haakon Saethre (1931) and Fritz Chotzen (1932) as acrocephalosyndactyly type 3.[2] The prevalence of SCS is estimated at 1/25000 to 1/50000 of live births.[3] Saethre-Chotzen syndrome may often go unrecognized, especially in the group that does not experience craniosynostosis and that is the reason why the real number of cases may be higher than estimated.[2,4] It affects both sexes equally.[5]

Gene mutations were proved to be responsible for SCS – mainly modifications in the *TWIST1* gene of chromosome 7p21, containing the bHLH domain, which is important for the development of the head and limbs and is inherited in an autosomal dominant manner.[2,6] Rarely, it may also be caused by FGFR2 and FGFR3 gene mutation.[7] However, occurrences of the novo mutation are also reported.[1]

The characteristic of SCS includes a premature closure of cranial sutures, particularly the coronal suture, which usually begins within the first 12 months of life. This coexists with finger and/or toe abnormalities. Coronal synostosis occurs in 20–30% of all craniosynostosis cases with females being more often affected than males.[2,8,9] Intraoral manifestations of SCS include maxillary hypoplasia, mandibular prognathism, and high arched palate.[2]

The aim of this study is to present a case report of a 9-year-old girl with SCS treated in our clinic and to emphasize the wide variability in the phenotypic expression of this syndrome on the basis of literature review.

Case report

A 9-year-old female was referred to the Department of Orthodontics, Division of Facial Abnormalities (Wroclaw Medical University, Poland) by a general dentist who was concerned about her malocclusion.

According to the medical history, the girl was born in a natural way after 40 weeks of gestation with a birth weight of 3180 g. This was the mother's 3rd pregnancy and the 1st that was full-term. After birth, apart from the features of craniofacial dysmorphism, she was diagnosed with cyanosis, reduced muscle tension, and poor reflexes. Moreover, the girl required pneumonia, respiratory and renal failure treatment shortly after labor. Advanced care was provided and she had been under the care of numerous specialists since she was a neonate: cardiologist due to congenital valvular pulmonary stenosis and interatrial septal defect, endocrinologist because of hypothyroidism and ophthalmologist due to divergent strabismus and myopia. There was no family history of acrocephaly. The parents underwent a genetic test that showed a correct karyotype, indicating that SCS was caused by de novo mutation in the *TWIST1* gene.

A general examination revealed features of craniosynostosis and face dysmorphic traits, such as a broad forehead with low hairline, hypotelorism, a "beaked" nose with a depressed nasal bridge, and small low-set ears. The profile of the patient is straight with the light retrusion of the chin (Fig. 1). Finger abnormalities were also present in the form of brachydactyly with a significant shortening of the little finger and nail dysplasia (Fig. 2).

Intraoral examination revealed a high arched palate, crowding in the upper and lower arch, angle class I on both sides, canine class I on the right side, class II on the left side, and a dual tooth 12. The midline of the lower arch was shifted to the left side and mixed dentition was observed. The deciduous canine, molars, permanent incisors, and first molars in the upper and lower arches were present, which is correct for the patient's age (Fig. 3). In the 1st step of diagnostic imaging, an orthopantomo-

Fig. 1. Extraoral photographs

Fig. 2. Fingers abnormalities

Fig. 3. Intraoral photographs

graph evaluation (Fig. 4) was performed and it demonstrated the presence of all permanent teeth. Poor oral hygiene and severe decay are observed. The calculated DMFT index was 12 indicating the need for conservative treatment of the patient. The cephalometric analysis verified maxillary retrognathia (SNA = 73.0°), mandibular retrognathia (SNB = 75.9°), skeletal class III malocclusion (ANB = –2.5°), which confirmed relative mandibular prognathism (Fig. 5, Table 1)

A physical examination confirmed by a radiological X-ray showed a lack of the coronal suture. The psychological examination revealed hyperactivity, with no abnormalities in intellectual development. The mother reported that the girl removed her hair excessively, which was confirmed by a bald spot on her head (Fig. 1). Further genetic diagnostics are planned. The diagnosis was performed on the basis of clinical features.

