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Spis treści

Prace kazuistyczne

From Editor-in-Chief

Dear Readers,

First and foremost, I would like to draw your attention to the constantly growing significance of our periodical among dental journals in Central Europe. Apart from being indexed in Scopus since 2009, which is the longest in Poland, *Dental and Medical Problems* is the only Polish dental journal indexed in MEDLINE, starting from the first issue of 2018. Therefore, the journal is searchable via PubMed within the National Center for Biotechnology Information (NCBI) system. Abstracts of all articles published in the abovementioned and all subsequent issues are now available in this database, whereas full articles can be accessed free of charge via our website. Among similar periodicals from Central and Eastern European countries indexed in the SCImago Journal & Country Rank for 2017, we are preceded only by *Acta Stomatologica Croatica*. Since March 2019, we have also been present in the Directory of Open Access Journals (DOAJ). All this has contributed to a considerable increase in the number of papers submitted to our Editorial System – with 234 in 2018, including 187 from abroad. Our team of experts exercise the utmost care to maintain the highest scientific quality of the articles published – the rejection rate has exceeded 55% and is the greatest for case reports (65%). We do expect a significant rise of citations for 2018, and for the first time we are looking forward to mid-June, as this is usually the time when the updated Journal Citation Reports (JCR) list is published.

The success of *Dental and Medical Problems* is mainly conditioned by 3 factors. Firstly, our University greatly supports editorial initiatives. The increasing rank of *Advances in Clinical and Experimental Medicine* is truly inspiring. Secondly, the team of Wroclaw Medical University Press comprises highly competent and dedicated people, responsible for comprehensive development of all our scientific journals. And last but not least, the reviewers – a true asset to each editor-in-chief. Taking the opportunity, I once again express my gratitude to all those people for their everyday arduous work. To give you a boost of positive thoughts, let me paraphrase the words of my favorite poet, Edward Stachura:

But is it worth it?

Maybe not?

Well, maybe it's worth it...

Yes, yes, it's worth it.

Very much worth it.

Oh, yes! It's worth it!

Indeed, it's worth it!

Professor Tomasz Konopka
Editor-in-Chief

Acknowledgements

Editors of *Dental and Medical Problems* would like to take this opportunity to thank the following people for their long-lasting contribution to the journal and for their work in the Editorial Board:

- Professor Raphaël Olszewski – Vice-Editor-in-Chief in 2017–2018;
- Professor Teresa Bachanek – Editorial Board member of *Wrocławska Stomatologia* in 1997–2001, Editorial Board member of *Dental and Medical Problems* in 2002–2013, and Thematic Editor for Cariology in 2014–2018;
- Professor Beata Kawala – Editorial Board member in 2009–2011 and Thematic Editor for Orthodontics in 2012–2018;
- Professor Alina Pürienè – Thematic Editor for Periodontology in 2012–2018;
- Professor Maria Buscemi – Editorial Board member in 2003–2018;
- Professor Nazan Küçükkeleş – Editorial Board member in 2010–2018;
- Professor Petr Dítě – Editorial Board member in 2014–2018;
- Professor Elena Borisovna Zueva – Editorial Board member in 2014–2018;
- Professor Mykola Mychajlovych Rozhko – Editorial Board member in 2016–2018.

New Members of the Editorial Board

Patrizia Defabianis

Patrizia Defabianis graduated in medicine and surgery in 1981 at the University of Turin, Italy. She specialized in odontostomatology at the same university. At present, she holds the position of associate professor at the Department of Surgical Sciences, Pediatric Dentistry. Her academic activity comprises teaching as well as research. Her scientific activity is documented by numerous publications in Italian and international journals. She is an author of several books and monographs. She has also participated as a speaker in many congresses. Since 2002, she has been a member of the editorial committee of the international magazine "Journal of Clinical Pediatric Dentistry". She is a member of Italian Society of Odontostomatology and Maxillofacial Surgery (SIOCMF), Italian Society of Orthodontics (SIDO), Italian Society of Pediatric Dentistry (SIOI), European Academy of Craniomandibular Disorders (EACD), American Association for Functional Orthodontics (AAFO), and American Academy of Pediatric Dentistry (AAPD).

Agnieszka Mielczarek

Agnieszka Mielczarek is Head of the Department of Conservative Dentistry at Medical University of Warsaw, Poland, and National Consultant in Conservative Dentistry and Endodontic Therapy. She qualified in dentistry at Medical University of Warsaw in 1990. In 2002, she obtained her PhD under the supervision of prof. Maria Wierzbicka in early caries diagnosis. She did internships and participated in various kinds of training in foreign research centers. She completed her habilitation in 2013 based on the research concerning the assessment of enamel remineralization potential, and she became an assistant professor at Medical University of Warsaw. She has focused her research principally on oral health promotion, early caries diagnosis and treatment, implementation of new technology in dental tissue assessment, oral biofilm, and oral infection control. She is actively involved in laboratory and clinical research based on collaboration with many international centers. She is a committed and enthusiastic teacher of undergraduate and postgraduate students. Agnieszka Mielczarek is an author of more than 90 publications in Polish and international journals. She is a member of International Association for Dental Research, Polish Dental Association, Polish Association of Periodontology, Polish Association of Dental Education, and the coordinator of the Polish section of the Alliance for a Cavity-Free Future (ACFF) group, focused on caries prophylaxis in the adult population.

Korkud Demirel

Korkud Demirel qualified in dentistry at Istanbul University, Turkey, in 1985. He obtained his PhD in 1992, and in 2002 he was conferred the title of professor. He started working at the Department of Periodontology at Istanbul University in 1985. In the years 1989–1990 he worked at State University of New York at Stony Brook School of Dental Medicine, USA. At present, he still conducts scientific and teaching activity at his alma mater. He supervises both MSc and PhD theses. Since 2018, he has been honorary professor of the P.L. Shupyk National Medical Academy of Postgraduate Education (NMAPE) in Kiev, Ukraine. His fields of interest are periodontal plastic surgery and soft tissue regeneration, dental implants and bone regeneration as well as smoking and periodontal disease.

Korkud Demirel has authored 30 articles in international journals and 3 books. He has also been a translation editor of 2 books. He is a member of Turkish Society of Periodontology (former president,) European Federation of Periodontology (former president) and Turkish Dental Association.

Marcin Kos

Marcin Kos completed both medical studies at Faculty of Medicine (1991) and dental studies at Faculty of Dentistry (1993) of Wroclaw Medical University, Poland. He is a pediatric surgeon (specialization in 1995) and a specialist in maxillofacial surgery in Poland (1999) and Germany (2007). In 2009 in Germany, he additionally got certified in plastic and reconstructive surgery. In 2000, he obtained his PhD in medicine on the basis of the thesis "Bone morphogenetic protein – isolation and testing of osteogenic activity" at Wroclaw Medical University and habilitated at the same faculty with his post-doctoral thesis entitled "Risk factors of bisphosphonate-related osteonecrosis of the jaw with special attention to increased bacterial adhesion and biofilm formation on the surface of hydroxyapatite" (2016). Since 2010, Marcin Kos has been working as Deputy Head of the Department of Adult and Pediatric Maxillofacial Surgery and Facial Plastic Surgery at University Hospital Oldenburg, Germany. His professional interests concentrate on tumor surgery and reconstructive surgery, especially using free flaps, on orthognatic surgery, traumatology, temporomandibular joint surgery, and bone necrosis related to treatment with bisphosphonates. He is an author of several dozen of publications in recognized journals and several presentations at international congresses, concerning the abovementioned topics.

János Vág

János Vág completed dental studies at Semmelweis University of Medicine in Budapest, Hungary, in 1995. He became a certified specialist in dental and oral diseases (1997) as well as in conservative dentistry and prosthodontics (2006). In 2003, he obtained his PhD on the basis of the thesis "The role of nitric oxide and angiotensin II in regulation of the submandibular gland blood flow". He started working at the Department of Conservative Dentistry at Semmelweis University of Medicine first as an assistant lecturer, and then as an assistant professor. After receiving a post-doctoral scholarship from the Ministry of Education, for 2 years (2005–2007) he did research at the Department of Oral Biology. At present, he is an associate professor at the Department of Conservative Dentistry. He did internships in Dublin (Ireland), Stockholm (Sweden) and Helsinki (Finland). He is a teacher of dentistry and a PhD supervisor. He is also involved in the activity of Students' Scientific Association and takes part as a mentor in the talent support program. Apart from his research activities, he practices as a general dentist. His interests are focused on operative dentistry, prosthodontics (including implant prosthetics), endodontics, and minor oral surgery. János Vág is an author of 35 publications in recognized journals and of a book chapter on restorative dentistry and endodontics (2006). He has delivered 143 lectures at scientific conferences. He has been awarded several prizes, also during his studies. He is a member of Hungarian Physiology Society, Hungarian Society of Endodontics (board member), Hungarian Dental Association, Association of Clinical Biostatistics, and Hungarian Association for Esthetic and Restorative Dentistry (founder and first president).

Original papers

Does metabolic control affect salivary adipokines in type 2 diabetes mellitus?

Czy kontrola metaboliczna cukrzycy typu 2 ma wpływ na adipokiny w ślinie?

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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. Adipokines produced by adipose tissue initiate pro-inflammatory events and contribute to the pathogenesis of diabetic periodontitis.

Objectives. The aim of this study was to evaluate the effect of the metabolic status on the level of salivary adipokines in type 2 diabetes mellitus (T2DM) patients.

Material and methods. A total of 239 individuals, including 161 T2DM patients and 78 healthy (H) controls, participated in the study. The metabolic control status was evaluated in each person. Periodontal measurements were recorded. Periodontal epithelial surface area (PESA), periodontal inflamed surface area (PISA) and the total dental index (TDI) were calculated. The salivary adiponectin, tumor necrosis factor α (TNF-α), interleukin 6 (IL-6), and vaspin levels were determined.

Results. The T2DM patients had higher periodontal parameters and adiponectin, TNF-α, IL-6, and vaspin levels as compared with the H controls ($p < 0.05$). As the metabolic control worsened, periodontal pocket depth (PPD) and clinical attachment level (CAL) increased. When covariates (age, gender, body mass index – BMI, education level, smoking, dental visit and tooth brushing frequency) were adjusted, only the TNF-α and vaspin levels were significantly higher in the T2DM patients ($p < 0.05$). In the T2DM patients, positive correlations were found between the TNF-α level and the percentage of bleeding on probing (BOP%), PPD, PESA, and PISA, and between the adiponectin level and PISA. Moreover, there was a negative relationship between the salivary volume and TDI. While the correlations IL-6–TNF-α, vaspin–triglycerides and vaspin–tooth brushing frequency were positive, the statistically significant associations vaspin–IL-6 and vaspin–low-density lipoprotein (LDL) were negative ($p < 0.05$).

Conclusions. The severity of periodontal disease increases as the metabolic control status worsens. The levels of salivary adipokines were changed by T2DM, while being independent from the metabolic control.

Key words: adipokines, saliva, periodontal disease, diabetes mellitus type 2, vaspin

Słowa kluczowe: adipokiny, ślina, choroba przyzębia, cukrzyca typu 2, waspina

Introduction

Type 2 diabetes mellitus (T2DM) is a disease characterized by a chronic hyperglycemic condition, which is caused by the apparent or relative lack of insulin release and/or the effect of released insulin. As a result of persistent hyperglycemia in T2DM, the proteins are irreversibly glycosylated, leading to advanced glycation end-products (AGEs). It has been suggested that an increased level of AGEs aggravates inflammatory tissue destruction by increasing cytokine secretion in response to periodontopathogens, and impair biological functions via the cell–cell and cell–matrix associations in connective tissue.[1] An increase in the glycated hemoglobin A (HbA_{1c}) levels, an indicator of glycemic control in T2DM, is related to the severity of periodontitis, and the control of periodontal disease is considered necessary for the management of T2DM.[1–3]

Adipocytes, also considered specific endocrine cells, produce many cytokines/adipokines that act as pro- (e.g., interleukin 6 – IL-6, tumor necrosis factor α – TNF-α) or anti-inflammatory (e.g., adiponectin) agents and participate in inflammation. Adipokines are important in regulating some processes, including insulin resistance, energy balance, inflammation, blood pressure, hemostasis, and endothelial function, which play key roles in the mechanism of T2DM.[4] The systemic TNF-α and IL-6 levels increase as a function of the severity of the 2 diseases in patients with periodontitis, with and without T2DM.[5] Unlike other adipokines, the circulating concentration of adiponectin is low in obesity, hypertension, T2DM, and cardiovascular diseases.[6] Vaspin is defined as an adipokine and may have a causative or protective effect in various inflammatory diseases.[7]

Saliva is a biological fluid that can be collected noninvasively. The mediators or biomarkers in saliva indicate oral and general health.[8] This study hypothesized that there exists a relationship between the metabolic control and the levels of salivary adipokines in T2DM patients. Therefore, the effect of the metabolic status on the salivary adipokine levels in T2DM patients was evaluated and their clinical periodontal parameters were compared with those of systemically healthy (H) individuals.

Material and methods

Subject selection

This study was conducted in accordance with the ethical standards of the Helsinki Declaration (1975, revised in 2002). It was approved by the Clinical Research Ethics Committee, Süleyman Demirel University, Faculty of Medicine, Isparta, Turkey (March 1, 2017/4). Of the 360 individuals who came to the diabetes clinic between March 2017 and February 2018, a total of 239 (161 T2DM patients and 78 H individuals) participated in this study. All of them signed an informed consent form.

The criteria adopted for inclusion in the study were the following: age >35 years; at least 8 natural teeth, excluding third molars; no periodontal intervention ≤6 months prior to the study; and no antibiotics and/or anti-inflammatory drugs ≤3 months before the study. The systemic status of each participant was determined by detailed examinations and biochemical analyses. The T2DM patients were diagnosed with the disease according to the diagnostic criteria recommended by the American Diabetes Association (ADA).[9] The participants were excluded if they presented with aggressive periodontitis, oral pathology or immunodeficiency, needed a premedication for dental treatment, were undergoing hormone replacement therapy or chemotherapy/radiotherapy, were pregnant/lactating, had an active infection, a rheumatic or malignant disease, were using drugs that cause gingival overgrowth (cyclosporin, etc.), and if diabetes diagnosis age was <1 year. The T2DM patients were divided into subgroups, based on the HbA_{1c} level regarding the metabolic control status (<7%: good; ≥7%: poor). The H individuals did not have any systemic disease.

Data related to systemic conditions (blood pressure, body mass index – BMI, medications, and serum parameters: fasting blood sugar – FBS, HbA_{1c}, total cholesterol – TC, low-density lipoprotein – LDL, high-density lipoprotein – HDL, triglycerides – TG, C-reactive protein – CRP, neutrophil-to-lymphocyte ratio – NLR, creatinine, alanine aminotransferase – ALT) were recorded. The participants were asked to complete a questionnaire that included questions about their sociodemographic characteristics and habits (oral care, smoking, etc.).

Periodontal examination

Periodontal measurements, as well as the plaque index (PI),[10] the gingival index (GI),[11] periodontal pocket depth (PPD), percentage of bleeding on probing (BOP%), and clinical attachment level (CAL) were performed by 1 calibrated dentist (E.T.) using a William's periodontal probe (Hu-Friedy, Chicago, USA). Periodontal pocket depth and CAL were measured at 6 sites, whereas PI, GI and BOP% were evaluated at 4 sites per tooth. Periodontal epithelial surface area (PESA) and periodontal inflamed surface area (PISA) of each individual were calculated in a Microsoft Excel spreadsheet, accessible online at www.parsprototo.info.[2] The number of caries and periapical lesions were determined according to oral and radiographic evaluations, and the total dental index (TDI)[12] was calculated. The number of missing teeth was also recorded.

Salivary sampling

Unstimulated total saliva samples were collected in the morning before the periodontal examination. Individuals were asked to lean forward in front of the test tube for 10 min, allowing the passive release of saliva and the anticipation of an open mouth.[13] The collected samples were stored at −80°C until assayed. Before analysis, the saliva samples were stored at −20°C for 12 h, then warmed to 4°C for dissolution. After vortexing, they were centrifuged at 9000 × g for 6 min at 4°C and the resultant supernatants were collected.

Adipokine measurements

The salivary adiponectin, IL-6, vaspin, and TNF-α levels were determined by the sandwich enzyme-linked immunosorbent assay (ELISA) method, according to the manufacturer's recommendations (BMS2032/2 – Bender MedSystems GmbH, Vienna, Austria; BMS213/2 – Bender MedSystems GmbH; 201-12-0922 – Sunred Biological Technology Co., Inc., Shanghai, China; KAP1751 – DIAsource ImmunoAssays S.A., Ottignies-Louvain-la-Neuve, Belgium, respectively). The absorbance of the calibrators, controls and samples of all the tests performed was read at 450 nm and 630 nm (reference filter 550 nm or 650 nm) in a microplate reader (Epoch™; BioTek Instruments, Inc., Winooski, USA). The optical densities of the samples in each well were converted to concentration by software-mediated comparison, via a standard curve through the same analytical run, using a 4-parameter curve-fitting software (http://www.myassays.com/).

Statistical analyses

The IBM SPSS v. 20.0 software (IBM, Chicago, USA) was used to evaluate the study findings. The Kolmogorov–Smirnov test was used for normal distribution suitability, in controlling the parametric assumptions of the variables. The homogeneity of the variances was assessed by Levene's test. The significance of the relationships between the categorical variables was examined by the χ^2 independence test. The comparisons of the continuous variables, according to the groups, were analyzed by multivariate analysis of variance (MANOVA), with covariates (age, gender, BMI, education level, smoking, dental visit and tooth brushing frequency) unadjusted and adjusted. When statistical significance in the comparisons was found, the least significant difference multiple comparison test was used for binary comparisons of group means. The significance of the linear relationships between the periodontal, metabolic and salivary parameters was analyzed by Pearson's correlation (r). The significance level was set at $p = 0.05$.

Results

Based on the sociodemographic and anthropometric characteristics of the individuals (Table 1), there was a significant difference between the T2DM patients and H individuals ($p < 0.05$), except for gender. When individuals were grouped based on the metabolic control status, there were significant differences in all characteristics ($p < 0.05$), except for smoking. Diabetes diagnosis age and drug use were similar between the T2DM patients with good and poor metabolic control ($p > 0.05$).

Table 2 shows the metabolic parameters. It was found that the levels of FBS, HbA_{1c} and CRP, and the TC-to-HDL ratio (TC/HDL) were significantly higher in the T2DM patients than in the H individuals, and also higher in the T2DM patients with poor metabolic control than in the T2DM patients with good metabolic control ($p = 0.000$). When covariates (age, gender, BMI, education level, smoking, dental visit and tooth brushing frequency) were adjusted, the TC, TG and ALT levels were similar between the T2DM patients with good and poor metabolic control, and also the H controls ($p > 0.05$). Significantly higher systolic–diastolic blood pressures and NLR were demonstrated in the T2DM patients as compared with the H individuals ($p < 0.001$). The HDL levels were found to be lower in the T2DM patients than in the H controls, regardless of the metabolic control status ($p = 0.000$). Also, the mean CRP levels in the T2DM patients with poor metabolic control were different from those in both the T2DM patients with good metabolic control and the H individuals ($p < 0.05$). There was no significant difference between the T2DM groups regarding LDL and creatinine ($p > 0.05$).

Periodontal parameters (PI, GI, BOP%, PPD, CAL), the number of missing teeth, PESA, PISA, and TDI scores were increased in the T2DM patients ($p < 0.001$). When covariates (age, gender, BMI, education level, smoking, dental visit and tooth brushing frequency) were adjusted, the differences in the oral parameters between comparisons continued, except for PI ($p < 0.05$). The salivary volume was decreased in the T2DM patients compared with controls, but independent from the metabolic control status ($p < 0.05$). Both PPD and CAL were higher in the T2DM group with poor metabolic control than in the T2DM group with good metabolic control, with covariates unadjusted, although the difference between the T2DM patients with good and poor metabolic control became statistically insignificant when covariates were adjusted ($p = 0.05$) (Table 3).

The salivary adipokine levels are shown in Table 3. While the TNF-α, IL-6 and vaspin levels in saliva were increased in the T2DM subjects, regardless of the metabolic control status, adiponectin was decreased. Although the salivary adiponectin levels were higher in the H individuals than in the T2DM patients with poor

Table 1. Comparisons of sociodemographic and anthropometric characteristics

Variables	Group H n = 78	Group T2DM n = 161	Good metabolic control n = 79	Poor metabolic control n = 82	*p*-value 1	*p*-value 2
Age [years]						
35–44	$15^{A,a}$ (19.2)	11^{B} (6.8)	7^{ab} (8.9)	4^{b} (4.9)		
45–54	$40^{A,a}$ (51.3)	61^{B} (37.9)	29^{a} (36.7)	32^{a} (39)	0.000	0.001
55–65	$23^{A,a}$ (29.5)	89^{B} (55.3)	43^{b} (54.4)	46^{b} (56.1)		
Gender						
female	$39^{A,ab}$ (50)	90^{A} (55.9)	53^{b} (67.1)	37^{a} (45.1)	0.391	0.014
male	$39^{A,ab}$ (50)	71^{A} (44.1)	26^{b} (32.9)	45^{a} (54.9)		
BMI [kg/m^2]						
normal (BMI < 25)	$40^{A,a}$ (51.3)	9^{B} (5.6)	6^{b} (7.6)	3^{b} (3.7)		
overweight (25 ≤ BMI <30)	$36^{A,a}$ (46.2)	127^{B} (78.9)	60^{b} (75.9)	67^{b} (81.7)	0.000	0.000
obese (BMI ≥ 30)	$2^{A,a}$ (2.6)	25^{B} (15.5)	13^{b} (16.5)	12^{b} (14.6)		
Education level						
primary	$20^{A,a}$ (25.6)	88^{B} (54.7)	45^{b} (57)	43^{b} (52.4)		
high school	$42^{A,a}$ (53.8)	v58^{B} (36.0)	24^{b} (30.4)	34^{ab} (41.5)	0.000	0.001
university	$14^{A,a}$ (17.9)	12^{B} (7.5)	7^{a} (8.9)	5^{a} (6.1)		
postgraduate	$2^{A,a}$ (2.6)	3^{A} (1.9)	3^{a} (3.8)	0^{a} (0)		
Dental visit frequency						
≤ once a year	$4^{A,a}$ (5.1)	143^{B} (88.8)	67^{b} (84.8)	76^{b} (92.7)		
once a year	$35^{A,a}$ (44.9)	16^{B} (9.9)	11^{b} (13.9)	5^{b} (6.1)	0.000	0.000
≥ twice a year	$39^{A,a}$ (50.0)	2^{B} (1.2)	1^{b} (1.3)	1^{b} (1.2)		
Tooth brushing frequency						
≤ once a day	$9^{A,a}$ (11.5)	116^{B} (72.0)	61^{b} (77.2)	55^{b} (67.1)		
once a day	$32^{A,a}$ (41.0)	38^{b} (23.6)	15^{b} (19.0)	23^{ab} (28.0)	0.000	0.000
≥ twice a day	$37^{A,a}$ (47.4)	7^{b} (4.3)	3^{b} (3.8)	4^{b} (4.9)		
Smoking						
none	$63^{A,a}$ (80.8)	106^{B} (44.35)	55^{ab} (69.6)	51^{b} (62.2)		
former	$12^{A,a}$ (15.4)	22^{B} (9.2)	10^{a} (12.7)	12^{a} (14.6)		
<10 cigarettes/day	$3^{A,a}$ (3.8)	18^{B} (7.53)	9^{a} (11.4)	9^{a} (11.0)	0.016	0.054
10–20 cigarettes/day	$0^{A,a}$ (0)	13^{B} (5.4)	$4^{a\ b}$ (5.1)	9^{b} (11.0)		
>20 cigarettes/day	$0^{A,a}$ (0)	$2^{\ B}$ (0.8)	1^{a} (1.3)	1^{a} (1.2)		
Diabetes diagnosis age [years]						
0–4		69 (42.9)	36^{a} (45.6)	33^{a} (40.2)		
5–9	–	60 (37.3)	30^{a} (38)	30^{a} (36.6)	–	–
≥10		32 (19.9)	13^{a} (16.5)	19^{a} (23.2)		
Drug use						
oral antidiabetic		141 (87.6)	66^{a} (83.5)	75^{a} (91.5)		
oral antidiabetic + insulin		20 (12.4%)	13^{a} (16.5)	7^{a} (8.5%)		
antihypertensive	–	26 (16.1)	14^{a} (17.7)	12^{a} (14.6)	–	–
antilipemic		16 (9.9)	7^{a} (8.9)	9^{a} (11)		
cardiovascular		28 (17.4)	11^{a} (13.9)	17^{a} (20.7)		

Categorical variables are presented as n (%). The *p*-values were computed with the χ^2 independence test. BMI – body mass index; H – healthy controls; T2DM type 2 diabetes mellitus patients. Capital letters and *p*-value 1: significant difference between groups T2DM and H; small letters and *p*-value 2: significant difference between group H and patients with good and poor metabolic control; different letters denote statistical significance at $p < 0.05$ for each parameter after the least significant difference (LSD) multiple comparison test.

metabolic control ($p < 0.05$), good metabolic control did not lead to a significant decrease in adiponectin ($p < 0.05$). However, when covariates were adjusted, statistical differences in the IL-6 and adiponectin levels became insignificant and, furthermore, significantly higher vaspin levels in the T2DM patients, regardless

Table 2. Comparisons of metabolic parameters according to metabolic control status

Parameters	Metabolic control	n	Mean ±SD	*p*-value 1	*p*-value 2
FBS [mg/dL]	healthy	78	90.87 ±8.33[a,A]	0.000	0.000
	good	79	127.73 ±16.56[b,B]		
	poor	82	174.45 ±38.08[c,C]		
HbA_{1c} [%]	healthy	78	5.12 ±0.30[a,A]	0.000	0.000
	good	79	6.44 ±0.40[b,B]		
	poor	82	7.63 ±0.41[c,C]		
TC [mg/dL]	healthy	78	148.82 ±42.37[a,A]	0.000	0.236
	good	79	173.86 ±45.32[b,A]		
	poor	82	183.86 ±54.04[b,A]		
TG [mg/dL]	healthy	78	112.12 ±32.76[a,A]	0.000	0.260
	good	79	158.83 ±62.72[b,A]		
	poor	82	169.10 ±88.33[b,A]		
HDL [mg/dL]	healthy	78	64.06 ±10.69[a,A]	0.000	0.000
	good	79	47.37 ±9.68[b,B]		
	poor	82	45.61 ±9.16[b,B]		
LDL [mg/dL]	healthy	78	107.43 ±20.47[a,A]	0.066	0.394
	good	79	117.76 ±34.28[b,A]		
	poor	82	116.36 ±33.05[ab,A]		
TC/HDL	healthy	78	2.42 ±0.89[a,A]	0.000	0.001
	good	79	3.75 ±0.98[b,B]		
	poor	82	4.12 ±1.26[c,B]		
ALT [U/L]	healthy	78	22.40 ±11.60[a,A]	0.017	0.175
	good	79	29.63 ±18.41[b,A]		
	poor	82	27.82 ±18.19[b,A]		
Creatinine [mg/dL]	healthy	78	0.97 ±0.17[a,A]	0.913	0.811
	good	79	0.98 ±0.24[a,A]		
	poor	82	0.99 ±0.24[a,A]		
NLR	healthy	78	1.70 ±0.63[a,A]	0.000	0.001
	good	79	2.27 ±0.87[b,B]		
	poor	82	2.29 ±0.98[b,B]		
CRP [mg/L]	healthy	78	3.33 ±0.98[a,A]	0.000	0.004
	good	79	4.39 ±2.2[b,A]		
	poor	82	4.97 ±2.02[c,B]		
Systolic blood pressure [mmHg]	healthy	78	10.77 ±0.98[a,A]	0.000	0.000
	good	79	12.35 ±0.75[b,B]		
	poor	82	12.32 ±0.84[b,B]		
Diastolic blood pressure [mmHg]	healthy	78	7.38 ±0.61[a,A]	0.000	0.000
	good	79	8.37 ±0.6[b,B]		
	poor	82	8.37 ±0.62[b,B]		

The *p*-values were computed by multivariate variance analysis (MANOVA). ALT – alanine aminotransferase; CRP – C-reactive protein; FBS – fasting blood sugar; HbA_{1c} – glycated hemoglobin A; HDL – high-density lipoprotein; LDL – low-density lipoprotein; NLR – neutrophil-to-lymphocyte ratio; SD – standard deviation; TC – total cholesterol. Small letters and *p*-value 1: significant difference when covariates (age, gender, BMI, education level, smoking, dental visit and tooth brushing frequency) unadjusted; capital letters and *p*-value 2: significant difference when covariates adjusted; different letters denote statistical significance at $p < 0.05$ for each parameter after the LSD multiple comparison test.

of the metabolic control status, were noticed when compared with the H individuals ($p < 0.05$).

The significant correlations are presented in Table 4. In the H controls, there were significant positive correlations as follows: FBS–GI; TC–CAL; TC–BOP%; ALT–GI; ALT–PPD; ALT–TC/HDL; number of missing teeth–salivary volume; and number of missing teeth–LDL. When adipokines were considered, TNF-α–IL-6; TNF-α–CRP;

Table 3. Intraoral parameters and adipokines according to metabolic control status

Parameters	Metabolic control	n	Mean ±SD	*p*-value 1	*p*-value 2
PI	healthy	78	1.79 ±0.40^{a,A}	0.000	0.207
	good	79	2.07 ±0.42^{b,A}		
	poor	82	2.15 ±0.43^{b,A}		
GI	healthy	78	1.60 ±0.40^{a,A}	0.000	0.006
	good	79	1.89 ±0.20^{b,B}		
	poor	82	1.92 ±0.20^{b,B}		
BOP%	healthy	78	59.66 ±35.14^{a,A}	0.000	0.000
	good	79	93.30 ±14.94^{b,B}		
	poor	82	96.39 ± 9.58^{b,B}		
Number of missing teeth	healthy	78	2.13 ±2.00^{a,A}	0.000	0.002
	good	79	4.57 ±2.55^{b,B}		
	poor	82	3.94 ±2.80^{b,B}		
PPD [mm]	healthy	78	3.02 ±0.72^{a,A}	0.000	0.002
	good	79	3.59 ±0.87^{b,AB}		
	poor	82	3.92 ±0.84^{c,B}		
CAL [mm]	healthy	78	3.33 ±0.82^{a,A}	0.000	0.004
	good	79	3.90 ±0.82^{b,AB}		
	poor	82	4.22 ±0.87^{c,B}		
PESA [mm^2]	healthy	78	1773.83 ±565.13^{a,A}	0.000	0.001
	good	79	2194.12 ±574.61^{b,B}		
	poor	82	2311.15 ±524.9^{b,B}		
PISA [mm^2]	healthy	78	1236.47 ±707.84^{a,A}	0.001	0.003
	good	79	2077.93 ±2430.34^{b,B}		
	poor	82	1992.91 ±663.62^{b,B}		
TDI	healthy	78	2.40 ±1.05^{a,A}	0.000	0.000
	good	79	4.67 ±1.43^{b,B}		
	poor	82	4.62 ±1.48^{b,B}		
Salivary volume [mL/min]	healthy	78	0.54 ±0.07^{a,A}	0.000	0.000
	good	79	0.44 ±0.05^{b,B}		
	poor	82	0.44 ±0.06^{b,B}		
TNF-α [pg/mL]	healthy	78	10.60 ±8.22^{a,A}	0.000	0.000
	good	79	21.70 ±18.18^{b,B}		
	poor	82	21.02 ±17.60^{b,B}		
IL-6 [pg/mL]	healthy	78	2.64 ±1.72^{a,A}	0.040	0.840
	good	79	3.60 ±2.74^{b,A}		
	poor	82	3.50 ±3.10^{b,A}		
Adiponectin [ng/mL]	healthy	78	17.10 ±12.72^{a,A}	0.026	0.517
	good	79	13.88 ±10.85^{ab,A}		
	poor	82	12.63 ±8.07^{b,A}		
Vaspin [pg/mL]	healthy	78	931.43 ±695.04^{a,A}	0.055	0.030
	good	79	1116.37 ±471.45^{b,B}		
	poor	82	1112.96 ±448.99^{b,B}		

The *p*-values were computed by multivariate variance analysis (MANOVA). BOP% – percentage of bleeding on probing; CAL – clinical attachment level; GI – gingival index; Il-6 – interleukin 6; PESA – periodontal epithelial surface area; PI – plaque index; PISA – periodontal inflamed surface area; PPD – periodontal pocket depth; TDI – total dental index; TNF-α – tumor necrosis factor α. Small letters and *p*-value 1: significant difference when covariates (age, gender, BMI, education level, smoking, dental visit and tooth brushing frequency) unadjusted; capital letters and *p*-value 2: significant difference when covariates adjusted; different letters denote statistical significance at $p < 0.05$ for each parameter after the LSD multiple comparison test.

Table 4. Significant correlations

Correlation	*r*	*p*-value
Group H		
GI–FBS	0.290**	0.010
GI–ALT	0.237*	0.037
BOP%–TC	0.315**	0.005
BOP%–TK/HDL	0.312**	0.005
BOP%–ALT	0.276**	0.015
PPD–ALT	0.291**	0.010
CAL–TC	0.227*	0.046
CAL–TC/HDL	0.249*	0.028
CAL–ALT	0.312**	0.005
Number of missing teeth–LDL	0.246*	0.030
Number of missing teeth–salivary volume	0.240*	0.035
TNF-α–CRP	0.240*	0.034
TNF-α–IL-6	0.284*	0.012
IL-6–NLR	0.288*	0.010
IL-6–vaspin	0.303**	0.007
Adiponectin–NLR	0.284*	0.012
Adiponectin–IL-6	0.240*	0.034
BMI–TC	0.300**	0.008
BMI–LDL	0.334**	0.003
BMI–TC/HDL	0.301**	0.007
Group T2DM		
PI–FBS	0.157*	0.047
PI–CRP	0.207**	0.009
BOP%–FBS	0.156*	0.048
PPD–HbA_{1c}	0.178*	0.024
CAL–FBS	0.186*	0.018
CAL–HbA1c	0.185*	0.019
CAL–CRP	0.190*	0.016
PISA–NLR	0.262**	0.001
Number of missing teeth–HbA_{1c}	−0.172*	0.029
Number of missing teeth–creatinine	0.176*	0.025
Number of missing teeth–CRP	−0.173*	0.028
TNF-α–BOP%	0.173*	0.028
TNF-α–PPD	0.195*	0.013
TNF-α–PESA	0.223**	0.004
TNF-α–PISA	0.227**	0.004
TNF-α–creatinine	0.165*	0.037
IL-6–tooth brushing frequency	−0.169*	0.032
IL-6–TNF-α	0.193*	0.014
IL-6–vaspin	−0.180*	0.022
Adiponectin–PISA	0.227**	0.001
Vaspin–tooth brushing frequency	0.178*	0.024
Vaspin–TG	0.227**	0.004
Vaspin–LDL	−0.250**	0.001
Salivary volume–TDI	−0.164*	0.037
Salivary volume–tooth brushing frequency	0.229**	0.003

* $p < 0.05$; ** $p < 0.01$.

IL-6–adiponectin, IL-6–vaspin; IL-6–NLR; and adiponectin–NLR were positively correlated. In addition, positive correlations were found between BMI and the lipid parameters (TC, LDL, TC/HLD).

In the T2DM patients, the following positive correlations were determined: FBS–PI; FBS–BOP%; FBS–CAL; HbA_{1c}–PPD; HbA_{1c}–CAL; CRP–PI; CRP–CAL; and NLR–PISA. While negative correlations were found between the number of missing teeth and HbA_{1c}, and the number of missing teeth and CRP, there were positive correlations between the number of missing teeth and creatinine, and the salivary volume and the tooth brushing frequency. Salivary TNF-α was positively related with BOP%, PPD, PESA, PISA, and creatinine. While the correlations IL-6–TNF-α, vaspin–TG and vaspin–tooth brushing frequency were significantly positive, both vaspin–IL-6 and vaspin–LDL had negative correlations. In addition, there was a positive relationship between the salivary adiponectin levels and PISA, and a negative correlation between the salivary volume and TDI.

Discussion

A bidirectional relationship between periodontitis and T2DM, which are both chronic inflammatory diseases, is reported in many studies.[14] It has been suggested that cytokines released during chronic inflammation lead to the development of insulin resistance.[1,15] Adipokines and cytokines secreted from adipose tissue regulate energy consumption, insulin resistance, inflammation, and wound healing.[1,4] Adipokines have pro- (IL-6, TNF-α, etc.) or anti-inflammatory (adiponectin, etc.) effects.[1,4] If the factors released from the salivary glands participate in the inflammatory responses associated with T2DM,[15] it offers an avenue for the treatment of this disease. The present research assessed whether the metabolic control status affects the levels of salivary adipokines in T2DM.

Clinical studies reported that patients with diabetes had more frequent and more severe periodontal disease than those without diabetes.[1,5] Severe periodontitis makes metabolic control in T2DM more difficult.[1] In the current investigation, all periodontal parameters were higher in the T2DM patients as compared with H controls. However, significant differences in CAL and PPD were only found between the T2DM patients with poor metabolic control and the H individuals when covariates were adjusted. The correlations HbA_{1c}–CAL, HbA_{1c}–PPD, FBS–CAL, and FBS–BOP% in the patients with diabetes provided evidence that poor metabolic control had an adverse influence on periodontal health.

Periodontal inflamed surface area was higher in the T2DM patients than in the H controls.[3] Nesse et al. suggested the existence of a dose-response relationship exists between the HbA_{1c} levels and PISA.[2] Our findings did not reveal a significant correlation between HbA_{1c} and PISA in diabetics.[3] However, a positive correlation between PISA and NLR supported the claim that periodontal inflammation could contribute to systemic inflammation in diabetics.

Oral complications, hyposalivation, infections, caries, and periodontal abscess, for example, increase due to poor metabolic control in T2DM patients. In diabetes, salivary hypofunction is revealed to be associated with drugs and poor metabolic control. In diabetes with poor metabolic control, the salivary volume decreases as compared with diabetes with good metabolic control and healthy individuals.[8] In the present study, despite the fact that the salivary volume was lowered in the T2DM group, the metabolic control was ineffective. Hyposalivation in diabetes causes not only an increase in caries and periodontal disease, but also oral inflammation. Oikarinen et al. recorded higher TDI scores in patients with coronary artery disease and, moreover, diabetes was more common in those with coronary artery disease.[16] Nylund et al. noticed that TDI scores increased in diabetes with nephropathy as compared with the patients with other chronic renal diseases.[17] No participants in the current analysis had a high creatinine level and nephropathy. An increased oral inflammatory burden and higher TDI scores in the T2DM patients as compared with the H controls were consistent with a negative relationship between the salivary volume and TDI. There was no difference in the TDI scores between the T2DM patients with good and poor metabolic control.

The increases of BMI may disrupt the metabolic control. The BMI values in the subjects with diabetes were higher, but without any relation to the metabolic control, than those in the H individuals. In this study, only 1 patient had a BMI >32 and no individual was morbidly obese. The lipid parameters alter due to diabetes (increases in TC, TG and LDL, and a decrease in HDL) and despite good metabolic control, dyslipidemia often continues in T2DM patients.[18] Laws and Reaven suggested that low HDL levels lead to hyperinsulinemia and insulin resistance.[19] The increased TC/HDL ratio in relation to the impairment of the metabolic control found in the current work emphasized the importance of dyslipidemia in T2DM.

C-reactive protein has been associated with both periodontitis and T2DM.[3,5] It has been suggested that CRP may contribute to insulin resistance by damaging intracellular signalling.[5] In this study, the increased CRP levels in the T2DM patients were related to diabetes and impaired metabolic control. Also, CRP associated with CAL in T2DM revealed that periodontal disease impacted on systemic inflammation.

Adiponectin, an adipokine that has anti-inflammatory and anti-atherogenic effects, modulates glucose and lipid metabolism.[6,20] The amelioration of the metabolic control related to diabetes has been reported to increase the serum adiponectin level.[21] In this study, the T2DM patients had decreased salivary adiponectin levels as compared with the H controls, although there was no difference in the salivary adiponectin levels between good and poor metabolic control in diabetes. The salivary adiponectin level has not been associated with BMI in T2DM patients or controls.[6,20] Although no significant differences in the serum adiponectin levels have been found between individuals with and without periodontitis,[22] Zimmermann et al. reported that the serum adiponectin levels decrease in periodontitis.[23] In the present study, when covariates were adjusted, the salivary adipokine levels were not statistically different among the groups. There was no relationship between salivary adiponectin and tooth brushing and the salivary adiponectin level was associated with PISA in T2DM, which is in accordance with the findings of Riis et al.[20] Our results demonstrate that salivary adiponectin has beneficial functions in periodontal health, and the properties of salivary adiponectin may be different from serum adiponectin due to systemic or local inflammation.[6]

The adipokines TNF-α and IL-6, produced in adipose tissue, and are also cytokines that play an important role in tissue destruction in periodontitis.[5,6] The overproduction of TNF-α induces inflammation and the death of pancreatic beta cells, which contributes to insulin resistance and T2DM pathogenesis.[24] In the present study, higher TNF-α levels in T2DM patients and the relationships between the salivary TNF-α level and the periodontal parameters corroborated an increased severity of periodontal disease in patients with diabetes. Both TNF-α and IL-6 have synergistic effects and increase the severity of periodontitis.[5] The salivary IL-6 levels in T2DM patients are increased as compared with healthy controls, and this is related to the metabolic control.[25] Although we found a positive correlation between the levels of TNF-α and IL-6 in saliva, only the salivary TNF-α levels in patients with diabetes were prominently increased relative to the metabolic control. Increased salivary IL-6 in individuals with diabetes was not statistically different from the values obtained for the H controls.

Vaspin produced by adipose tissue, skeletal muscle, pancreas, and skin, has a regulatory role in glucose and lipid metabolism.[7] The serum vaspin levels are reportedly higher in diabetes patients than in healthy controls, and also they are higher in diabetes with poor metabolic control as compared with diabetes with good metabolic control,[7] although Yang et al. observed that vaspin decreased in T2DM.[26] Balli et al. suggested that the gingival cervical fluid (GCF) vaspin levels increased in obese individuals with chronic periodontitis as compared with obese individuals without chronic periodontitis and non-obese individuals with chronic periodontitis.[27] They found positive correlations between the GCF vaspin levels and the periodontal parameters, and also between the GCF vaspin levels and BMI.[27] In our study, the low distribution of individuals with diabetes over 10 years in the T2DM group may have caused the vaspin levels to be independent of the metabolic control. Based on a review of the current literature, this is the first study to evaluate the salivary vaspin levels. In the T2DM patients, the increased salivary vaspin levels were not related to the metabolic control when compared with the H group. Although we did not detect any significant association between salivary vaspin and BMI, and salivary vaspin and the periodontal parameters in the H individuals, the protective role of oral vaspin was supported by the vaspin–tooth brushing frequency parallelism in the T2DM patients. In the T2DM group, the positive correlation between TG and salivary vaspin was compatible with previous findings,[28] while a negative correlation appeared between LDL and salivary vaspin. Also, there were negative correlations between salivary IL-6 and vaspin in both groups (T2DM and H). Insulin and anti-diabetic drugs have brought the vaspin levels in patients with diabetes to normal.[29] Statins increase the vaspin levels in serum.[30] In this study, the T2DM patients had a decreased salivary volume. Microvascular changes and inflammatory tissue destruction caused by T2DM may result in structural degeneration in periodontium and other organs.[1] Moreover, some T2DM patients take some medicines together; however, the precise effects of drugs on the salivary adipokine levels are not yet known.

Conclusions

Metabolic control in T2DM should be considered a conflicting factor in the relationship between periodontal and systemic diseases. Higher periodontal parameters in the T2DM patients than in the H controls are the evidence that metabolic control has a significant influence on periodontal health. This study is the first to evaluate the vaspin levels in saliva in relation to the metabolic control in T2DM patients. The levels of salivary adipokines were changed by T2DM, while being independent from the metabolic control. The salivary TNF-α and vaspin increases in the T2DM patients were significant as compared with the H individuals when covariates were adjusted. However, there was only 1 patient with a BMI >32, no individuals had HbA_{1c} >8.5, and none of the individuals had a mean CAL <6 mm. Therefore, more severe impairment of the metabolic control in diabetes may influence the salivary adipokine levels. Also, the association between increased periodontal breakdown and more impaired metabolic control may contribute to altering the adipokine levels in saliva and cause a prominent difference in the adipokine levels between T2DM patients with poor and good metabolic control.

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Original papers

Investigation of the determinants of the mandibular cortical morphology

Badanie determinant morfologii warstwy korowej żuchwy

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Abstract

Background. The mandibular cortical index (MCI) is a measurement based on the visual assessment of changes in the morphology of the mandibular cortex on panoramic radiographs.

Objectives. The present study aimed to investigate age, gender, dental status (DS), occlusal function, and presence of torus mandibularis (TM) as variables that might have a possible effect on MCI.

Material and methods. A total of 381 patients (155 men and 226 women) aged 21–84 years (mean age: 43.8 ±14.5 years) were included in this study. Age, gender and DS were recorded for each patient. The occlusal function was evaluated using the Eichner index (EI). The presence of tori was assessed by visual inspection and digital palpation. The MCI assessments were done based on Klemetti's classification (C1–C3). Statistical comparisons were performed using the χ^2 test, independent samples *t*-test and multiple logistic regression analysis ($p < 0.05$).

Results. Significant differences were observed between the MCI categories regarding age, gender, DS, EI, and TM. The likelihood of the MCI categories C2 and C3 was increased in males (odds ratio (OR) 9.33; $p < 0.001$), when TM was absent (OR 2.73; $p < 0.001$), in EI Class B (OR 2.68; $p = 0.027$), and in the age group 50–70 years (OR 2.5; $p = 0.018$).

Conclusions. Morphological changes of the mandibular cortical bone are related to gender, presence of TM, occlusal function expressed as EI, and age.

Key words: panoramic radiography, mandibular cortical morphology, bone hyperplasia

Słowa kluczowe: radiografia panoramiczna, morfologia warstwy korowej żuchwy, hiperplazja kości

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Introduction

The skeletal system is a dynamic organ that undergoes remodeling throughout life. With increasing age, bone resorption exceeds bone formation, leading to remodeling imbalance, which results in a physiological decrease in bone mass.[1] Due to postmenopausal hormonal changes, in association with osteoporosis, women are more prone to lose mineralized bone compared to men. The condition known as osteoporosis is a systemic skeletal disease characterized by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk.[2]

The evidence suggests that the jawbones of subjects with osteoporosis show reduced bone mass and altered morphology.[3] Since morphological changes involving the cortical layers of the mandible are shown to be dependent on age and mineral loss within the skeleton,[4,5] investigations of the morphology of the jawbones in relation to osteoporosis, based on panoramic radiographs, are often done by evaluating the thickness and integrity of the inferior mandibular cortex.[6] The thickness of the inferior mandibular cortex at the mental foramen region has often been measured directly (mental index) or as a ratio of the thickness divided by the distance from the mental foramen to the inferior border (panoramic mandibular index). Erosions of the inferior mandibular cortex are evaluated using the mandibular cortical index (MCI).

The mandibular cortical index, devised by Klemetti et al., is a simple ordinal scale, based on the visual evaluation of the mandibular cortex, and requires no measurements or calculations.[5] Studies have shown that MCI is significantly correlated with bone mineral density (BMD) in the hip, lumbar spine, femoral neck, and mandible.[7,8]

Tori and exostosis are common bony growths of the mandibular and maxillary bones, which are visualized predominantly in the 3rd decade of life.[9] Mandibular tori are usually bilateral, located at the canine-premolar region, on the lingual aspect of the mandible, above the mylohyoid ridge. Previous studies suggest that bone metabolism might be involved in the development of torus mandibularis (TM) based on the correlations between the presence of tori and high BMD.[10,11]

Studies have reported associations between MCI and age, gender and the number of teeth.[12–14] A significant correlation between MCI and skeletal BMD has also been demonstrated.[5,7] Based on the proposition that bone metabolism could play a role in the TM formation, a possible association between MCI and TM was suggested in this study. The aim of this study was, therefore, to evaluate age, gender, dental status (DS), occlusal function, and presence of TM as variables that might have a possible effect on MCI.

Material and methods

Selection of patients

The study was approved by the Non-Interventional Clinical Research Ethics Board of Hacettepe University, Ankara, Turkey (No. 16969557-91). Written informed consent was obtained from all participants.

A total of 381 patients (155 men and 226 women) who visited the Department of Dento-Maxillofacial Radiology, Faculty of Dentistry, Hacettepe University between January and June 2015 for a complete oral examination were randomly selected for the study. The mean age of the patients was 43.8 ±14.5 years, ranging from 21 to 84 years.

All patients were over 20 years of age and had been indicated for panoramic radiography. The exclusion criteria comprised systemic diseases or the use of medications that affect bone metabolism, the presence of cancer with bone metastasis, and local pathologies that affect the evaluation of MCI or TM.

Procedures

After informed consent was obtained, patients underwent a clinical examination. The following data was recorded for each patient: age, gender, DS, the Eichner index (EI), and the presence or absence of TM. Radiographic analysis was performed in separate sessions after completing all clinical examinations.

Clinical examination

The existence of TM was evaluated on visual inspection and by means of a digital examination. Small thickenings or a questionable TM were considered as a normal lingual outline.

The dental status was recorded using a simple classification system (third molars excluded): full dentition, partial dentition (missing any teeth) and edentulous.[12,13]

The Eichner index was used to evaluate the occlusal function, which was determined by the number of functioning posterior teeth. According to EI, there are 4 occlusal supporting zones in the jaws, 2 in the molar region and 2 in the premolar region. An occlusal supporting zone must have at least 1 contact between a tooth and its antagonist in order to be counted. In this study, patients were grouped based on a modified version of EI[15]: Class A had contacts in 4 support areas; Class B in 1–3 areas or in the anterior area only; Class C, with few if any remaining teeth, had no contact in any area.

Radiographic analysis

The images were obtained from 2 panoramic X-ray units (Orthophos XG 5; Sirona Dental Systems GmbH, Bensheim, Germany, and Veraview IC5 HD; J. Morita

Manufacturing Corp., Kyoto, Japan). The images were transferred to a digital archiving system (Turcasoft Software, Ltd., Samsun, Turkey).

The panoramic radiographs were assessed by 2 oral radiologists. The morphology of the inferior mandibular cortex was determined by observing both sides of the mandible distally from the mental foramen according to the criteria defined by Klemetti et al. (Fig. 1)[5]:

– C1: endosteal cortical margin even and sharp on both sides;
– C2: endosteal margin with semilunar defects (lacunar resorption) or endosteal cortical residues on one or both sides;
– C3: the cortical layer consists of heavy endosteal cortical residues and is clearly porous.

For the intra- and inter-observer reliability, 40 samples were randomly selected and the MCI measurements were reassessed over a distance of 2 weeks.

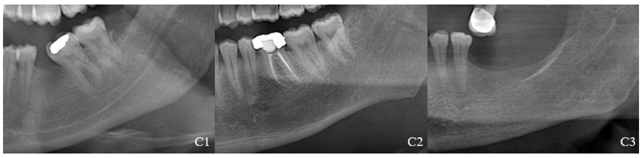

Fig. 1. Examples of the mandibular cortical index (MCI) classification (C1, C2 and C3)

Statistical analysis

The data was analyzed using the IBM SPSS Statistics v. 17.0 (IBM Corp, Armonk, USA) package. Categorical variables were compared using the χ^2 test. The independent samples t-test was used to compare mean values between the groups. The kappa statistic was used to evaluate the intra- and inter-observer agreements.

Multiple logistic regression analysis was used to determine whether an independent variable remained statistically significant after controlling for other confounding variables. Risk estimates were presented as odds ratios (ORs) with 95% confidence intervals (CIs). The results were considered significant if $p < 0.05$.

Results

Regarding the MCI assessments, the kappa values for the intra-observer agreements were 0.93 and 0.94, and for the inter-observer agreements – 0.82 and 0.93 in the 1st and 2nd session, respectively.

The characteristics of the sample according to the MCI classification are presented in Table 1. All 3 categories of MCI were observed; the majority (74%) demonstrated category C2, whereas the remainder was divided between categories C1 (20.7%) and C3 (5.3%). Cross-tabulation of MCI by age demonstrated an age-related pattern (χ^2 test; $p < 0.001$); the extremes of cortical appearance (categories C1 and C3) were mostly found in the extreme age groups. Significant differences were observed between the MCI categories regarding gender (χ^2 test; $p < 0.001$); categories C1 and C3 were more frequently seen in females, whereas category C2 showed an equal distribution among females and males. The MCI categories were significantly correlated with DS and EI (χ^2 test; $p < 0.001$); as the number of teeth or occlusal supporting zones decreased, categories C2 and C3 increased, whereas category C1 decreased. A statistically significant relationship was found between TM and MCI (χ^2 test; $p < 0.001$); the percentage of patients with TM in category C1 was significantly higher compared to those in categories C2 and C3.

Age, gender, DS, EI, and TM were the parameters having a significant impact on MCI. These parameters were included in multiple logistic regression analysis to assess their

Table 1. Characteristics of the sample according to the mandibular cortical index (MCI) classification

Variables		Total n	MCI			*p*-value
			C1 n (%)	C2 n (%)	C3 n (%)	
Age [years]	21–49	235	65 (82.3)	169 (59.9)	1 (5)	<0.001
	50–70	134	12 (15.2)	106 (37.6)	16 (80)	
	>70	12	2 (2.5)	7 (2.5)	3 (15)	
Gender	female	226	70 (88.6)	142 (50.4)	14 (70)	<0.001
	male	155	9 (11.4)	140 (49.6)	6 (30)	
DS	fully dentate	102	37 (46.8)	65 (23.1)	0 (0)	<0.001
	partially dentate	265	41 (51.9)	207 (73.4)	17 (85)	
	edentulous	14	1 (1.3)	10 (3.5)	3 (15)	
EI	Class A	245	68 (86.1)	177 (62.8)	0 (0)	<0.001
	Class B	102	9 (11.4)	78 (27.6)	15 (75)	
	Class C	34	2 (2.5)	27 (9.6)	5 (25)	
TM	present	109	35 (44.3)	73 (25.9)	1 (5)	<0.001
	absent	272	44 (55.7)	209 (74.1)	19 (95)	

MCI – mandibular cortical index; C1–C3 – MCI categories; DS – dental status; EI – Eichner index; TM – torus mandibularis; n – number of patients.

significance in determining an eroded mandibular cortex (MCI C2–C3). Regression analysis revealed that males (OR 9.33; 95% CI 4.29–20.30; $p < 0.001$), patients without TM (OR 2.73; 95% CI 1.49–4.99; $p < 0.001$), EI Class B (OR 2.68; 95% CI 1.11–6.42; $p = 0.027$), and patients aged 50–70 years (OR 2.50; 95% CI 1.17–5.35; $p = 0.018$) showed an increased risk of having eroded cortices (Table 2).

Table 2. Contributions of significant variables to the mandibular cortical index (MCI) categories (C2–C3)

Variables		Contributions		
		p-value	OR	95% CI
Age [years]	21–49	–	1.00	–
	50–70	0.018	2.50	1.17–5.35
	>70	0.381	0.41	0.05–2.98
Gender	female	–	1.00	–
	male	<0.001	9.33	4.29–20.30
DS	fully dentate	–	1.00	–
	partially dentate	0.157	1.52	0.83–2.99
	edentulous	0.727	1.72	0.08–36.84
EI	Class A	–	1.00	–
	Class B	0.027	2.68	1.11–6.42
	Class C	0.246	4.11	0.37–44.86
TM	present	–	1.00	–
	absent	<0.001	2.73	1.49–4.99

OR – odds ratio; CI – confidence interval.

Discussion

It has been reported that the systemic environment and local factors could have an influence on the mandibular bone morphology: subjects with low BMD, older age and a reduced number of teeth may present altered mandibular cortical morphology.[16–18] The mandibular cortical index is a simple method to assess the mandibular bone quality and possible signs of osteoporosis based on the evaluation of the cortical shape of the mandible.[19,20] Although the MCI assessments are subjective by nature, the results of previous studies suggest that MCI has satisfactory reliability in terms of repeatability and reproducibility.[5,12–14] In line with previous findings, this study demonstrated excellent intra- and inter-observer agreements regarding the MCI assessments.

In the present study, age, gender, dentition, and TM were the parameters significantly related to the cortical shape of the mandible (MCI). The age-related distribution of MCI in this study is consistent with the literature.[12,13] However, we did not observe these differences in the age group >70 years, which might be attributed to the small sample size. It is well-known that the bone mineral status is related to physical and muscular activity. Moreover, bone undergoes substantial and morphological changes to adapt to its mechanical environment. An increase in age is often accompanied by a decrease in the number of teeth, which may cause lower masticatory forces, leading to low quality of the mandibular bone and higher MCI values.

In this study, males showed an increased risk of having eroded cortices (MCI C2–C3) compared to females. Our study group of patients represented a typical range of female and male patients who had undergone a panoramic radiographic examination as part of diagnostic procedures or treatment planning. Although there are conflicting results in previous studies regarding the relationship between MCI and gender,[13,21] these discrepancies might be related to population differences (e.g., number of postmenopausal women, race) and individual variations in the rate of bone loss (e.g., body mass index – BMI, physical activity, diet, heredity).

It has been suggested that the absence of occlusal support in the premolar and molar regions reduces the transfer of occlusal forces on the mandible, which may affect the mandibular cortex and result in higher MCI values.[22] In the present study, in accordance with the results of previous research,[12–14] patients having fewer teeth were found to have higher MCI values. We are aware that precise evaluation of the occlusal function cannot be obtained solely from the number of teeth. Therefore, we examined the occlusal function using EI, which was previously used in epidemiological studies and found to be related to the masticatory ability and bite force.[23] Although the association between EI Class C and an eroded mandibular cortex was not at the level of significance (Table 2; $p = 0.246$) based on the results of multiple regression analysis, we suggest that the effect of the occlusal function on MCI is better reflected by EI rather than DS or the number of teeth.

The prevalence of TM has been correlated with the number of functioning teeth, parafunctional activity and age.[24,25] However, the etiology and morphological significance of TM are still unclear. It is also uncertain if tori are the expression of systemic conditions or bone metabolism. On the other hand, recent knowledge emphasizes the importance of genetic and local factors on the formation of TM.[26–30] The results of previous studies implicate common mechanisms involved in the elevation of skeletal BMD and the formation of TM.[10,11] Our findings showing a correlation between the C1 category of MCI and the presence of TM suggest that subjects with TM may have higher skeletal bone mass and mandibular bone quality compared to subjects without TM. In the literature, there have been very few studies investigating the relationship between MCI and TM. The results of our study are in agreement with the results reported by Cortes et al.[28] However, the study of Uysal et al. failed to establish an association between MCI and TM.[22]

Conclusions

This observational study demonstrated that gender, presence of TM, occlusal function expressed as EI, and age are related to morphological changes in the mandibular cortical bone, evaluated by means of MCI.

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Original papers

Finite element analysis of stress distribution around a dental implant with different amounts of bone loss: An in vitro study

Analiza metodą elementów skończonych rozkładu naprężeń dookoła implantu zębowego ze zróżnicowaną utratą kości – badanie in vitro

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

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Abstract

Background. The choice between reducing the bone height and inserting a shorter implant with a greater diameter or a longer and narrower implant without altering the bone height is a challenge in clinical practice.

Objectives. The purpose of this finite element analysis (FEA) was to compare the pattern and level of stress around implants with different lengths and diameters and with different amounts of bone loss, which changes the implant–crown ratio over time, depending on the available bone and the treatment modality.

Material and methods. The FEA was carried out to evaluate the stress distribution in bone around 3.25 × 13 mm and 4 × 11 mm 3i implants, and 3.3 × 12 mm and 4.1 × 10 mm Straumann® implants. A 3D segment of the mandible was reconstructed from a computed tomography image of the posterior mandible. Occlusal force was simulated by applying 200 N vertical and 40 N horizontal loads to the occlusal node at the center of the abutment. The pattern of stress distribution in bone was evaluated in 10 models for each implant, representing 0–9 mm of bone resorption.

Results. The results showed that along with decreasing the implant insertion depth, and consequently the implant–crown ratio, the amount of stress in bone increased. The amount of stress increased with an increase in depth of bone loss in all models, but there was no significant change in the amount of stress in the first several millimeters of bone loss.

Conclusions. The results suggest that in terms of stress distribution, it is better to reduce the bone height and insert shorter implants with a greater diameter than longer implants with a smaller diameter.

Key words: dental implant, finite element analysis, alveolar bone loss

Słowa kluczowe: implant zębowy, analiza metodą elementów skończonych, utrata kości wyrostka zębodołowego

Introduction

Marginal bone loss is a major concern in the long-term success and survival of dental implants.[1] Initially, bone loss may occur in the crestal area of the cortical bone and progress apically. It has been reported that during the first year of implant functioning, crestal vertical bone loss by 1 mm is not uncommon and is often followed by an additional 0.1 mm bone loss in every subsequent year.[2,3] Crestal bone loss has been attributed to several factors. In an earlier report, microbial accumulation around the implant and in the peri-implant tissues, and inadequate mechanical stimuli/loading transferred to the crestal bone were considered as possible factors responsible for bone resorption.[4]

Bone quality and quantity have been shown to affect the stress/strain distribution in bone around dental implants. The level of strain around dental implants is higher in the low-density cancellous bone.[5] The thickness of the cortical bone and the available bone height in relation to the size of the implant can also have an influence on the stress/strain distribution in bone.

Some researchers have tried to increase the bone-to-implant contact area to decrease stress in the cortical bone and minimize crestal bone loss. Attempts to increase the bone-to-implant contact area have focused on increasing the diameter and/or length of implants, or altering the fixture micro and/or macro design.[6] Some researchers believe that the implant diameter is a more important factor in decreasing stress in bone,[7] while according to others, the implant length has a more significant effect on the strain/stress distribution in bone around dental implants.[8] On the other hand, it has been shown that neither the implant diameter nor its length are as important as the technique of surgery, sufficient primary stability, and pre- and postoperative oral hygiene.[9]

Larger implants, in terms of both diameter and length, improve the stress/strain distribution patterns; however, in many clinical situations, the alveolar bone does not have sufficient thickness or height for the insertion of such implants.[6]

There are cases in which the clinician must choose between inserting a longer implant with a smaller diameter or decreasing the bone height and using a shorter implant with a greater diameter. The subsequent crestal bone resorption is another concern in changing the stress/strain distribution pattern, as the crown–implant ratio changes over time.

Finite element analysis (FEA) allows the researchers to predict the stress/strain distribution patterns in the peri-implant bone.[10] This FEA was designed to compare the pattern and level of stress around implants with different lengths and diameters, and simulate gradual crestal bone resorption.

Material and methods

The 3D geometry of the posterior segment of the mandible consisting of both the cancellous and cortical bone was reconstructed from a proper 2D image of computed tomography scans taken from an edentulous mandible. This 2D image was transferred to computer-aided design (CAD) software to extract the border contours and make a solid model by extruding the borders.

Different implant systems were evaluated: 2 regular neck 3i implants (Implant Innovations, Inc., Palm Beach Gardens, USA) – one with a diameter of 3.25 mm and a length of 13 mm, and the other one with a diameter of 4 mm and a length of 11 mm; and 2 Straumann® implants (Institut Straumann AG, Waldenburg, Switzerland) – one with a diameter of 3.3 mm and a length of 12 mm, and the other one with a diameter of 4.1 mm and a length of 10 mm. The implants were digitized using an optical digitizing system (ATOS® II; GOM GmbH, Braunschweig, Germany). This system digitizes objects with high accuracy and 3D local resolution in a short time. The measured data can be exported as a point cloud, sections or stereolithography (STL) data. Here, the STL data was imported to Rapidform® software (INUS Technology, Inc., Seoul, South Korea) to make solid models of the implant systems.

To imitate crestal bone resorption over time and altering the implant–crown ratio, the 4 implants were assembled over the bony part. From each of these 4 non-resorption (N-R) models, 9 or 10 resorption models (depending on the length of the implant) were generated, each with 1 mm more resorption than the previous model in a stepwise manner.

It was assumed that all the represented materials were isotropic, homogeneous and linearly elastic. The material properties were extracted from the literature[11,12] and are listed in Table 1.

The different anatomical parts were meshed with linear tetrahedral solid elements. Each model was comprised of approx. 550,000 elements and 110,000 nodes.

It was assumed that the interface between the implant and bone was perfectly tight, and also the same type of contact was provided when the alveolar bone was resorbed at different levels.

The fixed boundary conditions included restraints in all 6 degrees of freedom, involving rotation and translation in 3 coordinate axes for the nodes located at the mesial

Table 1. Material properties

Material	Young's modulus [MPa]	Poisson's ratio
Cortical bone	13,700	0.30
Cancellous bone	1,370	0.30
Mucosa	1	0.37
Titanium	110,000	0.33

and distal surfaces of the bone. In all cases, a vertical load of 200 N (along the longitudinal axis of the implant) and a horizontal load of 40 N (buccolingually) at an angle of 15° were simultaneously applied to the occlusal node at the center of the abutment.[13]

The statistical analysis was done using a 3D FEA package (ABAQUS v. 6.9-3; Simulia Corp., Providence, USA).

Results

The amount of von Mises stress was calculated in the cortical and cancellous bone in all finite element models with different levels of bone resorption.

Stress distribution

Figures 1 and 2 show von Mises stress (MPa) in the crestal cortical and cancellous bone, respectively, with different implant systems and different levels of bone resorption. Each column demonstrates an implant system with a different level of bone resorption (rows). Row 1 shows the amount of von Mises stress in the models without bone resorption (depth of resorption: 0 mm), in the 3i implants with diameters of 4 mm and 3.25 mm, and the Straumann implants with diameters of 4.1 mm and 3.3 mm,

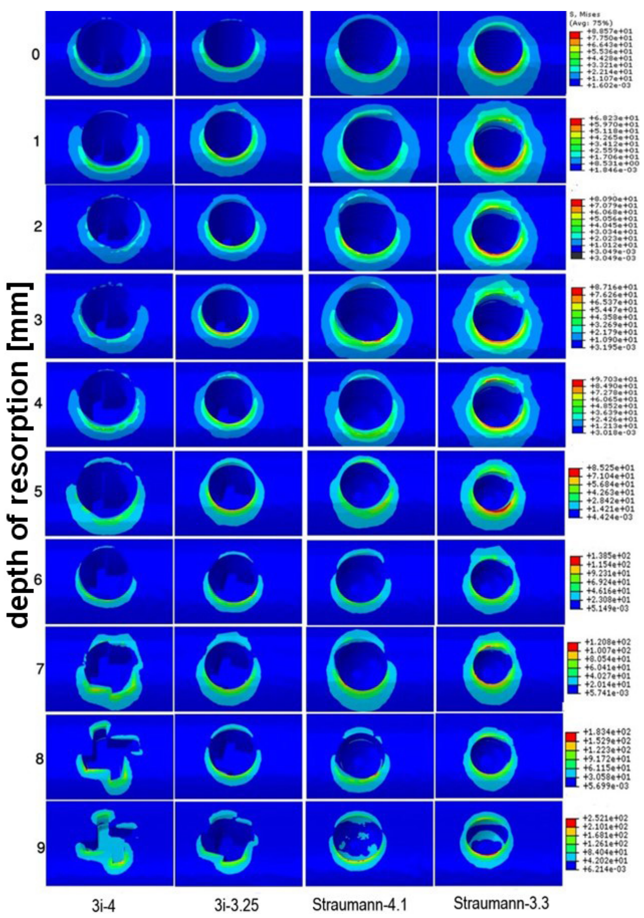

Fig. 1. Von Mises stress distribution in the cortical bone

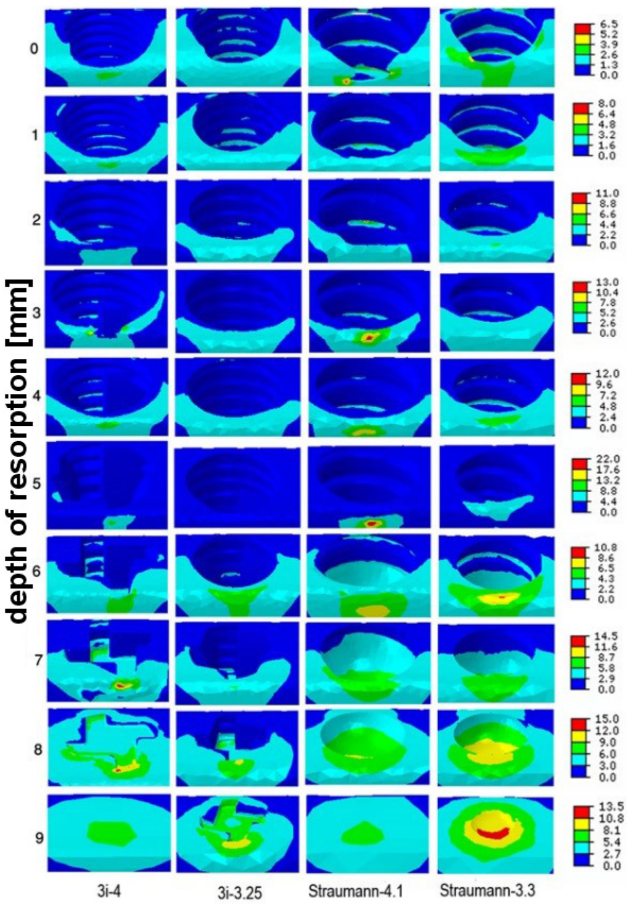

Fig. 2. Von Mises stress distribution in the cancellous bone

respectively, from left to right. The data for the models with 1–9 mm of bone resorption is presented in the subsequent rows.

A high level of stress was noted in the cortical and cancellous bone surrounding the implant neck, and the highest values were found lingually in all models (Fig. 1,2). The comparison of the amount of stress at different depths of resorption showed that the amount of stress increased with an increase in depth of resorption in all models, but there was no significant change in the amount of stress in the first several millimeters of resorption. The amount of stress in the models with the highest depth of resorption increased by up to 3 times the value for the lowest depth of resorption.

Although the 3i implants had a smaller diameter than the Straumann implants, the 3i implants showed lower stress with a relatively even distribution pattern (Fig. 1,2 – columns 1 and 2 compared to columns 3 and 4).

Maximum von Mises stress

Figure 3 shows the maximum von Mises stress in the models with the same fixture length in bone: the shorter model with a greater diameter without any resorption compared to the longer model with a smaller diameter with 2 mm of bone resorption and so on, so they had

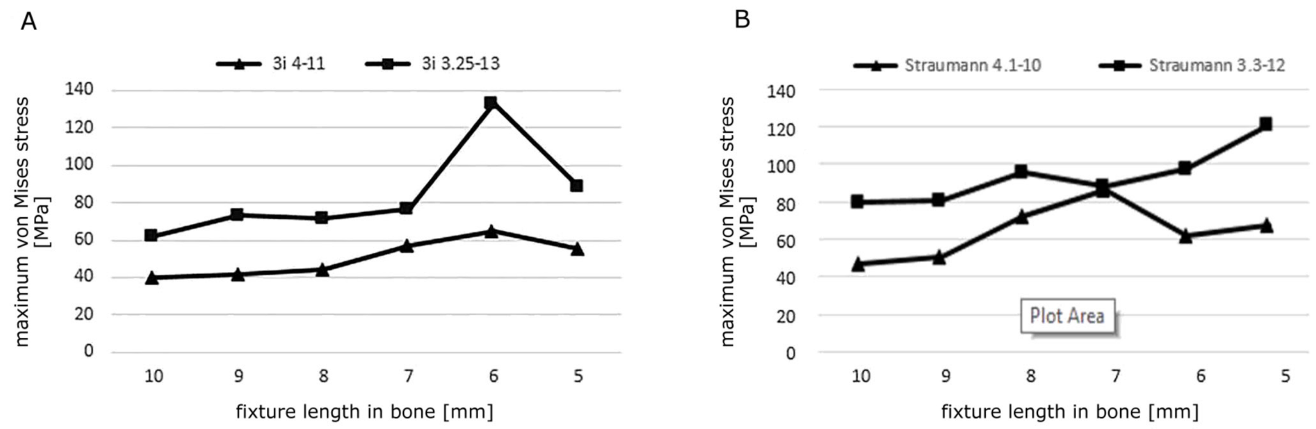

Fig. 3. Maximum von Mises stress in the cortical bone
A – 3i implant models; B – Straumann implant models.

the same fixture length in bone (Fig. 4); for example, the 3i implant with a diameter of 4 mm without bone resorption compared to the 3i implant with a diameter of 3.25 mm and 2 mm of bone resorption, or the 3i implant with a diameter of 4 mm and 1 mm of bone resorption compared to the 3i implant with a diameter of 3.25 mm and 3 mm of bone resorption.

The comparison of all models with the same fixture length in bone revealed that the implants with a greater diameter created lower stress in bone than the implants with a smaller diameter. The implants with a greater diameter in all depths of resorption (with different fixture lengths in bone) created lower stress in bone than the implants with a smaller diameter and no bone resorption (Fig. 3).

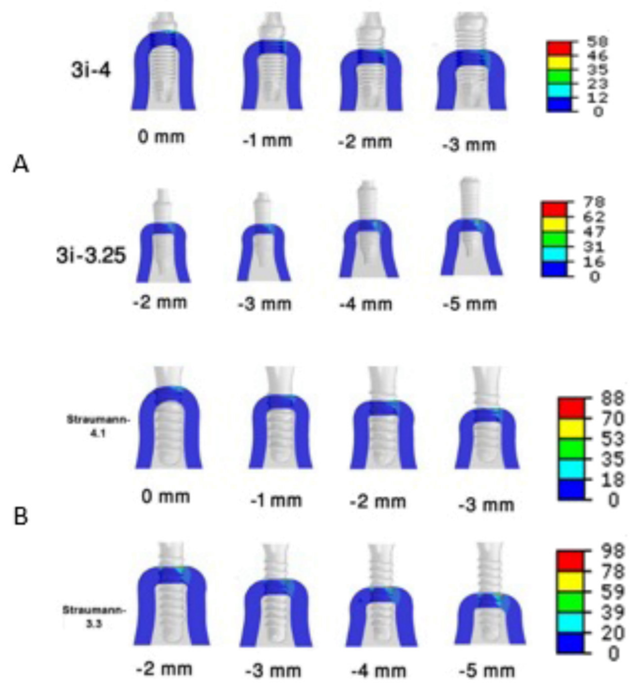

Fig. 4. Von Mises stress distribution in the cortical bone
A – 3i implant models; B – Straumann implant models.

Figure 4 shows that the implants with a greater diameter caused lower stress in bone.

The smaller diameter models with some depths of resorption had almost the same implant-to-bone contact area as the greater diameter implants with no or lower depth of resorption. However, a higher level of stress was observed in the former models.

Discussion

The stress distribution pattern is completely different around dental implants and natural teeth due to the absence of the periodontal ligament around dental implants. Dental implants may be more susceptible to occlusal overloading, which is often regarded as one of the potential causes of peri-implantitis when inflammation is present.[14] In our study, the highest stress values were found mainly in the crestal bone around the implant neck and in the lingual side in all models, because the force was applied at a buccolingual angle. This was in agreement with the results of other finite element study,[15] and also corroborated the clinical observation that marginal bone loss often occurs around the implant neck.[16] The level of stress in the cortical bone was much higher than that in the cancellous bone, mainly reflecting the difference in Young's modulus, as mentioned in other studies.[17,18]

Several finite element studies have reported a reduction in the crestal bone strain by increasing the implant diameter.[8,13,19–21] Also, it has been stated that the implant diameter is more important than its length in improving the stress distribution pattern.[19,22] Greater diameter implants have a larger bone-to-implant contact area, higher resistance to fracture and higher initial stability, and create less stress in bone.[8,23] However, in the clinical setting, the use of wide implants is limited by the thickness of the residual alveolar ridge. Yu et al. suggested that the implant diameter should be at least half the ridge width; however, narrower alveolar ridges can increase bone stress in narrow bone walls along the implant and may result in rapid bone resorption, which decreases the crown–root ratio and further aggravates the stress accumulation in the crestal bone.[24]

A prospective cohort study reported that narrow diameter implants (2.75–3.25 mm) could be successfully used as alternatives to bone augmentation in the posterior mandible, but their follow-up time was about 1 year, and they suggested that narrow diameter implants should be splinted with a bridge instead of using a single molar crown.[25]

Several clinical reports have shown that the long-term success of narrow diameter implants is less frequent than that of standard diameter implants.[23,26,27] A recent prospective study evaluated narrow diameter implants with a 5-year follow-up clinically and radiographically, and explained that the use of 2-piece narrow 3.0 mm dental implants was useful in the case of stable marginal bone levels, but suggested their appropriateness for the restoration of upper lateral or lower incisors.[28]

In another finite element study, the effects of the implant diameter, length and taper on the crestal bone strain around implants were evaluated in the premolar region of the mandible.[13] The results showed a 3.5-fold reduction in the crestal bone strain by increasing the implant diameter. The authors suggested that narrow, short implants should be avoided, especially in low-density bone.[13]

Our findings support the preference for the insertion of larger diameter implants, in agreement with the study of Ohyama et al.[29]

In our study, modeling gradual crestal bone resorption, simulating the clinical situation and altering the crown–implant ratio increased the level of stress in bone, which was in accordance with the findings of Qian et al.[16] The results of the present study also supported the findings of other research, reporting no significant difference in the level of stress at 1 mm of crestal bone resorption; however, higher levels of stress were noted following bone resorption of 2 mm or more.[30]

Considering the inherent limitations of FEA, the findings of this study indicate the reduction of bone height and insertion of a shorter implant with a greater diameter in preference to no bone reduction and the placement of longer implants with smaller diameters, with regard to the optimal stress and strain distribution in bone. Apparently, this is feasible only if allowed by the topography of the alveolar ridge, and this is true both at the time of insertion and over time following gradual bone resorption, which was simulated in this study.

Conclusions

An implant with a maximal possible diameter, considering the alveolar ridge topography, would be ideal. The effect of the implant height was not as profound as that of the implant diameter.

The stress increase following the first several millimeters of resorption was insignificant. There was an increase in the level of stress as the crown–implant ratio changed over time following crestal bone resorption.

Based on the obtained results, it may be recommended to reduce the bone height at the time of the implant insertion and use a wider implant rather than to insert a longer implant with a smaller diameter.

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Original papers

Comparison of the effect of regular and probiotic cake (*Bacillus coagulans*) on salivary pH and *Streptococcus mutans* count

Porównanie wpływu spożywania ciastek zwykłych i probiotycznych (*Bacillus coagulans*) na pH śliny i liczbę *Streptococcus mutans*

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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. Dental caries is considered the most common infectious disease in humans worldwide. Cariogenesis is the outcome of a complex interaction between the host's oral flora and diet. The consumption of snacks such as cake, which have the potential to promote dental caries, has increased.

Objectives. The aim of this study was to investigate the effect of including probiotic bacteria (*Bacillus coagulans* – *B. coagulans*) in consumed snack cake on the *Streptococcus mutans* (*S. mutans*) count and salivary pH.

Material and methods. We conducted a randomized, double-blind, cross-sectional cohort study on 40 healthy volunteers. The subjects were divided into 2 groups. In the 1st group, the subjects consumed probiotic cake as breakfast for 1 week and then, following a 4-week wash-out period, consumed regular cake as breakfast for 1 week. In the other group, the administration of probiotic and regular cake was reversed. For both groups, samples of at least 5 mL of non-stimulated saliva were collected using the spitting technique before and after the 1st and the 6th week. A colony counter was used to determine the number of *S. mutans* colonies. Salivary pH was measured before eating (8–9 a.m.).

Results. We detected no statistically significant difference in the *S. mutans* count before and after the consumption of probiotic cake, but noted a statistically significant difference in the count before and after the consumption of regular cake. We did not detect a significant difference in salivary pH with respect to the consumption of probiotic and regular cake, although the consumption of both foods caused a drop in salivary pH.

Conclusions. The addition of probiotic bacteria to sweet snack cake caused a minimal increase in the salivary count of *S. mutans*, a bacterial species with a definite role in cariogenesis, but did not impact salivary pH. Since probiotic cake has a slight impact on the *S. mutans* count, it is preferred over regular cake as a snack food.

Key words: salivary pH, *Streptococcus mutans*, *Bacillus coagulans*

Słowa kluczowe: pH śliny, *Streptococcus mutans*, *Bacillus coagulans*

Introduction

Probiotics are a group of live microorganisms that can have salutary effects on the host's health when properly supplemented or added to food.[1] Probiotics have a variety of effects, including immunity enhancement.[2] The latter may be achieved by stimulating the phagocytic leukocytes, increasing the secretion of immunoglobulin A (IgA), and affecting the production and activity of enzymes. In the gastrointestinal tract, probiotics help maintain the balance within the digestive tract and improve mucosal immunity.[3,4] The benefits of probiotics are facilitated through several mechanisms, including the alteration of the flora composition and immunomodulation.[5] The oral cavity is an extremely complex ecosystem with 700 bacterial species, 30 fungal species, several species of protozoa, and intracellular viruses.[6] Any factor perturbing the balance of these species can potentially affect oral health. Multiple studies have confirmed the potential impact of probiotics on regulating oral microflora, supporting a role for probiotics in the prevention of gingivitis, periodontitis, recurrent aphthous stomatitis, oral candidiasis, and dental caries.[7–9]

Streptococcus mutans (*S. mutans*) is an acidogenic bacterium and one of the major etiologic factors in dental caries.[10] Probiotic species, such as *Lactobacillus rhamnosus*, *Lactobacillus acidophilus*, *Lactobacillus casei*, *Lactobacillus reuteri*, and *Bifidobacterium animalis* subsp. *lactis* (*Bb-12*) can suppress the growth of *S. mutans*.[11] An in vitro study confirmed the growth inhibition of salivary *S. mutans* evoked by sucrose-containing commercial probiotics.[12] There is also an in vivo study supporting the effect of probiotic ice cream on the reduction of the *S. mutans* count.[13] In vivo studies using dairy products also demonstrated a significant reduction in the salivary *S. mutans* count.[14,15]

There is evidence that lactic acid-producing bacteria, and especially the *Bacillus* species, remain stable in heat and maintain their activity after baking.[16] The stability of these bacteria is facilitated by the presence of heat-resistant spores.[17] *Bacillus coagulans* – *B. coagulans* (*Lactobacillus sporogenes*) is a gram-positive, spore-forming, facultative anaerobe, which resists high pressure and temperature, and can function as a probiotic of choice in non-dairy products.[16] Other probiotic microorganisms, such as *Lactobacillus reuteri*, *Lactobacillus acidophilus* and *Bifidobacterium* are not spore-forming, and therefore are sensitive to temperature, pressure and stomach acid. *Bacillus coagulans* is a probiotic approved by the U.S. Food and Drug Administration (FDA) for use in animals and humans.[18] *Bacillus coagulans* has been shown to increase the antimicrobial properties of proteins as well as to decrease the clinical signs of induced rheumatoid arthritis in rats.[19] In this novel study, we used cake as the carrier of *B. coagulans* in order to evaluate the impact of probiotics on salivary pH and the *S. mutans* count.

Material and methods

This study was reviewed and approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1396.2754). The people involved in this study were informed about the study and all of them signed the informed consent forms. All volunteers were from the same geographical region and had a comparable socioeconomic status. The study was a randomized, double-blind, crossover trial. Following informed consent, a total of 40 healthy adults without gingivitis, periodontal disease or active caries were enrolled. Excluded from participation were pregnant females, women using contraceptives, and subjects using xylitol gum, probiotic products, corticosteroids, or antibiotics within 3 months of the study initiation. Prior to the start, the subjects were provided oral hygiene instruction, issued toothbrushes, toothpaste and dental floss, and asked to maintain thorough oral health care for 2 weeks. A questionnaire was used to collect information about demographics, oral and general health, oral hygiene practices (frequency of brushing, flossing, mouthwash use, etc.), nutritional habits (consumption of sweet and sour foods), and social history (tobacco and alcohol consumption) from each participant. Our study followed a rigorous selection process and recorded all the behaviors considered likely to affect the *S. mutans* count.