Table 1. Cephalometric measurements of 11-year old patient

Description	Cephalometric measurements	Value	Mean	SD
Maxilla to cranial base	SNA	73.0°	82.0°	±3.0°
	NL-NSL	9.5°	8.0°	±4.0°
Mandible to cranial base	SNB	75.9°	80.0°	±3.0°
	ML-NSL	40.7°	28.0°	±5.0°
Maxilla to mandible	ANB	–2.0°	2.0°	±2.0°
	wits	–4.6°	0°	±2.0°
	ML- NL			
Maxillary dentition	U1-NA [mm]	8.0°	3.7°	±2.0°
	U1-NA	30.0°	21.0°	±4.0°
Mandibulary dentition	L1-NB	3.1°	3.8°	±5.0°
	L1-NB	23.8°	24.0°	±4.0°
Soft tissue	naso-labial angle	104.4°	110.0°	±7.0°

SD – standard deviation.

Fig. 4. Orthopantomograph

Fig. 5. Lateral cephalometric radiograph

Table 2. Systematic review from 2000 to 2017

Article	Publication type	A	Details about patients	Genetic confirmation	B	C	D	E	F	G	Conclusion
Shimbo et al., 2017[10]	case report	1	15-month-old male	de novo 0.9-Mb microdeletion in 7p21	–	–	+	+	+	–	HDAC9 was suggested to contribute to developmental delay in SCS patients with 7p21 microdeletions
Mitsukawa et al., 2016[11]	case report	4	4-year-old male	mutation in the *TWIST* gene, 445C> T	+	+	0	+	–	–	familial case report of 4 individuals with SCS of 3 generation and surgical management of brachycephaly and blepharoptosis in these patients
			11-year-old male		+	+	0	+	–	–	
			45-year-old female		+	+	0	–	–	–	
			72-year-old female		0	+	0	–	–	–	
Tahiri et al., 2015[12]	case report	5	7-year-old female	duplication of 21 bp from nucleotide 396 to 416 of the *TWIST* gene resulting	0	+	–	0	–	–	new and unique pattern of sutural fusion "peace sign synostosis" (PSS) characterized by synostosis of the metopic, bicoronal and sagittal sutures
			13-month-old male	8.72Mb de novo deletion in 7p21.2p15.3	0	+	–	0	–	–	
			18-month-old male	I point mutation in the *TWIST* gene c.421 G → A	0	+	–	0	–	–	
			9-month-old male	12Mb 7p21.1:7p15.1 deletion	0	+	–	0	–	–	
			10-month-old male	1.0Mb interstitial deletion of 7p21.1 240 kb away from the *TWIST* gene	0	+	–	0	–	–	
Di Rocco et al., 2015[13]	case report	1	22-month-old male	0	–	+	+	–	–	–	case of a patient with complex craniosynostosis with a unique antenatal progressive fusion of both coronal sutures and of the metopic suture with an absence of mental retardation
Shimada et al., 2013[14]	case report	1	5-year-old male	microdeletions in 4q13.2 and 7p21.1	–	+	–	+	–	–	case report of the patient with a typical SCS phenotype and additional severe neurological features
Cho et al., 2013[15]	case report	1	16-month-old boy	deletion of 148 kb, involving *TWIST1*	–	+	–	+	–	–	author emphasizes important contribution of array CGH to the identification of *TWIST* microdeletions, even in a patient not showing the phenotype typical of SCS
Zechi-Ceide et al., 2012[16]	case report; research support	1	15-year-old female+	7p21 and 3p21.31 microdeletions	+	+	+	+	–	–	patient displays clinical findings that fit into both diagnoses: SCS and hyper IgE syndrome
Spaggiari et al., 2012[17]	case report	1	23 weeks of gestation	11.4 Mb deletion from nt 17,042,756 to nt 28,469,318 in chromosomal region 7p15.1-p21.1.	–	+	+	0	–	0	first prenatal case of a de novo molecularly well delineated *TWIST1* gene deletion associated with SCS. The pregnancy was terminated
Fryssira et al., 2011[18]	case report	1	newborn boy	microdeletion on chromosome 7p21.1–p14.3 detected by array-CGH and encompassing the *TWIST* and *HOXA* gene cluster	–	+	+	0	+	–	patient with a combined phenotype of SCS and hand-foot-uterus syndrome. Deletion encompassed 74 genes and caused haploinsufficiency of 6 genes known to be implicated in different autosomal dominant genetic disorders: *TWIST, DFNA5, CYCS, HOXA11, HOXA13,* and *GARS*
De Jong et al., 2011[19]	research support	21	0	0	0	0	0	0	0	0	moderate hearing loss was diagnosed in 28.6% of patients with SCS
Rosen et al., 2011[20]	comparative study	29	12 males	0	62% +						most patients with SCS suffered from hearing loss at some point during their childhood, but it usually resolved. Research shows that 59% of patients had at least 1 abnormal audiogram, but 72% had normal hearing on their last audiogram
			17 females	0	38% –	0	0	0	0	0	
			from 0.7 to 24.5 years	0							