The subjects were divided into 2 groups. Prior to the start of the project in both groups, a minimum of 5 mL of saliva was collected from each subject using the spitting method (the subjects allowed saliva to gather in the mouth for 60 s and then spit it into a sterile container; this process continued for a total time of 5 min). These specimens were used to determine pH and the *S. mutans* count at baseline. The subjects were asked to refrain from actions that affect the secretion of saliva, such as eating, drinking and smoking. Sampling was performed before breakfast and at a specific time (8–9 a.m.) to maintain consistency with the circadian rhythm. The latter is known to impact the salivary flow rate, microbial dilution and salivary composition (IgA, cortisol, etc.). In the 1st group, the subjects consumed 70 g of probiotic cake containing the probiotic bacteria *B. coagulans* (Dorna Food Industrial Group, Tehran, Iran) as breakfast for 1 week. After that time, saliva samples were collected in the manner previously described and used to measure salivary pH and the *S. mutans* count. The 2nd–5th weeks of the study were considered as a wash-out period with no pertinent data collection. Following the wash-out period, baseline saliva samples were collected and the subjects consumed regular cake as breakfast for 1 week. The saliva samples were collected for the 4th time after the 6th week and were used to measure pH and the *S. mutans* count. This protocol was also followed for the 2nd group, but the order of probiotic and ordinary cake consumed was reversed (regular cake consumed during the 1st week and probiotic cake consumed during the 6th week). The subjects in both groups were blinded to the content of the cake consumed. Figure 1 provides a flowchart of the study protocol. The collected samples were stored at −70°C, and 100 μL of the specimen were used to make 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5} dilutions in phosphate buffered saline (PBS) and in the calibrator diluent buffer, respectively. To culture the saliva samples, the specimen was streaked on 96-well plates containing the Mitis Salivarius Agar medium (Merck, Darmstadt, Germany). The agar plates were incubated at 37°C for 48 h. The bacterial colonies were counted with a colony counter using different dilutions; their mean value was reported as the final *S. mutans* count. The GC pH strips (900 200; GC America, Inc., Alsip, USA) were used for the measurement of salivary pH. A single sheet of the GC pH strips was dipped into saliva for 40 s to allow complete wetting of the strip. The color change in the GC pH strip was compared with the standard chart to determine salivary pH.

Statistical analysis

Statistical analysis was carried out using the IBM SPSS Statistics software, v. 21.0 (IBM Corp., Armonk, USA) for Windows. The data was analyzed using the *t*-test and the paired samples method. Differences were considered significant at $p < 0.05$.

Results

A total of 40 subjects were enrolled in the study. Twenty-one (52.5%) subjects were male and 19 (47.5%) were female. The age range of the participants was 15–73 years with an average of 41.67 ±16.80 years. Eleven subjects were smokers (at least 1 cigarette per day) and 17 participants reported having consumed alcohol regularly (at least once a day). Ten subjects were both smokers and regular alcohol drinkers and 18 of the 40 neither smoked nor drank alcohol regularly. The mean value of the *S. mutans* count was 6.42 × 10^6 CFU/mL at baseline, 6.95 × 10^6 CFU/mL after the weekly consumption of probiotic cake and 1.23 × 10^7 CFU/mL after eating regular cake for 1 week (Table 1). The mean value for salivary pH at baseline, after the consumption of probiotic and regular cake, was 7.125, 6.902 and 7.000, respectively (Table 1).

Table 1. Mean and standard deviation (*SD*) of salivary pH and the *Streptococcus mutans* (*S. mutans*) count at baseline and after 1-week consumption of probiotic and regular cake

Status of cake consumption	pH (mean ±*SD*)	*S. mutans* count (×10^6) [CFU/mL] (mean ±*SD*)
Baseline	7.125 ±0.493	6.42 ±13.53
Probiotic cake	6.902 ±0.231	6.95 ±10.42
Regular cake	7.000 ±0.472	1.23 ±20.16

Table 2 summarizes the results of the statistical analysis for the salivary *S. mutans* count and pH. Following the consumption of regular cake, the *S. mutans* count increased in comparison with the baseline *S. mutans* count and the difference was statistically significant ($p = 0.027$). Although the *S. mutans* count increased slightly after the consumption of probiotic cake in comparison with the baseline value, the difference was not statistically significant ($p = 0.795$). The mean *S. mutans* count after

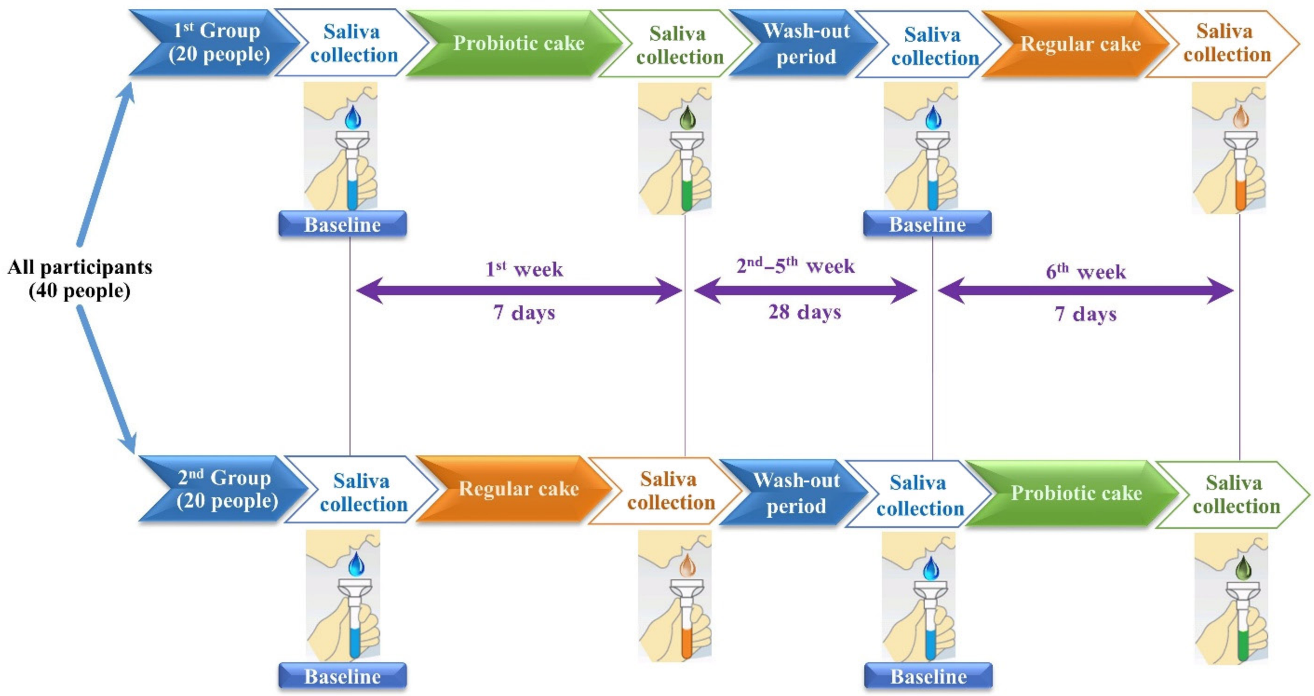

Fig. 1. Flowchart of saliva collection in the 1st and the 2nd group

Table 2. Statistical analysis of the *Streptococcus mutans* (*S. mutans*) count and salivary pH at baseline and after probiotic and regular cake consumption

Comparison between groups		Paired samples correlation (*p*-value) *S. mutans* count		Paired samples test Sig(2-tailed) (*p*-value) *S. mutans* count	Paired samples test Sig(2-tailed) (*p*-value) pH
		correlation	Sig		
Pair 1	average *S. mutans* count at baseline average *S. mutans* count probiotic cake	0.439	0.005	0.795	0.068
Pair 2	average *S. mutans* count at baseline average *S. mutans* count regular cake	0.139	0.392	0.027	0.723
Pair 3	average *S. mutans* count probiotic cake average *S. mutans* count regular cake	0.204	0.208	0.030	0.183

eating regular cake was significantly higher than the mean *S. mutans* count following the consumption of probiotic cake ($p = 0.030$).

We did not detect a statistically significant difference in salivary pH after eating probiotic or regular cake in comparison with the baseline level, although both food types caused a minor drop in salivary pH (Table 2).

Discussion

Utilizing probiotics as a supplement in foods that are potentially cariogenic is an interesting approach for improving oral health, as seen in a number of recent studies aimed at controlling caries, periodontal disease and oral candidiasis.[20] In this study, we chose cake as a carrier of *B. coagulans* to reduce the *S. mutans* count. This choice is consistent with the prevalent consumption of sucrose-containing snacks in modern societies, especially among children.

Our results showed that short-term consumption of probiotic cake did not significantly increase the *S. mutans* count in saliva, while week-long consumption of regular cake caused a significant increase in the *S. mutans* count. The results of previous studies show a similar trend. In contrast, Keller et al. demonstrated that consuming probiotic-containing tablets did not significantly reduce the *S. mutans* count.[21] Siddiqui et al. showed that the consumption of probiotic-containing dairy products decreased the *S. mutans* count.[22] In several studies, a reduction in the *S. mutans* count with the consumption of probiotic-containing dairy products or lozenges was significant.[23,24] Our study differs from previous research with respect to the design, choice of probiotic species and the carrier food, period when the probiotic food was consumed, and culture medium. In addition, the dairy products utilized in earlier studies did not contain glucose or sucrose, both of which are shown to increase the *S. mutans* count.[22,25]

Two review studies, by Laleman et al. and Seminario-Amez et al., provide support for the efficacy of probiotics in reducing the *S. mutans* count.[11,20] The role of *S. mutans* in cariogenesis is well-established and despite the inadequacy of evidence for caries prevention properties of probiotics, a reduction in the *S. mutans* count is a step forward.[7] We did not find a significant difference in the baseline *S. mutans* count between smokers and non-smokers. This observation is consistent with the findings of Sheth et al. and Voelker et al.[26,27] Our results show that the consumption of regular cake in smokers greatly increased the count of *S. mutans* bacteria and the rate of increase in smokers was much higher than in non-smokers. Compared to regular cake, the consumption of probiotic cake caused a much smaller change in the *S. mutans* count in both smokers and non-smokers. The difference in the *S. mutans* count after the consumption of probiotic cake compared to regular cake was greater in smokers than in non-smokers. The consumption of probiotic cake in smokers led to a much smaller increase in the *S. mutans* count compared to that observed with regular cake, while the consumption of probiotic cake in non-smokers caused a reduction in the *S. mutans* count. A plausible explanation for the lower efficacy of probiotic cake in reducing the *S. mutans* count in smokers is tobacco smoke-induced disturbance of oral microflora and its interactions with the probiotic species.[28,29]

Our results show a higher *S. mutans* count among the subjects who regularly consumed alcohol compared to those who did not regularly drink alcohol in all groups. This finding contradicts the results reported by Sheth et al.[26] It may be attributed to the difference in the study design, amount and type of alcohol as well as duration of drinking. In the subjects who regularly consumed alcohol, the consumption of regular cake increased the *S. mutans* count compared to the baseline. In comparison with regular cake, the *S. mutans* count increased slightly with the consumption of probiotic cake, irrespective of alcohol use, and the increase in the *S. mutans* count was more pronounced in the subjects who were not habitual users of alcohol. This difference may be attributed to the bacteriostatic effects of some types of alcohols on oral microflora. The consumption of regular cake by the users of both substances (alcohol and tobacco) increased the *S. mutans* count. A similar but less pronounced trend was also observed with the probiotic cake consumption in the subjects who both smoked and used alcohol regularly. Cigarette smoking reduces salivary pH, which predisposes the hard and soft tissues of the oral cavity to a variety of diseases over time.[30] The highest level of *S. mutans* at baseline was observed in the non-smoker alcoholic subjects and the lowest level of *S. mutans* at baseline referred to the non-alcoholic smoker subjects. The highest level of *S. mutans* after the consumption of regular cake was observed in smokers that simultaneously consumed alcohol. The highest value of the *S. mutans* count after eating probiotic cake was observed in smokers who simultaneously consumed alcohol as well. In all groups, except for the non-smoker alcoholics, the consumption of regular cake led to a significant increase in the *S. mutans* count.

Conclusions

Although the development of dental caries depends on a complex interaction between the host's oral flora and diet, the role of *S. mutans* in cariogenesis is well-accepted. The addition of probiotic bacteria (*B. coagulans*) to sweet snack cake caused a minimal increase in the salivary count of *S. mutans*, but did not impact salivary pH. As probiotic cake has a low impact on the *S. mutans* count, it is preferred over regular cake as a snack food. Considering the frequent consumption of snacks such as cakes, in modern societies, the addition of probiotic flora (*B. coagulans*) to cakes may offer a strategy for reducing the *S. mutans* count in the oral cavity.

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Original papers

Bond strength of Biodentine to a resin-based composite at various acid etching times and with different adhesive strategies

Wytrzymałość wiązania bioaktywnego substytutu zębiny z żywicą kompozytową w różnym czasie wytrawiania kwasowego i przy zastosowaniu różnych technik adhezyjnych

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Abstract

Background. Biodentine® is a bioactive calcium silicate-based material, with better strength parameters, an easier application method and a shorter setting time than mineral trioxide aggregate (MTA). The bond strength between Biodentine and the composite material is essential for the durability of the layered restoration.

Objectives. The objective of this study was to evaluate the bond strength of Biodentine to a resin-based composite at various acid etching times and with different adhesive strategies.

Material and methods. In the 1st part of the experiment, the specimens were divided into 2 groups: the adhesive was applied in the total-etch (TE) and self-etch (SE) techniques. In the TE group, 37% orthophosphoric acid was applied after 30 s (TE 30) and 240 s (TE 240). In the SE group, the SE system was applied for 30 s (SE 30) and 240 s (SE 240). In the 2nd part, the SE systems Clearfil® SE Bond and Clearfil S3 Bond Plus were evaluated (the CSE and CS3 groups, respectively). In each group, the adhesive system was applied in 1 (the CSE 1 and CS3 1 subgroups) or 2 layers (the CSE 2 and CS3 2 subgroups). The specimens were subjected to a shear bond strength (SBS) test in a universal testing machine.

Results. Shear bond strength was higher after a prolonged etching procedure in the TE (TE 30: 2.51 MPa, TE 240: 9.39 MPa) and SE techniques (SE 30: 5.92 MPa, SE 240: 7.89 MPa). A statistically significant influence was detected in relation to 30 s of surface preparation time for Clearfil S3 Bond Plus ($p < 0.001$). Greater bond strength was revealed after the application of 1 layer of the Clearfil S3 Bond Plus single-bottle system (CS3 1: 6.42 MPa).

Conclusions. The SBS of Biodentine to the composite depends on both the etching time and the mode of application of the adhesive systems. Higher bond strength was obtained for the SE adhesive in a shorter application time.

Key words: shear bond strength, Biodentine, adhesive systems, calcium silicate cement

Słowa kluczowe: wytrzymałość wiązania na ścinanie, bioaktywny substytut zębiny, systemy wiążące, cement krzemianowo-wapniowy

Introduction

The goal of biological treatment is to maintain healthy, vital pulp and to promote its repair ability using bioceramic materials. One of the representatives of this new class of materials is Biodentine®, a tricalcium silicate bioactive cement with mechanical properties similar to those of healthy dentin.[1] Its microhardness as well as flexural and compressive strength allow us to name this material a 'dentin substitute'. Observations made in several studies suggest that Biodentine demonstrates better mechanical properties, easier application and a shorter setting time than previously used mineral trioxide aggregate (MTA).[2,3] Biodentine also has a broad-spectrum antibacterial effect and low cytotoxic activity.[4,5] Due to the brittleness and unsatisfactory esthetics of Biodentine, it is necessary to make the final filling with another restorative material, usually a composite one. The bond strength between Biodentine and the composite plays a vital role in achieving the final, lasting restoration, which depends to a large extent on the procedures associated with the application of the adhesive system.

There is a divergence of views about the time after which the bioceramic material should be covered with the composite and the appropriate adhesive strategy. Some authors recommend performing the final filling after at least 2 weeks, which allows Biodentine to obtain full maturity.[6,7] Others argue that the final reconstruction is possible immediately after the application of Biodentine.[8] There is also no consensus as to the type of the adhesive strategy which would give the highest bond strength between Biodentine and the composite. Some authors suggest the superiority of the self-etch (SE) systems over the total-etch (TE) technique,[9,10] while other publications indicate that the TE technique provides higher bond strength of the tested materials,[8,11] or that the choice of the adhesive strategy is irrelevant.[6,12]

The aim of the study was to evaluate the bond strength of Biodentine to a resin-based composite at various acid etching times and with different adhesive strategies.

Material and methods

The materials used in the study are presented in Table 1. The method of their application was consistent with the manufacturers' recommendations.

A total of 250 cylindrical acrylic blocks (Villacryl® IT; Zhermapol, Warszawa, Poland) with a central hole of 4 mm in both diameter and depth were prepared, and then filled with Biodentine (Septodont, Saint-Maur-des-Fossés, France) with slight excess. After 12 min (the Biodentine setting time), the surfaces of the samples were sanded wet with abrasive papers of 320 C and 400–600 C, and rinsed with water. All samples were stored in 0.9% NaCl. The study consisted of 2 parts.

In the 1st experiment, the specimens were divided into 2 groups depending on the adhesion system used: the TE technique – Adper® Single Bond (3M ESPE, Seefeld, Germany) (the TE group) or the SE technique – Clearfil® S3 Bond Plus (Kuraray Medical, Kurashiki, Japan) (the SE group). In the TE group, the samples were etched for 30 s (TE 30) and 240 s (TE 240), and then the Adper Single Bond adhesive system was applied. In the SE group, the SE adhesive Clearfil S3 Bond Plus was applied to the Biodentine surface for 30 s (SE 30) and 240 s (SE 240). The samples were dried with a gentle stream of air for 10 s

Table 1. Materials used in the study

Material	Product description	Composition	Manufacturer
Biodentine	bioactive dentin substitute	powder: tricalcium silicate, dicalcium silicate, calcium carbonate and oxide filler, iron oxide, zirconium oxide radiopacifier liquid: calcium chloride accelerator, hydrosoluble polimer water reducing agent	Septodont, Saint-Maur-des-Fossés, France
Adper Single Bond	etch-and-rinse dental adhesive	Bis-GMA, HEMA, dimethacrylates, methacrylate functional copolymer of polyacrylic and polyitaconic acids, ethanol, photoinitiator system, water	3M ESPE, Seefeld, Germany
Clearfil S3 Bond Plus	1-step SE adhesive system (single-bottle)	Bis-GMA, HEMA, hydrophilic aliphatic dimethacrylate, ethanol, sodium fluoride, colloidal silica, DL-Camphorquinone, 10-MDP, initiators, accelerators, water	Kuraray Medical, Kurashiki, Japan
Clearfil SE Bond	2 step SE adhesive system (2-bottle)	primer: 10-MDP, HEMA, hydrophilic dimethacrylate, N,N-diethanol-p-toluidin, camphorquinone, water bond: 10-MDP, HEMA, Bis-GMA, hydrophilic dimethacrylate, N,N-diethanol-p-toluidin, camphorquinone, colloidal silica, diethanol	Kuraray Medical, Kurashiki, Japan
Filtek Z250	microhybrid universal restorative	zirconia/silica, Bis-GMA, Bis-EMA, UDMA, TEGDMA	3M ESPE, St. Paul, USA
Blue Etch®	etching gel	36% orthophosphorid acid	Cerkamed, Stalowa Wola, Poland

Bis-EMA – bisphenol A ethoxylated dimethacrylate; Bis-GMA – bisphenol A glycidyl methacrylate; HEMA – 2-hydroxyethyl methacrylate; SE – self-etch; TEGDMA – triethylene glycol dimethacrylate; UDMA – urethane dimethacrylate; 10-MDP –10-methacryloyloxydecyl dihydrogen phosphate.

and polymerized for 20 s. In the control group, the Adper Single Bond system was used, which was applied without the prior etching of Biodentine.

In the 2nd part of the study, the specimens were also divided into 2 groups according to the SE system applied: the 2-bottle Clearfil SE Bond (Kuraray Medical) (the CSE group) or the single-bottle Clearfil S3 Bond Plus (the CS3 group). In each group, the adhesive system was applied in 1 layer (subgroups CSE 1 and CS3 1) or in 2 layers (subgroups CSE 2 and CS3 2). In the control group, a composite material was applied directly to Biodentine.

In all groups, both in the 1st and the 2nd part of the study, a light-cured composite material Filtek™ Z250 (3M ESPE, St. Paul, USA) was used. The material was applied through a canal of a non-translucent, cylindrical, silicone matrix of an internal diameter and height of 3 mm, and polymerized with 2-millimeter-thick layers. The light-emitting diode light-curing unit Demi® Plus (Kerr, Orange, USA) with an intensity of 1200 mW/cm^2 was used. The shear bond strength (SBS) of Biodentine to the composite was assessed by means of a universal testing machine Zwick/Roell Z020 (Zwick/Roell, Ulm, Germany) at the crosshead speed of 2 mm/min.

The experiment was performed by 2 operators; the first was responsible for the specimen preparation, the other for the testing. The data was subjected to statistical analysis. Average measures were calculated: mean (*M*) and measures of variation (standard deviation – *SD* and coefficient of variation). The Friedman analysis of variance (ANOVA) and generalized linear models in the multiagent system with flexible standard errors were used. The results of the relevant procedures were considered statistically significant if $p < 0.05$.

Results

The values of the SBS of Biodentine to the composite material depending on the time of etching and the adhesive system application techniques are summarized in Tables 2 and 3 and illustrated in Fig. 1–3.

The results of the 1st part of the study (Table 2, Fig. 1,2) indicate that the etching time had a significant effect on the bond strength both in the TE group ($p < 0.001$) and the SE group ($p = 0.033$). After the prolongation of the etching time, the bond strength increased in the case of the TE (from TE 30: 2.51 MPa to TE 240: 9.39 MPa) and SE techniques (from SE 30: 5.92 MPa to SE 240: 7.89 MPa). The differences between the 2 assessed adhesive systems were not statistically significant ($p = 0.257$), which was confirmed by means of the multivariate analysis. In the univariate analysis, SBS was higher after 30 s of application of Clearfil S3 Bond Plus ($p < 0.001$). However, there were no statistically significant differences in SBS between the TE system after the 240-second etching time and the SE system after 240 s of application ($p = 0.456$).

Table 2. Descriptive statistics of the shear bond strength (SBS) values T_{max} [MPa] with regard to the bonding system and different adhesive strategies

Group	Subgroup	Statistical parameter	
		M	*SD*
Adper Single Bond (TE)	TE 30	2.51	2.18
	TE 240	9.39	6.65
	overall	5.82	5.94
Clearfil S3 Bond Plus (SE)	SE 30	5.92	3.21
	SE 240	7.89	4.29
	overall	6.98	3.93
Control	–	6.89	2.97

M – mean; *SD* – standard deviation; TE – total-etch; 30, 240 – etching time [s].

Table 3. Descriptive statistics of the shear bond strength (SBS) values T_{max} [MPa] with regard to the type of the adhesive system and the number of layers of the adhesive system

Group	Subgroup	Statistical parameter	
		M	*SD*
Clearfil S3 Bond Plus (single-bottle)	CS3 1	6.42	4.60
	CS3 2	5.40	3.61
Clearfil SE Bond (2-bottle)	CSE 1	2.88	2.46
	CSE 2	1.38	0.67
Control	–	2.27	1.94

In the 2nd part of the study (Table 3, Fig. 3), no statistically significant differences were observed in the CS3 group between the CS3 1 and CS3 2 subgroups ($p = 0.550$), while in the CSE group, the difference between the CSE 1 and CSE 2 subgroups was statistically significant ($p = 0.039$; the Mann–Whitney *U* test). Higher SBS was observed after a single application of the Clearfil S3 Bond Plus system (CS3 1: 6.42 MPa). The application of the 2nd layer of the SE system did not increase the bond strength. The differences between the alternative surface preparation methods – relative to the control system – were highly statistically significant for both adhesive systems used in the experiment ($p < 0.001$; the Kruskal–Wallis test).

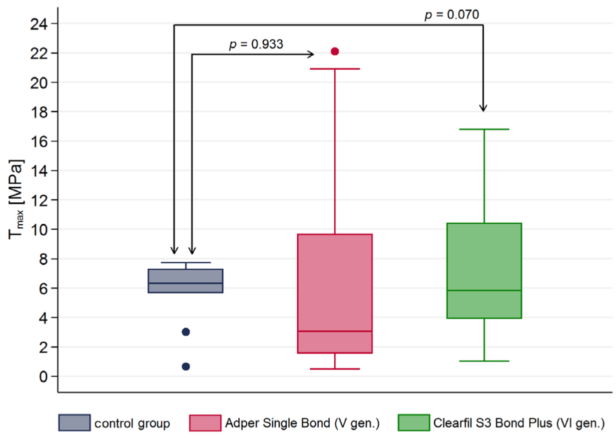

Fig. 1. Distribution of the shear bond strength (SBS) values in relation to the type of the bonding system and the control group

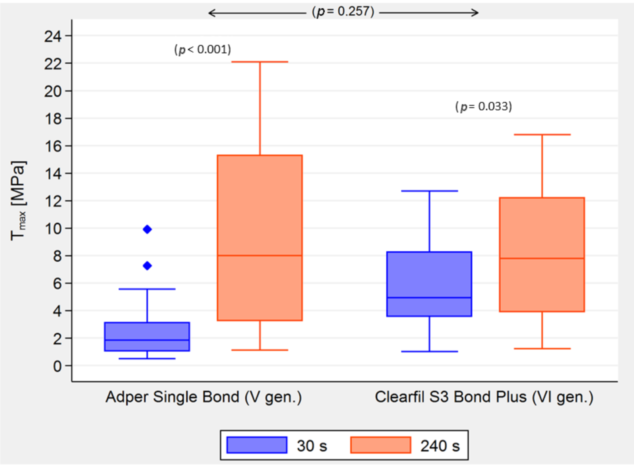

Fig. 2. Distribution of the shear bond strength (SBS) values in relation to the type of the bonding system and the application time

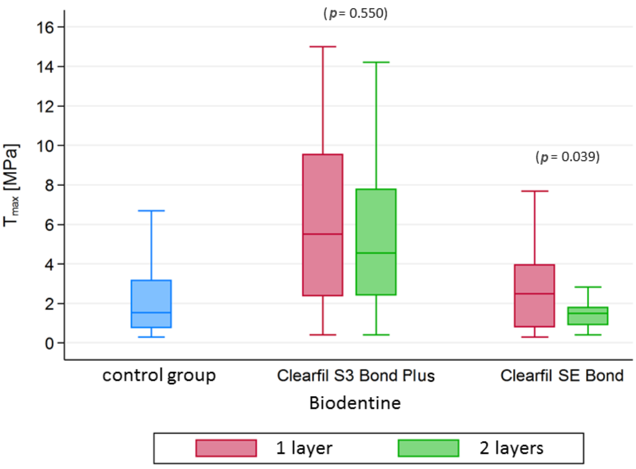

Fig. 3. Distribution of the shear bond strength (SBS) T_{max} [MPa], broken down by the type of the adhesive system and the number of layers of the adhesive system vs the control system

Discussion

During the reconstruction of lost tooth tissues, the most advantageous clinical variant is to carry out the entire procedure at one visit. The durability of such a reconstruction, apart from the materials used, is influenced by the quality and sufficiency of their bond. The use of Biodentine requires, as the manufacturer suggests, covering it with a final material after the prior use of an adhesive agent. For this reason, the aim of the present study was to evaluate the SBS of Biodentine to a composite material. The research concerned the assessment of the bond strength quality after the prolongation of the etching time or the application of the SE system as well as the comparison of SE systems with different clinical application protocols, applied in 1 or 2 layers.

Bond durability may be affected by the surface conditioning effect of calcium silicate cements.[13] Etching with 37% orthophosphoric acid is the first procedure in the TE technique before the insertion of a composite material that is to strengthen the bond between the materials and prevent microleakage. The examination of Biodentine under a scanning electron microscope confirmed the structural and chemical changes occurring after 20 s of etching with 37% orthophosphoric acid. According to previous research, the enhanced micromechanical connection could affect the bond strength of Biodentine with a resin composite material.[3] Kayahan et al. assessed the effect of the etching procedure on the compressive strength of calcium silicate materials: Angelus® MTA, ProRoot® MTA, the calcium-enriched mixture (CEM) cement, and Biodentine.[14] The study was carried out 7 days after the preparation of the materials. Biodentine turned out to be the material with the highest compressive strength ($p < 0.0001$) among all tested cements. The quality and durability of the bond between pulp capping and restorative materials is essential for the success of the treatment. As far as the choice of the adhesive strategy is concerned, prior, well-documented studies assessing the bond strength of a composite to MTA suggested the superiority of the TE technique over the SE systems.[15–17] However, reports on similar studies regarding Biodentine are ambiguous.

Cengiz and Ulusoy presented interesting results regarding the microshear bond strength (μSBS) of Biodentine and other material from the silicate-based group – TheraCal LC® to different glass-ionomer and composite materials, using the TE and SE techniques.[8] The authors noted higher μSBS in the groups in which they applied the Prime & Bond NT® TE adhesive system (13.99 MPa) or Scotchbond® Universal Adhesive (13.25 MPa) to Biodentine, while lower values were observed in the Biodentine–Clearfil SE Bond SE system (11.45 MPa). Similarly, Meraji and Camilleri assessed the SBS between Biodentine, TheraCal LC and Fuji IX®, but used different bonding systems in the TE (ExciTE® F) and SE techniques (AdheSE® One F).[11] In the group in which they used the SE primer, the composite resin was lost from all Biodentine samples during thermocycling, while higher and measurable values were noted in the group where they used the TE technique (4 MPa).

On the contrary, different conclusions were presented by Çolak et al.[9] They compared the SBS between a composite and Biodentine with different adhesives – TE (Prime & Bond NT) and 2 SE (Clearfil S3 Bond and Adper Prompt L-Pop®) in 2 periods: 9 min and 48 h after the preparation of Biodentine. The highest SBS values were observed in the group with the SE Clearfil S3 Bond, regardless of the time elapsed since its preparation (13.32 MPa after 9 min and 15.09 MPa after 48 h). Odabaş et al. used 3 adhesive systems for the study: the TE Prime & Bond NT, the 2-step SE Clearfil SE Bond and the 1-step SE Clearfil S3 Bond. The tests were carried out 12 min and 24 h after the preparation of the Biodentine material.[10] The highest bond strength (19.56 MPa) was found in the 2-stage SE system after 24 h. According to our study, the highest bond strength (5.92 MPa) was also noted for the SE system, but used in the 1-stage strategy, with the application time of 30 s. Odabaş et al. reported that the lowest values were recorded in the group where the TE system was used after 12 min,[10] which was confirmed by our earlier study[18] and the present one. Hashem et al. pointed out that the choice of the adhesive strategy is not that important for improving the reliability of the bond strength of a resin composite to Biodentine.[6]

As it can be seen, in the published literature there is no consensus as to the type of the adhesive system that would guarantee the highest bond strength. What is important is the time that has elapsed since the preparation of Biodentine, necessary to achieve the internal maturity of the material. Alsubait carried out a study to assess the compressive strength of Biodentine, ProRoot® MTA and the endosequence bioceramic root repair material-fast set putty (ERRM-FSP®) 24 h and 7 days after the preparation.[19] Significantly higher values of compressive strength were obtained after longer time (7 days), which could be related to the hydration reaction, crucial for binding materials based on calcium silicates. These conclusions coincide with the previous reports by Kayahan et al. on MTA, which showed that extending the time of binding of a bioactive material before its etching resulted in its optimal physical properties.[14] Similar observations were presented in the work by Tulumbaci et al., who evaluated the SBS of Biodentine and MTA to a composite (Filtek Z250), compomer (Dyract XP®) and the resin-modified glass-ionomer cement (RMGIC) 72 h after the preparation of materials.[20] The authors obtained significantly lower values of the SBS of Biodentine compared to MTA, which was explained by the incomplete maturation of the material. According to the manufacturer's recommendations, the Biodentine initial setting reaction takes approx. 12 min, but it can take from 2 to 4 weeks to achieve full maturation.[21] Similar conclusions were also formulated by Deepa et al., who obtained in their study the lowest SBS values in the Biodentine–composite group, evaluated immediately after 12 min, in comparison with the TheraCal LC–composite and RMGIC–composite groups.[22]

On the contrary, different results comparing the SBS of 3 different liner flowable composites to MTA and Biodentine at 3 different time intervals were published by Schmidt et al.[23] The tests were carried out 3 min, 15 min and 2 days after mixing the materials based on calcium silicate. The obtained results did not confirm the increase of SBS, a longer waiting time after mixing did not increase the adhesion and there were no statistically significant differences between the groups assessed. It is difficult to comment on the presented results, because in our study, Biodentine was evaluated after 12 min, which is in accordance with the waiting period suggested by the manufacturer, taking into account the use of a tricalcium silicate cement in the clinical procedure.

The discrepancies in the data from other studies may also result from the type of the adhesive system used. Neelakantan et al. used 3 different adhesive systems: a 1-stage TE system (Prime & Bond NT), a 2-stage SE system (AdheSE) and the 1-step SE system Clearfil S3 Bond.[24] Investigating the combination of MTA and a composite material, they obtained the highest SBS for the group in which they applied a single-step SE adhesive system. The authors paid particular attention to 2 parameters: pH and the type of the solvent. The pH value for the 2-stage SE AdheSE system is 1.4, while for the single-step SE system Clearfil S3 Bond – 2.0. Their results coincide with the reports by Bayrak et al. and Inoue et al., and confirm that low pH of the adhesive system translates into lower SBS.[25,26] Shin et al., assessing the bond strength of MTA and a composite with 4 adhesive systems, among them AdheSE and Clearfil SE Bond, with a pH of 1.4 and 1.9, respectively, noted the highest bond strength for AdheSE single-step system with lower pH, thus questioning the importance of pH as a dominant contributor to the superior bond strength.[13]

In the aforementioned study, Çolak et al. used SE systems with different functional monomers and different pH (Clearfil S3 Bond and Adper Prompt L-Pop).[9] Clearfil S3 Bond, pH 2.7, is a mild SE agent that guarantees greater bond strength when compared with Adper Prompt L-Pop, pH 0.8. The authors also concluded that the 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) acid monomer contained in this system could affect bond strength, since it can bind chemically to the calcium ions present in Biodentine, creating chemical adhesion and improving micromechanical attachment. However, they did not record statistically significant differences in SBS measured at different time intervals.

In our study, higher SBS was obtained after a single application of Clearfil S3 Bond Plus in comparison to Clearfil SE Bond (6.42 MPa vs 2.88 MPa). In addition, this SE adhesive allowed higher strength in the 30-second application time compared with the TE system evaluated at the same time (5.92 MPa vs 2.51 MPa). It should also be emphasized that the Clearfil S3 Bond Plus system used in this study, with the highest SBS, contains water and ethanol as the solvent. This may favor better wettability of a cement based on silicates and create its effect on bond strength.

The composition of Biodentine is similar to that of MTA. The hydration of both materials is similar, hence it may be assumed that the exposure of Biodentine to low pH, e.g., when applying orthophosphoric acid, may affect the chemical binding process by disrupting the hydration of tricalcium silicates and adversely affecting its microstructure. Milder etching performed in a shorter period, according to Kayahan et al., may cause less selective loss of matrix and better visibility of the crystalline structures, thus encouraging successful adhesion through micromechanical retention.[14]

Conclusions

Within the limitations of the study, it can be concluded that the SBS of Biodentine to a composite material depends on the time of etching and on the application of the adhesive strategies. There has been found an increase in bond strength after the prolongation of the etching time with respect to the TE and SE techniques. The SE bonding system allowed for greater SBS in a shorter application time. In the assessment of the impact of the number of self-adhesive layers, greater bond strength was obtained after a single application of the 1-bottle system; the application of the 2nd layer did not affect the bond strength between Biodentine and the composite.

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Original papers

Assessment of root canal morphology of maxillary and mandibular second molars in the Iranian population using CBCT

Ocena morfologii kanałów korzeniowych drugich górnych i dolnych zębów trzonowych w populacji irańskiej z wykorzystaniem tomografii stożkowej

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Abstract

Background. Inability to efficiently clean all root canals due to the complex anatomy of the root canal system is a common cause of endodontic treatment failure.

Objectives. This study aimed to assess the root canal morphology of the maxillary and mandibular second molars using cone-beam computed tomography (CBCT).

Material and methods. This descriptive study evaluated 502 CBCT scans taken in the years 2014–2017. The number of roots and canals, type of canals according to the Vertucci classification, presence of maxillary second molars with 2 palatal roots, and C-shaped canals in the maxillary and mandibular second molars were evaluated on CBCT scans separately by a radiologist and 2 endodontists. The data was analyzed using SPSS via descriptive statistics, Fisher's exact test, the independent samples t-test, and the χ^2 test. All the analyses were performed with a confidence level of 95%.

Results. The majority of the palatal, mesiobuccal and distobuccal roots of the maxillary second molars had 1 single canal of Vertucci type I; 21.5% of the mesiobuccal roots had a second mesiobuccal canal ($p = 0.05$).

Conclusions. Two-rooted mandibular second molars and 3-rooted maxillary second molars were the most common in our study population. Cone-beam computed tomography as a non-invasive and highly accurate imaging modality is efficacious for the detection of additional roots and C-shaped canals.

Key words: cone-beam computed tomography, morphology, root canal

Słowa kluczowe: tomografia stożkowa, morfologia, kanał korzeniowy

Introduction

Inability to efficiently clean and treat all root canals due to the complex anatomy of the root canal system is a common cause of failure of non-surgical endodontic treatment. Missing a canal, inadequate knowledge on the morphological and anatomical variations of the root canals and teeth, incorrect interpretation of the angulated radiographs of the respective tooth, inappropriate access cavity design, and inefficient cleaning, shaping or obturation of the root canals are among the main causes of endodontic treatment failure.[1] Therefore, knowledge of the complex internal morphology of the root canal system is imperative, prior to treatment planning and the commencement of treatment. Also, adequate knowledge of the root canal morphology of all teeth is a prerequisite for successful endodontic treatment.[2] The molar teeth commonly require endodontic treatment due to the high prevalence of caries.[3] On the other hand, endodontic treatment of the mandibular teeth is challenging due to the variations in their morphology.[4] The molar teeth have a wide range of anatomical variations with respect to the number of roots and canals.[5]

Several methods have been employed for the assessment of roots and canals. The clearing and staining technique is among the most commonly used methods for the evaluation of the root canal system.[3] However, recent studies have used cone-beam computed tomography (CBCT) for this purpose, since this imaging modality enables accurate visualization of details without noise or the superimposition of adjacent structures.[6]

Cone-beam computed tomography has been used in endodontics since the 1990s. The applications of CBCT in endodontics include the assessment of endodontic and non-endodontic pathologies, internal and external root resorption, and anatomical variations of the root canal system.[7] Cone-beam computed tomography enables 3-dimensional visualization of anatomical structures and pathological lesions, and is a highly valuable modality for this purpose.[8]

Despite the presence of numerous studies on the root and canal morphology of the maxillary and mandibular molars, studies on this topic using CBCT are scarce. Considering the diversity in the anatomical and morphological variations of the tooth roots in different populations and races, and the significance of knowledge on this subject for successful endodontic treatment, this study aimed to assess the root canal morphology of the maxillary and mandibular second molars in the Iranian population using CBCT.

Material and methods

This descriptive, cross-sectional study was performed on 502 CBCT scans. The CBCT scans belonged to patients who required orthodontic, surgical or implant treatment in the years 2014–2017. The study was approved by the ethics committee of Hamadan University of Medical Sciences, Iran (IR.UMSHA.REC.1396.239).

The inclusion criteria were as follows: high-quality CBCT scans, visualization of the maxillary and mandibular second molars on CBCT scans, absence of restorations and no previous endodontic treatment of the molar teeth, absence of periapical lesions or periodontal ligament widening, absence of internal and external root resorption, and presence of completely formed roots.[9] All CBCT scans had been obtained with a CRANEX® 3D CBCT system (Soredex, Tuusula, Finland) with 0.2 mm voxel size and 6 × 8 cm^2 field of view. All images were evaluated in axial, coronal and sagittal sections using OnDemand3D™ Dental software (Cybermed, Inc., Seoul, South Korea). To assess the number of roots and types of canals, the cross-sectional images were reconstructed along the parasagittal and paracoronal planes so that the path and morphology of the canals could be easily evaluated and analyzed from the buccolingual and mesiodistal directions. The slice thickness was 0.5 mm and the slice interval was 1 mm in the parasagittal and paracoronal image reconstructions.

The CBCT scans of the teeth that met the eligibility criteria were evaluated in terms of the number of roots (Fig. 1) and types of canals in each root according to the Vertucci classification[6]:

– type I: 1 single canal from the pulp chamber to the apex;
– type II: 2 separate canals exiting the pulp chamber, but merging close to the apex;
– type III: 1 canal exiting the pulp chamber and branching into 2 canals that eventually merge;
– type IV: 2 separate canals from the pulp chamber to the apex;
– type V: 1 canal exiting the pulp chamber and branching into 2 canals that eventually lead to 2 separate apical foramina;
– type VI: 2 separate canals exiting the pulp chamber, merging at the mid-root, branching again, and ending at 2 apical foramina;
– type VII: 1 canal exiting the pulp chamber, branching into 2 canals at the mid-root that merge again and branch again ending at 2 apical foramina;
– type VIII: 3 separate canals from the pulp chamber to the apex (Fig. 2).