De Marco et al., 2011[21]	case report; research support	1	5-year-old female	de novo balanced translocation 46, XX, t(7;12)(p21.2;p12.3	–	+	–	–	–	–	confirmatory case report providing further evidence for *TWIST1* haploinsufficiency in SCS, and a possible role of PTP-oc as a genetic factor underlying or at least influencing the development of craniosynostosis
Busche et al., 2011[22]	case report; research support	3	2-year-8-month-old female	11.7Mb deletion in the 7p21.2p15.2	–	–	+	+	–	–	clinical manifestations of SCS depend of the deletion size
			1-year-8-month-old female	526 kb deletion in the 7p21.1	0	–	–	–	–	–	
			16-year-old male	9.2 Mb deletion in the chromosomal region 7p15.2p21.1	0	+	+	+		hypo-dontia	
Lamônica et al., 2010[23]	case report; research support	3	45-year-old female (mother) 14-year-old male (son) 12-year-old female (daughter)	Pro136His mutation	+	+	+	+	–	–	report suggests that there may be a correlation between Pro136His mutation and hearing loss in a patient with SCS
Foo et al., 2009[24]	case report	22	birth – 32-year-old	23% complete deletions of the *TWIST1* gene; 77% unique missense, nonsense, insertion, or intragenic deletion mutation of the TWIST1 gene.	0	+	+	+	+	–	different locations of the *TWIST1* gene mutation in this study did not correlate to a specific surgical outcome
De Jong et al., 2009[25]	research support	35		0	0	0	0	0	0	0	refractive error 14 of 27 (52%); strabismus 13 of 35 (37%); impaired hearing 35 (37%); OSA 2/38 5%
Peñ et al., 20092[6]	case report	1	3-week-old female	novel sequence variant, c.G572T, predicting p.R191M in the *TWIST* 1 gene	+	+	+	+	–	–	case report of a girl with clinical features of SCS who has a previously undescribed sequence variant in the *TWIST1* gene, corresponding to p.R191M
Stoler et al., 2008[27]	case report; comparative study	51		0	0	0	0	0	0	0	high-arched palate in 43%, bifid uvula in 10%, cleft palate in 6%
Schlut-Bolard et al., 2008[28]	case report; research support	1	4.5-year-old male	translocation between the short arms of chromosomes 2 and 7 and an insertion of the 7(q21.3q22) 690 kb deletion in 7p21.3 involving the *TWIST* gene	–	+	+	+	–	–	case report of a patient with characteristic features of SCS diagnosed by array CGH
Raybud et al., 2007[29]	review	2	6 years; 14 years	0	0	0	0	0	0	0	neurological non-specific finding about the presence of a mega cisterna magna and poor contrast for age between the grey and white matter
Shetty et al., 2007[30]	research support	1	female infant	translocation between chromosomes 7 and 18 46,XX,t(7;18)(p15.3;q11.2); interstitial 7.6–10.6-Mb deletion of the region between bands 7p21.2 and 7p21.3 on the derivative chromosome 18.	–	+	+	+	–	–	patient with a complex mutation of genes and serious symptoms of SCS
Seifert et al., 2006[31]	case report	1	5-year-old female	a new stop mutation (c.570GOA; p.Trp190X) and a known missense mutation (c.379GOC; p.Ala127Pro) in	–	+	+	–	–	–	case of a patient with SCS associated with metastatic renal cell carcinoma originating in the right kidney
Lopes Burrone De Freitas et al., 2004[32]	research support	24	0	Q289P mutation in the FGFR2; 3/24	+	24/24	24/24	2/24	–	–	case report of 4 families suffering from SCS
De Heer et al., 2004[33]	case report	13	0	small mutation in *TWIST* gene	+	2/13	12/13	0/13	0	0	a large 5-generation family with characteristics of SCS
Chun et al., 2002[34]	research support	11	1–13 years old	mutation in *TWIST* gene 2/11	1/2	1/2	1/2	0/2	–	–	initial screening for the FGFR3 P250R mutation, followed by sequencing of *TWIST* and then fluorescence in situ hybridization (FISH) for deletion detection of *TWIST*, is sufficient to detect mutations in >80% of patients with the Saethre-Chotzen phenotype
			7 females	deletion in *TWIST* gene 3/11	1/3	3/3	2/3	3/3	0	0	
			4 males	no mutation 6/11	2/6	6/6	3/6	1/6	0	0	
Dollfus et al., 2002[35]	research support	16		0	+	4/16	3/16	0	–	–	4-generation Indian family
Lee et al., 2002[36]	case report; review	1	18-month-old male	*TWIST* mutation	–	+	+	–	–	–	patient with a severe profound sensorineural hearing loss
Boeck et al., 2001[37]	case report	2	7-year-old male female (mother)	11 bp deletion in *TWIST* gene	+ –	+ –	– –	+ –	– –	– –	combination of SCS and rare primary immunodeficiency in a 7-year-old boy