Fig. 1. A: Axial cone-beam computed tomography (CBCT) section of a single-rooted maxillary second molar; B: Axial CBCT section of a maxillary second molar with 3 roots and 3 canals; C: Axial CBCT section of a maxillary second molar with 2 palatal roots

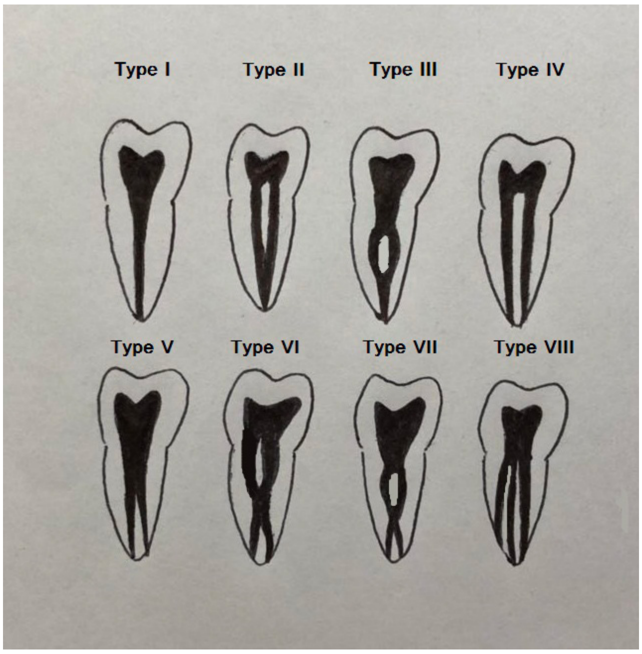

Fig. 2. Canal types according to Vertucci classification

Other evaluated items included the presence of maxillary second molars with 2 palatal roots (Fig. 1C), presence of C-shaped canals in the maxillary and mandibular second molars (Fig. 3), and presence of a second mesiobuccal canal in the maxillary second molars (Fig. 4). Age and gender of the patients were recorded as well. One radiologist and 2 endodontists separately viewed the images twice within a 2-week interval. The data was analyzed using the IBM SPSS Statistics software v. 22 (IBM, Inc., Armonk, USA) via descriptive statistics, Fisher's exact test, the independent samples *t*-test, and the χ^2 test.

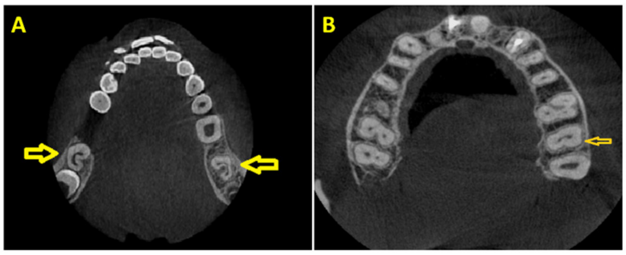

Fig. 3. A: Axial CBCT section of a C-shaped canal of a mandibular second molar; B: Axial CBCT section of a C-shaped canal of a maxillary second molar

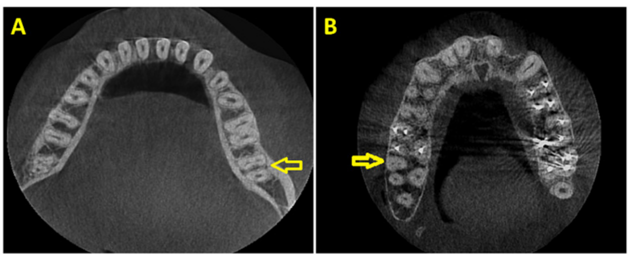

Fig. 4. A: Axial CBCT section of a mandibular second molar with 2 roots and 2 canals in the mesial root and 1 canal in the distal root; B: Axial CBCT section of a second mesiobuccal canal of a maxillary second molar

Results

A total of 502 CBCT scans of patients were evaluated, which belonged to 301 females (60%) of a mean age of 38.04 ±12.73 years and 201 males (40%) of a mean age of 40.60 ±12.58 years. The overall mean age of the patients was 39.06 ±12.72 years. The intra-observer and inter-observer agreements were found to be 96% and 89%, respectively, which indicated high agreement. A total of 1,082 second molars (447 mandibular and 635 maxillary second molars) were evaluated. Table 1 presents the frequency distribution of different types of roots. Tables 2 and 3 show the frequency of different types of canals in different roots according to the Vertucci classification. Tables 4 and 5 present the number of canals in the roots of the mandibular and maxillary second molars. Of 635 maxillary second molars, only 2 had 4 roots and showed a second palatal root. Of 447 mandibular second molars, 41 (9.2%) had C-shaped canals. Specifically, 29 females (10.5%) and 12 males (7.0%) had C-shaped canals in their mandibular second molars. According to Fisher's exact test, the difference between males and females in the prevalence of C-shaped canals in the mandibular second molars was not significant ($p = 0.240$). The mean age of the patients with C-shaped canals of the mandibular second molars was 34.17 ±13.83 years and of those without C-shaped canals in the mandibular second molars – 36.84 ±12.05 years. According to the independent samples *t*-test, this difference was not significant (Tables 6,7). An assessment of the maxillary second molars revealed only 1 case of a C-shaped canal.

Of 635 maxillary second molars, 558 had 1 mesiobuccal root, out of which 120 had a second mesiobuccal canal. The χ^2 test showed a significant correlation between the prevalence of maxillary second molars with a second mesiobuccal canal and gender ($p = 0.002$; Table 8).

The independent samples *t*-test showed a significant correlation between the mean age of patients and prevalence of maxillary second molars with 2 canals in the mesiobuccal root ($p = 0.001$; Table 9).

Table 1. Frequency distribution of the root variations in the mandibular and maxillary second molars

Number of roots	Mandible		Maxilla		Total	
	number of teeth	percentage [%]	number of teeth	percentage [%]	number of teeth	percentage [%]
1 root	41	9.2	50	7.9	91	8.4
2 roots	397	88.8	27	4.2	424	39.2
3 roots	9	2.0	556	87.6	565	52.2
4 roots	0	0	2	0.3	2	0.2
Total	447	100	635	100	1,082	100

Table 2. Prevalence of Vertucci canal types for different roots in the mandibular second molars

Root	Vertucci type of canal						
	I	II	III	IV	V	VIII	Total
Mesial	65 (16.0)	222 (54.7)	0 (0)	116 (28.6)	3 (0.7)	0 (0)	406 (100)
Distal	396 (97.54)	5 (1.23)	0 (0)	5 (1.23)	0 (0)	0 (0)	406 (100)
Additional root in mandibular second molar	9 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	9 (100)
Single-rooted mandibular second molar	10 (24.4)	14 (34.1)	3 (7.3)	7 (17.1)	2 (4.9)	5 (12.2)	41 (100)
Total	480 (55.7)	241 (27.9)	3 (0.34)	128 (14.9)	5 (0.58)	5 (0.58)	862 (100)

Data presented as number (percentage).

Table 3. Prevalence of Vertucci canal types for different roots in the maxillary second molars

Root	Vertucci type of canal						
	I	II	III	IV	V	VIII	Total
Palatal	580 (99.1)	5 (0.9)	0 (0)	0 (0.0)	0 (0)	0 (0)	585 (100)
Mesiobuccal	438 (78.5)	101 (18.1)	0 (0)	19 (3.4)	0 (0)	0 (0)	558 (100)
Distobuccal	556 (99.6)	0 (0)	0 (0)	1 (0.2)	1 (0.2)	0 (0)	558 (100)
Additional root in maxillary second molar	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (100)
Single-rooted maxillary second molar	14 (28.0)	9 (18.0)	0 (0)	14 (28.0)	5 (10.0)	8 (16.0)	50 (100)
Buccal root of double-rooted maxillary second molar	10 (37.0)	8 (29.7)	0 (0)	9 (33.3)	0 (0)	0 (0)	27 (100)
Total	1,600 (89.9)	123 (6.9)	0 (0)	43 (2.41)	6 (0.34)	8 (0.45)	1,780 (100)

Data presented as number (percentage).

Table 4. Frequency of different number of canals in different roots of the mandibular second molars

Root	1 canal	2 canals	3 canals	Total
Mesial	65 (16.0)	341 (84.0)	0 (0)	406 (100)
Distal	396 (97.5)	10 (2.5)	0 (0)	406 (100)
Additional root in mandibular second molar	9 (100)	0 (0)	0 (0)	9 (100)
Single-rooted mandibular second molar	10 (24.4)	26 (63.4)	5 (12.2)	41 (100)
Total	480 (55.7)	377 (43.7)	5 (0.6)	862 (100)

Data presented as number (percentage).

Table 5. Frequency of different number of canals in different roots of the maxillary second molars

Root	1 canal	2 canals	3 canals	Total
Palatal	580 (99.1)	5 (0.9)	0 (0)	585 (100)
Mesiobuccal	438 (78.5)	120 (21.5)	0 (0)	558 (100)
Distobuccal	556 (99.6)	2 (0.4)	0 (0)	558 (100)
Additional root in maxillary second molar	2 (100)	0 (0)	0 (0)	2 (100)
Single-rooted maxillary second molar	15 (30.0)	27 (54.0)	8 (16.0)	50 (100)
Buccal root of double-rooted maxillary second molar	10 (37.0)	17 (63.0)	0 (0)	27 (100)
Total	1,601 (89.95)	171 (9.6)	8 (0.45)	1,780 (100)

Data presented as number (percentage).

Table 6. Correlation of the prevalence of C-shaped canals and the gender of patients (Fisher's exact test)

C-shaped canal	Females		Males		Total		*p*-value
	number of teeth	percentage [%]	number of teeth	percentage [%]	number of teeth	percentage [%]	
Absence of C-shaped canal	246	89.5	160	93.0	406	90.8	0.240
Presence of C-shaped canal	29	10.5	12	7.0	41	9.2	
Total	275	100	172	100	447	100	

Table 7. Correlation of the prevalence of C-shaped canals and the age of patients (the independent samples *t*-test)

C-shaped canal	Number of teeth	Mean age [years]	*SD*	*MD*	*p*-value
Absence of C-shaped canal	406	36.84	12.05	0.598	0.182
Presence of C-shaped canal	41	34.17	13.83	2.160	0.238

SD – standard deviation; *MD* – mean deviation.

Table 8. Prevalence of a second mesiobuccal canal in the maxillary second molars and its correlation with gender (the χ^2 test)

Type of canal in mesiobuccal root	Females		Males		Total		*p*-value
	number of teeth	percentage [%]	number of teeth	percentage [%]	number of teeth	percentage [%]	
Single-canal mesiobuccal root	273	83.0	165	72.1	438	78.5	0.002
Double-canal mesiobuccal root	56	17.0	64	27.9	120	21.5	
Total	329	100	229	100	558	100	

Table 9. Correlation of the prevalence of C-shaped canals and the age of patients (the independent samples *t*-test)

Type of canal in mesiobuccal root	Number of teeth	Mean age [years]	*SD*	*MD*	*p*-value
Single-canal mesiobuccal root	438	37.73	13.01	0.621	0.001
Double-canal mesiobuccal root	120	33.50	11.11	1.010	0.000

Discussion

In this study, 502 CBCT scans of patients were evaluated. A total of 1,082 second molars, including 447 mandibular and 635 maxillary second molars, were assessed. The results showed that the prevalence of single-rooted, 2-rooted, 3-rooted, and 4-routed maxillary second molars was 7.9%, 4.2%, 87.6%, and 0.3%, respectively. Vertucci type I was the most common canal type in the palatal, mesiobuccal, distobuccal, and additional roots of the maxillary second molars. One single canal was the most common canal type in the palatal (99.1%), mesiobuccal (78.5%) and distobuccal (99.6%) roots of the maxillary second molars.

Neelakantan et al. showed that of maxillary second molars, 0.9% were single-rooted, 5.8% were 2-rooted, 93.1% were 3-rooted, and 0.9% were 4-rooted.[10] Similarly in our study, maxillary second molars with 3 roots had the highest and those with 4 roots had the lowest frequency. In line with our findings, Ng et al. observed in their study that all maxillary second molars had 3 separate roots.[11] All palatal roots (100%) and the majority of the distobuccal roots (96%) had 1 single canal and were Vertucci type I. A mesiobuccal root with 2 canals was observed in 68%, 49% and 39% of first, second and third molars, respectively. Vertucci types II and IV were the most common canal morphology in the mesiobuccal root.[11]

The current findings, compared to other studies, showed that the maxillary second molar root and canal morphology had high variability in the Iranian population and its anatomical variants were different from those in other populations. In the present study, 78.5% of the maxillary second molars had single-canal mesiobuccal roots, which were Vertucci type I, and 120 (21.5%) mesiobuccal roots had a second mesiobuccal canal, out of which 18.1% were Vertucci type II and 3.4% were Vertucci type IV. Similarly, Sadeghi and Sadr reported that 74% of the mesiobuccal roots of second molars were Vertucci type I,[12] whereas Kim et al. reported the prevalence of a second mesiobuccal canal in the mesiobuccal roots of second molars to be 34.39%.[13] This value was 42.2% in a study by Lee et al.[14] Alavi et al. and Ng et al. reported the presence of additional canals in the mesiobuccal root in 56% and 49% of second molars, respectively.[15,11] This rate was 58% in a study by Shalabi et al.[16]

According to previous studies, the prevalence of a second mesiobuccal canal in the mesiobuccal root of maxillary second molars is significantly correlated with age, gender and position of the tooth.[13,17,18] The current study also showed a significant correlation between the age and sex of patients and the occurrence of a second mesiobuccal canal in the maxillary second molars, i.e., the prevalence of a second mesiobuccal canal in the maxillary second molars was higher in males and in younger patients.

Gomes et al. used CBCT and demonstrated that 68.23% of maxillary molars had a second mesiobuccal canal, and a significant correlation existed between the prevalence of a second mesiobuccal canal and the age and gender of patients.[17] The prevalence of a second mesiobuccal canal was higher in younger patients irrespective of gender. Conversely, another study reported higher prevalence of a second mesiobuccal canal in older individuals.[19]

Knowledge of the morphology of the roots and canals of the mandibular second molars in different races and populations is imperative. The current results revealed that the prevalence of mandibular second molars with one, 2 or 3 roots was 9.2%, 88.8% and 2.0%, respectively.

The most common canal type in the mesial (54.7%) and distal (97.5%) roots of the mandibular second molars was Vertucci type II and I, respectively. The most frequent number of canals in the mesial (84.0%) and distal (97.5%) roots of the mandibular second molars was 2 canals and 1 single canal, respectively. In a study by Gulabivala et al., 58% of second molars had 2 roots, and Vertucci types II and IV were the most common canal types in the mesial root.[20]

In a study by Zhang et al., 76% of second molars had 2 roots, 22% had 1 root and 2% had 3 roots.[21] Their results are in agreement with our findings. Moreover, 97% of the distal roots and 42% of the mesial roots were Vertucci type I, 65% of the mesial roots had 2 canals and were Vertucci type IV, and 27% were Vertucci type V. Compared to our study, 84.0% of the mesial roots had 2 canals, out of which 54.4% were Vertucci type II and 28.6% were Vertucci type IV.

Our findings, compared to those of the above-mentioned studies and the results of Ahmed et al.[22] and Weine et al.,[23] indicated that the frequency of mandibular second molars with 2 roots in our study was higher than the rate reported in other populations, and the anatomical and morphological variations of the second molars in our study were different from those in other populations.

The current results indicated that of 447 mandibular second molars, 9.2% had C-shaped canals. No significant correlation was noted between the prevalence of C-shaped canals in the mandibular second molars and age or gender of the patients. The prevalence of C-shaped canals was reported to be 13.8% in a study by Ashraf and Grayeli and 3% in a study by Nourmandipour and Nasiri.[24,25] In a study by Weine et al., the prevalence of C-shaped canals in Caucasians was reported to be 7.2%,[23] while this rate was 6.7% in the United States.[26] The prevalence of C-shaped canals in the mandibular second molars of the Chinese, Taiwanese and Burmese populations ranges from 22.4% to 32.5%, which is largely different from the value found in our study.[20] This difference may be attributed to racial differences as well as different clinical criteria used for the detection of C-shaped canals.[20,26] On the other hand, our findings, similar to those of previous studies, confirmed the absence of a significant correlation between the prevalence of C-shaped canals and age or sex of the patients.[27–29] The use of CBCT and the large sample size were among the strengths of this study, which increased the accuracy of the results.

Conclusions

The results of this study revealed higher prevalence of 2-rooted mandibular second molars and 3-rooted maxillary second molars in our study population. Considering the 9.2% prevalence of C-shaped canals in our study population, dental clinicians should pay utmost attention to detecting such canals in order to increase the success rate of root canal treatment. Failure in detection and treatment of a second mesiobuccal canal decreases the long-term success rate of endodontic treatment. Cone-beam computer tomography can be used as a non-invasive imaging modality with high accuracy for the detection of additional roots and canals, including C-shaped canals. It provides clinicians with valuable information about the root canal anatomy.

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Original papers

Assessment of the apically extruded debris between a rotary system, a reciprocating system and hand files during the root canal instrumentation of the deciduous molars

Ocena przepchnięcia wierzchołkowego zawartości kanałów po zastosowaniu systemu rotacyjnego, recyprokalnego i pilników ręcznych podczas opracowywania kanałów korzeniowych mlecznych zębów trzonowych

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Abstract

Background. One of the factors that most negatively affect the endodontic instrumentation process in primary teeth is the presence of extruded debris in the periapical region. Therefore, different techniques have been evaluated to reach an answer to the question regarding which root canal preparation method produces the least amount of debris extrusion.

Objectives. The main objective of this study was to assess the amount of debris extrusion as well as irrigation associated with 3 different instrumentation techniques: a rotary system (PROTAPER NEXT® – PTN), a reciprocating system (WaveOne® – WO) and hand K-files.

Material and methods. Forty-eight primary mandibular molars with a single distal canal were selected and randomly divided into 3 groups ($n = 16$). Three different techniques were used for the canal instrumentation of each group, comprising PTN, WO and hand K-files. Pre-weighed Eppendorf tubes were used for the collection of debris extrusion, then stored in an incubator at 70°C for 5 days. A one-way analysis of variance (ANOVA) test was used for data analysis, followed by Tukey's post hoc test.

Results. Statistically significant differences were found while comparing the PTN and WO systems with the hand files. Both PTN and WO showed less debris extrusion toward the periapical tissues than the hand files. Still, no statistically significant differences were seen between the PTN and WO groups.

Conclusions. Generally, debris extrusion occurred in all of the 3 experimental groups. The PTN and WO systems showed the least debris extrusion as compared to the hand files during the root canal instrumentation of the primary teeth, and for these reasons along with the shorter operating time, it may be concluded that using rotary and reciprocating systems rather than manual files is highly advisable. However, a clinical assessment is suggested.

Key words: extruded debris, hand files, rotary system, primary teeth, reciprocating system

Słowa kluczowe: przepchnięta zawartość kanałów, pilniki ręczne, system rotacyjny, zęby mleczne, system recyprokalny

Introduction

Keeping the primary dentition healthy is crucial for maintaining normal development of the jawbones, natural muscle function, good speech, and even natural eruption of the secondary dentition. However, it has been reported that premature eruption of the primary teeth may lead to many problems, some of which are bad oral habits and changes in the arch dimensions, as well as disturbances in the eruption sequence of the permanent dentition.[1]

Despite the fact that the endodontic treatment of the primary teeth with the optimal preparation has been recommended as a successful therapy for irreversible pulpitis or even pulp necrosis,[2] a few reports have mentioned that using traditional endodontic files for this purpose is time-consuming and causes fatigue for both dentists and patients.[3]

Since the introduction of rotary-file systems for the endodontic treatment of the primary teeth by Barr and his colleagues in 2000,[4] many studies have reported the efficacy of these instruments in maintaining the original root canal anatomy of the primary teeth and reducing the frequent errors that usually occur during the traditional treatment process with the use of normal hand files.[4,5] The use of nickel-titanium (NiTi) rotary instruments makes the endodontic treatment faster and easier with less file breakage incidents. Furthermore, NiTi instruments provide better shaping for the cleaning procedure, irrigation and obturation during the root canal therapy.[5]

Debris extrusion resulting from the endodontic preparation and irrigation during the root canal treatment, including dentinal fragments, microorganisms and irrigation solutions, can all cause pain and inflammation, and delay the healing of the periapical tissues. Most traditional techniques, which depend on normal hand files, lead to these undesired effects. Therefore, eliminating debris extrusion in the apical region has been recommended for the successful root canal therapy of the primary teeth.[6]

The primary teeth are subject to physiologic resorption due to the eruption of the succedaneous teeth. This causes more apical foramen enlargement of the primary teeth, which, in turn, allows more extrusion of the debris periapically.[7] However, the amount of the extruded debris is affected by the techniques and systems used during the endodontic treatment.[8–10]

Recently, PROTAPER NEXT® (PTN) rotary files (Dentsply Maillefer, Ballaigues, Switzerland) have utilized different designs that contribute to both increased flexibility and increased cyclic fatigue resistance. These designs incorporate an M-wire alloy, which, in turn, enables an off-centered rectangular cross-section and the application of variable tapers of rotary files.[11]

Reciprocating rotation was suggested as an alternative to continuous rotation for the preparation of curved canals by applying a single instrument.[12] This technique forms the root canal safely,[13] enabling better irrigation as well as removing less dentin from the internal walls of the canals, especially in the danger zones, which decreases the possibility of damage or fracture in the dentinal walls or in the file itself.[14] The WaveOne® (WO) system (Dentslpy Maillefer) applies a reciprocating movement using just 1 instrument with 3 size options (small – 21/06; primary – 25/08; and large – 40/08).[15]

The aim of this study was to evaluate the differences in the amount of the extruded debris between the WO file, PTN files and hand K-files, used in the treatment of the primary teeth.

Material and methods

The protocol of this in vitro study was approved by the research ethics committee of Damascus University, Syria (No. of the ethical approval: 1788/2017). This study was carried out on 48 distal canals of primary mandibular molars extracted due to periapical pathology and preventive orthodontic treatment. The teeth were cleaned of the external debris and soft tissue remnants, then stored in a saline solution at room temperature to be used later.

The study, according to the required criteria, involved primary mandibular molars with 2/3 of the root present and the moderate curvature of the distal root ranging between 10° and 20°, according to the Schneider protocol,[16] without pathological resorption, fracture, cracks, or caries in the root. The teeth were examined by means of digital periapical radiography to confirm the presence of a single canal.

Each primary tooth was sectioned at the furcation area using a low-speed diamond saw (IsoMet™ 1000; Buehler, Lake Bluff, USA) with water cooling to separate the mesial root with its respective section of the crown from the distal one. Then, the mesial portion was discarded and the distal portion was kept for further investigations. The access cavities were prepared using an Endo-Z® bur (Dentsply Maillefer) at a high speed under cooling. All root canals were prepared by the same researcher and randomly divided into 3 groups.

A size 10 K-file (Dentsply Maillefer) was inserted in the distal root canal to verify its patency. This was followed by determining the working length; firstly, the size 10 K-file was inserted into the distal canal until it became visible at the apical foramen, then the working length was calculated by subtracting 1 mm from the previous measurement. Moreover, a radiograph was taken using the parallel technique to ensure correct measurement of the working length. It was considered that the canals with dimensions greater than those of the International Organization for Standardization (ISO) size 15 were to be excluded.[17]

In this study, the experimental model mentioned by Myers and Montgomery was used for the evaluation of the extruded debris collection (Fig.1).[18] A hole was created in each stopper of the Eppendorf tube and each tooth was inserted under pressure through the stopper to the level of the cementoenamel junction. In order to ensure balance of the air pressure between the inside and outside of the tube, a 27-gauge needle was inserted into each Eppendorf tube. Then, each stopper with its tooth and needle were attached to the Eppendorf tube, which, in turn, was fitted into a vial. All the equipment was handled using the vial without touching it with fingers. Furthermore, a microbalance was used to weigh the Eppendorf tube with 10^{-5} precision. Three weights were taken sequentially, and the mean value was registered for each tube. The irrigation protocol was standardized using 5 mL of distilled water with a 29-gauge needle (NaviTip®; Ultradent Products, Inc., South Jordan, USA) after using each file or after 3 pecks of the reciprocating file (as recommended by the manufacturer). The 48 specimens were randomly assigned to 3 groups after marking each tooth for encoding. Each group was made up of 16 samples as follows:
– hand file control group (group 1): hand preparation was completed using a stainless steel K-file taper 0.02 in the step-back technique, starting with size 15 and continuing in the following sequence: 20, 25 and 30;
– PTN (group 2): the PTN files were applied using an endodontic motor (X-Smart Plus; Dentsply Maillefer) in the following order: X1 (size 17, taper 0.04) and X2 (size 25, taper 0.06); the rotational speed was set at 300 rpm and 2 Ncm torque (according to the manufacturer's instructions); brushing movements were performed gently using an in-and-out motion;
– WO group (group 3): a small file (21/06) was used with a reciprocal motion (according to the manufacturer's instructions).

The evaluation of the debris was performed by a single, blinded operator. Finally, the Eppendorf tubes were separated from the vials after the successful completion of the canal preparation. Then, the debris stuck to the root surface was collected by rinsing the root with 1 mL distilled water in the Eppendorf tube. Evaporation of the distilled water was performed using an incubator at 70°C for 5 days before weighing the dry debris.[19] The net weight of the dry debris was calculated by subtracting the weight of the empty Eppendorf tube from the total weight.

Fig. 1. Experimental system used to evaluate the debris extrusion

Statistical analysis

The Kolmogorov-Smirnov test showed that the data was normally distributed. Then, Levene's test for homogeneity was used to confirm the homogeneity between the variances. The differences between the groups were analyzed with one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for multiple comparisons, and the level of significance was set at 0.05. The IBM SPSS software v. 20.0 (IBM SPSS, Inc., Chicago, USA) was used for data analysis.

Results

The mean values, standard deviations (*SD*) and ANOVA results regarding the 3 groups are listed in Table 1. The *p*-value was ≤0.05 for the ANOVA test, which showed significant differences between the experimental groups. Tukey's post hoc test showed that there were no statistically significant differences in the extruded debris between the PTN and WO groups ($p > 0.05$), as shown in Table 2. The highest amount of the apically extruded debris was seen in the hand file group. In other words, there were statistically significant differences between the PTN and manual file group, in addition to the presence of statistically significant differences between the WO and manual file groups, but at the same time there were no statistically significant differences between the PTN and WO groups while comparing their results.

Table 1. Weight of the extruded debris in the experimental groups (one-way analysis of variance – ANOVA)

Group	n	Mean	*SD*	F	*p*-value
WO	16	0.00242	0.00033	72.716	0.000*
PTN	16	0.00262	0.00030		
Hand file	16	0.00379	0.00039		

WO – WaveOne; PTN – PROTAPER NEXT; *SD* – standard deviation;
* significant difference at p ≤ 0.05.

Table 2. Pairwise comparisons with Tukey's test

Pair		Mean differences of debris weight	*p*-value
WO	PTN	–0.00019	0.240
WO	Hand files	–0.00137	0.000*
PTNt	Hand files	–0.00117	0.028*

*significant difference at p ≤ 0.05.

Discussion

Root canal treatment may lead to dramatic effects in the periapical tissues. Many inflammatory changes and pain that occur during the mechanical and chemical preparation of the root canals are a result of debris extrusion into the periapical region. The debris contains dentinal particles, irrigation solutions, necrotic pulp, and microorganisms. On the other hand, the undesirable effects of the extruded debris pose a threat to the permanent dentition, as they may alter the morphology of the permanent tooth germ.[6] Therefore, the major purpose of this study was the assessment of the apically extruded debris and irrigants as a result of the root canal preparation with different instrumentation system techniques.

In the present study, 5 mL of distilled water was used for the root canal irrigation to prevent the crystallization of sodium hypochlorite, which may cause misleading findings of the debris.[17] The generally accepted method of Myers and Montgomery was used for the collection of the extruded debris.[18] There have been different results obtained in studies in vivo and in vitro due to the fact that the normal periapical tissues act as a physical barrier that helps to control the extrusion of the necrotic debris.[20] Therefore, there is a limitation when applying the results of this study clinically due to the lack of a back pressure, naturally caused by the periapical tissues. Floral foam has been mentioned in the literature as a substance used for the periapical tissue stimulation.[21] However, this material may absorb the irrigating solution as well as the resulting debris, and hence influence the results.

The distal root of the primary mandibular molar was chosen for this study, because it has a large single canal, a regular canal outline and less intracanal divergence as compared to the mesial root of the primary mandibular molar. The current study revealed that all of the preparation techniques caused the apical extrusion of debris and irrigants. It is in agreement with the findings of other studies, which have mentioned the lack of any existing technique that could totally prevent debris extrusion.[22,23] Different authors have stated that the PTN system extruded significantly less debris than the hand file technique.[23,24] Madalena et al. reported that the amount of the apically extruded debris was smaller in the case of the root canal preparation with a single reciprocating file (WO) as compared to the hand files.[25] This study confirmed that observation.

To the best of our knowledge, no study has ever evaluated the apical extrusion of the debris during the root canal instrumentation of the primary teeth by comparing the PTN and WO systems. Thus, the results of our study can only be compared with the results of other studies that have used both instrumentation techniques in the treatment of the permanent teeth. In this study, no statistically significant differences between the reciprocating single-file WO system and the rotary multiple-file PTN system were observed, which corresponds to the observations of Ozsu et al.[26]

There are several factors responsible for differences between the root canal preparation systems, such as technique, direction and kinematics of the instrumentation. Different files have different cross-sectional designs. For example, the PTN file has a rectangular cross-section with a unique design (an offset center of mass and rotation). This design provides greater cross-sectional space for reinforced cutting, loading and the movement of the debris toward the orifice area of the canal, and results in less extruded debris in the PTN group when compared with the hand file group.[27] Another reason for decreasing the amount of debris in the PTN group could be the instrumentation technique. Since the PTN file is a rotary system file, the method used for the canal preparation is the crown-down technique, depending on the early flaring of the coronal area of the canal, which may increase directing the debris toward the orifice area during the rotational movement.[28] On the other hand, the middle and coronal portions of the WO files have a convex triangular cross-section, whereas the tip portion has a modified convex triangular cross-section.[13] There is consensus that balanced forces lead to good control of the apically extruded debris. Due to the reciprocating motion of the WO file, leading to automatically balanced forces with less pressure, the amount of the apical debris during the canal preparation is well-controlled.[29]

Finally, regarding the hand file group, the step-back technique was used for the root canal shaping of the primary teeth during biomechanical preparation. The hand file was acting as a piston in the apical area of the canal, which increased the amount of the apically extruded debris in the periapical region.[30]

Conclusions

The results of the present study showed that all instrumentation techniques used for the root canal preparation of the primary teeth caused debris extrusion. However, the hand files extruded more debris than both PTN and WO, whereas the PTN and WO systems both extruded less debris and showed better results.

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Original papers

Effect of nano-zinc oxide and fluoride-doped bioactive glass-based dentifrices on esthetic restorations

Wpływ past do zębów zawierających tlenek nano-cynku oraz bioaktywne szkło z fluorkami na estetyczne materiały wypełniające

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Abstract

Background. Over time, improvements have been made in dentifrices and recently bioactive components have been added. It is important to address the abrasivity of these dentifrices, which can cause wear of dental restorative materials.

Objectives. A comparative study was conducted to examine the effects of commercial and experimental dentifrices upon commonly used dental restorative materials.

Material and methods. Three types of experimental dentifrices were prepared with variable concentrations of fluoride-based bioactive glass, nano-zinc oxide (ZnO) and titanium dioxide (TiO_2) powder as active ingredients. A custom-made toothbrush simulator was used with variable cycles (0; 5,000; and 10,000) to treat samples prepared from dental restorative materials. Prior to and after the treatment cycles, the physical properties of the restorative materials were assessed and compared with commercial toothpaste through micro-hardness, surface roughness and color stability testing.

Results. The restorative materials showed an insignificant difference in terms of micro-hardness before and after the treatment with all dentifrices. A significant difference was observed in terms of surface roughness. With respect to color stability, there has been observed an insignificant difference between the control and the other 3 experimental dentifrices for all the cycles – pre, post-5,000 and post-10,000.

Conclusions. Experimental fluoride-containing bioactive dentifrices caused a change in the restorative material properties; however, it was minimal and the properties still met the requirements for clinical applications.

Key words: zinc oxide, dentifrices, dental composites, fluoride-bioactive glass, resin-modified glass-ionomer cement

Słowa kluczowe: tlenek cynku, pasty do zębów, kompozytowe materiały dentystyczne, bioaktywne szkło z fluorkami, modyfikowany żywicą cement szkło-jonomerowy

Introduction

Since the introduction of restorative materials to the dental field, a paradigm shift has been observed toward esthetic dentistry, and due to the esthetic demands, more emphasis has been put on color-, shade-, texture-, and shape-matching materials, like resin-based composites (RBCs).[1] Resin-based composites have been used to restore damaged, aged and traumatized teeth.[2] The physical and mechanical properties of esthetic restorative materials provide an indication of how the material will behave in the oral environment. While using these materials, an important property to be considered is surface roughness. This property has a high impact on the quality of the esthetic restoration in terms of color stability and gloss.[3]

Tooth brushing is considered a significant factor in improving oral health[4]; on the other hand, some untoward effects of using a toothbrush and dentifrices on color stability and surface roughness have been observed.[5–8] It has been reported that brushing increases the surface roughness and subsequently leads to plaque accumulation.[3,9,10] What has to be taken into consideration is the abrasiveness of the dentifrice. Some studies have claimed that dentifrices might cause the deterioration of restorative materials.[8,11] The size of particles and the type of abrasive agents used have an influence on the abrasiveness of the dentifrice.[5,12]

A desire to improve the quality of oral hygiene has given rise to many types of dentifrices. Experimental toothpaste, containing 5% calcium sodium phosphosilicate has shown a positive effect with regard to the reduction in sensitivity.[13] A comparative in vitro study showed that calcium sodium phosphosilicate-based dentifrices (i.e., NovaMin®; GSK, Brentford, UK) showed a significant increase in micro-hardness and a decrease in surface roughness of the tooth structure.[14] The bioactive glass material has been used in toothpaste to impart some advantages, such as dentinal tubule occlusion and the remineralization effect. It has been observed that the addition of bioactive glass (45S5 bioglass) affects the subsurface and surface erosion of the enamel by improving the micro-hardness of the enamel.[15] However, the 45S5 bioglass used in the toothpaste was harder than the enamel tissue; therefore, it could wear the enamel.[16] Another study has reported that the DP-bioglass toothpaste has a considerable effect on reducing sensitivity by sealing dentinal tubules.[17]

Fluoridated toothpaste plays a positive role in preventing dental caries and the remineralization effect on the early stages of a carious lesion, and subsequently, it can slow down the demineralization process.[18] The fluoride ions can inhibit the production of bacterial acids in dental plaque by changing the metabolic process of bacterial flora.[19] Zinc oxide (ZnO) is known for its anti-gingivitis and bactericidal effect.[12,20] Dentifrices containing ZnO have also been demonstrated to have a positive effect on the dentin by reducing demineralization.[21] Moreover, due to its antibacterial and anti-gingivitis action, zinc (Zn) has been incorporated into bioactive glass dentifrices, and it is suggested that increasing the content of Zn in dentifrices could result in a better antibacterial and anti-gingivitis effect.[20]

Fluoride-doped bioactive glass (F-BG) has recently been synthesized by our group and the long-term fluoride release behavior of F-BG as well as its effect on pH has been evaluated.[22] Zinc oxide nanoparticles used in this study have been synthesized in our laboratory.[23]

The purpose of this study was to utilize F-BG (with 5 mol% concentration of fluoride in bioactive glass), ZnO nanoparticles and titanium dioxide (TiO_2) as active agents in experimental dentifrices and compare their physical and mechanical effect on different restorative materials with a commercial dentifrice. Previously, bioactive glass-based dentifrices had been evaluated as a remineralizing agent on tooth surfaces. However, the authors could not find any study where any toothpaste containing bioactive glass had been applied on restorative materials and evaluated in terms of the surface roughness changes, micro-hardness and color stability. The null hypothesis was that the effect of experimental and commercial dentifrices on dental restorative materials would be the same.

Material and methods

In this study, 3 commercially used restorative materials were applied: Filtek™ Bulk Fill (3M ESPE, Seefeld, Germany), Filtek Z350 XT (nano-hybrid composite; 3M ESPE) and GC Fuji II LC (resin-modified glass-ionomer cement (RMGIC); GC Corp., Tokyo, Japan). The composition of these materials is given in Table 1. A commonly used commercial dentifrice, Colgate Advanced Whitening (Colgate-Palmolive Company, New York, USA) was used as the control (CT) and 3 experimental dentifrices, containing F-BG, ZnO nanoparticles and TiO_2 powder as active ingredients, were synthesized in our laboratory. Initially, the basic ingredients were prepared, and then TiO_2 (1.5% (w)) and ZnO nanoparticles (3% (w)) were added. Fluoride-doped bioactive glass was used in various concentrations, i.e., 1.5%, 2.5% and 3.5% (w/w), and the experimental dentifrices were denoted on the basis of these concentrations as ExpT-A, ExpT-B and ExpT-C, respectively. The composition of both the control and experimental dentifrices is given in Table 2.

Sample preparation

The restorative materials were used as received, and samples were prepared according to the manufacturers' instructions. A total of 96 disc-shaped (10 mm in diameter and 2 mm in height) samples of each group were prepared in a custom-made silicone mold. After being placed in a mold, the light-cured based restorative material samples were photoactivated using high-intensity LED blue light (LITEX™ 695C Cordless LED Curing Light; Dentamerica, Inc., City of Industry, USA), with the intensity

Table 1. Frequency distribution of the root variations in the mandibular and maxillary second molars

Restorative material	Company	Composition
Bulk-fill composite (Filtek Bulk Fill)	3M ESPE, Seefeld, Germany	bis-GMA, UDMA, bis-EMA, and Procrylat resins; fillers: zirconia/silica (a particle size range of 0.01–3.5 µm and ytterbium trifluoride filler (a particle size range of 0.1–5.0 µm); the inorganic filler loading is approx. 64.5% (w) (42.5% (v))
Nano-hybrid universal restorative (Filtek Z350 XT)	3M ESPE, Seefeld, Germany	bis-GMA, UDMA, bis-EMA, PEGDMA, and TEGDMA resins; fillers: surface-modified zirconia/silica (a median particle size – approx. 3 µm or less), non-agglomerated/non-aggregated 20 nm surface-modified silica particles; the filler loading is 82% (w) (68% (v))
RMGIC (GC Fuji II LC)	GC Corp, Tokyo, Japan	HEMA 15–40%, polybasic carboxylic acid 3–7%, UDMA 1–5%, dimethacrylate 1–5% plus nonhazardous additions

bis-EMA – bisphenol A-diglycidyl methacrylate ethoxylated; bis-GMA – bisphenol A-diglycidyl methacrylate; HEMA – 2-hydroxyethyl methacrylate; PEGDMA – polyethylene glycol dimethacrylate; RMGIC – resin-modified glass-ionomer cement; TEGDMA – triethylene glycol dimethacrylate; UDMA – urethane dimethacrylate.

Table 2. Composition of experimental and commercial dentifrices

Ingredients	Experimental dentifrice (A)	Experimental dentifrice (B)	Experimental dentifrice (C)	Commercial dentifrice
Basic ingredients		glycerol methylcellulose calcium carbonate sodium lauryl sulfate flavoring agent aqua (water)		sorbitol hydrated silica glycerin sodium lauryl sulfate polyethylene glycol cellulose gum xanthan gum cocamidopropyl betaine sodium saccharin sodium hydroxide limonene flavoring agent coloring agent aqua (water)
Active ingredients	F-BG (1.5%) + ZnO (3%), TiO_2 (1.5%)	F-BG (2.5%) + ZnO (3%), TiO_2 (1.5%)	F-BG (3.5%) + ZnO (3%), TiO_2 (1.5%)	sodium fluoride 0.22% (1000 ppm fluoride) penrasodium triphosphate tetrapotassium pyrophosphate

F-BG – fluoride-doped bioactive glass; TiO_2 – titanium dioxide; ZnO – zinc oxide.

of 1,200 mW/cm^2 and the wavelength of 470 nm. The samples were placed on a glass slab and covered with a Mylar strip to avoid an oxygen inhibition layer, and were cured for 60 s from both sides. For RMGIC, the capsular type was used and properly condensed in a mold. After photoactivation, all samples were polished with alumina paste using a polisher (MetaServ™ 250 Grinder-Polisher with Vector® Power Head; Buehler, Lake Bluff, USA). The polished samples were sonicated and washed with water to remove any particles of the polishing paste. The samples of each material were divided into 4 main groups (n = 24) based on the dentifrices and prepared for pre-treatment analysis (micro-hardness, surface roughness and color stability testing). After this, the samples were treated with the dentifrices.

Tooth brush simulation

The groups of materials were subjected to each dentifrice in the toothbrush simulator ZM-3.8 (SD Mechatronik GmbH, Feldkirchen, Austria). Prior to the start of testing, each dentifrice was mixed with distilled water at a 1:2 ratio (1 g of dentifrice to 2 mL water) to make a slurry. The slurry was applied to each toothbrush (manual, medium toothbrush; TARA Toothbrush Company, Dammam, Saudi Arabia). The prepared samples were put in a silicone mold and placed in an appropriate place. It was ensured that the samples contacted the toothbrush head once in each cycle. A load of 200 g was applied to the toothbrush head so that it contacted the samples; it was controlled by a central drive system. A total of 6 manual toothbrushes were placed and fixed in the holders, in which the head of the brush with its nylon bristles was seated perpendicular to the specimens, mounted at the same level, with the bristles touching the specimens without bending. Then, the machine was programmed to perform a complex motion. The reciprocation and speed were 2 mm and 160 cycles/min, respectively, up to 5,000 cycles (simulating 6 months). After that, the specimens were analyzed with regard to the 3 parameters – micro-hardness, surface roughness and color stability. Then, they were reinserted into the brushing machine to complete 10,000 cycles (simulating 1 year). The motion sequences were done by a programmed optional software module. After completing the cycles, the samples were examined again.

Vickers micro-hardness measurement

Vickers micro-hardness value for all samples was evaluated using the MicroMet® 6040 tester (Buehler) before and after the treatment cycles. The indent load was adjusted to 200 g and the dwell time was 10 s. A total of 8 samples from each group were evaluated and 3 indents were taken on each sample.

Surface roughness measurement

To evaluate the 3D surface roughness before and after the treatment, 8 samples were examined using the Contour® GT-K optical microscope (Bruker Optics, Inc., Billerica, USA) under the load of 50 g for 15 s, with the vibration resistance, air isolation, time-tested properties, which provided an accurate result in terms of repeatability and quantity.