+ present ; – absent; 0 no information. SCS – Saethre-Chotzen syndrome. A – No. of patients; B – family history; C – craniosynostosis; D – limb abnormalities; E – mental retardation; F – cleft; G – dental abnormalities.

Currently, the patient is under the care of our clinic and is treated with a removable expansion appliance – a Schwartz plate with a Fischer screw, which is activated once every 2 weeks (Fig. 6).

Fig. 6. Schwartz plate

Literature review

The electronic databases – PubMed and Scopus were searched from years 2000 to 2017. The language of the articles was restricted to English. The following keyword was used for the search: "Saethre-Chotzen syndrome". 170 articles from PubMed, 199 articles from Scopus were initially included in the study. Then, references of the articles were searched manually. The inclusion criteria were as follows: case reports with described features of the syndrome in detail; articles on the frequency of occurrence of a particular feature, review of the literature focused on SCS. The exclusion criteria: not enough details about the patients, animal studies, studies focused on genetic diagnostic methods (Table 1).

Twenty eight articles[10–39] were finally chosen after applying the selection criteria and removing duplicated papers (Fig. 7, Table 2). The above-mentioned articles, which described more than 10 cases of SCS, were additionally screened to show the frequency of the most common features (Table 3).[24,34,35,38,39]

Discussion

Saethre-Chotzen syndrome belongs to a group of rare genetic disorders known as acrocephalosyndactyly disorders. This genetic condition is characterized by the premature fusion of certain bones of the skull (at 1–3 years of age) and the fusion of certain fingers or toes.[40] The most common is the premature fusion of the coronal suture, which is located between the frontal bone and the parietal bone and is perpendicular to the sagittal suture.[3] These changes can result in various cranial dysmorphologies depending on where the premature closure of the coronal suture occurs: acrocephaly, which includes the premature closure of the coronal sutures alongside any other suture, like the

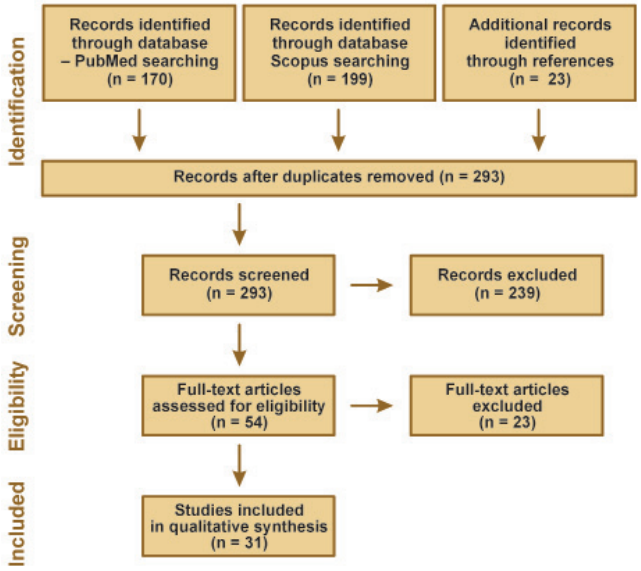

Fig. 7. PRISMA flow diagram
Based on Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

lambdoid, resulting in an abnormally high, peaked, or cone-shaped cranium,[6] and brachycephaly, where the premature fusion of the coronal sutures includes both the right and the left side of the skull.[2] In rare cases, trigonocephaly, cloverleaf deformity, and oxycephaly can also be observed.[4] In some cases the cranial sutures may fuse unequally and thus contribute to facial asymmetry. Asymmetric craniosynostosis is called plagiocephaly and it occurs in approx. 25% of patients suffering from SCS.[4] An early fusion of cranial sutures may lead to increased pressure within the skull (intracranial pressure) and contribute to neurological disorders. According to De Jong et al., SCS is associated with a 21% risk of elevated intracranial pressure (ICP).[25]

Despite the improper shape of the skull, many abnormalities relating to the face may be observed: a broad forehead with a low hairline, small, low-set ear, and many defects of the nose such us a "beaked" nose, deviated nasal septum, and a depressed nasal bridge.

When it comes to the eyes, ocular hypertelorism (widely spaced eyes), unusually shallow eye cavities (orbits), ptosis (drooping or falling of the upper eyelids), and strabismus were observed.[25] Moreover, a nasolacrimal duct stenosis causing decreased tear secretion and susceptibility to eye infections may be presented.[3,41]

Many individuals with SCS demonstrate hypoplastic maxilla and midface hypoplasia with relative mandibular prognathism. Moreover, a highly arched palate may be observed. According to Stoler et al., it occurs in 43% of cases.[27] In rare cases, cleft palate is diagnosed, which is described by Stoler et al. in 6% of patients, while a bifid uvula was observed in 10% of cases.[27]

Table 3. Phenotypic representation

Phenotype	Dollfus et al.[35]	Nascimento et al. [38]	Heer et al.[33]	De Heer et al.[39]	Chun et al.[34]	Foo et al.[24]
Number of patients	16	24	13	32	15	22
Cranial features						
craniosynostosis	25% oxycephaly	–	15%	7	100%	100%
other	–	100% brachycephaly	–	4% brachycephaly	60% brachycephaly	–
Facial asymmetry	N/A	83%	85%	N/A	73%	59%
Ears features						
prominent ears crus	69%	62.5%	69%	56%	N/A	64%
low set ears	N/A	58%	N/A	N/A	20%	N/A
different ears anomalies	37% small ears	42% posterior rotated ears	N/A	N/A	27%	N/A
Maxillary hypoplasia	N/A	54%	N/A	N/A	N/A	0%
Nose features						
prominent nasal bridge	N/A	54%	N/A	65%	N/A	N/A
nasal septal deviation	75%	37.5%	N/A	N/A	N/A	N/A
beaked nose	N/A	29%	N/A	N/A	N/A	
Eyes features						
eyelid ptosis	93%	50%	85%	53%	53%	82%
occular hypertelorism	N/A	46%	23%	N/A	53%	N/A
epicanthus	N/A	17%	8%	N/A	13%	N/A
strabismus	N/A	12.5%	N/A	N/A	20%	27%
ocular hypotelorism	N/A	4 %	N/A	N/A	N/A	N/A
downslanting palpebral fissures	N/A	N/A	15%	N/A	N/A	73%
lacrimal duct stenosis	N/A	N/A	8%	N/A	N/A	N/A
proptosis	18%	N/A	N/A	N/A	N/A	N/A
blepharophimosis	12.5%	N/A	54%	N/A	N/A	N/A
Limbs abnormalities						
cutaneous syndactyly	100%	79%	8%	N/A	27%	27%
clinodactyly	81%	54%	15%	N/A	33%	18%
broad great toes	93%	54%	N/A	N/A	27%	N/A
cutaneous syndactyly of the feet	N/A	37.5	N/A	N/A	N/A	N/A
brachydactyly	100%	25%	69%	N/A	20%	4,5%
single transverse palmar crease	N/A	25%	N/A	N/A	33%	N/A
digit form thumb	N/A	21%	N/A	N/A	N/A	N/A
broad thumb	N/A	8%	N/A	N/A	N/A	N/A
bifid digit externity	18%	N/A	N/A	N/A	N/A	N/A
Other mental retardation	N/A	8%	0%	N/A	27%	27%
Epilepsy	N/A	4%	N/A	N/A	N/A	N/A
High arched palate	69%	N/A	N/A	N/A	N/A	N/A
Lowset hairline	N/A	50%	N/A	56%	27%	63.6
Hearing loss	N/A	N/A	N/A	N/A	33%	27%
Heart defects	N/A	N/A	N/A	N/A	7%	4.5%
Cleft palate	N/A	N/A	N/A	N/A	N/A	14%
Dental malocclusion	N/A	21%	N/A	N/A	N/A	N/A