Color stability measurement

Regarding the evaluation of color stability, the Color-Eye® 7000A spectrophotometer (X-rite, Grand Rapids, USA) was used with the International Commission on Illumination (Commission internationale d'eclairage – CIE) L^* a^* b^* based on the same illuminant against a black and white background (L^* refers to a gray degree corresponding to lightness; a^* stands for the red-green axis; and b^* for the blue-yellow axis). The spectrophotometer was used before and after the brushing simulating process for each group (n = 8). The calibration of the unit was performed before measurement according to the manufacturer's instructions. The color change (ΔE) was calculated using the following formula:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

where

ΔL^*, Δa^*, Δb^* represent differences in L^*, a^*, b^*, respectively, before and after brushing.

For statistical analysis, one-way analysis of variance (ANOVA) Tukey's post hoc test was used with IBM SPSS Statistics software v. 22 (IBM, Inc., Armonk, USA). For significant difference, the p-value was set at 0.05.

Results

Vickers micro-hardness measurement

The micro-hardness results of all samples before and after the treatment are given in Fig. 1. The values for the resin-based composites (Filtek Bulk Fill and Filtek Z350 XT) showed an insignificant difference ($p \geq 0.05$) before and after the toothbrushing treatment as compared to the control and all 3 types of experimental dentifrices. An insignificant difference ($p \geq 0.05$) in the micro-hardness values was observed among the experimental dentifrices after the treatment with 5,000 and 10,000 cycles. For RMGIC (GC Fuji II LC), all dentifrice treatments showed a significant difference ($p \leq 0.05$) in values, with the values decreased after the treatment.

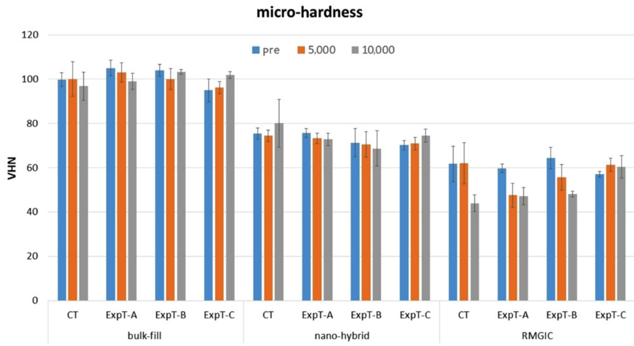

Fig. 1. Micro-hardness values of restorative materials before and after the treatment with commercial and experimental dentifrices

VHN – Vickers hardness number.

Surface roughness measurement

The surface roughness was analyzed before and after the treatment, and the images of all groups are given in Fig. 2–4. The Ra values for all samples are given in Table 3. The surface roughness increased along with the treatment, and it was observed that the values for the resin-based composites (Filtek Bulk Fill and Filtek Z350 XT) and RMGIC (GC Fuji II LC) showed a significant difference ($p \leq 0.05$) before and after the toothbrushing treatment as compared to the control and all 3 types of experimental dentifrices. Among these, RMGIC showed higher surface roughness compared to the resin-based composites, whereas the nano-hybrid composite showed the least. The change in the surface roughness values was irrespective of an increase in the concentration of F-BG in the experimental dentifrices.

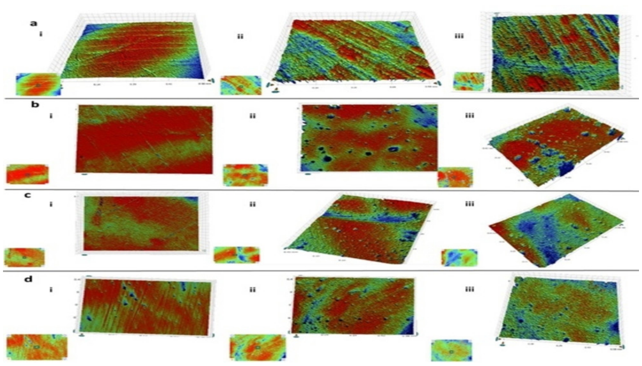

Fig. 2. 3D surface images of Filtek Bulk Fill composite treated with CT (A), ExpT-A (B), ExpT-B (C), and ExpT-C (D), with the number of cycles: (i) 0, (ii) 5,000 and (iii) 10,000; red area represents high point, while blue area represents low point

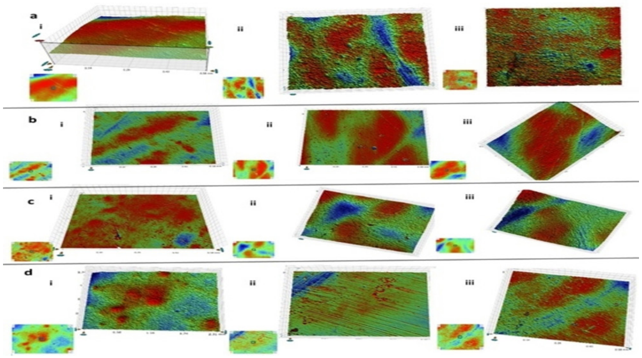

Fig. 3. 3D surface images of Filtek Z350 XT composite treated with CT (A), ExpT-A (B), ExpT-B (C), and ExpT-C (D), with the number of cycles: (i) 0, (ii) 5,000 and (iii) 10,000; red area represents high point, while blue area represents low point

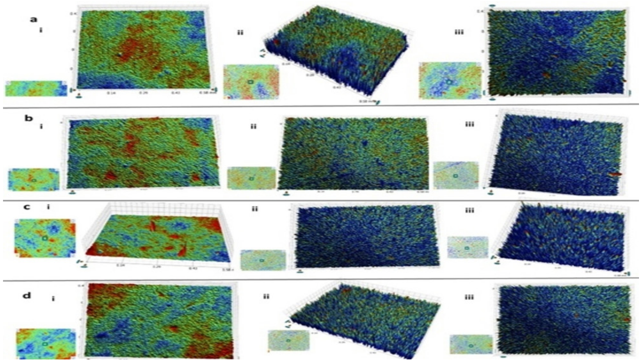

Fig. 4. 3D surface images of GC Fuji II LC composite treated with CT (A), ExpT-A (B), ExpT-B (C), and ExpT-C (D), with the number of cycles: (i) 0, (ii) 5,000 and (iii) 10,000; red area represents high point, while blue area represents low point

Color stability measurement

In terms of color stability, all samples showed an insignificant difference ($p \geq 0.05$) as compared to the control and to the 3 experimental dentifrices for all the cycles – pre, post-5,000 and post-10,000. The values are given in Fig. 5.

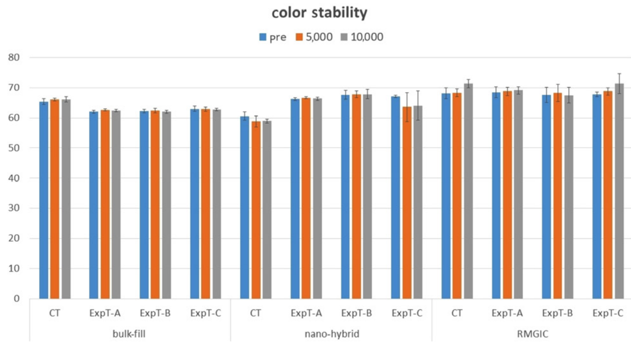

Fig. 5. Color stability measurements before and after the tooth brushing treatment

Discussion

The influence of dentifrices on the surface of restorations have been noticed and their effect has been linked to dentifrice ingredients. Components such as bioactive glass, calcium carbonate, ZnO, TiO_2, and other, which have the capability to influence the substratum surface, subsequently influence the characteristics of esthetic restorative materials. The dentifrices exerted a significant effect on the surface roughness when comparing the control and treated samples. The presence of active ingredients in the experimental dentifrices, i.e., F-BG, TiO_2 and ZnO, showed a significant effect. The effect with regard to the various concentrations of F-BG in the samples was insignificant. The presence of abrasive particles in the dentifrice is a factor that affects the surface roughness of the esthetic restoration. The surface roughness of esthetic restorations have been further linked on a deeper level to the size and type of the abrasive agent used.[5]

In another aspect, different behavior has been observed with respect to the composition of the restorative materials. The nano-hybrid composite has been

Table 3. Mean surface roughness values (*Ra*) of all esthetic restorative materials after 0; 5,000; and 10,000 cycles

Groups	Restorative materials	*Ra* values [nm] and *SD* with regard to the number of cycles		
		0	5,000	10,000
CT	Filtek Bulk Fill	34.60 ±11.01	49.86 ±18.14	43.85 ±19.81
	Filtek Z350 XT	39.60 ±3.11	80.89 ±10.31	82.63 ±16.85
	GC Fuji II LC	104.50 ±36.06	1,747.75 ±131.41	1,808.06 ±129.95
ExpT-A	Filtek Bulk Fill	30.40 ±3.66	110.80 ±13.22	237.50 ±16.20
	Filtek Z350 XT	31.90 ±2.58	43.50 ±18.76	77.10 ±22.24
	GC Fuji II LC	104.80 ±26.2	175.68 ±28.94	243.65 ±65.34
ExpT-B	Filtek Bulk Fill	30.40 ±10.61	321.00 ±21.21	399.00 ±22.45
	Filtek Z350 XT	32.40 ±15.05	264.90 ±83.49	351.40 ±85.28
	GC Fuji II LC	99.70 ±12.54	383.35 ±52.94	1,094.70 ±69.23
ExpT-C	Filtek Bulk Fill	33.00 ±10.51	83.09 ±17.55	121.56 ±18.76
	Filtek Z350 XT	29.90 ±3.88	66.88 ±18.20	137.61 ±13.75
		99.50 ±18.71	474.90 ±77.31	473.00 ±121.70

CT – control (commercial dentifrice); ExpT-A, ExpT-B, ExpT-C – experimental dentifrices; *SD* – standard deviation.

noticed to present a smaller change in the surface roughness than the bulk-fill one. This difference is claimed to be due to the filler particles, which can be displaced, causing more surface exposure of the weak parts of the composite (the organic matrix). The distribution and size of the filler have an impact on the surface roughness.[4,8] In this study, the resin-based composites showed an insignificant change in the micro-hardness values and less increase in the surface roughness as compared to RMGIC. The results were justified by the fact that composites have silane coupling agents, which bind the filler particles chemically with the resin matrix, and the same material accounts for their hydrolytic stability.[13] The presence of zirconia and silica particles resulted in more resistance in terms of surface roughness; however, it was increased. Compared with micro-particles, the nano-particle-based composite showed relatively better results. The resin-modified glass-ionomer cement contained alumina-silicate particles, and their interaction with dentifrices caused more surface roughness and wear, and subsequently, the micro-hardness values changed.

Prior to the treatment, all samples were polished, because delivering a restoration which has well-polished, smooth surface gives the most favorable esthetic result, with less plaque accumulation.[3,24] It is reported that 0.2 μm of surface roughness is a critical value in the retention of bacteria, while surface roughness of 0.3 μm can be detected by the tongue.[3,25] In this study, the surface roughness result for Filtek Bulk Fill after 5,000 cycles of brushing with ExpT-A and ExpT-C was favorable, with a value of <0.2 μm. However, the Ra value after proceeding to 10,000 cycles of brushing with the same experimental toothpastes (ExpT-A and ExpT-C) increased to >0.2 μm, though not exceeding 0.3 μm. The Ra values for Filtek Z350 XT after 5,000 cycles with ExpT-A and ExpT-C were <0.2 μm. After completing 10,000 cycles with ExpT-C, the Ra value remained below 0.2 μm, whereas with ExpT-A, the Ra value increased to >0.2 μm, though not exceeding 0.3 μm.

In assessing the effect of the dentifrice on the micro-hardness of the restoration, one should take into consideration the dentifrice pH. It is reported that dentifrices with natural or acidic pH values cause more micro-hardness changes than alkaline ones.[26] An analysis of pH of the experimental dentifrices is beyond the scope of the present study. However, it will be published later. In our previous study, it was observed that pH of F-BG (5 mol%) was 8.0 in deionized water and upon aging it did not change significantly.[22] It is anticipated that the presence of alkaline contents (both F-BG and ZnO nanoparticles) as active agents made these experimental dentifrices alkaline. Therefore, an insignificant difference was observed related to the micro-hardness of RBCs. The presence of F-BG in an aqueous medium can lead to the breakage of bonds within a bioactive glass network, as the network breakage reaction is highly sensitive to the attack of molecular water. This breakage can enhance the dissolution rate of bioactive glass, and subsequently, the effect on the properties of restorative materials. It may leave deposits on the surface of these materials, and alter the physical and mechanical properties. It has been reported that the presence of fluoride in bioactive glass results in slower dissolution as compared to bioactive glass alone.[27] However, the dissolution of bioactive glasses is a complex process and there is still no complete consensus on the basic mechanism.

Limited studies have been conducted to evaluate the color stability of esthetic materials after using dentifrices. Previously, it was reported that along with the application of whitening dentifrices, significant changes in color stability were observed.[11] However, this study showed insignificant changes with regard to the application of the commercial and experimental dentifrices. Regarding the effects of the commercial and experimental dentifrices on the samples, no difference was observed in color stability, surface roughness or micro-hardness. However, more roughness and change in the micro-hardness values were noticed along with the increase in the concentration of the active ingredient in the experimental dentifrices. On the basis of these evaluations in the current study, it is suggested that among these toothpaste groups, the experimental dentifrices with 3.5% F-BG and 3% ZnO as active ingredients showed better performance in terms of micro-hardness and surface roughness. It is also expected that these active ingredients have the potential to reduce demineralization and hypersensitivity, and increase the antibacterial properties of the toothpaste. However, these characteristics are beyond the scope of the present study and will be presented later.

Conclusions

It appears from this study that introducing experimental dentifrices containing fluoride-based bioactive glass and ZnO oxide have a safe effect on esthetic restorations. This study is considered to be a pioneer in evaluating the effects of bioceramic and metal oxide-based experimental dentifrices on esthetic restorations. Future studies are needed with patient involvement, for better simulation of normal circumstances, to give a more precise assessment of experimental dentifrices.

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Original papers

Evaluation of the effect of storage time and disinfectant solutions on the dimensional accuracy of impression materials with digital radiography

Ocena wpływu czasu przechowywania oraz roztworów odkażających na wierność odtwarzania kształtu przez materiały wyciskowe z użyciem radiografii cyfrowej

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Abstract

Background. The dimensional accuracy of impression materials has been evaluated for a long time, but thus far, digital radiography has not been used for this purpose. The dimensional accuracy of impression materials is very important for the final adaptation of dental prostheses.

Objectives. The objective of this study was to evaluate the effects of different disinfectant solutions and storage times on the dimensional stability of different impression materials by means of digital radiography.

Material and methods. Polyether (PE), hydrocolloid (IH), condensation silicone (CS), and addition silicone (AS) materials were used for preparing impressions, taken from an acrylic master model with 2 vertical and 2 horizontal reference points. Water (W), sodium hypochlorite (SH) and a disinfectant solution without aldehyde (Z) were applied on the impressions. Half of the impressions were poured over immediately and half of them – 1 day after. Digital radiography was used to determine the dimensional accuracy of the impression materials. The data was analyzed with a variance analysis and Tukey's multiple comparison test.

Results. While PE showed the smallest dimensional changes, IH showed the greatest in all lines. Applying SH and pouring 1 day after caused the greatest dimensional changes in all impression materials.

Conclusions. Different disinfectant solutions and storage times had a different effect on the impressions, but the dimensional changes were clinically acceptable.

Key words: dimensional accuracy, storage time, impression material, digital radiography, disinfection solution

Słowa kluczowe: wierność odtwarzania kształtu, czas przechowywania, materiał wyciskowy, radiografia cyfrowa, roztwór odkażający

Introduction

Dental impression materials are used to register the form and relation of the teeth and the surrounding oral tissues. The accuracy of the impression is related to the dimensional stability of the impression material, and this is affected by many factors, such as the impression technique, impression tray, selection of a proper impression material, and properties of the material.[1–3] An accurate impression is the most important stage for the construction of a dental prosthesis.[4] Polysulfide polymers, condensation silicones and the addition type of silicones, synthetic elastomers containing polyether, and hydrocolloids are widely used in dentistry to obtain the copy of oral tissues.[5] Impression materials are exposed to some factors, which may result in dimensional changes.[6] The dimensional stability and accuracy of impression materials are significant for the adaptation of the final prosthetic restoration. The dimensional accuracy of impressions is mostly influenced by the procedure of disinfection and the time period after which the model is poured over with dental stone. In terms of the latter, the best results are obtained by pouring the dental stone immediately after removing the impression from the mouth. For practical reasons, the impressions may nevertheless sometimes not be poured over immediately. Some producers claim that recently produced impression materials can be kept in appropriate conditions for longer periods of time without loss of clinical accuracy. Glutaraldehyde and sodium hypochlorite are frequently used for disinfecting dental impressions.[7] Sodium hypochlorite, which is an effective disinfectant recommended by the American Dental Association (ADA), is used in a 1:10 dilution for a 10-minute immersion to disinfect irreversible hydrocolloid impressions.[8] The use of glutaraldehyde is not preferred due to its harmful and irritant effect. Therefore, dentists may prefer aldehyde-free disinfectant solutions.

Various dimensional measuring techniques are used in clinical and academic dentistry for dental stone models and scanned models. Manual measurements are performed with a Vernier caliper or needle-point calipers, and they are the standard method to evaluate the accuracy of dental models. Manual measurements have some advantages, such as the ease of application, low cost and immediate applicability. Alternatively, 3-dimensional computer dental models, scanned with an optical or laser beam, are considered appropriate in clinical applications. In this study, the dimensional changes of different impression materials were evaluated with digital radiography, which differs from the methods described in the current literature. Digital radiography is considered to be more economical than the 3-dimensional computer application and more reliable than the manual methods.[8,9]

The aim of this study was to evaluate the effect of different disinfectant solutions and storage times on the dimensional stability of different impression materials. The hypothesis of the study was that different storage times and disinfectant solutions would affect the dimensional stability of impression materials in different ways, depending on the type of impression material.

Material and methods

In this study, a denture base from heat-polymerized acrylic, prepared on a stone model of the edentulous maxilla, was used as a master model. Holes were drilled in the places corresponding to the right and left canines and tuber maxillary ridges on the acrylic base with a steel round drill of a diameter of 0.2 mm, and 4 different reference points were determined. Then, metal balls of a diameter of 1 mm were placed in the reference points of the master model and fixed with dental wax. Two vertical (line 1 and line 2) and 2 horizontal (line 3 and line 4) reference lines were identified on both sides between the 4 different reference points. The reference lines were determined as follows:

– line 1 – the distance between the steel balls in the region of the left canine and left tuber maxilla;

– line 2 – the distance between the steel balls in the region of the right canine and right tuber maxilla;

– line 3 – the distance between the steel balls in the region of the right and left canines;

– line 4 – the distance between the steel balls in the region of the right and left tuber maxillae.

Therefore, it was aimed to evaluate the dimensional changes that might occur in the impression materials both horizontally and vertically by measuring the vertical and horizontal reference lines. The master model was fixed inside the lower part of a dental prosthesis flask with dental white stone. Thus, it was ensured that the model remained stable during impression procedures.

The master model was placed in a digital radiography unit (PHOT-xII; Takara Belmont USA, Inc., Somerset, USA) and its image was taken with occlusal radiography. The reference measurements, determined by the reference points, were carefully performed digitally by 2 researchers (Fig. 1). These measurements were used as references and compared to those of the subsequent stone models. The dimensional changes that occurred due to the impression materials were evaluated by subtracting the 1st reference measurement value from those of the stone models.

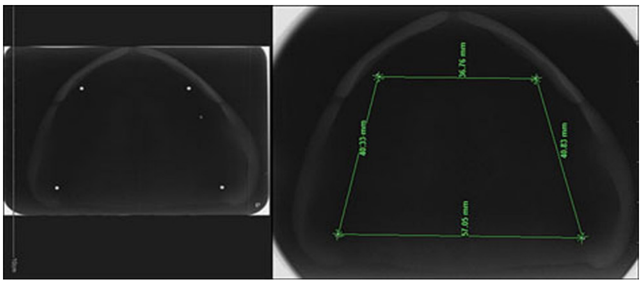

Fig. 1. The radiographic image and reference lines on the master model

Table 1. Impression materials used in the present study

Impression material	Product	Manufacturer	Lot number	Code
Polyether	Impregum™ Penta™ Soft	3M ESPE, Neuss, Germany	624182	PE
Irreversible hydrocolloid	Hydrogum 5	Zhermack SpA, Badia Polesine, Italy	212976	IH
Addition silicone	Elite P&P	Zhermack SpA, Badia Polesine Italy	234875	AS
Condensation silicone	Zetaflow	Zhermack SpA, Badia Polesine Italy	242997	CS

Four different impression materials were used to produce the stone models (Table 1). A total of 240 impressions were taken from the master model.

Apart from polyethers (PE), all impressions of the master model were taken using a standard metal tray (Jescoform®; Aesculap AG, Tuttlingen, Germany). The irreversible hydrocolloid (IH) impression material was prepared by mixing powder and water in the amount suggested by the producer in an automatic mixing machine (Hurrimix™; Zhermack SpA, Badia Polesine, Italy). Room temperature water was consistently used for the mixtures so that the hardening time of the impression material could not be affected. The condensation (C-type) silicones (CS) were prepared by mixing a catalyzer and the base at the rates suggested by the producer with clean bare hands. Gloves were not used, because the powder in latex gloves may affect the hardening reaction of the impression material. The double mixing technique was used for the silicone-based impression materials (CS and addition silicone – AS). It was also applied for the light bodies of the silicone-based impression materials. A special tray was used for the PE impression material. A tray adhesive (EXAMIX™; GC America, Inc., Alsip, USA) was applied in a thin layer to the inside and edges of the special tray. The PE impression material was mixed in an automatic mixing machine (Pentamix™, 3M ESPE, Seefeld, Germany), placed in the special impression tray, and an impression was taken from the master model.

The impressions were separated into 6 equal groups, and 3 different disinfectant solutions were applied with 2 different storage times. The disinfectants were: water (W), 1% sodium hypochlorite (SH) and an aldehyde-free disinfectant solution – Zeta 7 spray (Z) (Zhermack SpA).

The disinfection procedures were as follows: W – washing with water for 45 s; SH – applying 1% SH and keeping it for 10 min; and Z – applying the ready impression disinfectant solution and keeping it for 3 min. While half of the impressions were immediately poured over, the other half were poured over 1 day after. The IH impressions were kept in a closed plastic box. Other impressions were kept at normal room temperature (23°C), humidity 55 ±5%. Type IV hard stone (Moldano®; Heraeus Kulzer GmbH, Hanau, Germany) was used to obtain the stone models from the impressions. The hard stone mixture was prepared by mixing powder (100 g) and water (30 mL) in the amount suggested by the producer. The required precautions were taken to prevent air bubbles in the stone during mixing and pouring it into the impression.

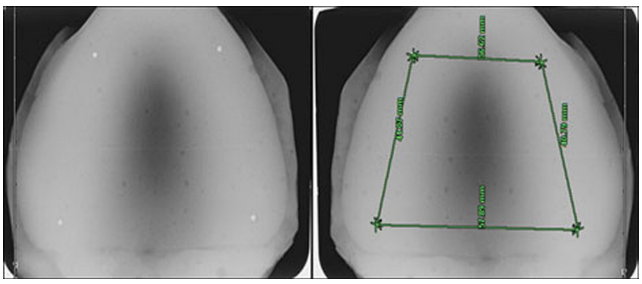

Fig. 2. The radiographic image of the metal balls and reference lines on the stone model

The resulting stone models were immediately removed from the impressions as soon as the stone was hardened.

As with the master model, metal balls of a diameter of 1 mm were placed in the reference points of the stone models and fixed with dental wax (Fig. 2), and then occlusal radiographs were taken. The measurements between the steel balls were performed on the radiographic images. All measurements were repeated 5 times and their averages were calculated. The digital measurements on the stone models were carefully performed by 2 researchers.

The mean, standard deviation (*SD*) and percentage values of the data of the line 1, line 2, line 3, and line 4 reference measurements were calculated. An analysis of variance (ANOVA) was conducted to evaluate the effect of the different impression material types, storage times and disinfectant solutions on 4 different reference measurements. Tukey's multiple comparison test was performed to compare the averages. A p-value ≤0.05 was considered statistically significant.

Results

The results of ANOVA regarding the effect of the impression material type, storage time and disinfectant on the dimensional changes in the impression materials are presented in Table 2. According to the Table, both the factors and the interactions between them were found to be statistically significant in all measurements performed in 2 vertical and 2 horizontal directions ($p < 0.001$).

The mean and *SD* values obtained with Tukey's multiple comparison test for line 1 are presented in Table 3. While the smallest dimensional change was observed in PE, the greatest dimensional change was observed in IH, and the differences between the impression materials were found statistically significant in the poured-immediately groups. The effect of different disinfectant solutions was also observed, but the differences were

Table 2. Results of the analysis of variance (ANOVA)

Variation	df	Line 1		Line 2		Line 3		Line 4		*p*-value
		MS	F	*MS*	F	*MS*	F	*MS*	F	
Storage time	1	0.010	209.509	0.107	1312.577	0.087	721.609	0.105	926.181	0.000
Impression material	3	0.020	405.128	0.035	427.465	0.046	379.392	0.063	552.373	0.000
Disinfection	2	0.010	208.981	0.017	213.605	0.017	140.900	0.022	190.995	0.000
Storage time × impression material	3	0.004	80.244	0.038	466.741	0.032	261.950	0.036	319.272	0.000
Storage time × disinfection	2	0.014	278.398	0.005	62.310	0.005	42.616	0.005	46.981	0.000
Impression material × disinfection	6	0.004	80.473	0.010	117.626	0.011	93.896	0.011	97.767	0.000
Storage time × impression material × disinfection	6	0.005	94.440	0.009	105.981	0.009	78.161	0.012	104.586	0.000

df – degrees of freedom; *MS* – mean square; F – F-test of ANOVA.

Table 3. Multiple comparison test results with mean ± standard deviation (*SD*) for line 1

Storage time	Impression material	W	Z	SH	Total
		mean ±*SD*	mean ±*SD*	mean ±*SD*	mean ±*SD*
Immediately	AS	0.0338 ±0.007[c]	0.0343 ±0.002[c]	0.0352 ±0.002[c]	0.0344 ±0.004[c]
	IH	0.0727 ±0.007[a]	0.0741 ±0.004[a]	0.0756 ±0.003[a]	0.0741 ±0.005[a]
	CS	0.0522 ±0.010[b]	0.0569 ±0.007[b]	0.0627 ±0.014[b]	0.0573 ±0.011[b]
	PE	0.0149 ±0.014[d]	0.0157 ±0.006[d]	0.0163 ±0.007[d]	0.0156 ±0.009[d]
1 day after	AS	0.0342 ±0.006[c]	0.0349 ±0.003[c]	0.0358 ±0.004[a]	0.0350 ±0.004[b]
	IH	0.0733 ±0.004[a]	0.0752 ±0.004[a]	−0.0170 ±0.008[c]	0.0438 ±0.004[a]
	CS	0.0564 ±0.006[b]	0.0645 ±0.008[b]	−0.0190 ±0.005[c]	0.0340 ±0.004[b]
	PE	0.0151 ±0.005[d]	0.0169 ±0.006[d]	0.0176 ±0.007[b]	0.0165 ±0.006[c]

W – water; Z – Zeta 7 spray (aldehyde-free disinfectant solution); SH – sodium hypochlorite. There are statistically significant differences between the values indicated with different letters ($p < 0.05$).

not statistically significant in the poured-immediately groups. Moreover, all impression materials poured over immediately showed dimensional expansion. Considering the effect of different storage times, there were no statistically significant differences between the poured-immediately and poured-1-day-after groups, except for the case when SH was applied. While the smallest dimensional change was observed in PE, the greatest dimensional change was observed in IH, and the differences between the impression materials were found statistically significant in the poured-1-day-after groups, except for AS and CS. Water and Z had the same effect on the dimensional accuracy of all impression materials, but SH showed a statistically significant effect in all poured-1-day-after groups. While the AS and CS groups after applying SH showed dimensional contraction, all other groups showed dimensional expansion. The percentages of the dimensional changes observed in the impression materials were also found to be statistically significantly different from each other. However, the dimensional changes observed in the impression materials were clinically acceptable (–0.047–0.187%) (Fig. 3).

The mean and *SD* values obtained with Tukey's multiple comparison test for line 2 are presented in Table 4. While the smallest dimensional change was observed in PE, the greatest dimensional change was observed in IH. There were no statistically significant differences between AS and CS in the poured-immediately groups. The effect

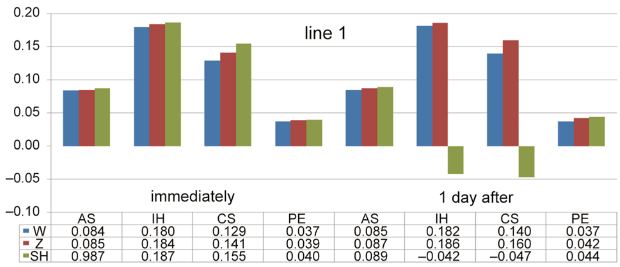

Fig. 3. Line 1 mean differences between dental impression materials

of different disinfectant solutions was also varied, but the differences were not statistically significant, except for CS, with SH applied in the poured-immediately group. Furthermore, all impression materials that were poured over immediately showed dimensional expansion, except for the CS group where SH was applied. Considering the effect of different storage times, statistically significant differences were observed between the poured-immediately and poured-1-day-after groups. While the smallest dimensional change was observed in CS, the greatest dimensional change was observed in AS, and the differences between the impression materials were found statistically significant in the poured-1-day-after groups. This might be caused by expansion and contraction occurring at the same time. Addition silicone and PE showed dimensional expansion, and CS showed dimensional contraction after applying different disinfection solutions. The IH group

Table 4. Multiple comparison test results with mean ± standard deviation (*SD*) for line 2

Storage time	Impression material	W	Z	SH	Total
		mean ±*SD*	mean ±*SD*	mean ±*SD*	mean ±*SD*
Immediately	AS	0.0468 ±0.008^{b}	0.0471 ±0.004^{b}	0.0478 ±0.004^{b}	0.0472 ±0.005^{b}
	IH	0.0844 ±0.018^{a}	0.0849 ±0.012^{a}	0.0853 ±0.008^{a}	0.0849 ±0.013^{a}
	CS	0.0745 ±0.008^{a}	0.0811 ±0.013^{a}	−0.0192 ±0.007^{d}	0.0455 ±0.009^{b}
	PE	0.0206 ±0.012^{c}	0.0220 ±0.008^{c}	0.0229 ±0.012^{c}	0.0218 ±0.011^{c}
1 day after	AS	0.0472 ±0.004^{b}	0.0477 ±0.003^{a}	0.0483 ±0.004^{a}	0.0477 ±0.004^{a}
	IH	0.0862 ±0.010^{a}	−0.0209 ±0.009^{c}	−0.0328 ±0.005^{c}	0.0108 ±0.006^{c}
	CS	−0.0355 ±0.008^{d}	−0.0491 ±0.007^{d}	−0.0672 ±0.009^{d}	−0.0506 ±0.015^{d}
	PE	0.0209 ±0.011^{c}	0.0228 ±0.005^{b}	0.0244 ±0.007^{b}	0.0227 ±0.008^{b}

There are statistically significant differences between the values indicated with different letters ($p < 0.05$).

showed dimensional expansion when W was applied, and after applying Z and SH, showed dimensional contraction. The percentages of the dimensional changes observed in the impression materials were also found to be statistically significantly different from each other. However, the dimensional changes observed in the impression materials were clinically acceptable (−0.087–0.211%) (Fig. 4).

The mean and *SD* values obtained with Tukey's multiple comparison test for line 3 are presented in Table 5. While the smallest dimensional change was observed in PE and CS, the greatest dimensional change was observed in IH. There were no statistically significant differences between PE and CS in the poured-immediately groups. The effect of different disinfectant solutions was varied and the differences were statistically significant, except for IH in the poured-immediately groups. Moreover, all impression materials that were poured over immediately showed

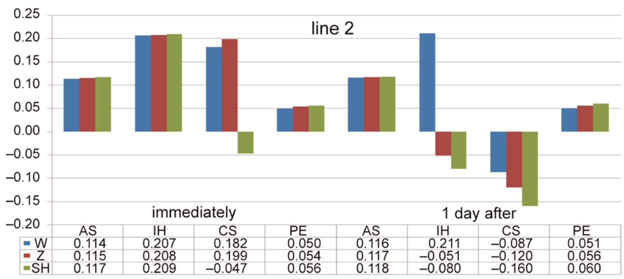

Fig. 4. Line 2 mean differences between dental impression materials

dimensional expansion, except for the CS group where SH was applied. Considering the effect of different storage times, statistically significant differences were observed between the poured-immediately and poured-1-day-after groups. While the smallest dimensional change was observed in CS, the greatest dimensional change was observed in AS, and the differences between the impression materials were found statistically significant in the poured-1-day-after groups. This might be caused by expansion and contraction occurring at the same time. Addition silicone and PE showed dimensional expansion, and CS showed dimensional contraction after applying different disinfection solutions. The IH group showed dimensional expansion when W was applied, and after applying Z and SH, showed dimensional contraction. The percentages of the dimensional changes observed in the impression materials were also found to be statistically significantly different from each other. However, the dimensional changes observed in the impression materials were clinically acceptable (−0.135–0.223%) (Fig. 5).

The mean and *SD* values obtained with Tukey's multiple comparison test for line 4 are presented in Table 6. While the smallest dimensional change was observed in PE and CS, the greatest dimensional change was observed in IH. There were no statistically significant differences between PE and CS in the poured-immediately groups. The effect of different disinfectant solutions was also varied and the differences were statistically significant, except for IH

Table 5. Multiple comparison test results with mean ± standard deviation (*SD*) for line 3

Storage time	Impression material	W	Z	SH	Total
		mean ±*SD*	mean ±*SD*	mean ±*SD*	mean ±*SD*
Immediately	AS	0.0401 ±0.010^{c}	0.0406 ±0.008^{b}	0.0417 ±0.006^{b}	0.0408 ±0.008^{b}
	IH	0.0801 ±0.015^{a}	0.0808 ±0.015^{a}	0.0818 ±0.004^{a}	0.0809 ±0.012^{a}
	CS	0.0642 ±0.009^{b}	0.0708 ±0.034^{a}	−0.0495 ±0.012^{d}	0.0285 ±0.006^{c}
	PE	0.0199 ±0.009^{d}	0.0237 ±0.010^{b}	0.0286 ±0.009^{c}	0.0241 ±0.009^{c}
1 day after	AS	0.0405 ±0.012^{b}	0.0412 ±0.003^{a}	0.0424 ±0.008^{a}	0.0414 ±0.008^{a}
	IH	0.0811 ±0.004^{a}	−0.0174 ±0.012^{c}	−0.0269 ±0.006^{c}	0.0123 ±0.005^{c}
	CS	−0.0405 ±0.003^{d}	−0.0591 ±0.007^{d}	−0.0738 ±0.004^{d}	−0.0578 ±0.015^{d}
	PE	0.0214 ±0.004^{c}	0.0264 ±0.003^{b}	0.0297 ±0.004^{b}	0.0258 ±0.005^{b}

There are statistically significant differences between the values indicated with different letters ($p < 0.05$).

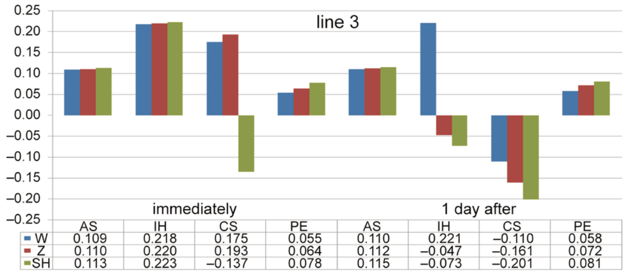

Fig. 5. Line 3 mean differences between dental impression materials

in the poured-immediately groups. Also, all impression materials that were poured over immediately showed dimensional expansion, except for the CS group where SH was applied. Considering the effect of different storage times, statistically significant differences were observed between the poured-immediately and poured-1-day-after groups. While the smallest dimensional change was observed in CS, the greatest dimensional change was observed in AS, and the differences between the impression materials were found statistically significant in the poured-1-day-after groups. Addition silicone and PE showed dimensional expansion, and CS showed dimensional contraction after applying different disinfection solutions. The IH group showed dimensional expansion when W was applied, and after applying Z and SH, showed dimensional contraction. The percentages of the dimensional changes observed in the impression materials were also found to be statistically different from each other. However, the dimensional changes observed in the impression materials were clinically acceptable (−0.090–0.156%) (Fig. 6).

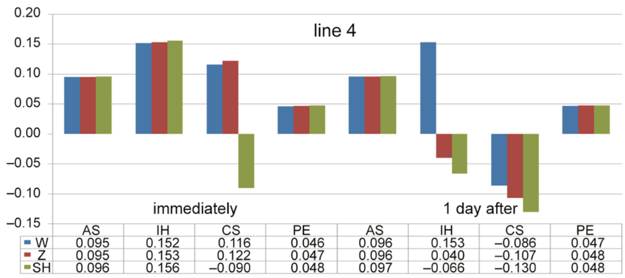

Fig. 6. Line 4 mean differences between dental impression materials

Discussion

The results obtained in this study support our hypothesis. In the study, the dimensional changes observed in the impression materials were found to be different from each other in relation to the type of impression material, storage time and type of disinfectant solution. However, the dimensional changes occurring in the impression materials were at a clinically acceptable level according to the ADA specification No. 19 (<0.5%).[9]

While reviewing the literature, it can be observed that the dimensional changes in impression materials have been evaluated manually or with laser scanning and computed tomography.[8,9] It has been reported that there are some drawbacks in such methods; specifically, the manual methods are not sensitive enough and the other methods imply increased cost.[9] In this study, digital dental radiography, which had never been used until this time in the evaluation of dimensional changes, was utilized. It is considered that it is technically and financially more economical than computed tomography, and more sensitive than the manual methods. However, it does not enable monitoring 3-dimensional tooth movements, as in computed tomography. Zilberman et al., in their study in which they evaluated the dimensional stability of impression materials with the conventional measurement method and the 3-dimensional computed model method, reported that the conventional method proved to be better.[10] In the present study, all reference measurements on the stone model were evaluated with single radiography, using occlusal radiography procedures. Moreover, 4 different reference measurements – in total 2 vertical (line 1 and line 2) and 2 horizontal (line 3 and line 4) – were performed on the master model to evaluate the dimensional changes occurring in the impression materials in multiple ways. After obtaining the radiographs of the stone models, the measurements were digitally performed on a special system of the radiography software program. The measurements were repeated 5 times in the digital environment, in an attempt to increase the sensitivity of the results.

Table 6. Multiple comparison test results with mean ± standard deviation (*SD*) for line 4

Storage time	Impression material	W	Z	SH	Total
		mean ±*SD*	mean ±*SD*	mean ±*SD*	mean ±*SD*
Immediately	AS	0.0541 ±0.007^{c}	0.0543 ±0.002^{c}	0.0547 ±0.002^{b}	0.0544 ±0.004^{b}
	IH	0.0869 ±0.006^{a}	0.0875 ±0.002^{a}	0.0888 ±0.003^{a}	0.0877 ±0.004^{a}
	CS	0.0659 ±0.014^{b}	0.0697 ±0.005^{b}	−0.0514 ±0.015^{d}	0.0281 ±0.006^{c}
	PE	0.0263 ±0.009^{d}	0.0268 ±0.017^{d}	0.0273 ±0.006^{c}	0.0268 ±0.011^{c}
1 day after	AS	0.0545 ±0.002^{b}	0.0549 ±0.004^{a}	0.0556 ±0.003^{a}	0.0550 ±0.003^{a}
	IH	0.0875 ±0.004^{a}	−0.0228 ±0.002^{c}	−0.0377 ±0.007^{c}	0.0090 ±0.006^{c}
	CS	−0.0493 ±0.014^{d}	−0.0610 ±0.015^{d}	−0.0744 ±0.003^{d}	−0.0616 ±0.015^{d}
	PE	0.0270 ±0.003^{c}	0.0273 ±0.003^{b}	0.0274 ±0.004^{b}	0.0272 ±0.003^{b}

There are statistically significant differences between the values indicated with different letters ($p < 0.05$).

If irreversible hydrocolloid impression materials are to be kept without being poured over immediately, they lose water in their structure and shrink, or if there is water in the environment, they tend to absorb it, and then they are exposed to dimensional changes by expanding.[11,12] Therefore, impressions taken with irreversible hydrocolloid impression materials should not be kept in the mouth for more than 10 min and should be poured over within 1 h at the latest. Otherwise, shrinkage or expansion may be observed in the impression.[13] Alkurt et al., in their study in which they evaluated the effect of storage time on the dimensional change of different impression materials with computed tomography, reported that irreversible hydrocolloids exhibited the greatest dimensional change and this change was at a clinically acceptable level.[14] In our study, the IH group was determined to be the group exhibiting the greatest dimensional change. Furthermore, the researchers stated that the use of computed tomography was non-economic and required professional help.

In the present study, PE was determined to be the impression material exhibiting the smallest dimensional change, depending on the applied storage time and disinfectant solutions. The differences between other impression materials were found to be statistically significant. On the other hand, Alkurt et al. reported in their study that polyether impression material was dimensionally the most stable impression material, taking into account different storage times.[14] Polyether impression materials are significantly sensitive impression materials that do not create by-products when they harden. However, due to their hydrophilic structure, they may be exposed to dimensional changes if they are kept in a humid and aqueous medium. In this study, the impressions taken were dried after applying the disinfectant solutions and kept in an environment of 23°C with 55 ±5% humidity. Kamble et al., in their study in which they examined the effect of different disinfectant procedures on the dimensional change of elastomeric impression materials, stated that polyether impression material was exposed to more dimensional change compared to addition silicone; however, this change was at a clinically acceptable level.[15]

Silicone impression materials are separated into 2 groups as addition and condensation silicones according to whether they create a by-product during the hardening reactions or not. While by-products are not formed in addition silicones, volatile by-products are formed in condensation silicones. In this regard, addition silicones are dimensionally more stable.[5] As it was shown in the results of the present study, AS was exposed to less dimensional change compared to CS, and the dimensional stability of both materials was found to be significantly higher compared to IH. Since mixing in latex gloves during the preparation of CS exhibits an inhibitory effect on the polymerization reaction, it was mixed with clean bare hands.