Dental anomalies in a patient with SCS were reported first by Goho.[42] A characteristic dental feature of this anomaly is the presence of teeth with broad, bulbous crowns, long, narrow tapering roots, and multiple pulp stones in the pulp chambers of all posterior teeth.[42] Moreover, in patient with SCS, we can notice the absence of certain teeth or supernumerary teeth.[40] Unfortunately, 42% of patients with craniosynostosis require restorative treatment, but poor oral hygiene and high plaque accumulation are not connected with the presence of syndactyly.[43] These dental findings may influence dental care for these patients.

The hands and feet may also be affected by SCS. The most common defects are brachydactyly (unusually short digits) and cutaneous syndactyly of certain fingers and toes, which is usually observed between the 2nd and 3rd fingers and 2nd and 3rd toes and, less frequently, from the 2nd to the 4th fingers.[3,41] Less frequent signs include clinodactyly of the 5th fingers (abnormally bent or curved fingers), "finger-like" thumbs and broad, deviating great toes.[38]

The disorder is also associated with musculoskeletal abnormalities including a union or fusion of certain bones of the spinal column within the neck, short stature, an

abnormal fusion of the forearm bones, limited extension of the elbows or knees, short collarbones, and hip deformities.[3,41] Trusen et al. reported that pathognomonic signs in the skeletal system for SCS are a triangular shape of the epiphysis and a duplicated distal phalanx of the hallux.[41]

Less common symptoms of SCS involve hearing loss, kidney abnormalities, and heart defects.[36] In the literature we can observe that SCS is associated with a higher risk of breast cancer.[7] However, James et al.[44] showed that breast cancer risk is not increased in patients with a *TWIST* mutation.

Most people with this condition display normal intellectual development, but mild-to-moderate disabilities are possible. Some authors reported that children affected by SCS suffer from mental disability and exhibit autistic behavior.[45] The literature features some explanations that SCS caused by microdeletion can affect mental disability.[46] It has been described that the deletion of the *TWIST1* gene contributes to significant developmental delay and most patients with intragenic mutation do not show severe developmental delay.[10,45,47] Shimbo et al. suggested that the developmental delay in SCS patients is connected with a mutation of HDAC 9, which is responsible for the regulation of neocortical neuronal development.[10] Fehlow et al.[48] suggested that in patients with SCS, excessive anxiety, obsessions, compulsions, phobias, irritability, and depression may be displayed.

Differential diagnosis

The diagnosis of patients with SCS is difficult, because the symptoms vary to a large extent from person to person, including affected members of the same family. The differential diagnosis includes other syndromes belonging to a group of craniosynostosis, like Crouzon syndrome, Apert syndrome, Pfeiffer syndrome, Antley-Bixler syndrome, Muenke syndrome, Baller-Gerold syndrome, Robinow-Sorauf syndrome. All these syndromes are characterized by the premature fusion of certain bones of the skull during development, which affects the shape of the head and face. The strong correlation between the genotype and phenotype is only observed in Apert syndrome, where 2 mutations in *Ser252Trp* and *P253* are connected with a larger incidence of cleft palate in the 1st mutation and syndactyly in the 2nd mutation. In the other syndromes, the correlations between phenotype and genotype are less clearly marked. The researchers indicate that some craniosynostosis, which differ clinically, may show identical mutations or be allelic diseases.

Conclusions

Saethre-Chotzen syndrome reveals a huge variability of symptoms (Table 3). Depending on the degree of severity, they can be mild, sometimes even undetectable, or very advanced causing numerous physical defects and mental retardation. Patients suffering from SCS require long-term care from many specialists. Our patient exhibited minor dysmorphic changes within the skull and limbs and proper intellectual development, which is the reason why we can identify the severity of her condition as mild. Furthermore, despite the fact that craniosynostosis usually requires a complex orthodontic therapy, only a minor malocclusion and dental abnormalities have been reported in the presented patient.

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