Since the present study did not imitate intraoral conditions, new studies can be conducted under in-vivo conditions using the same techniques. Thus, the reliability of digital radiography in the determination of dimensional changes can be tested. Moreover, the reliability of digital radiography can be evaluated by comparing it with the previously used methods.

Conclusions

The type of impression material causes some dimensional changes. While PE is dimensionally the most stable impression material, the changes observed in IH are greater. Different disinfectant solutions applied to impression materials cause dimensional changes. Notably, the application of SH caused the greatest dimensional change in all the impression materials. Significant differences were observed between the poured-immediately and poured-after-1-day groups. More dimensional changes were identified in the impressions stored for 1 day. The dimensional changes were clinically acceptable according to the ADA specification No. 19 for all lines (<0.5%).

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Original papers

Effect of acute methyl methacrylate vapor inhalation on smokers' and non-smokers' respiratory function in a sample of male dentistry students

Wpływ wdychania znacznych ilości oparów metakrylanu metylu na funkcje oddechowe osób palących i niepalących – na przykładzie studentów stomatologii 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. Methyl methacrylate (MMA) is one of the widely used organic monomers in dentistry. It may cause multiple adverse reactions, ranging from allergic reaction to systemic toxicity. Dentistry students are exposed to MMA in an acute manner; however, the concentration of its vapor cannot be estimated well.

Objectives. The aim of this study was to evaluate the effect of acute MMA vapor inhalation on the pulmonary function of dental students, both smokers and non-smokers.

Material and methods. Thirty-eight male dental students were divided into 2 groups (group 1 – smokers and group 2 – non-smokers). The lung function parameters of the students were tested with a spirometer during their ordinary training work in a prosthodontics laboratory, before contact with MMA and immediately after it. The lung function test was performed using a standard protocol. The students were asked not to use any perfume or aromatic overlaps for a period of 24 h before starting the tests.

Results. The researchers noted a statistically significant decrease ($p \leq 0.05$) in forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), peak expiratory flow (PEF), forced expiratory flow at 25–75% of the pulmonary volume (FEF25–75), and forced expiratory flow at 25% (FEF25) and 50% (FEF50) of the pulmonary volume in smokers and non-smokers by comparing the pre- and post-work tests.

Conclusions. Acute inhalation of MMA vapor induced a moderate restriction of pulmonary function in dental students, both smokers and non-smokers, during their routine prosthodontics laboratory training work. No differences in the results of the pulmonary function tests between smokers and non-smokers were observed.

Key words: spirometer, pulmonary function, smokers, methyl methacrylate

Słowa kluczowe: spirometr, funkcjonowanie płuc, osoby palące, metakrylan metylu

Introduction

Dental practitioners and dentists are frequently in contact with multiple types of polymers, especially methyl methacrylate (MMA).[1] Metyl methacrylate is a clear organic dissolvent, which is used in the preparation of complete or partial dentures and other dental composite restorations, as well as in the preparation of orthopedic cement. The vapor of MMA has been known for its effect on health, especially when used chronically in poorly ventilated areas.[2] The major documented health problems associated with the exposure to MMA include irritation of skin, eyes and the mucus membrane of both the upper and lower respiratory tract.[3,4] Multiple measures have been taken to decrease contact with MMA, such as gloves, masks and proper ventilation, but this is still not enough to limit the exposure to the widely used MMA and stop the inhalation.[5] For decades, many studies have attempted to determine the degree of toxicity of MMA, including animal and human studies. These studies clarified the mechanism of MMA toxicity, which can be attributed to a local interaction between MMA and the mucus membrane of the respiratory system. The local interaction consists in the neural stimulation, appearing in the form of coughing, mucus secretion and accumulation, which leads to the narrowing of the airways and bronchospasm, in addition to lacrimation, resulting from the cholinergic stimulation. Although it is reversible, upon continuous exposure, cellular damage and necrosis may happen.[6]

Dentistry students are exposed to MMA in an acute manner. As the concentration of its vapor cannot be estimated well, they are secondary users with a great chance of hypersensitivity development.[7,8] Vaporization takes place upon mixing a monomer with acrylic powder, leading to the irritation of lung and respiratory epithelia. Since MMA is lipophilic, it has the ability to penetrate the epithelial cell wall, causing lipid peroxidation, lactate dehydrogenase leakage, generation of free radicals, and accumulation of inflammatory cells, which leads to capillary hyperemia, edema, loss of respiratory epithelial cilia, and necrotic cell death, depending on the exposure concentration as explained by previous studies on an animal model and the alveolar cell line.[9–11]

Smokers already have an irritated respiratory epithelium as a result of the direct effect of cigarette smoke on the endothelial integrity. The consequences are increased vascular contraction of small blood vessels and decreased pulmonary vascular lumen capacity due to the reduction of endothelial nitric oxide-dependent vasodilation, which leads to emphysema with pulmonary hypertension, causing deleterious changes similar to those typical of chronic obstructive pulmonary disease.[12] Changes in lung function among smokers vary according to age, sex and the number of cigarettes smoked per day.[13]

The lung function tests represent a good and efficient method to predict the risk of obstructive pulmonary disease and cardiovascular problems due to the restricted air flow, caused by cigarette smoke and other irritating inhalants.[14,15]

The aim of this study was to evaluate the acute effect of MMA on the lung function of dental students, including male smokers and non-smokers.

Material and methods

The study was conducted in the Faculty of Dentistry, University of Babylon, Hilla, Iraq (from September to December, 2017). This is a comparative, non-randomized study that included student volunteers. The applied procedures were in accordance with the ethical standards of the Dentistry College scientific committee and with the Helsinki Declaration of 1975, as revised in 2000. Ethical committee approval number: 109-2017.

Volunteers

A total of 38 male dentistry students aged 20–22 years were divided into 2 groups (Fig. 1): group 1 included 19 smokers with a history of smoking about 20 cigarettes a day for more than 2 years; group 2 included 19 non-smokers, all of whom were healthy, with good general and respiratory conditions, according to the survey performed by the researchers.

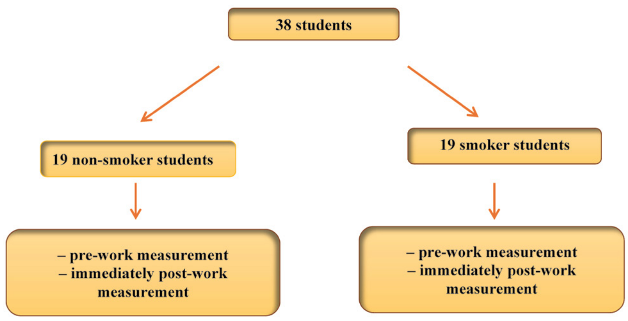

Fig. 1. Study design

Exclusion criteria

Before starting the tests, the volunteers were interviewed. Students with systemic respiratory disease or diagnosed with respiratory allergic reaction to chemicals were excluded from the study. The students were asked not to use any perfume or aromatic overlaps for a period of 24 h.

Pulmonary function test (procedures)

At the beginning, a complete history of the student, especially in the case of smokers (duration of smoking), was obtained. Then, a stadiometer was used to record height and weight without shoes, by means of standard techniques (in the Frankfort horizontal plane, the patient standing in the upright position).[16,17] Information regarding the students, such as age, race/ethnicity and other data was entered into the software program of the spirometer (Spirobank II®; MIR, Rome, Italy).[16,18] A spirometer is an apparatus that measures the air which is breathed into the lungs through inspiration and out of the lungs during expiration (Fig. 2).[18]

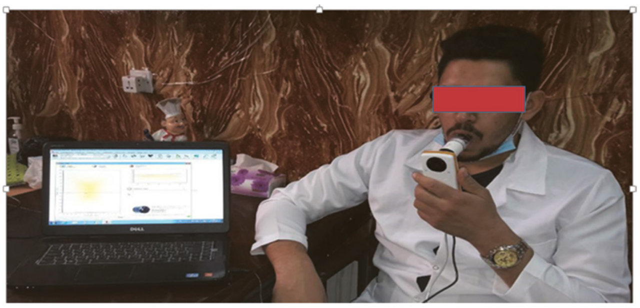

Fig. 2. Spirometer handling and work (The photograph was taken with the approval of the scientific committee of the Department of Prosthodontics, Faculty of Dentistry, University of Babylon, Hilla, Iraq, and with the consent of the student.)

Before the pre-work measurement, the method was thoroughly explained to the study volunteers. Then, a nose clip was applied to plug the nasal pathway. After that, the participants were asked to take a deep breath and put a mouthpiece in their mouth. The mouthpiece was fixed inside the mouth by the teeth and lips to achieve complete sealing, and also to make sure the air did not excite during maximal forced expiration, which takes at least 6 s.

The test measurements were repeated 3 times and the greatest of the records were taken into consideration, according to the spirometer protocol. The data was presented as a percentage of the value predicted for age, height and weight, based on the spirometer table.

The immediate post-work measurement was performed using latex gloves, protective glasses, a mask, and a laboratory coat. The cold-cured acrylic (Vertex®; Vertex-Dental B.V., Soesterberg, the Netherlands) (30 mL of powder and 10 mL of monomer) was mixed by the participants to construct a custom tray or record base in a well-ventilated laboratory (9 × 6 m); the time of exposure to the monomer was approx. 30 min. The test was taken immediately after the students' exposure to the monomer in the laboratory, in the same way as previously described.

Parameters tested

The lung function test uses a standard protocol with a spirometer to measure: forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), the ratio of forced expiratory volume in 1 s / forced vital capacity (FEV1/FVC), peak expiratory flow (PEF), forced expiratory flow at 25–75% of the pulmonary volume (FEF25–75), and forced expiratory flow at 25% (FEF25) and 50% (FEF50) of the pulmonary volume, where 25%, 50% and 75% reflect the bronchial diameter from bigger to smaller, respectively.[16,17]

Statistics

Statistical data was presented as mean ± standard deviation (*SD*) and percentage. The analysis of data was performed with the IBM SPSS Statistics software, v. 21.0 (IBM Corp., Armonk, USA), using the independent samples *t*-test and one-way analysis of variance (ANOVA) with a *p*-value ≤0.05 considered statistically significant.

Results

The current study found a statistically significant decrease in FVC and FEV1 ($p \leq 0.05$) in both smokers and non-smokers, comparing the pre- and post-work tests (Fig. 3,4), while the FEV1/FVC percentage showed a non-significant change while comparing the pre- and post-work tests in each group and the results of the groups together.

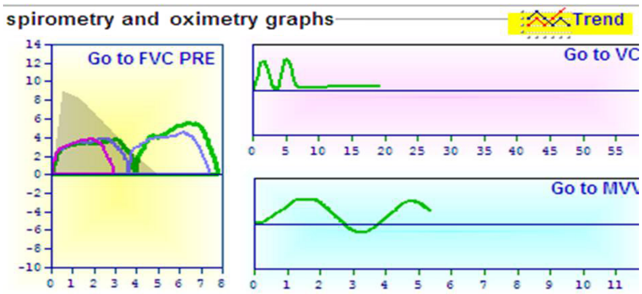

Fig. 3. Illustration of the results of one of the spirometer tests

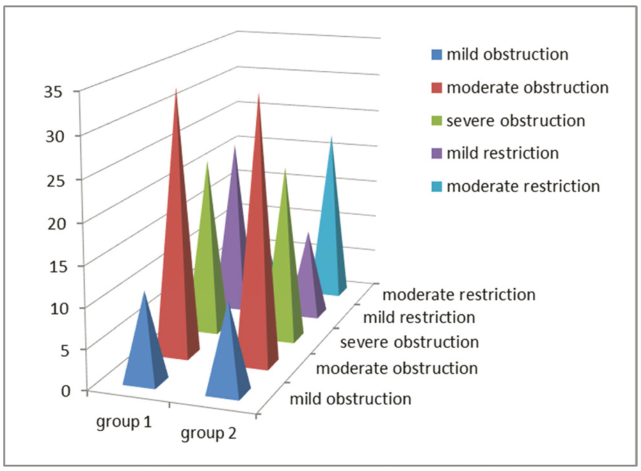

Fig. 4. Spirometer diagnostic diagram referring to the pre- and immediately post-work tests

On the other hand, PEF, FEF25–75 and FEF25 showed a statistically significant reduction ($p \leq 0.05$) while comparing the pre- and post-results in group 1, and PEF, FEF25–75, FEF25, and FEF50 in group 2 showed a significant decrease ($p \leq 0.05$) (Table 1). No significant differences were observed among the groups when all test results were compared ($p > 0.05$) (Table 2).

Discussion

Normal respiratory function is of great value for a normal healthy life without morbidity. The work environment is filled with different types of pollutants, but the exact effect of these pollutants depends on their concentration, the exposure time and the circumstances of exposure. Methyl methacrylate accounts for the most widely known toxicant vapor, especially in the dentistry field.[19]

Dental students are exposed to MMA vapor during their ordinary work when constructing special trays and record bases of complete and partial dentures, as required in their studies. Previous research showed that MMA vapor induced acute pulmonary obstruction, depending on certain exposure time and concentration.[20] In the current study, our aim was to evaluate its effect on smoker and non-smoker students based on the spirometer results.

Table 1. Differences of mean ± standard deviation (*SD*) between group 1 (smokers) and group 2 (non-smokers) in the pre- and immediately post-work tests

Variables	Groups	Mean ±*SD*	Level of significance (*p*-value)
FVC [L]	pre-work – group 1	5.2667 ±0.99785	≤0.05*
	immediately post-work – group 1	3.3556 ±1.03020	
	pre-work – group 2	6.1767 ±1.47148	≤0.05*
	immediately post-work – group 2	3.7522 ±0.80585	
FEV1 [L]	pre-work – group 1	4.3011 ±1.32953	≤0.05*
	immediately post-work – group 1	2.7822 ±0.98089	
	pre-work – group 2	4.0867 ±1.28802	≤0.05*
	immediately post-work – group 2	3.0656 ±0.60411	
FEV1/FVC [%]	pre-work – group 1	79.5556 ±13.72344	≥ 0.05
	immediately post-work – group 1	80.8889 ±17.78211	
	pre-work – group 2	67.6444 ±22.01426	≥ 0.05
	immediately post-work – group 2	79.7556 ±15.12813	
PEF [L/s]	pre-work – group 1	7.3722 ±3.29167	≤0.05*
	immediately post-work – group 1	3.4933 ±2.15975	
	pre-work – group 2	6.2911 ±2.69870	≤0.05*
	immediately post-work – group 2	4.1967 ±1.93203	
FEF25 [L/s]	pre-work – group 1	7.1422 ±2.57513	≤0.05*
	immediately post-work – group 1	4.3478 ±2.73020	
	pre-work – group 2	5.3722 ±2.63617	≤0.05*
	immediately post-work – group 2	2.9089 ±0.90625	
FEF50 [L/s]	pre-work – group 1	4.6056 ±1.97946	≥ 0.05
	immediately post-work – group 1	3.7622 ±1.84475	
	pre-work – group 2	4.1522 ±1.43137	≤0.05*
	immediately post-work – group 2	2.6944 ±1.05081	
FEF75 [L/s]	pre-work – group 1	3.0933 ±1.35765	≥ 0.05
	immediately post-work – group 1	2.9956 ±1.00397	
	pre-work – group 2	3.6022 ±1.12491	≥ 0.05
	immediately post-work – group 2	2.3711 ± 1.49729	
FEF25–75 [L/s]	pre-work – group 1	4.2333 ±1.26824	≤0.05*
	immediately post-work – group 1	2.3878 ±1.38542	
	pre-work – group 2	3.8867 ±1.26912	≤0.05*
	immediately post-work – group 2	3.0322 ±0.80114	

FVC – forced vital capacity; FEV1 – forced expiratory volume in 1 s; PEF – peak expiratory flow; FEF25, FEV50, FEV75 – forced expiratory flow at 25%, 50% and 75% of the pulmonary volume, respectively; FEV25–75 – forced expiratory flow at 25–75% of the pulmonary volume; * statistical significance.

Table 2. Results of the analysis of variance (ANOVA)

Parameters	Relation	*p*-value
FVC [L]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEV1 [L]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEV1/FVC [%]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
PEF [L/s]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEF25 [L/s]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEF50 [L/s]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEF75 [L/s]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05
FEF25–75 [L/s]	group 1 and group 2 pre- and immediately post-work tests	≥ 0.05

The choice of smoker volunteers was motivated by their irritated respiratory airways due to chronic exposure to nicotine, which was supposed to render them highly susceptible to MMA vapor.[21]

The spirometer results revealed a significant reduction of FVC and FVC1 as we compared the pre- and post-work findings for smokers and non-smokers; this indicates restricted pulmonary function, with or without obstruction. This could be explained by the effect of MMA on the chemical receptors of respiratory epithelia, leading to the stimulation of the respiratory center, and thus causing bronchoconstriction.[22] Our results coincide with those presented by Marez et al., who observed an obstructive effect of MMA vapor during inhalation, but related to the duration of exposure.[23] Borak et al. also confirm that MMA is a lung-irritating substance and affects the airways causing obstruction and bronchial hyperactivity.[24]

Upon the comparison of the results between smokers and non-smokers, we found no statistically significant differences, which may be due to the small sample size or the number of cigarettes smoked per day. Apart from that, students were young and physically active males. This explanation is confirmed by Urrutia et al., who found that the level of pulmonary problems depended on the number of cigarettes smoked and age.[13]

Non-smokers showed respiratory reactivity in the post-exposure results, especially at the level of FEV50 and FEV25, while smokers were found to have a restriction at the level of FEV25 only. This could be explained by the thickening of lining epithelia and mucus secretion, which could interrupt the diffusion of MMA vapor across the small bronchioles of smokers, in addition to decreased endothelial responsiveness. Although no statistical significant difference was observed between the groups, the recorded results of non-smokers showed more pulmonary restriction. The reason for that may be the absorption of organic vapor through respiratory epithelia, causing a moderate restrictive response, as the vapor is non-polar, molecularly small-sized organic substance that easily passes to the lower respiratory tract, leading to a delayed effect when exposure is extensive.[25] It requires future evaluation of the students near the end of their training course to provide enough information about that delayed response.

Conclusions

Although the sample size was small, the findings of the current study revealed that a moderate pulmonary restriction, with or without obstruction, was observed in both smokers and non-smokers exposed to acute MMA vapor, with more reactivity in non-smokers. No statistically significant differences in the results of the respiratory function tests were found between smokers and non-smokers exposed to acute MMA vapor inhalation.

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Comparative assessment of condylar position in patients with temporomandibular disorder (TMD) and asymptomatic patients using cone-beam computed tomography

Ocena porównawcza położenia wyrostka kłykciowego u pacjentów z zaburzeniami stawów skroniowo-żuchwowych i bez objawów klinicznych z wykorzystaniem tomografii stożkowej

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Abstract

Background. Temporomandibular disorders (TMD) are the most common reason of non-dental pain in the orofacial region. A clinical examination of the temporomandibular joint (TMJ) with additional imaging is the most recommended procedure for TMD diagnosis.

Objectives. The objective of this study was to evaluate the association between TMD and the condylar position in the glenoid fossa by examining a group of patients suffering from TMD compared with a control group of patients without TMD. In this study, we used cone-beam computed tomography (CBCT) images for measurements.

Material and methods. Sixty-five symptomatic joints were selected from 48 patients with TMD. Sixty-five joints were selected from a total of 96 asymptomatic joints in the control group. The superior, anterior and posterior area of the joint, and the steepness of the articular eminence were measured on the CBCT images. The data was analyzed using Pearson's χ^2 test.

Results. The position of the condyle was significantly more posterior in the joints with TMD, and more anterior and centric in the asymptomatic joints. Statistically, the vertical position of the condyle and the steepness of the articular eminence had no significant relation with the occurrence of TMD.

Conclusions. In this study, we observed that the posterior condylar position is more common in TMD patients, but it is not the reason for diagnosing TMD, and the reason of the posterior position of the condyle should be investigated before any decisions pertaining to treatment are made. In future, studies should focus on evaluating how the position of the condyle will change after the treatment of patients with TMD.

Key words: cone-beam computed tomography, temporomandibular disorders, condylar position

Słowa kluczowe: stożkowa tomografia komputerowa, zaburzenia stawów skroniowo-żuchwowych, położenie wyrostka kłykciowego

Introduction

The term 'temporomandibular disorders' (TMD) refers to a group of pathologic conditions that affect the temporomandibular joints, jaw muscles, or all of the associated tissues.[1] Temporomandibular disorders are the most common reason for non-dental pain in the orofacial region, which can be accompanied by otalgia, headache, neuralgia, and toothache.[2] It is estimated that 6–12% of Americans suffer from TMD symptoms.[3]

According to the American Dental Association (ADA) guidelines, TMD comprise a triad of the temporomandibular joint (TMJ) pain, TMJ sounds during jaw function, and deviation or restriction of mandibular movements.[4] The research diagnostic criteria for temporomandibular disorders (RDC/TMD) have been the most frequently employed diagnostic protocol for TMD research since its publication in 1992. This method has been based on physical and psychological criteria.[5]

The TMJ imaging, in addition to clinical assessment, is the most recommended procedure for diagnosing TMD in the literature.[1] Plain film radiography, conventional tomography, computed tomography (CT), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) are different radiographic methods that have been used in previous studies for TMJ assessment.[6,7] Cone-beam computed tomography is suggested as a high resolution and precise 3-dimensional (3D) technique for analyzing the condylar position in the glenoid fossa.[8]

Some of the reasons why CBCT is preferred when compared with other imaging techniques at the region of TMJ are as follows: 3D images, higher accuracy and a smaller slice thickness as compared to the conventional tomography and radiography[6]; spatial resolution even higher than in the case of spiral CT[6]; effective dose and scanning time, and cost lower than in spiral CT[6,8]; the fact that MRI is not suitable for the evaluation of hard tissue.[9]

The position and function of the condyle is directly controlled by the oral structures.[10] Many dynamic variables, such as growing, remodeling, functional matrix activities, occlusion changes, and physiologic adaptations, affect the condylar position. A considerable posterior position of the condyle often reveals a disorder.[11] It appears that joints with disk displacement tend to have a posterior condylar position.[12] The TMJ disk is interposed between the posterior slope of the eminence and the functional surface of the condyle to act as a buffer between the 2 bones. It appears that disk displacement can change the condylar position.[13]

Some studies suggest that the condyle–fossa relationships can be used as a significant index for TMD and, consequently, therapeutic procedures based on optimizing the condylar position have been indicated. However, other studies deny this association.[6]

The condylar movements and pathways during mouth opening and closing are different, depending on the condylar position in the glenoid fossa. Physical loading on the articular disk and the condylar head would also be different in various condylar positions.[14]

The purpose of this study was to evaluate the association between TMD and the condylar position in the glenoid fossa by examining a group of patients suffering from TMD and comparing it with a control group of patients without TMD. In this study, we used CBCT images for measurements.

Material and methods

Forty-eight patients with symptomatic TMD were referred to the Department of Oral and Maxillofacial Prosthodontics, at Hamadan Dental School in Iran. An expert prosthodontist visited the patients and filled out the questionnaire, and then ordered a CBCT image for the symptomatic TMJ. Patients were selected according to RDC/TMD, which is an international diagnostic system and is widely used as a valid and reliable system.[15] This study was carried out in 2017.

From a total of 96 joints in the patients' group, 65 symptomatic joints were diagnosed and their CBCT images were analyzed.

The criteria for the selection of patients in the TMD group were as follows:
- any history of pain in the region of TMJ, or pain during function or palpation of TMJ;
- TMJ noises during opening and closing, or lateral jaw movements;
- limitation in jaw movements.

In the control group, 48 patients were selected from those who had CBCT images as a result of implant treatment or surgery of impacted teeth, and who also had no signs and symptoms of TMD. Patients with malocclusion were excluded from the study. Since in the TMD group 65 symptomatic joints were selected, we also selected 65 asymptomatic joints from a total of 96 asymptomatic joints in the control group.

The criteria considered for the selection of the control group were as follows:
- no history of TMD observed;
- no signs and symptoms of TMD observed during the visit;
- no deviation during jaw function;
- no asymmetry observed;
- no history of trauma to the jaw;
- the difference between the centric relation and centric occlusion position <1 mm;
- no radiographic signs of TMD observed (patients with radiographic symptoms of osteoarthritis, joint lesions and cysts, subcortical sclerosis, and congenital and size abnormalities in the condylar head were excluded from the study).

In both groups, patients with any congenital abnormalities or systemic diseases that could be related to the TMJ morphology, like rheumatoid arthritis, were excluded from the study. Patients with a history of prosthetic or occlusion treatment were also excluded.

All patients took part in the study voluntarily and written consent forms were taken from each of them after they had been informed about the study. The study was approved by the local ethical committee of Hamadan Dental School, Iran (No. 16/35/9/221).

The CBCT scans were performed with the ProMax® apparatus (Planmeca, Helsinki, Finland) with a field of view of 8 × 8 cm^2, maximum output of 84 KVP and time exposure of 12 s.

The CBCT images were taken in the position of habitual occlusion with the mouth closed. Linear measurements of the superior, anterior and posterior joint space between the condyle and the glenoid fossa, and also the steepness of the articular eminence were performed through the landmarks defined in the sagital CBCT images. Multiplanar CBCT images were reconstructed with the Romexis® software v. 3.8.0 (Planmeca).

The axial view, in which the condylar process had the widest mediolateral diameter, was chosen as the reference view for secondary reconstruction. On this selected view, a panoramic curved line, parallel to the long axis of the condylar process was drawn and lateral slices were reconstructed with 1-millimeter slice intervals and a thickness of 0.5 mm. The central saggital slice was selected as the reference image for the assessment of the condylar position.

Assessment of horizontal (antero-posterior) position of condyle in saggital plane

Two lines were traced from the most superior point of the glenoid fossa adjacent to the most anterior and posterior points of the condyle. The shortest distance to the anterior and posterior border of the glenoid fossa was called the anterior and posterior TMJ space, respectively (Fig. 1). The condylar position was analyzed with Pullinger and Hollender's formula:

$$\text{condylar ratio} = \frac{P - A}{P + A} \times 100 \quad (1)$$

where:
P – posterior joint space;
A – anterior joint space.

The position of the condyle was considered concentric if the ratio was within ±12%. If the ratio was smaller than –12%, the condylar position was considered posterior, and if the ratio was greater than +12%, the condylar position was considered anterior.[16]

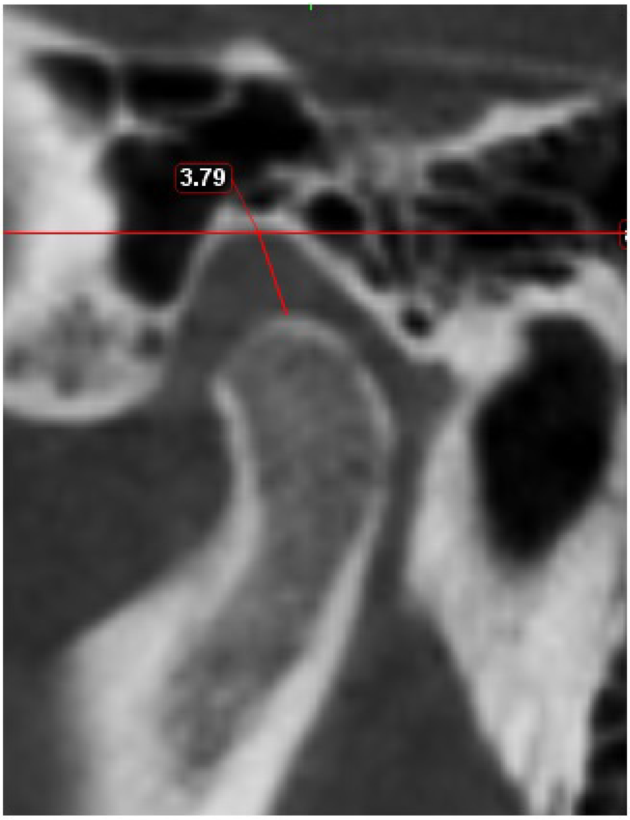

Fig. 1. Two lines traced from the most superior point of the glenoid fossa adjacent to the most anterior and posterior points of the condyle. The shortest distance to the anterior and posterior border of glenoid fossa was called the anterior and posterior TMJ space, respectively

Assessment of vertical position of condyle in saggital plane

The distance from the most superior point of the condyle to the deepest point of the glenoid fossa was measured (Fig. 2). The vertical distance of 1–4 mm was considered as normal. The distance >4 mm and <1 mm were considered as the lower and upper condyle vertical position, respectively. The value of 0 mm was indicated as the bony contact.[17]

Assessment of articular eminence steepness in saggital plane

A tangent line to the anterior wall of the glenoid fossa was drawn. The true angle between this line and the true horizontal line (THL) was measured as the slope of the articular eminence (Fig. 3). Angles of 15–30°, 30–60° and 60–90° degrees were considered as mild, moderate and severe articular eminence steepness, respectively.[18]

Statistical analyses were performed with the IBM SPSS software v. 22 (IBM Corp., Armonk, USA) using Pearson's χ^2 test to compare the TMJ measurements between the 2 groups of patients at the significance level of 0.05. All measurements were performed twice with an interval of 1 week, and the inter- and intraclass correlation

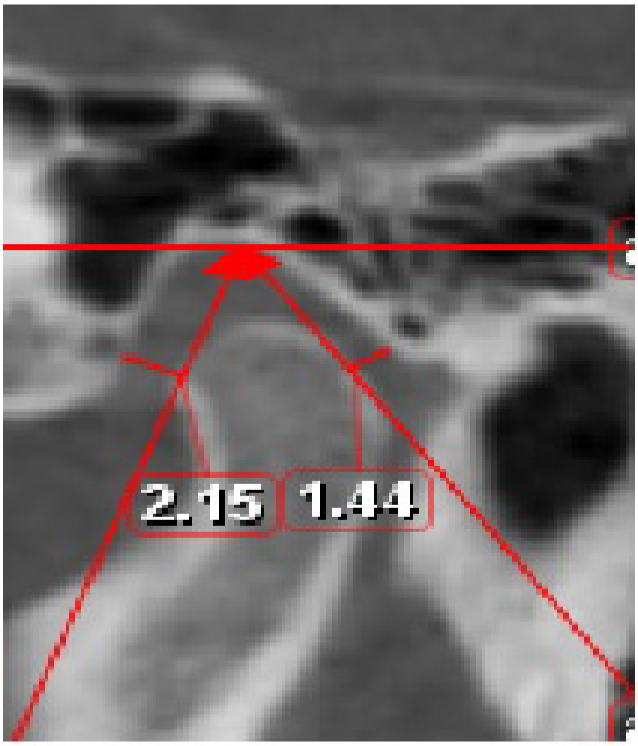

Fig. 2. Distance from the most superior point of the condyle to the deepest point of the glenoid fossa, called the superior joint space

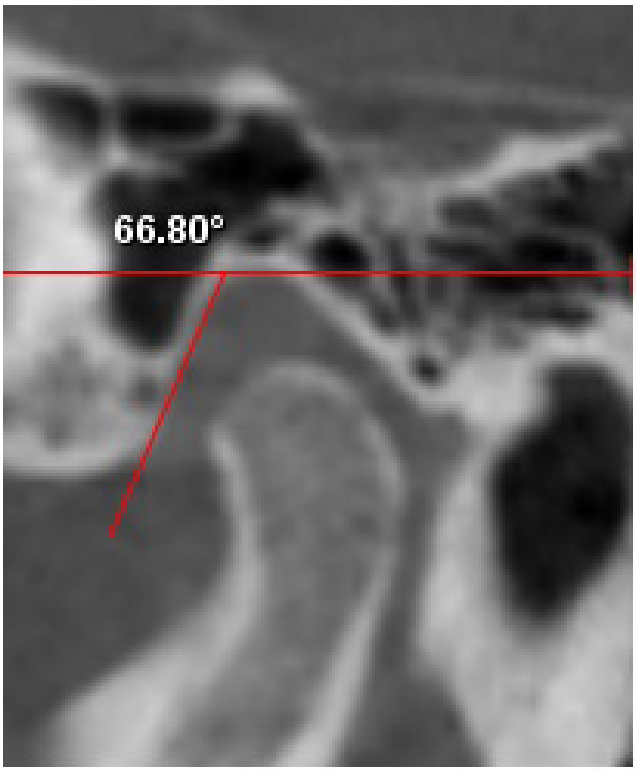

Fig. 3. A tangent line to the anterior wall of the glenoid fossa was drawn. The true angle between this line and the true horizontal line (THL) measured as the steepness of the articular eminence

coefficients (ICC) were analyzed using the paired *t*-test for any errors in the measuring process with a level of significance set at $p < 0.05$.

Results

Out of 130 patients (both symptomatic and asymptomatic groups) in our study, 29 were male and 101 were female. Thirty-one percent of males suffered from TMD, but this value for females was 55.4%. The average age in the TMD group was 31 years. This value for the control group was 25 years.

There were no significant differences between dual measurement values, which shows a minimum error in identifying the reference points in the study. The value for intraclass correlation was 93% and for interclass correlation – 97%.

The relation between TMD and the horizontal position of the condyle was statistically significant ($p < 0.05$). The results showed that the position of the condyle with TMD was mostly posterior (52.3%), and the position of the asymptomatic condyle was mostly anterior (38.5%) and concentric (33.8%) (Table 1).

There was no significant difference between the symptomatic and asymptomatic groups with regard to the steepness of the articular eminence and the vertical position of the condyle in the glenoid fossa ($p > 0.05$) (Tables 2,3).

Table 1. Results of the assessment of the horizontal condylar position in patients

Group	Horizontal condylar position			*p*-value
	posterior	concentric	anterior	
Symptomatic TMD group (65 joints)	34 (52.3)	18 (27.7)	13 (20)	0.011
Asymptomatic group (65 joints)	18 (27.7)	22 (33.8)	25 (38.5)	0.011

Data presented as numer (percentage). TMB – temporomandibular disorders.

Table 2. Results of the assessment of the steepness of the articular eminence in patients

Group	Steepness of articular eminence			*p*-value
	mild	moderate	severe	
Symptomatic TMD group (65 joints)	1 (1.5)	48 (73.8)	16 (24.6)	0.312
Asymptomatic group (65 joints)	1 (1.5)	40 (61.5)	24 (36.9)	0.312

Data presented as numer (percentage).

Table 3. Results of the assessment of the vertical position of the condyle in the glenoid fossa in patients

Group	Vertical position of condyle			*p*-value
	upper	normal	lower	
Symptomatic TMD group (65 joints)	1 (1.5)	49 (75.4)	15 (23.1)	0.312
Asymptomatic group (65 joints)	0 (0)	48 (73.8)	17 (26.2)	0.312

Data presented as numer (percentage).

Discussion

Our study evaluated the relationships between TMD and age, gender, horizontal condyle position, vertical condyle position, and steepness of articular eminence.

In our study, the average age in the TMD group was 31 years and in the asymptomatic group – 25 years. We were not able to select exactly the same age of the control group as in the study group because of the ethical limitations for CBCT imaging regarding the ALARA (as low as reasonably achievable) principle for radiation protection.

Manfredini et al. indicated 2 age peaks of patients seeking the TMD treatment: 30–35 years and 50–55 years.[19]

It is widely recognized that females more often suffer from TMD.[20–22] Warren and Fried indicated the prevalence of TMD in females of up to 70% of the population in some studies.[23] Furthermore, they indicated the peak age of involving in TMD as 20–40 years, which is similar to the gestational age of females. That is why they proposed a relationship between the TMD pathogenesis and hormonal changes in females.[23] Nevertheless, Widmalm et al. found no gender relation with TMD.[24]

We indicated that the position of the condyle was more posterior in the joints with TMD, and was more anterior and centric in the asymptomatic joints. Paknahad and Shahidi observed that the condylar position was more posterior in severe TMD patients.[9] Imanimoghaddam et al. also showed that decreased posterior joint space is a ore prominent finding in TMD patients.[11] Cho and Jung reached a similar conclusion, which is in agreement with the present study.[25] Lelis et al. found that there were no significant differences in the condylar positions between the centric relation and the maximum intercuspation in either symptomatic or asymptomatic young adults.[26] This could be due to different accuracy of the imaging technique, different anatomy of the samples or the young age of the patients in this study (the patients did not have enough time to develop changes in the condylar position).[26]

Some researchers believe that the reasons for the posterior condylar position arise from disk displacement,[13] osteoarthritis,[23] bone remodeling of the articular eminence and the condyle,[27] and osteoarthrosis.[28]

One MRI study revealed that the posterior condyle position was the main feature of TMJ with slight and moderate anterior disk displacement.[29] Magnetic resonance imaging is the best way to assess disk displacement; nevertheless, Ikeda and Kawamura indicated that changes in the disk position, particularly the posterior band position, can be detected as changes in the joint space on the CBCT images in adolescents and young adults, which is why they concluded that the direction and extent of disk displacement could be observed on the CBCT images.[13]

Some studies revealed that the condylar position in TMD patients is directly relevant to the condition of the articular disk during function, which is classified into 2 groups of anterior disk displacement – with and without reduction.[30–32] The condylar position was more posterior in anterior disk displacement with reduction, and more concentric and anterior in anterior disk displacement without reduction.[33]

Yang et al. selected a total of 52 TMJs with the anterior, concentric and posterior condylar position.[14] They traced the condylar movements by simulating mandibular movements with 3D CT data and a position tracking camera. They observed that the joint space during TMJ movements was significantly narrower, and the length of the condylar pathways with narrower joint space was larger in the posterior condylar position than in the concentric and anterior condylar position. Therefore, the condylar position can have an accelerating or worsening effect on biomechanical loading on the TMJ components during function.[14]

However, there is a question pertaining to whether repositioning the condyle can be used as a treatment for the reduction of the TMD symptoms. There is a hypothesis here that the posterior position of condyle can press the retrodiscal tissues and perceptional nerves; therefore, repositioning the condyle can reduce the pressure on the retrodiscal tissues.[34,35]

There exists a disagreement in recent studies as to the significance level of the relationship between the condylar position in the glenoid fossa and TMD. Some studies suggested that the posterior horizontal position of the condyle is associated with TMD.[13,36–38] However, others have disagreed on this relationship.[6,39–41]

The former group suggested repositioning the condylar position in order to optimize the treatment of TMD,[42] while the latter group of studies did not recommend such a treatment.[43] Therefore, evidence-based and organized studies are needed to answer the above-mentioned question.

The subjects' age, ethnicity, gender, the morphology of the craniofacial complex, and also different radiographic techniques, accuracy of clinical examinations and the methods of measurements can explain such a difference in the results of the studies.[9] In the present study, we excluded patients with a history of prosthetic or occlusion treatment and systemic diseases, which could affect the measurements of the condylar position.

In our study, there was no significant difference between the TMD and asymptomatic patients in the vertical position of the condyle. Mazzetto et al. indicated that the superior space of the joint was slightly increased in the TMD group, but it was not statistically significant.[1] The same observation was made in our study. They also noticed that males had the superior joint space higher than females in the asymptomatic joints.[1]

In our study, there was no significant difference between the TMD and asymptomatic group regarding the steepness of the articular eminence. Shahidi et al. reached the same conclusion. They indicated that there was no apparent relationship between the articular eminence inclination and clinical dysfunction.[44]

Toyama et al. suggested that an increase in the articular eminence gradient was one of predisposing factors of disk displacement,[45] and Ren et al. indicated that the articular eminence gradient was decreased in patients with TMJ disorders.[46] This can due to degenerative or remodeling changes in the joint. However, these changes are not observable in the preliminary phase and are more considerable with disease progression in older patients.[47]

Conclusions

In this study, we observed that the posterior condylar position is more common in TMD patients, but it is not the reason for diagnosing TMD. Therefore, the reason of the posterior position of condyle should be investigated before any decision regarding treatment is made.

In future, studies should focus on evaluating how the position of the condyle will change after the treatment of patients with TMD.

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Original papers

Needs for gerodontological treatment in the elderly living in Lower Silesia

Gerostomatologiczne potrzeby lecznicze u dolnośląskich seniorów

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Abstract

Background. Many factors influence decisions regarding gerodontological treatment. Apart from the clinical condition of a patient, there is a complex of crucial socioeconomic factors, comorbidities, place of residence, and psychological aspects. Therefore, gerodontological treatment plans are significantly diversified.

Objectives. One of the goals of our cross-sectional epidemiological study of Lower Silesia seniors aged 65–74 was to identify all their needs related to gerodontological treatment.

Material and methods. From the randomly selected sample group of 1,600 people, 387 inhabitants of Wrocław and Oława reported to take part in the study. The anamnestic study identified demographic and socioeconomic determinants, coexistence of general diseases and behavioral variables related to oral health behaviors. In the clinical study, the decayed-missing-filled (DMF) index, the community periodontal index (CPI), oral hygiene indices, clinical pathological lesions in oral mucosa, and the index of prosthetic reconstruction of missing teeth according to the World Health Organization (WHO) were determined. Criteria for the need for prosthetic treatment, dental caries treatment, periodontal disease treatment, improvement of oral hygiene, and treatment of mucosal diseases, including potentially pre-cancerous and cancerous disorders, were defined.

Results. As many as 95.6% of all respondents required at least 1 form of dental treatment. The most common need (75%) was prosthetic treatment of missing teeth either in the maxilla or in the mandible. Forty-nine percent of the respondents needed treatment of caries in the clinical crown or root of at least 1 tooth. Further, these needs were related to the following factors: treatment of oral mucosal diseases (35.4%), professional periodontal treatment (35%), improvement of very bad oral hygiene (29.2%), and oncological treatment of pre-cancerous and cancerous lesions in the oral cavity (9.6%).

Conclusions. The needs for gerodontological treatment found in the regional study of young Lower Silesian seniors are very high and cannot be met by services provided and funded by the state.

Key words: the elderly, oral health, treatment needs, dental treatment

Słowa kluczowe: osoby starsze, zdrowie jamy ustnej, potrzeby lecznicze, leczenie stomatologiczne

Introduction

The elderly form a very heterogeneous group in terms of clinical dental status. There is an issue significant in their case, which is the accumulation of consequences of caries along with periodontopathies, which generates dental treatment needs. These usually include conservative treatment of natural dentition (including, in particular, root caries treatment), treatment of periodontal and oral mucosa diseases, as well as prosthetic treatment (most often of severe tooth loss and edentulism). The general schedule of gerodontological treatment should include[1]: emergency care, maintenance and monitoring (treatment of carious lesions, non-surgical periodontal treatment, improvement of oral health behaviors, protection of abutment teeth, and reconstructive prosthetic treatment) and rehabilitation phase (surgical pre-prosthetic treatment, implantological treatment, prosthetic rehabilitation treatment, including the improvement of esthetics).

The possibilities of gerodontological treatment, as well as the expectations of these patients and their sense of need for treatment, and – in consequence – the scope of dental services, depend largely on the economic situation of the society. In developing countries, the treatment of oral cavity pathologies focuses on the control of pain, and the functional and esthetic rehabilitation of the masticatory system is not a priority. In societies with higher health awareness, comprehensive dental treatment aims to preserve or restore the function of the stomatognathic system to the highest possible level. Therefore, patients often expect an improvement of the esthetics of teeth, in connection with integrated gerodontological treatment.

A plan for such integrated treatment should take into account not only clinical indications, but also the expectations, general health and financial status of a patient. Many patients expect to undergo treatment solely refunded by the National Health Fund (NFZ).[2] According to the assessment of the size and structure of public and non-public expenditure allocated to healthcare in Poland in 2009–2015, NFZ's expenditure on healthcare services in total increased by 17.7%, while its expenditure on dental services decreased by 5.4%.[3] As a result, the number of dental consultations and procedures in NFZ-financed facilities has dropped. According to the Statistics Poland, 70.9% of visits to a dentist are financed from patients' own funds.[4] In 2013, the lack of sufficient financial resources was the reason for not using dental care services in the case of 30.7% of people with an income up to PLN 400 per family member and 9.5% of people earning an income above PLN 1,600 per family member.[3] In 2016, only 14.4% of outpatient dental consultations financed from public funds took the form of advice given to people over 65.[5]

In Polish conditions, under the NFZ contract, both the conservative treatment of carious disease and its complications, as well as the non-surgical periodontal and prosthetic treatment with movable restorations are often the procedures of choice. However, this is not usually the most effective process and does not take into account many basic possibilities of modern dentistry. The inability to carry out many additional tests free of charge often makes it difficult to diagnose oral mucosa diseases and to choose the most appropriate method of periodontal treatment. The material status of a patient may be an obstacle to the comprehensive rehabilitation of the stomatognathic system.[6]

The needs of the elderly in the field of dental treatment are considerable. The profile of these needs is changing along with the prolongation of professional activity of older people, the increase in the importance of self-presentation and their greater awareness of therapeutic possibilities offered by modern dentistry. Adequate orientation of the healthcare system in relation to oral health issues should be based on current epidemiological data.

One of the goals of this cross-sectional epidemiological study of the population of Lower Silesia inhabitants aged 65–74 was to identify the majority of needs regarding gerodontological treatment.

Material and methods

The methodology for selecting the study population aged 65–74 for a cross-sectional epidemiological study among the inhabitants of Wrocław and its surrounding area was presented in another paper.[7] The research was conducted from June 25 to October 30, 2017, at the Department of Periodontology, Faculty of Dentistry of Wroclaw Medical University, and in a private specialist dental practice in Oława (Praktyka Prywatna, Dentyści Oława), Poland. The persons reporting to take part in the study signed written consent approved by the Bioethics Commission at Wroclaw Medical University (opinion No. KB-712/2017). In total, 387 people were examined (136 men and 149 women from Wrocław, and 50 men and 52 women from Oława). The response rate for research was 24.2% (28.5% for a large city and 17% for a small city).

The following information on variables was obtained in the interview:
- place of residence (Wrocław, Oława);
- age (based on PESEL number);
- gender;
- education (primary, secondary, higher);
- income per capita in the household (PLN 800 and below; PLN 801–2,500; PLN 2,500 and above);
- body weight and height, along with the body mass index (BMI) based on these measurements (proper weight – BMI < 25 kg/m^2; overweight – $25 \leq$ BMI ≤ 30 kg/m^2; obesity – BMI > 30 kg/m^2);
- general diseases: cardiovascular diseases (conditions without incident, e.g., coronary heart disease, cardiac arrhythmias or thrombotic diseases; and with a previous incident – myocardial infarction or stroke), diabetes, hypertension, osteoporosis (with the pharmacological

treatment of the declared disease taken as the diagnostic criterion);
– nicotine addiction – in line with the WHO guidelines,[8] the participants were classified as follows: non-smokers (people who had never smoked or had smoked fewer than 100 cigarettes throughout their lives); ex-smokers (people who used to smoke regularly, but had been free of addiction for at least a year at the time of the examination); and current smokers (people who had been smoking a minimum of 1 cigarette a day during the 6 months preceding the examination);
– oral health behaviors: average number of visits in a dental office during the previous 5 years (at least 2 visits per year were considered regular); the frequency of brushing natural teeth or prosthesis (brushing at least twice daily was considered regular); daily additional cleaning of the interdental spaces with dental floss or a special brush (yes/no);
– forms of dental treatment funding: only in state-financed facilities (NFZ); only in private facilities; or the mixed way.

The clinical examination was performed in LED lighting, with the use of a dental mirror and the PCPUNC 15 periodontal probe (Hu-Firedy Mfg Co., LLC, Chicago, USA).

The following parameters were determined during the examination:
– the number of preserved natural teeth, excluding third molars;
– the occurrence of tooth caries and its consequences, expressed numerically by the decayed-missing-filled tooth (DMFT) index and its components;
– the occurrence of plaque on the vestibular and lingual surfaces of the teeth, and the modified plaque control record (PCR) according to O'Leary et al. [9];
– the occurrence of plaque in the interproximal spaces, and the approximal plaque index (API) according to Lange et al.[10];
– the community periodontal index (CPI) codes,[11] calculated on the basis of a periodontal examination, including the assessment of pocket depth, gingival bleeding and the presence of calculus for each sextant (sextant I: teeth 17–14, II: teeth 13–23, III: teeth 24–27, IV: teeth 37–34, V: teeth 33–43, and VI: teeth 44–47); moreover, CPI was determined for the highest code value for each participant;
– the occurrence of clinical oral mucosal lesions, excluding congenital abnormalities or lesions not requiring treatment, e.g., dislocated sebaceous glands, linea alba or varicose veins of the tongue;
– the type and number of fixed and/or removable prosthetic restorations used; the condition and suitability of these prosthetic restorations were also assessed: the quality of the fixed restorations in the gingival area was evaluated, along with the reconstruction of occlusal points/planes, absence of interference with central and non-central occlusion, and absence of mechanical damage; with regard to the movable restorations, attention was paid to their adhesion to the prosthetic base, their retention and stabilization, as well as restored occlusion height (inappropriate or worn out restorations were counted as a prosthetic treatment need); a single missing tooth that would not cause a loss of occlusion point contacts in the dental arch and premature occlusion obstacles was not counted as an indication for prosthetic reconstruction;
– the need for prosthetic reconstruction of missing teeth according to the WHO classification[12] was assessed separately for the maxilla and the mandible, and the following codes were assigned:
  - 0 – no prosthetic treatment needed;
  - 1 – the need for a single-unit prosthesis;
  - 2 – the need for a multi-unit prosthesis;
  - 3 – the need for a combination of a single- and/or multi-unit prosthesis;
  - 4 – the need for prosthetic treatment of edentulism.

The following criteria conditioning the needs of dental treatment were adopted:
– cariological: visible clinical lesions, classified on the basis of the WHO clinical criteria[13]; caries lesions (without classification as clinical crown and root caries) at D3 irreversible stage (evident defect including the external part of dentin/cementum[14]) were registered as requiring treatment;
– periodontological: the criterion for the need for periodontal treatment was the one adopted in 1992 by the American Academy of Periodontology, namely the Periodontal Screening and Recording (PSR) index – more than 2 sextants with code 3 or 1 with code 4 in CPI[15];
– oral hygiene: the absolute necessity to improve the effectiveness of tooth brushing and cleaning interdental spaces with the values of both periodontal index (PI) and API above 70%;
– clinical oral mucosal pathology: the presence of at least 1 lesion requiring specialized treatment, e.g., prosthetic stomatitis, candidiasis, herpetic lesions, or burning mouth syndrome;
– pre-cancerous or cancerous: the presence of at least 1 potentially malignant disorder in the oral cavity (e.g., leukoplakia, lichen planus) or the presence of 1 benign/malignant neoplastic lesion;
– prosthetic: the WHO value[12] above 0 in the maxilla or in the mandible.

The hypothesis of equality of average parameters in 2 groups was verified with the Mann–Whitney test. The hypothesis of equality of average parameters in more than 2 groups was verified with the Kruskal–Wallis rank sum test (the homogeneity of variance was checked by the Levene test). For the parameters for which statistically significant differences were shown in the comparison of all 3 groups, multiple comparisons of mean ranks for all trials were carried out. For discrete parameters, the frequency of occurrences in the groups was analyzed by the χ^2 *df* test (sometimes the χ^2 test with the Yates correction). For each test, $p < 0.05$ was considered statistically significant. Statistical analysis was carried out using the Statistica software v.13.1 (StatSoft Polska, Kraków, Poland).

Results

In the entire study group with as many as 370 people, which constituted 95.6% of all the participants, required at least 1 form of dental treatment. The demand for the identified 6 main needs regarding gerodontological treatment, as well as the accepted criteria for needs are summarized in Table 1. The most common need concerned 75.5% indications for the prosthetic treatment of missing teeth defined on the basis of the WHO index for people with a code greater than 0 in the maxilla or in the mandible. The second need concerned 49.1% of the participants, requiring treatment of dental caries in the crown or root of at least 1 tooth. The average DMFT index for the entire study group was 17.8 and its components were as follows: decayed teeth (DT) – 1.05; missing teeth (MT) (due to caries only) – 12.28; and filled teeth (FT) – 4.48. The third most frequently defined need was related to the indication for specialist periodontal treatment in 35% of the participants. The percentage of indications regarding the treatment of oral mucosa diseases (35.4%) was quite similar. It included the need for treatment of such diseases as prosthetic stomatitis, angular cheilitis, leukokeratosis, candidiasis, herpes simplex, geographic tongue, burning mouth syndrome, xerostomia vera, recurrent aphthous stomatitis, and smoker's palate, and potentially malignant and neoplastic disorders. The latter group concerned as much as 9.6% of the subjects and included such diagnoses as: leukoplakia, lichen planus, pigmented lesions, as well as benign tumors (hemangiomas, fibromas, papillomas, and epulises) and 1 case of tongue cancer. The necessity to improve very bad oral hygiene was found in 29.2% of the respondents.

The need for prosthetic treatment in the maxilla occurred in 61% of the subjects, in the mandible – in 66.9%. Regarding the maxilla, there was a significantly more frequent need for a multi-unit prosthesis (WHO code 2) ($p = 0.023$) and to restore prosthetically edentulism (WHO code 4) ($p = 0.0046$); regarding the mandible, there was a need to restore a combination of a single missing tooth and/or a multi-unit case (WHO code 3) ($p = 0.0001$) (Table 2). With regard to the maxilla,

Table 2. The need for prosthetic reconstruction of missing teeth according to the WHO classification in the whole group

WHO classification	Maxilla		Mandible		*p*-value
	number of people	percentage [%]	number of people	percentage [%]	
0	151	39	128	33.1	0.085
1	33	8.5	34	8.8	0.97
2	18	4.7	6	1.4	0.023*
3	119	30.7	180	46.5	0.0001*
4	66	17.1	39	10.1	0.0046*

* statistically significant.

Table 1. Dental treatment needs

Treatment need	Criterion	Percentage in the whole group [%]	Three subgroups* with the highest treatment needs [%]
Prosthetic treatment	WHO code >0 in the maxilla or in the mandible	75.5	irregular brushing – 83.3 male sex – 82.3 active smoking – 81.5
Dental caries treatment**	DT ≥ 1	49.1	lowest income – 77.7 primary education – 69.2 active smoking – 69.2
Specialist periodontal treatment**	>2 sextants with code 3 or 1 sextant with code 4 in CPI	35	active smoking – 57.7 cardiovascular disease with incidence – 57.1 male sex – 40.9
Necessity to improve very bad oral hygiene**	PI > 70% and API > 70%	29.2	irregular brushing – 50.6 active smoking – 46.1 lowest income – 44.7
Treatment of oral mucosa diseases	presence of at least 1 disease requiring treatment	35.4	active smoking – 47.7 lowest income – 47.4 treatment funded by NFZ – 43.6
Treatment of oral pre-cancerous and cancerous lesions	presence of at least 1 lesion	9.6	active smoking – 15.4 female sex – 12.9 cardiovascular disease – 11.9

API – approximal plaque index; CPI – community periodontal index; DT – decayed teeth; PI – periodontal index; WHO – World Health Organization;
* 14 subgroups were tested: place of residence, sex, education, income per capita, smoking status (current or former), obesity, diabetes, presence of cardiovascular disease or a previous incident – myocardial infarction or stroke, hypertension, osteoporosis, irregularity of visits to the dental office, irregularity of tooth brushing, no flossing, and treatment only in state-funded facilities (NFZ); ** Edentulous people were excluded.

the need for prosthetic treatment of more extensive tooth loss was found in people with primary education – as compared to persons with higher education ($p < 0.0001$), people treated in NFZ facilities – as compared to persons self-financing their dental treatment or only sometimes involving their own means ($p < 0.0001$), irregularly brushing teeth ($p < 0.0001$), ineffectively brushing teeth ($p = 0.0002$), having irregular dental visits ($p = 0.0005$), declaring tobacco addiction in the past – as compared to persons completely abstaining from smoking ($p = 0.015$), and living in a small town ($p = 0.0298$) (Table 3). For the mandible, the need for prosthetic treatment of more extensive tooth loss depended significantly on a smaller number of conditions: inefficient tooth brushing ($p < 0.0001$), dental treatment funded by the state – as compared to self-financed treatment ($p < 0.0001$), irregular tooth brushing ($p = 0.0002$), primary education – as compared to higher education ($p = 0.0009$), and irregular dental visits ($p = 0.0031$) (Table 4).

Discussion

In our study, according to the WHO classification, it was observed that 39% of the participants did not need any prosthetic restoration in the maxilla, and 33.1% – in the mandible. These findings were almost identical to those made in the analogous West Pomeranian study: 39.1% in the maxilla and 32.3% in the mandible.[16] However, this data was significantly worse than other European ones; for instance, the national Spanish study in 2005 showed that the absence of the said necessity for prosthetic treatment was determined in 76.3% of participants in the maxilla and 71.5% in the mandible, in people of the same age.[17]

In young Lower Silesian seniors, the need for prosthetic restoration of a single missing tooth or restorative prosthetic treatment in multi-unit or combined (single- and/or multi-unit) cases was found in 43.9% in the maxilla and 56.7% in the mandible; in the West Pomeranian group, these were 50.3% and 58.8%, respectively.[16]

Table 3. The need for prosthetic treatment in the maxilla according to the WHO classification, depending on chosen variables

Variable		Median value of WHO codes	*p*-value
Place of residence	Wrocław Oława	1 (0–4) 3 (0–4)	0.0298*
Sex	female male	1 (0–4) 3 (0–4)	0.0723
Education	elementary[1] secondary[2] higher[3]	3 (0–4) 2 (0–4) 1 (0–4)	0.0001* between [1] and [3] <0.0001 between [2] and [3] 0.02
Income	lowest average highest	3 (0–4) 1 (0–4) 2 (0–4)	0.094
Smoking status	current former[1] non-smoker[2]	3 (0–4) 3 (0–4) 1 (0–4)	0.0062* between [1] and [2] 0.015
BMI	normal weight overweight obesity	1 (0–4) 3 (0–4) 1 (0–4)	0.49
Diabetes	yes no	3 (0–4) 2 (0–4)	0.41
Cardiovascular disease	yes no	2 (0–4) 2 (0–4)	0.0913
Osteoporosis	yes no	0 (0–4) 2 (0–4)	0.0684
Effectiveness of tooth brushing	PI < 30% PI > 70%	0.5 (0–4) 3 (0–4)	0.0002*
Effectiveness of hygienic procedures in interdental spaces	API < 25% API > 70%	2.5 (0–4) 3 (0–4)	0.51
Dental appointments	regularly irregularly	1 (0–4) 3 (0–4)	0.0005*
Brushing teeth	regularly irregularly	1 (0–4) 3 (0–4)	0.0001*
Form of dental treatment funding	NFZ[1] mixed private	3 (0–4) 1.5 (0–4) 1 (0–4)	0.0001* between 1 and the rest <0.0001

BMI – body mass index; * statistically significant.

Table 4. The need for prosthetic treatment in the mandible according to the WHO classification, depending on chosen variables

Variable		Median value of WHO codes	*p*-value
Place of residence	Wrocław Oława	3 (0–4) 3 (0–4)	0.13
Sex	female male	3 (0–4) 3 (0–4)	0.16
Education	elementary[1] secondary higher[2]	3 (0–4) 3 (0–4) 1 (0–4)	0.0005* between [1] and [2] <0.0009
Income	lowest average highest	3 (0–4) 3 (0–4) 2 (0–4)	0.053
Smoking status	current former[1] non-smoker[2]	3 (0–4) 3 (0–4) 3 (0–4)	0.11
BMI	normal weight overweight obesity	3 (0–4) 3 (0–4) 3 (0–4)	0.85
Diabetes	yes no	3 (0–4) 3 (0–4)	0.2
Cardiovascular disease	yes no	3 (0–4) 3 (0–4)	0.29
Osteoporosis	yes no	1 (0–4) 3 (0–4)	0.0783
Effectiveness of tooth brushing	PI < 30% PI > 70%	0 (0–4) 3 (0–4)	0.0001*
Effectiveness of hygienic procedures in interdental spaces	API < 25% API > 70%	1 (0–4) 3 (0–4)	0.18
Dental appointments	regularly irregularly	1.5 (0–3) 3 (0–4)	0.0031*
Brushing teeth	regularly irregularly	3 (0–4) 3 (0–4)	0.0002*
Form of dental treatment funding	NFZ[1] mixed[2] private[3]	3 (0–4) 3 (0–4) 1 (0–4)	0.0001* between [1] and [3] <0.0001 between [2] and [3] 0.0019

* statistically significant.

However, in our study the need for prosthetic treatment of edentulism occurred more often in the maxilla (17.1% vs 10.1%), and this number was higher in comparison with the needs reported in the West Pomeranian study – 10.5% and 8.8%, respectively.[16] In the 2005 Spanish study, such a need occurred in 4.4% of people in the maxilla and 5% in the mandible.[17] This compilation shows considerable needs regarding the prosthetic treatment of young seniors in Poland, significantly higher than those in the richest European countries. Our own analysis showed the same variables related to the smaller needs for prosthetic treatment in the maxilla and the mandible, in line with the WHO classification, and these were as follows: higher education, self-financed dental treatment, effective tooth brushing, regular visits to the dental office, and the correct pattern of daily tooth brushing. In relation to the maxilla, 2 more factors displayed a significant impact on reducing the extent of prosthetic treatment, namely living in a big city and never smoking cigarettes. In the analogous assessment of the inhabitants of the West Pomeranian province, Wilczyński also noted the influence of behavioral factors (correct pattern of daily tooth brushing and regular visits to the dental office) and self-financed dental treatment upon the reduction of prosthetic treatment needs related to the maxilla and mandible, as classified by the WHO; factors such as the highest income, higher education and living in a big city reduced these needs only for the maxilla.[16]

In the assessed population of young Lower Silesian seniors, in relation to European reference points, the needs for dental caries treatment were similarly higher. In a current German national study there were only 21% of people at the same age with at least 1 carious defect,[18] or in a Kosovar study, at least 1 carious defect was found in 42.6% of respondents.[19] An optimistic aspect of our own study is the high caries treatment index – 81.1%, just slightly lower than the German one – 90.6%.[18] The DMFT index for the whole group of young seniors in the Lower Silesian region was 17.8 and the main component determining its level were extractions due to caries – more than 12 teeth per person on average. The average DT number was 1.05 and was significantly higher in men (1.4 vs 0.72), while the average FT number was 4.48. In the 1987 study of Wrocław residents aged 60–80, the DMFT index was 26.5, and its individual components were higher in relation to the current state: DT = 0.55 and MT = 9.9, while the FT was lower by 0.8.[20] The differences in men were even more marked (DMFT: 26.2 vs 17.2, DT: 1.9 vs 1.4, MT: 22.0 vs 11.4, and FT: 2.2 vs 4 4).[20] These compilations prove that the number of teeth removed due to caries and the average number of dental fillings declined significantly over 30 years, which should be evaluated as positive. In the available contemporary Polish literature, only 2 regional references were found. The first is the DMFT index 16.31 (DT = 2.95, MT = 10.91 and FT = 2.45) in the study of 106 men aged 65–74 from Białystok.[21] A comparison of the caries indices in both studies shows a similar frequency of teeth removal due to this reason, as well as a lower number of teeth with active caries and almost 2 filled teeth more in the study for Wrocław. The other reference point concerns people aged 65–74 from the West Pomeranian province, where the DMFT index was calculated depending on the type of dental treatment financing, and for those treated only in NFZ facilities and those treated in private facilities, the variables were, respectively, as follows: DT: 0.99 and 0.9 (in our own research: 1.41 and 0.87); MT: 18.14 and 9.73 (in our own research: 15.59 and 9.36); and FT: 3.74 and 9.43 (in our own research: 2.31 and 6.26).[16] This comparison reveals large differences between the two provinces, especially in the number of teeth removed for cariological reasons, the number of dental fillings and better care within NFZ facilities in this regard in the West Pomeranian province.

The periodontal care need index that amounts up to 35% in the examined population of young Lower Silesian seniors should be assessed as high. No such criterion of qualification for specialist periodontal treatment had been found in the available literature. However, this choice was driven by the desire to avoid measuring the position of the attachment in such a qualification, which at this age, regardless of periodontopathies, is moving apically,[22] which obviously may lead to an overestimation of therapeutic needs. In the 5-year cohort study, the most important risk factors for the progression of periodontitis in the 60–81 age group were identified – current nicotinism, elementary or secondary education, being single or divorced, and diabetes.[23] Periodontological treatment of the elderly has its own limitations, which include general health conditions, physical handicaps, as well as lower predictability of the healing process after surgical procedures.

The percentage of indications regarding the treatment of oral mucosal diseases (35.4%) was quite similar to the periodontal needs. A foreign regional study, in which the prevalence of oral mucosal lesions requiring treatment in subjects at the corresponding age was the closest to our observations, i.e., 36%, was carried out in a group of 537 Hong Kong residents.[24] Also in this group, the most frequently diagnosed diseases were prosthetic stomatitis, leukokeratosis, recurrent aphthous stomatitis, and angular cheilitis.[24] However, the frequency of occurrence of pathological oral mucosal lesions requiring treatment in the elderly is more diverse. In more recent observations, this percentage was 59.5% in the regional study in Valparaiso in Chile (the most common changes were prosthetic stomatitis, traumatic ulcer, fibroma, and atrophic inflammation of the tongue),[25] and 11.8% in the last national German study (the two most common clinical diagnoses were prosthetic stomatitis and leukoplakia).[26] In our own study, as high as 9.6% percentage of people with oral pre-cancerous and cancerous lesions is also noticeable, which reinforces the message concerning the requirement of oncological vigilance.

In 29.2% of the surveyed young Lower Silesian seniors, extremely poor oral hygiene was demonstrated in the form of over 70% average value of the index of teeth brushing effectiveness and interdental space cleaning. The adopted threshold is not very high; not reaching it indicates a practical absence of hygienic procedures in the oral cavity or their total ineffectiveness. Changing long-term habits regarding pro-health behaviors has a fairly bad prognosis – it is very difficult and requires constant re-education.

In Table 1, for each gerodontological treatment need there were given 3 subgroups of persons for whom they were the highest. In the case of the tobacco addiction syndrome, the distinguished subgroup of people placed itself among those 3 with the highest needs for each type of gerodontological treatment, and for periodontal treatment and oral mucosal diseases, this was the top subgroup with the highest needs. This shows very clearly the impact of nicotinism on the holistically perceived dentistry. Fortunately, it is a modifiable risk factor, which makes it possible to significantly reduce the need for gerodontological treatment once this addiction is dropped. It is absolutely necessary to conduct minimal anti-smoking interventions during every patient's visit to the dental office. The second modifiable risk factor forming subgroups with the highests need for gerodontological treatment is the incorrect pattern of daily tooth brushing. While nicotinism is an addiction, irregular brushing is only a bad habit and as such it does not involve any special financial consequences while being eradicated, but still it requires cooperation on the part of the patient. Focusing on preventive programs addressed to younger groups of Poles only in the area of these 2 risk factors should significantly reduce the needs for gerodontological treatment of young seniors in the future.

Our own research had a number of limitations. First of all, it is the low response rate of the elderly, which determines its low representativeness. The reported 24.2% response rate was higher than the response rates in other Polish regional dental examinations of young seniors – 7.2% in Białystok[27] and 11.8% in the West Pomeranian province.[16] However, these values are low compared to foreign ones; for example, in the last regional German cohort study, Study of Health in Pomerania (SHIP), carried out in the years 2008–2012, the response rate was 50.1%,[23] and in the Italian regional survey among the inhabitants of Turin conducted in 2009–2010, it was 50.12 %.[28] It is not known if people participating in epidemiological research in Poland represent larger or smaller needs in the area of gerodontological treatment. Secondly, it is advisable to conduct separate observations for root caries. Due to the inability to obtain a review radiographic image, the needs of endodontic and surgical treatment were not determined.

Conclusions

This is the first attempt in Poland to assess the majority of gerodontological treatment needs in a randomized regional cross-sectional study. It demonstrates high needs for the prosthetic, cariological and periodontal treatment. Such national studies are necessary, because on their bases we can more pragmatically create the scope of dental procedures financed by the public healthcare service and develop adequately focused preventive campaigns for younger groups.

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Reviews

Oral consequences of obesity and metabolic syndrome in children and adolescents

Konsekwencje otyłości i zespołu metabolicznego dla zdrowia jamy ustnej u dzieci i młodzieży

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Abstract

Nowadays, the epidemic of obesity and metabolic syndrome can be observed not only among adults, but also amid the younger population, with more than 380 million children and adolescents worldwide being affected by these phenomena. Obesity is considered a systemic chronic metabolic disease resulting from the imbalance between energy intake and expenditure. The World Health Organization (WHO) has identified obesity as the most serious chronic disease, which, if untreated, leads to dangerous health problems (hypertension, heart failure, as well as kidney, nervous system and eye diseases). Recent scientific findings indicate a close relationship between obesity/metabolic syndrome and changes in the oral environment in children and adolescents. Obesity significantly increases the incidence of dental hard tissue diseases, periodontal diseases and diseases of the stomatognathic system. It also affects the secretion activity of the salivary glands, which changes the quantitative and qualitative composition of unstimulated and stimulated saliva. It is believed that in the face of a growing epidemic of obesity in children and adolescents, dental practitioners should also participate in the systemic treatment and prevention in this group of patients.

Key words: metabolic syndrome, obesity, children, oral cavity, dental problems

Słowa kluczowe: zespół metaboliczny, otyłość, dzieci, jama ustna, problemy stomatologiczne

Introduction

The World Health Organization (WHO) estimates that over 1.9 billion adults in the world are already overweight (body mass index (BMI) > 25 kg/m^2), 650 million of whom are obese (BMI > 30 kg/m^2). More than 380 million children and adolescents worldwide are also affected by this phenomenon. In developing countries, 23.8% of boys and 22.6% of girls were overweight or obese in 2013.[1] The WHO has identified obesity as the most serious chronic disease, which, if untreated, leads to dangerous health problems (hypertension, heart failure, as well as kidney, nervous system and eye diseases). Other health problems associated with obesity include type 2 diabetes mellitus (T2DM), lipid metabolism disorders, reflux, and obstructive sleep apnea.[2,3] It has also been demonstrated that obese children experience psychological and psychosomatic problems such as depression, low self-esteem, eating disorders, and anxiety disorders much more frequently than their peers with normal body weight; furthermore, obese children are more likely to fall victim to social discrimination and bullying, which leads to the deterioration of the quality and comfort of their lives.[4]

The problem of metabolic disorders related to obesity and insulin resistance was first described in 1988.[5] However, it was only 10 years later, in 1999, that the WHO and the European Group for the Study of Insulin Resistance (EGIR) proposed a definition of metabolic syndrome. It was assumed that, in addition to abdominal obesity, at least 2 other metabolic disorders listed by the International Diabetes Federation (IDF) must occur simultaneously for metabolic syndrome to be diagnosed: increased triglyceride (TG) concentration (>150 mg/dL), decreased concentration of high density lipoprotein (HDL) (<40 mg/dL for men and <50 mg/dL for women), hypertension (≥130/85 mm Hg), T2DM, or impaired fasting glycemia (IFG) (≥100 mg/dL). In adults, abdominal obesity is defined as excessive adipose tissue deposited in the abdomen and accompanied by negative health effects. For children and adolescents, abdominal obesity was defined based on waist circumference (WC) ≥90th percentile value for age and sex.[6] Obesity is considered a systemic chronic metabolic disease resulting from the imbalance between energy intake and expenditure, which is a very serious health problem due to its prevalence.

Recent scientific findings indicate a close relationship between obesity/metabolic syndrome and changes in the oral environment in children and adolescents. Obesity significantly increases the incidence of dental hard tissue diseases, periodontal diseases and diseases of the stomatognathic system. It also affects the secretion activity of the salivary glands, which changes the quantitative and qualitative composition of unstimulated and stimulated saliva. Therefore, the aim of this article was to review contemporary literature on oral implications of obesity and metabolic syndrome in children and adolescents.

Obesity and periodontal disease

Adipose tissue is considered not only spare material for the body, but also a biologically active organ. With significant accumulation, this tissue is believed to be the largest endocrine organ in the body.[7,8] Obesity has been defined as a chronic inflammatory disease, in which the deposition of adipocytes may result in increased production of several cytokines, including tumor necrosis factor α (TNF-α), interleukins (IL) IL-1β, IL-6 and IL-8, and proinflammatory monocyte chemotactic protein-1 (MCP-1).[9,10] This facilitates macrophage infiltration and contributes to the formation of a proinflammatory environment, also in the periodontium.[11–13] Interleukin 1β and IL-8 are cytokines that stimulate the periodontal inflammatory processes. Interleukin 1β stimulates B and T type cells, endothelial cells, and, above all, osteoclasts, which results in the intensification of the bone resorption processes.[14,15] Moreover, the stimulating effect on osteoclasts is demonstrated by TNF-α.[16,17] Interleukin 8 chemotactically affects granulocytes, the role of which is to release lysosomal enzymes and metalloproteinases (MMPs), involved in the degradation of the extracellular matrix of periodontal tissues.[16,18] The activation of granulocytes also results in several dozen times higher oxygen consumption. This phenomenon is referred to as a respiratory burst and is aimed at the production and release of large amounts of superoxide anion radical and, consequently, other free oxygen radicals outside the cell.[19] Increased production of reactive oxygen species (ROS) with inadequate antioxidant response, observed in periodontal tissues of the obese, leads to the development of oxidative stress,[20–22] which intensifies inflammatory changes in the periodontium.[23]

Adipocyte activity has been confirmed to influence the development and/or severity of periodontal disease.[16,24–26] Furthermore, as shown by Reevez et al., even a 1-kilogram increase in body weight may increase the risk of periodontal disease by 6% in the group of obese teenagers over 17.[27] Zhao et al. observed that in the absence of considerable differences in the clinical condition of the periodontium, obese children demonstrate a significant increase in TNF-α concentration in the gingival pocket fluid compared to children with normal body weight.[28] This is confirmed by the results of the study by Lundin et al.[29] Modéer et al. noted an increase in the concentration of proinflammatory interleukins (IL-1β and IL-8) in gingival pocket fluid of obese children compared to healthy subjects with normal body weight.[30]

The immunological disorders associated with obesity modify the bacterial flora of the subgingival plaque, which also predisposes obese patients to the occurrence of periodontal disease. Three times as many bacteria (of the 23 species included in the study) were found in obese teenagers as in their peers without overweight, and the amount of proteobacteria, *Campylobacter rectus* and

Neisseria mucosa was even 6 times higher. However, the relationship between obesity and the number of bacteria in the subgingival plaque was not affected by the rate of saliva secretion, medications taken, chronic diseases, visible plaque index (VPI), bleeding on probing (BOP), or frequency of consumed meals.[31]

The number of scientific studies confirming the relationship between obesity and periodontitis in children and adolescents is low compared to the number of similar studies conducted among adults. In the study involving 12-year-old obese children, Sfasciotti et al. noted a significant increase in the full-mouth bleeding score (FMBS) (26.24%) compared to children with normal body weight (12.7%).[8] In the study conducted by Modéer et al., the number of obese teenagers with BOP < 25% did not differ considerably from the number of peers with normal body weight, but there were significantly more obese adolescents with BOP ≥ 25% compared to those with normal body weight.[25] The relationship between body weight and the periodontium condition was also found in the study involving adults. The study by Lehmann-Kalata et al. showed a statistically significant increase in the gingival index (GI) and sulcus bleeding index (SBI) values in obese people in comparison to those with normal body weight.[32] The study by Zeigler et al. showed no correlation between BMI, dietary habits, hygiene, and oral hygiene in obese adolescents.[33] However, obese teenagers with gingival pocket depth (PD) ≥4 mm had significantly more points with BOP ≥ 25% and considerably higher systolic blood pressure than obese teenagers with PD < 4 mm.[33] This data may confirm the assumption that periodontal disease in obese adolescents has an impact on organ complications of obesity, leading to the development of arteriosclerosis and cardiovascular diseases. Also Scorzetti et al. noted a significant increase in the values of periodontal disease indicators, including the oral hygiene index (OHI), approximal plaque index (API) and BOP, and a higher percentage of pockets with a probing depth exceeding 4 mm in obese children aged 6–13 compared to peers with normal body weight.[24] Although none of the subjects showed a loss of connective tissue attachment (clinical attachment level – CAL) ≥3, the authors observed an increase in the CAL value in obese children compared to healthy controls.[24] While studying adults, Saito et al. also observed that the number of people with deeper periodontal pockets increased with the increase in BMI.[34] The researchers found a significant correlation between the waist–hip ratio (WHR) and BMI, and increased risk of periodontitis.[34] However, Konopka et al. in their study involving 200 adults, did not find any relationship between the condition of the periodontium and BMI.[35] The authors only demonstrated a higher API value in subjects with excessive body weight compared to slim people.[35]

It should be recalled that the intensification of inflammatory lesions in the periodontium was also observed in the course of obesity complicated by T2DM. In the study by Janem et al., GI was significantly higher in obese children with T2DM than in obese children without diabetes and children with normal body weight aged 10–19.[36] Diabetes, which is considered part of the metabolic syndrome, affects the periodontium condition through a variety of factors, including weakened function of neutrophils, activity of advanced glycation end products (AGEs), microangiopathies, and change in collagen metabolism.[37] The study by Chacon et al. showed that the expression of monocytes after bacterial lipopolysaccharide (LPS) stimulation, manifested by increased production of TNF-α and IL-1β, was much higher in patients with T2DM than in non-diabetic patients.[38] Upon binding to AGEs, cells with receptor for advanced glycation end products (RAGE) on their surfaces, i.e., macrophages, monocytes and endothelial cells, increase the production of proinflammatory cytokines, permeability of blood vessels and oxidative stress. Excess free oxygen radicals can lead to tissue damage through, for instance, DNA damage. Excess AGEs also affect gingival fibroblasts by inhibiting the production of collagen and glycosaminoglycans by these cells.[37] The study by Kumar et al. indicates that patients with periodontitis, but without metabolic disorders, have 3 times lower concentrations of MMP-9 and 2 times lower concentrations of MMP-8 than patients with periodontitis and diabetes.[39] Increased concentrations of MMPs in the course of diabetes can lead to increased bone resorption.

Obesity and dental hard tissue diseases

Obesity and dental caries have many common causal factors, such as increased sugar intake, poor eating habits,[40,41] and regular consumption of snacks and soft drinks.[42] However, the results of studies on the relationship between metabolic syndrome or obesity and the prevalence of caries in children and adolescents are ambiguous. The studies by Gupta et al.,[43] Tong et al.,[44] Yen and Hu,[45] and Hilt and Daszkowska[46] demonstrated no correlation between the occurrence of caries and obesity, which is confirmed by the meta-analysis of data from the National Health and Nutrition Examination Survey (NHANES III and NHANES 1999–2002).[47] Hilt and Daszkowska even found that in the group of adolescents with high BMI, the percentage of people free from caries was higher than in the group of teenagers with normal body weight.[46] Gerdin et al. observed, however, that the prevalence of caries dropped with the increase in the socioeconomic status in each age group of children with overweight/obesity, while BMI of these children was unrelated to their socioeconomic status.[48] The researchers also found that obese children with BMI > 30 had more teeth with caries than children with normal body weight (BMI < 25), and that BMI correlated quite poorly with the decayed, missing and filled teeth (DMFT) index. Interestingly, Gerdin et al. also observed that children aged 5, 7 and 10 with normal body weight, but overweight/obese in the past (when aged 4), had significantly less caries than children aged 4–10 with normal body weight from birth.[48] On the other hand, Willerhausen et al. noted that out of 1,290 primary school pupils, as many as 44.7% of children with underweight and 40.7% with normal body weight had healthy teeth without caries, while in the group of children with overweight and obesity, the rate was 30.5% and 31.7%, respectively.[49] Costacurta et al. observed a close relationship between tooth decay and obesity in children aged 6–11 resulting from a very high positive correlation between the DMFT index and the percentage of adipose tissue in the body (body fat mass – FM%).[41] The results of the aforementioned study[41] are consistent with the observations of Modéer et al.[25] and Gunjalli et al.[50] Moreover, Bailleul-Forestier et al. found a positive correlation between BMI and the DMFT indicator.[51] However, Alm et al. demonstrated that in the group of overweight 15-year-olds (age-specific BMI ≥ 25), caries defects on the proximal surfaces were significantly more common and that regular consumption of sweet snacks and beverages in early childhood predisposes to a high risk of caries in 15-year-olds.[42] Also, the study conducted by Lehmann-Kalata et al. in a group of adults confirmed higher intensity of caries in obese people.[32] Pannunzio et al.[52] suggest that decreased activity of salivary peroxidase (an enzyme responsible for the antibacterial and antioxidant properties of saliva[53]) may be the cause of increased incidence of caries in obese children. The said reduction of salivary peroxidase activity and the observed raised content of protein and free sialic acid (SA) in the saliva of obese people may lead to increased bacterial adhesion and colonization of the oral cavity by carious bacteria (*Lactobacillus acidophilus* and *Streptococcus mutans*). As a result, the rate of plaque creation may increase, which may lead to the formation of new caries defects in the future. This hypothesis is contradicted by the studies by Fadel et al.[26] and Tong et al.,[44] as these researchers showed a similar microbiological profile and a comparable amount of carious bacteria in the saliva of obese children and children with normal body weight.

It is believed that both obesity and the severity of caries in children and adolescents are related to the education and economic status of their parents. Gerdin et al. demonstrated that parents of obese children with caries were less educated and in a worse socioeconomic situation than parents of children with normal body weight and without caries.[48] It should also be remembered that children/teenagers often have sweet snacks between meals, which leads to the development of obesity and caries. Costacurta et al. found no differences in the frequency of sugar consumption with main meals, home and school oral hygiene, and the habit of eating after brushing teeth between children with normal body weight without caries, obese children without caries and obese children with caries.[41] However, the group of obese children with caries was distinguished by higher frequency of sugar consumption between main meals, as well as higher intake of sweetened beverages.[41]

The existing literature contains data indicating the connection between obesity and the occurrence of tooth erosion in children and adolescents. Tong et al. believe that the teeth of obese children are less exposed to dental caries, but more susceptible to the development of non-carious cavities, i.e., erosion.[44] It has been demonstrated that obese children are 26 times more likely to experience dental erosion than children with normal body weight. Erosion in obese children occurs mainly on the palatal surface of the incisors, while in children with normal body weight, it occurs on various tooth surfaces. What is more, obese children had a higher degree of tooth erosion, but not a higher number of eroded tooth surfaces compared to children with normal body weight.[44] Increased dental erosion in obese children may result from excessive consumption of carbonated beverages, and in children on a slimming diet – from increased consumption of juices and energy drinks, as well as fruit, including citrus fruits.[44] Other reasons for the intensification of erosive lesions include the use of chlorinated pools, induced vomiting and gastroesophageal reflux disease (GERD). Also, asthma may increase the incidence of dental erosion in children, which most probably results from the influence of therapy of this disease on the secretion and composition of saliva.[54] The study by Pandolfino et al. confirmed the positive relationship between BMI and the risk of GERD.[55]

Obesity and the stomatognathic system

Obesity also affects the function of the respiratory system in children. Excessive adipose tissue in the thoracic-abdominal region changes the mobility of the chest and diaphragm, which in turn reduces the maximum ventilation capacity and fixes a fast, shallow pattern of breathing.[3] It has been proven that pressing the palate with fat cells results in decreased muscle tension, increased pharyngeal resistance and sleep apnea in obese people. Moreover, reduced thoracic cage compliance and an overload of the respiratory muscles interfere with breathing while sleeping.[56] As evidenced by Marino et al., obese children suffering from obstructive sleep apnea have mild mandible retrognathia and increased skeletal divergency of the lower facial height.[57] Increased pharyngeal resistance in children raises airflow through the mouth. The consequence of breathing through the mouth is an imbalance in the activity of the tongue, cheeks and lips (flaccid, incompetent lips). The lack of airflow through the nasal cavity entails the growth of the jaw and the formation of a narrow, high-arched palate. This leads to consequences of skeletal (development of skeletal Class II malocclusion), dental (front open bite, lateral crossbite, deep overjet), and facial (narrow nostrils, long face, incompetent lips) nature.[58]

Due to the increased release of growth hormone in the course of obesity[59,60] and intensified secretion of leptin by adipose tissue, affecting cartilaginous growth centres,[61] changes in skeletal and dental age are observed in obese children. These children present an earlier onset of puberty and shorter duration of puberty compared to the lean ones.[61] It is commonly known that dental and skeletal age are the determinants of the starting point for the application of permanent braces, as well as the choice of an appropriate orthodontic treatment method in adolescent patients. While examining children between 7 and 15 years of age, Hilgers et al. found that dental age, according to Demirjian, was higher in obese and overweight children compared to that of children with normal weight.[62] The study by Mack et al. demonstrated that each BMI percentile for a given age of a child means 0.005 years of growth for tooth age (which determines the stage of dentition development in relation to the metric age of a child).[60] This means that the difference in tooth age between slim and obese children may be even several months (about 5 months).[60] Moreover, it was observed that, in the period of mixed dentition, an obese child has approx. 1.44 times more teeth erupted than a child with normal body weight.[63] Considering the fact that an accelerated rate of teeth eruption may significantly affect the oral health of children – from periodontal inflammation, through increased intensity of caries and occlusion defects, to diseases of the temporomandibular joint – the need for more frequent periodic evaluation of the oral cavity in overweight or obese children and adolescents should be stressed.

In obese children (especially girls), deviant craniofacial morphology is also observed. These changes concern mainly the length of the mandible, which is approx. 6 mm longer in obese girls and 8.7 mm longer in obese boys compared to their slim peers. Obese adolescents show not only an increased anterior cranial base length, but also greater maxillary and mandibular prognathism.[61] Studies have shown that in obese teenagers, 13 years of age is most frequently the period of the peak growth of the mandible, which was not observed in a group of adolescents with normal body weight.[60] Achieving the peak of mandible growth corresponding to Stage 3 of cervical vertebral maturation is the moment when the orthodontic treatment of skeletal Class II malocclusion should be started.[64] Therefore, Mack et al. suggest that orthodontists, when planning treatment, should consider an earlier date of its commencement in obese patients with skeletal Class II malocclusion compared to patients with normal body weight.[60] In the study involving a group of teenagers with fixed braces, Saloom et al. found that obese adolescents had a significantly higher rate of tooth movement over the period of alignment than those with normal body weight.[65]

Changes in the quantitative composition of saliva in obese children

Saliva is a secretion of the salivary glands that provides a fluid environment for the oral ecosystem. Saliva moisturizes oral tissues, enables articulation and initial digestion of food, as well as swallowing, and protects the surface of the teeth and mucous membranes against biological, mechanical and chemical factors.[66] The proper activity of the salivary glands is essential for all these saliva functions. It is clinically proven to occur when unstimulated saliva is at a level of >0.2 mL/min and stimulated saliva is at a level of >0.7 mL/min. Despite the undoubtedly leading role of proper saliva secretion in maintaining oral homeostasis, the number of available scientific analyses concerning saliva secretion in children and adolescents with overweight/obesity problems is still low.

The results of the studies by Modéer et al.[25] and Fadel et al.[26] revealed a significant decrease in the secretion of stimulated saliva in obese teenagers (aged 10–18) compared to their peers without overweight, which was contrary to the reports of Pannunzio et al., who focused on the secretion of stimulated saliva in a group of children up to 10 years of age.[52] In the study by Fadel et al., the reduction of stimulated saliva secretion corresponded to the increase in BMI, which may suggest that the secretion activity of the salivary glands is impaired by increased body weight.[26] Also, the results of the study conducted in a group of adults by Lehmann-Kalata et al. confirmed decreased stimulated and unstimulated saliva secretion in obese people compared to those with normal body weight.[32] In the study conducted by Rodríguez et al.,[67] the secretion of unstimulated saliva, and in the study of de Campos et al.,[68] the secretion of both unstimulated and stimulated saliva did not differ significantly in the group of obese children and children with normal body weight. However, Rodríguez et al. observed that unstimulated saliva secretion was considerably higher in obese girls than in obese boys, which was not observed in a group of adolescents with normal body weight.[67]

The mechanisms by which obesity affects saliva production have not been fully examined. A significant degree of steatosis of the parotid glands of obese patients has been demonstrated in the absence of pathological morphological changes in the submandibular glands.[69] It is well-accepted that human parotid glands produce saliva mainly upon stimulation, while the submandibular glands provide unstimulated saliva.[70–73] Therefore, it is believed that changes in the composition or secretion of stimulated saliva signal abnormalities in the function of the parotid glands. Similarly, the dysfunction of the submandibular glands is connected with changes in unstimulated saliva secretion. In the parenchyma of the parotid glands there are adipocytes that stimulate the expression of proinflammatory cytokines, like tumor growth factor β1 (TGF-β1), IL-1, and, through ROS-mediated stimulation, the Akt-κB signalling pathway activates MMPs. DNA synthesis and the expression of Na^+/K^+ ATPase are hindered by TGF-β1, which negatively affects epithelial proliferation.[74] Increased activity of MMPs results in inflammation and the reconstruction of extracellular matrix. These factors are known to lead to decreased response of residual acinar cells to noradrenaline (NA) and acetylcholine (ACh), or receptor reconstruction. All these processes may result in diminished secretion of stimulated saliva and a weakened mechanism of protein synthesis/secretion, which is the phenomena that we observed in the saliva of obese adult patients.[75]

Summary

Childhood obesity is a complex and multidisciplinary clinical problem that is of interest to physicians of various specialities (including dentists). Recently, more attention has been paid to the metabolic consequences of obesity within the oral cavity, including increased incidence of caries and periodontal diseases, diseases of the stomatognathic system, as well as impaired saliva secretion and changes in its biochemical composition. It is believed that in the face of a growing epidemic of obesity in children and adolescents, dental practitioners should participate in the systemic treatment and prevention in this group of patients. Numerous changes in the oral cavity (e.g., caries, periodontal diseases) have a common etiological background stemming from metabolic obesity disorders. These include excessive consumption of sugars, sweetened beverages and fast food snacks. It is well-known that adipose tissue does not only store energy, but is also a biologically active organ influencing the hormonal and mineral metabolism, as well as the activity of children's immune system. Changes in the immune system (increase in proinflammatory cytokine secretion) may affect the condition of the periodontium, and – along with poor hygiene in obese children – also cause chronic systemic inflammation. Due to hormonal changes causing accelerated skeletal and dental growth, overweight/obese children and adolescents should be regularly examined by orthodontists.

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Treatment of the facial basal cell carcinoma with the use of photodynamic therapy: A case report

Leczenie ogniska raka podstawnokomórkowego skóry twarzy z użyciem terapii fotodynamicznej – opis przypadku

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Abstract

Basal cell carcinoma (BCC) is the most common skin cancer. It accounts for approx. 80% of human skin cancers and belongs to the group of non-melanoma skin cancers (NMSC). The highest incidence of this cancer is visible in older people, over 65 years of age. Photodynamic therapy (PDT) is a clinically approved method with a selective cytotoxic activity. It is used in the treatment of superficial forms of BCC, precancerous conditions (hyperkeratosis, actinic keratosis) and non-cancerous diseases (acne vulgaris, infection with herpes simplex virus – HSV, leukoplakia, lichen planus).

The aim of the study was to apply PDT to a patient with a clinical diagnosis and histopathologically confirmed BCC.

The patient, male, aged 82, reported to the Department of Oral Surgery at Wroclaw Medical University with BCC of dimensions 0.5 × 1.5 cm, present for 13 years in the area of the right mandibular angle, after previous surgical treatment. Photodynamic diagnosis (PDD) and PDT were employed using a semiconductor laser. 5-aminolevulinic acid (5-ALA) was used as a photosensitizer. The PDD and PDT procedures were applied at 2-week intervals for 3 months. Control visits after 3, 6 and 12 months did not show local recurrence. Photodynamic therapy is a highly useful, independent method of treating superficial forms of BCC.

Key words: basal cell carcinoma, photodynamic therapy, photodynamic diagnosis, aminolevulinic acid

Słowa kluczowe: rak podstawnokomórkowy, terapia fotodynamiczna, diagnostyka fotodynamiczna, kwas aminolewulinowy

Introduction

Basal cell carcinoma (BCC) is the most common skin cancer. It accounts for approx. 80% of human skin cancers and belongs to the group of non-melanoma skin cancers (NMSC). The highest incidence of this cancer is visible in older people, over 65 years of age, but in recent years, a significant increase in the incidence of BCC among young people has been observed.[1] The most common BCC locations include exposed parts of the body, such as the nose, forehead, upper lip, nasolabial fold, eyelids, and 90% of lesions are placed between the hairline and the upper lip. Furthermore, BCC may also appear in other areas (the back, shoulders, dorsal parts of the hands).[2,3] In relation to sex, men are slightly more likely to get ill. The main factor triggering this disorder is ultraviolet radiation, especially UVB (280–320 nm). This correlates with the highest number of cases in areas with high insolation. Additional features that predispose to carcinogenesis include skin contact with hydrocarbon or arsenic, ionizing radiation, human papilloma virus (HPV), as well as Gorlin and Goltz's syndrome. In the area of the head, BCC grows in the form of a nodule with heaped-up edges, often with central ulceration or as a red spot with minor ulcers, often with a central cavity and centers of more intense pigmentation (partially covered with a scab). On the other hand, in the area of the trunk, the macroscopic image is different. The cancer is presented as flat and brown lesions with delicate exfoliation on the surface, with elevated borders. The tumor shows slow growth and low local malignancy rates, rarely leading to distant metastases.[4] Long-term growth of untreated tumor causes extensive destruction of the skin, as well as destruction of the neighboring tissues, posing a significant threat to important anatomical structures, in particular in the area of the head and neck.

Basal cell carcinoma is derived from cells found in the basal layer of the epidermis. Histologically, the following forms of BCC have been distinguished: solidum, cysticum, adenoides, keratoticum, pigmentosum, superficiale multicentricum (located mainly on the trunk and limbs), cicatricans, and styloides – it is characterized by the least favorable prognosis; it grows deeper in the form of a separating strand that penetrates tissues.[5] Diagnostics of BCC usually does not cause any problems during an interview and physical examination of the patient. However, the final verification and diagnosis is based on a histopathological examination of the lesions – entirely cut out or their fragments.

In the treatment of BCC, surgical treatment remains the golden standard, but due to the limitations of this method in the particularly sensitive or esthetically important areas, behavioral methods play an important role and they include the following: photodynamic therapy (PDT), radiotherapy and local pharmacotherapy. In contrast, invasive methods include methods involving the excision of the lesion and ablative methods, based on destruction of pathological tissue, such as freezing, laser therapy and curettage, supplemented by electrodesiccation of tissues. For esthetic reasons, the tumor often cannot be cut out with the right margin, which results in later local recurrence. In these cases, an invaluable advantage is given by non-invasive methods, which include, among others, PDT.

Photodynamic therapy is a clinically approved method with a selective cytotoxic activity. It is used for the treatment of superficial forms of BCC, precancerous conditions (hyperkeratosis, actinic keratosis) and non-cancerous diseases (acne vulgaris, infection with herpes simplex virus – HSV, leukoplakia, lichen planus).[6–9] However, PDT is used for small and superficial lesions located on the skin and mucosa. The effectiveness of PDT is limited mainly by the ability of light to penetrate into tissues (approx. 3 mm). It is particularly recommended in the treatment of superficial BCC (sBCC).[10]

The main components of PDT are a compound called a photosensitizer and light. As a result of the absorption of energy coming from an incident light wave, the photosensitizer goes into an excited state. Excitation of the photosensitizer and transfer of the excess energy around the intracellular structures and tissues lead to a series of cytotoxic reactions, resulting in necrosis or induction of apoptosis. One of the widely used compounds which act as photosensitizers are porphyrin derivatives. These compounds have a maximum absorption around 405 nm. Therefore, it would seem that the best source of light to excite this group of photosensitizers is a light-emitting source in this range. Due to the presence of melanocytes, the skin and mucous membranes strongly attenuate ultraviolet radiation, which is why light in the range from blue to near infrared is used in PDT. Transmission of light in the skin and mucosa is increased along with the wavelength. In order to achieve greater effectiveness of PDT in deeper layers of the treated lesions, photosensitizers whose absorption window falls within the range from 600 nm to near infrared are used. Due to the fact that porphyrin-based photosensitizers have a high affinity for cells with increased metabolism, it is possible to preserve PDT selectivity only for the treated lesions. In addition to photosensitizers, their precursors are also used in PDT. One of the most frequently used precursors of protoporphyrin IX is 5-aminolevulinic acid (5-ALA) and its methyl derivative (MAL).

Case report

The patient, R.R. (man), aged 82, suffering from arterial hypertension, reported to the Department of Oral Surgery at Wroclaw Medical University concerned about a lesion of dimensions 0.5 × 1.5 cm, which had been recurring for 13 years in the area of the right mandibular angle (Fig. 1) after surgical treatment. Figure 2 shows the lesion during PDD – red fluorescence of the photosensitizer indicates neoplasm cells. Before the implementation of the treatment, a clinical diagnosis was confirmed by a histopathological examination. For 3 months, the patient had PDD at 2-week intervals and he was treated with PDT.

Fig. 1. Local state of patient before treatment

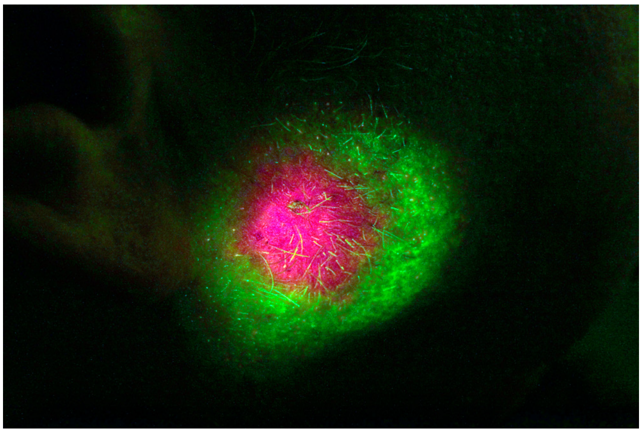

Fig. 2. Lesion during photodynamic diagnosis (PDD) – red fluorescence of photosensitizer indicates neoplasm cells

The treatment algorithm for PDT and PDD was as follows: clinical examination; collection of photographic documentation; local application of the photosensitizer on the BCC site – 20% 5-ALA ointment on eucerin base (Sigma-Aldrich, St. Louis, USA); after 2 h, PDD carried out with the following exposure parameters: wavelength – 405 nm, 50 mW/cm^2, source of radiation – a semiconductor laser (developed by professor Witold Trzeciakowski, Polish Academy of Science, Warszawa, Poland, patent No. 9223123 B2); photographic documentation during the PDD procedure; after PDD, another application of the photosensitizer –20% 5-ALA covered with dressing – for another 2 h; PDT carried out with the following parameters: wavelength – 630 nm, 250 mW/cm^2, total energy – 120 J, source of radiation – the above-mentioned semiconductor laser. After 3 months, the BCC outbreak partially regressed. Figure 3 presents the local condition. After another 3 months, the patient reported to the control visit – no recurrence was found (Fig. 4). The next control was performed 9 months after the procedure. There was no local recurrence in the postoperative area. The state after a period of 12 months is shown in Fig. 5. Photodynamic diagnosis after 12 months is shown in Fig. 6 – there is no red fluorescence of the photosensitizer, which indicates there are no more neoplasm cells. Figure 7 shows a standard histological pattern of BCC before treatment (magnification ×100, hematoxylin-eosin (H&E) stain).

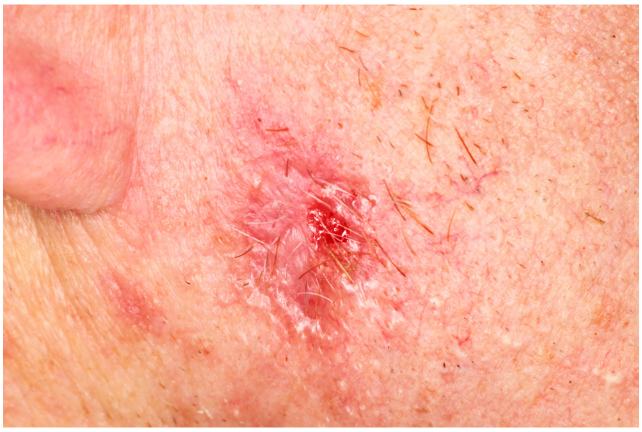

Fig. 3. Local state after 3 months

Fig. 4. Local state after 6 months

Fig. 5. Local state after 12 months

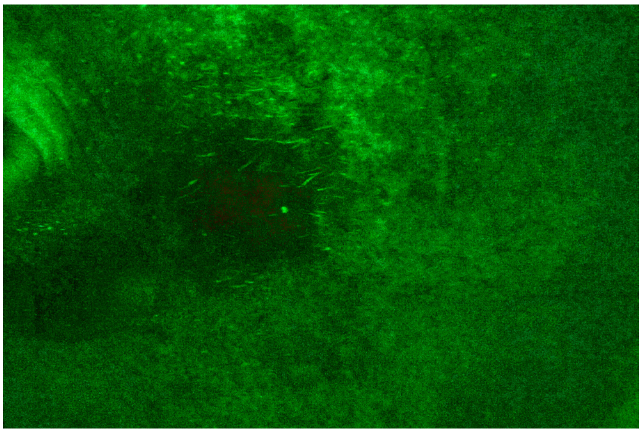

Fig. 6. Photodynamic diagnosis (PDD) procedure after 12 months – there is no red fluorescence of photosensitizer

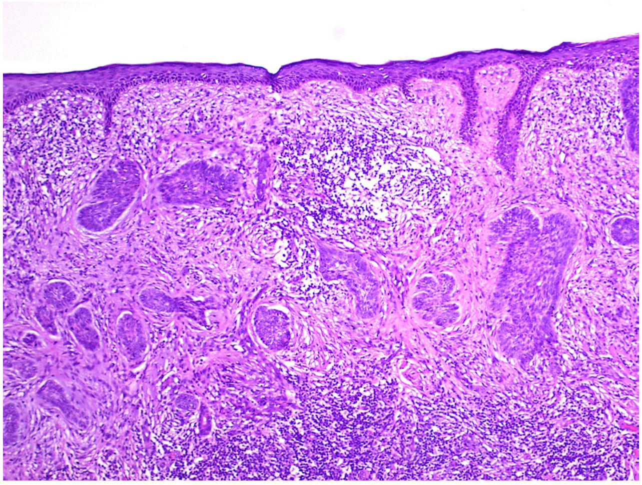

Fig. 7. Standard histological pattern of basic cell carcinoma (BCC) before treatment (magnification ×100, hematoxylin-eosin (H&E) stain

Discussion

Factors that should be taken into account before the selection of a treatment strategy for BCC include, among others, the following: degree of advancement and size of the tumor, infiltration of the tumor into the adjacent tissues, location of the tumor, general condition of the patient, and any previous treatment of the lesion. Among the many possible therapies, surgical treatment of BCC remains the golden standard. It ranks first among the methods with the lowest numbers of relapses in the 5-year period after the end of treatment – 98.6% effectiveness in primary BCC and 96% efficiency in secondary BCC.[11] In comparison with conservative therapies, surgical treatment gives the opportunity to evaluate the radicality of the resection of the tumor by performing intraoperative examinations with the use of the Mohs micrographic surgery (MMS). Moreover, it provides the final histopathological verification of the tumor, which is impossible with the use of conservative methods. The Mohs micrographic surgery is based on precise excision of lesions due to a histopathological examination of the edges in the removed tissues. This technique gives the maximum possibility of saving healthy tissues and it is recommended especially in areas requiring high esthetics after treatment, such as the face. Furthermore, it is preferred in the cases of recurrent BCC lesions with poorly marked borderlines and tumors exceeding 2 cm in diameter. The Mohs micrographic surgery gives less recurrence over a 5-year period compared to classical tumor excision.[12,13] When determining the extent of the surgical margin for BCC, the doctor should be guided mainly by the diameter of the tumor. Therefore, it is assumed that for lesions not exceeding 2 cm in diameter, a margin of 3 mm ensures effective resections in 85% of the cases and a 5-millimeter margin guarantees successful resections in 95% of the cases.[5] This significantly affects the post-operative esthetic effect in a given anatomical area, which is very important for the head and neck region. Scars after surgical treatment depend mainly on the extent of the tumor and the method of closing the defect in the resected tissues. Apart from the excised lesions in the treatment area, healthy tissues are often also excised in order to collect skin patches used to close the primary cavity. This procedure significantly increases the surgical area above the correct surgical margin of the resected tumor.

However, there are situations, especially in the head area, where the determination of a sufficient margin is limited by the presence of important anatomical structures, such as the eyeballs, eyelids and earlobes. In these cases, there are methods that work outstandingly selectively against cancer cells. They include PDT, local therapy with 5% imiquimod and 5-fluorouracil (5-FU), and targeted molecular therapy with vismodegib, all of which specifically save the healthy tissues adjacent to the tumor.

Comparing the response to treatment in the case of a surgical method and PDT with MAL as a photosensitizer (MAL-PDT), a complete response at the level of 96% for the surgical method and 73% for PDT (in the observation period of 5 years) has been shown.[14] However, when analyzing the esthetic effect of both methods obtained after the treatment, PDT significantly exceeds the surgical treatment.[14–16] Therefore, PDT has become an alternative method for patients excluded from the surgical treatment due to general health reasons and for patients in whom, because of the location of the lesion, scarring after the surgical treatment would disrupt the esthetic effect.

Methods including topical pharmacological therapy are mainly used for the treatment of small-size tumors. In these cases, imiquimod can be used. This is a modulator of the immune response, especially in the field of dendritic cells and monocytes. It has been approved by the Food and Drug Administration (FDA) and the European Medicines Agency (EMA) for the treatment of BCC with a diameter not exceeding 2 cm. In addition to anticancer activity, it is used in the treatment of viral diseases, especially related to HPV. It is used in the form of 5% cream in occlusive dressings, depending on the form of BCC, from 6 to 12 weeks, 5–6 times a week. A comparison of local treatment with the use of 5% imiquimod for 6 weeks in sBCC and for 12 weeks in the nodular form of BCC with the classical surgical excision showed a 5-year cure rate at the level of 82.5% for the group treated with imiquimod and 97.7% for the group where the lesion was excised.[17] Imiquimod is generally well-tolerated by patients, and the most common side effects observed during therapy are erythema, scabs, erosions, or dermatitis. The conducted research comparing the topical therapy with imiquimod and MAL-PDT showed a slightly higher effectiveness of the imiquimod treatment in the period of 3 months and 12 months – 83.4% of patients fully responding to the treatment in relation to 72.8% in the case of MAL-PDT.[18]

Another topical treatment of BCC, approved by FDA, is the 5-FU therapy. 5-fluorouracil is a locally used pyrimidine analog in the form of a cream which acts as an antimetabolite disturbing the local DNA synthesis. Pilot studies on the efficiency of this monotherapy demonstrated 90% of responses to the treatment with 5% cream with 5-FU on the phosphatidylcholine substrate. Among patients treated with 5-FU on the petrolatum substrate, a positive response was received in 57% of the lesions.[19] Other studies examined the effectiveness of MAL-PDT compared to the 5-FU therapy. These examinations showed that the percentage of patients fully responding to the treatment in the period of 3 months and 12 months was 72.8% for MAL-PDT and 80.1% for the 5-FU therapy. Patients after local pharmacotherapy more often reported moderate or severe swellings, erosions, scab formation, and itchy skin compared to patients treated with MAL-PDT. On the other hand, during MAL-PDT, moderate or severe pain, burning sensation and redness of the skin were most commonly reported.[18]

Non-invasive BCC treatment methods include molecular therapy with the use of vismodegib. It works by interrupting the Hedgehog signaling pathway, which becomes excessively active in BCC. Vismodegib is an inhibitor of Smoothened transmembrane protein (SMO), involved in the activation of the Hedgehog pathway. By blocking this pathway, vismodegib inhibits the development of the tumor and slows down its growth. In 2012, it was approved by FDA for the treatment of BCC metastases, recurrence after the resection of the tumor, and for the treatment of patients excluded from surgery and radiotherapy. The Safety Events in VIsmodEgib study (STEVIE) is one of the largest examinations involving the use of vismodegib. It showed 66.7% of responses in patients with locally advanced BCC and 37.9% of responses in patients with a metastatic form of BCC. Patients took orally 150 mg of vismodegib in 28-day cycles. The median of response time was 22.7 months, with an average treatment time of 36.4 weeks. Side effects during the treatment were reported in 98% of patients. The most common side effects are the following: muscle spasms (64%,) baldness (62%), taste disorders (54%), weight loss (33%), fatigue (28%,) decreased appetite (25%), and diarrhea (18%).[20]

Furthermore, there are reports on the possibility of combining PDT with vismodegib. The research conducted in this direction showed that the combined therapy was well-tolerated by patients. The percentage of responses to the treatment was 90% (total) and 10% (partial) responses within 30 days since the end of the therapy. The combination of vismodegib and PDT is a potentially safe and effective therapy in the treatment of BCC. It increases the effectiveness of individual therapies, while maintaining a perfect cosmetic effect.[21]

Among the invasive methods of BCC treatment, cryotherapy (i.e., local freezing) deserves special attention. It involves the application of a freezing agent in the form of liquid nitrogen at a temperature of approx. −196°C to the pathological lesion, thus causing local tissue necrosis. In order to destroy BCC tumor cells, it is necessary to achieve a temperature in the tissue at the level of −50°C with 2 freezing and thawing cycles.[22] Cryotherapy, just like PDT, is applicable to the treatment of small and superficial forms of BCC. Conducted research concerning the comparison of cryotherapy and MAL-PDT in the treatment of sBCC has shown the response to treatment at a similar level. During a 5-year period, recurrence of the diseases at the level of 22% for MAL-PDT and 20% for cryotherapy was observed. However, the cosmetic effect obtained with the use of PDT significantly exceeded the results received after the use of cryotherapy, since healing after freezing very often leaves scars and discoloration on the skin.[23] August believes that this method should be avoided in the treatment of BCC on the scalp and in the nasolabial folds due to the large number of recurrences after the treatment.[24] Ceilley and Del Rosso also mentioned that cryotherapy can cause recurrence due to the survival of the tumor in the fibrous stroma of the scar.[25] Moreover, there was also an attempt to combine PDT with CO_2 laser ablation and modified cryotherapy. This attempt demonstrated high efficiency and a good cosmetic effect in the treatment of BCC in the nodular form.[26]

Conclusions

In the light of the above-mentioned factors, PDT is a highly useful, independent method of treating superficial forms of BCC. Furthermore, it provides a satisfactory effect in combination with other therapeutic options. Due to its advantage over other therapies in the form of highly selective action toward cancer cells and very good cosmetic results after the treatment, it has become an important alternative to other approaches, especially in esthetically sensitive areas, such as the head and neck. Studies on PDT with regard to sBCC show satisfactory treatment response rates. The surgery procedures are recommended for the treatment of BCC, but in special cases, PDT could be applied. Therefore, it can be considered as a reasonable therapeutic option, especially for patients who do not accept possible surgical complications or for patients excluded from the surgical treatment.

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Clinical cases

Er:YAG and diode laser application in implant bed preparation and implant uncovering: A case report

Zastosowanie lasera erbowo-jagowego i lasera diodowego przy wytwarzaniu łoża implantu oraz odsłanianiu implantu – opis przypadku

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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

The use of lasers in the field of dentistry has increased recently. Their numerous advantages and applications in soft and hard tissue surgeries make them a great alternative to conservative methods in dental implantology. The most commonly used lasers are diode and erbium-doped yttrium aluminium garnet (Er:YAG) lasers. The Er:YAG laser can be used in implant bed preparation, as it brings no thermal injury to the bone. The laser does not cause bone necrosis and positively affects osseointegration and the healing process. The use of the diode laser in soft tissue surgeries helps to obtain optimal hemostasis. Therefore, it can be used in implant exposure, since it allows performing immediate impressions.

The present case report describes the implementation of the Er:YAG laser in the implant bed preparation of a single-tooth dental implant in position 35 (according to the World Dental Federation (Fédération Dentaire Internationale – FDI) notation) for better bone regeneration. The implant exposure was performed with the diode 980-nm laser for hemostasis and immediate impressions. The results of laser employment were compared to traditional drilling and scalpel techniques. The advantages and disadvantages of the application of the above lasers were featured.

Key words: erbium-doped yttrium aluminum garnet lasers, diode lasers, blade implantation, single-tooth dental implant

Słowa kluczowe: lasery erbowo-jagowe, lasery diodowe, implantacja żyletkowa, pojedynczy implant

Introduction

The implementation of lasers has expanded recently in the field of dentistry, as they are innovative alternatives to traditional dental procedures and helpful supplementary treatment methods.[1–3] The wide range of laser applications includes soft and hard tissue surgery,[1,4,5] peri-implantitis treatment,[6] disinfecting implant surfaces,[6,7] implant exposure,[8,9] and assistance in orthodontic and prosthodontic procedures.[2,10] Their employment has increased notably in dental implantology.[1,4–8] The most prevalently used lasers in dental clinical practices are diode and erbium-doped yttrium aluminum garnet (Er:YAG) lasers.[5,6,9,11]

Generally, besides the bone quantity and quality, the surgical implantation technique is one of the most important factors responsible for the clinical success.[4,5,10,12–15] The surgical application of lasers in implant dentistry increases osseointegration and the healing process[5,13,14,16,17] as well as shortens the treatment procedures time.[1,5,7,8,10,17] Traditional protocols using drills can cause an interruption in the Haversian canals and Volkmann's canals, leading to the necrosis of the osteocytes, and thus to bone devitalization.[12,13] However, the necrosis of the osteocytes can result not only from wrong surgical techniques.[12,13,15] Bone devitalization can also happen during bone overheating at a temperature above 47°C[15] and may result in complete osseointegration failure.[12] Nonetheless, the correct application of the Er:YAG laser during implant bed preparation lowers the temperature of the bone compared to standard drilling methods.[4,18–22] Additionally, the use of the diode or Er:YAG laser while exposing the implant allows dentists to implement immediate impressions, due to the obtained hemostasis.[5,7,17] Moreover, laser irradiation of the surfaces of the implants decreases the number of bacteria living on implants and reduces the probability of infections in the peri-implant zone.[6,7]

As it has been described above, the use of lasers in implant dentistry has many advantages. The following case report describes a combined application of diode and Er:YAG lasers during an implantology procedure. The Er:YAG laser was employed in the implant bed preparation and the diode laser in the exposure of the implant.

Case report

A 34-year-old female patient was referred to our Private Dental Healthcare (NZOZ, Ka-Dent, Wschowa, Poland) for the extraction of tooth 35 (the World Dental Federation (Fédération Dentaire Internationale – FDI) notation used) and a single-tooth implant treatment after the bone healing period. A lateral panoramic radiograph (CS 9000 3D; Carestream Health, Inc., Rochester, USA) showed failed root canal treatment (RCT) of tooth 35 (Fig. 1). Due to the small percentage of successful conservative approaches, the decision to extract was made and the procedure was performed. After a 4-month healing period, the patient returned to continue the treatment. Her medical history revealed no drug allergies, current medications, smoking, or diseases relevant to dental implantation. An intraoral examination showed good oral hygiene. Before the surgical procedure, a cone beam computed tomography (CBCT) scan was taken (CS 9000 3D; Carestream Health, Inc.) (Fig. 2). The obtained sufficient bone quantity and quality confirmed for titanium implant insertion.

Fig. 1. Panoramic radiograph before the extraction of tooth 35

The treatment plan was a single-tooth dental implant in position 35. The implant bed preparation was planned with the application of the Er:YAG laser for better bone regeneration, and implant exposure with the diode laser for immediate impressions. The patient was informed about the treatment procedures, and consent was obtained. The surgery was performed under local anesthesia (articaine hydrochloride 4% with epinephrine 1:100k, Citocartin® 100; Molteni Dental, Kraków, Poland). The mucoperiosteal flap was elevated to gain access to the bone. The location of the implant bed was determined on the basis of CBCT, and then prepared using the Er:YAG laser (Lite Touch®, Syneron Dental, Yokneam, Israel) at the following parameters set: operation mode for soft tissues (ST); energy: 300 mJ; frequency: 35 Hz; pulse duration: 300 µs; energy density per pulse: 39.79–59.68 J/cm^2; distilled water spray cooling: 30 mL/min; tip angle set at 10°; tip size: 0.8–1.3 × 17 mm;

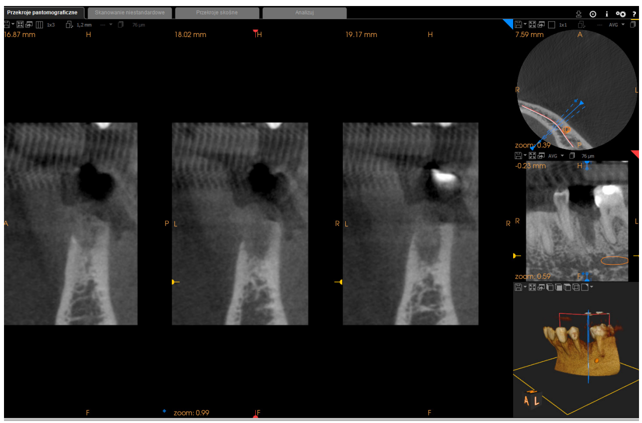

Fig. 2. Cone beam computed tomography before implant treatment, 4 months after the extraction of tooth 35

distance: 0–2 mm (Fig. 3). The implant bed preparation was adjusted to the shape of the implant (SuperLine®, Dentium Co., Ltd., Seoul, South Korea; titanium grade 4 implant, with a diameter of 4.0 mm and a length of 12 mm) (Fig. 4). The implant bed length was evaluated with a periodontal probe. The width of the prepared implant bed was controlled by placing drills from a surgical cassette of the system utilized in this case. The final dimension of the implant bed allowed us to manually apply a drill with a diameter of 3.6 mm and a length of 12 mm.

Due to photoacoustic phenomena (the cavitation effect) induced while using the Er:YAG system, the implantation site showed decreased bleeding compared to the procedure with bur cutting. The implant was inserted (Fig. 5) and non-absorbable sutures (Dafilon® 4.0; B. Braun Melsungen AG, Melsungen, Germany) were used to stabilize the wound edges. Directly after the implantation, the second panoramic radiograph (Fig. 6) was taken, which confirmed the proper implant position in relation to the adjacent teeth. The primary stability measured by means of the Periotest® device (Medizintechnik Gulden e. K., Modautal, Germany) was −3.6 PTV (Periotest value). The sutures were removed after 2 weeks.

Fig. 3. Implant bed preparation using the Er:YAG laser

Fig. 4. Surgical site before implant placement

Fig. 5. Surgical site after implant placement

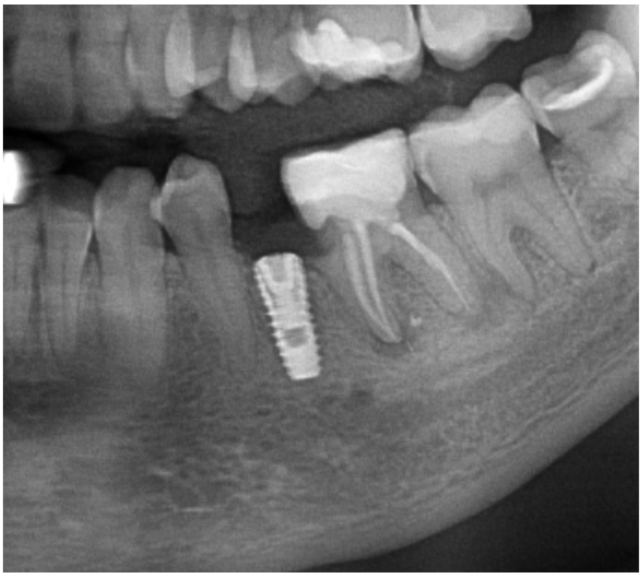

Fig. 6. Panoramic radiograph after implant placement

After 4 months of healing, the patient reported back to continue the treatment (Fig. 7). Using local anesthesia (articaine hydrochloride 4% with epinephrine 1:100k, Citocartin 100; Molteni Dental), the implant was uncovered with the diode laser (GENTLEray® 980, KaVo Dental GmbH, Berlin, Germany) (Fig. 8,9). The laser operated at the following parameters set: wavelength: 980 nm; power: 1.5 W in contact mode, continuous wave (CW); distance: 0 mm; power density: 9550 W/cm^2, tip angle set at 90°; fiber: 200 μm; without cooling. To gain a greater volume of the high keratinized tissue, a crescent-shaped cut in the attached gingiva (AG) around the uncovered implant was performed with the diode 980-nm laser and the flap was buccally displaced using a soft tissue elevator, which caused only minimal bleeding (Fig. 9).

A prosthetic impression with a connected impression transfer using an open tray method was taken 2 weeks later, and then after 3 days, a coupling was mounted onto the implant and the final prosthetic crown was cemented (Fig. 10,11).

Fig. 7. Healed surgery site 4 months after implantation

Fig. 8. Marked cutting line on the attached gingiva for implant uncovering using the diode laser

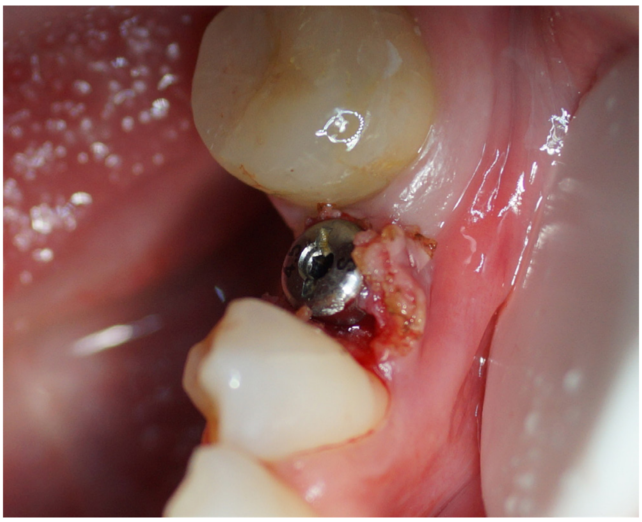

Fig. 9. Buccally displaced attached gingiva around the uncovered implant

Fig. 10. Coupling mounted on the exposed implant

Fig. 11. Cemented final prosthetic crown

Discussion

The implementation of the Er:YAG laser in implant dentistry has many advantages. A study by Zeitouni et al. has proven that the Er:YAG laser causes less thermal tissue damage, trabecular compaction and carbonization than conventional drilling techniques.[23] Although different studies reported that piezosurgery and drilling methods, when implemented correctly, did not cause thermal injury above the critical temperature,[18,19,21,23] their studies show that the Er:YAG laser causes a lower increase in the bone temperature[18,19,23] as well as in the soft tissue temperature.[21] Similar findings were reported by other researchers.[4,20] Therefore, no bone devitalization and necrosis occurs after the surgery.[12,13,15] The Er:YAG laser generates light at an energy level that is readily absorbed by water, and thus minimizes carbonization and the necrosis of the adjacent tissue.[20] Additionally, the small-diameter decortication performed by means of the Er:YAG laser appears to provide better primary stability as compared to drill and piezosurgery.[9] The use of the laser results also in minimized deformation of bone tissue, precision in osseous preparation and accelerated healing.[18,19,21–23] Furthermore, Baek et al. reported that the Er:YAG laser could partially diminish bleeding, which in turn could contribute to healing and therefore better osseointegration.[24] The application of the Er:YAG laser has also been confirmed useful in implantations near the maxillary sinus, since it reduces the risk of the iatrogenic perforation of the Schneiderian membrane.[19]

Although there are many studies demonstrating the application of lasers in bone and soft tissue surgery during dental implantation,[1–5,17–24] only few evaluate their advantages in implant bed preparation.[25–29] The research by Seymen et al. compared the differences between the planned and prepared implant beds for the erbium, chromium-doped yttrium scandium gallium garnet (Er,Cr:YSGG) laser group and the conventional drilling group in coronal and apical deviations.[25] The differences in the mean angular, coronal and apical deviations were reported to be marginally in favor of traditional drilling methods. However, the researchers considered the deviations clinically insignificant and described laser employment as a feasible method for implant bed preparation with desired depth, angle and diameter.[25] However, implant bed preparation using lasers entails some disadvantages.[25–27] The biggest drawback in laser osteotomy are wider peri-implant gaps, especially in the apical areas of the cavities, compared to conventional drilling.[26,27] Stübinger et al. reported that even a slight angulation of the laser beam direction can lead to a severe bone loss in the implant bed. To eliminate the peri-implant gaps, an individual template can be used.[28] Nevertheless, this method still excludes depth control. To eliminate both of the drawbacks mentioned above, Seymen et al. presented the employment of a stereolithographic (SLA) surgical guide for guiding the laser handpiece.[25] The described technique allowed not only for a desired angle of the implant bed preparation, but also for depth control. Additionally, Ingenegeren listed several factors needed for proper implant bed preparation using lasers: the laser tip needs to be longer than the implant, there must exist congruence between bone preparation and the shape of the implant (less critical with the utilized conical and self-tapping implants than with the cylindrical types), and the bone must be properly cooled with the water spray system of the laser.[29] Following the above instructions helps to achieve clinical success.[29] However, it should be also underlined that in our presented case, the main difficulty during implant bed preparation was the lack of precision regarding the assessment of the width and length of the prepared bed.

A crucial factor in the success of implant-prosthetic treatment, among others, is implant osseointegration. Factors influencing osseointegration are, e.g., dental implant composition, implant design, bone heat, bone contamination, primary stability, bone quality, soft tissue status, and loading time.[14] A modern high-power laser working in the wavelength of 3000 nm allows cutting both soft and hard tissues without visible thermal damage, due to the vaporization effect. It should be underlined that clinicians can use the Er:YAG laser not only for superficial vaporization of different tissues, but also for cutting, especially soft tissue, similar to cutting with a scalpel when using special chisel-type tips, without visible necrosis along the cutting line.[8,9] Implant bed preparation with low thermal damage at the bone level as well as other abovementioned factors are essential for short and long-term success of the treatment described in our present paper.

Additionally, the quantity and quality of AG around the prosthetic restoration supported on implants are important factors in maintaining the restoration.[8,30] The sufficiency of AG around fixed restorations is the key factor in choosing a technique for uncovering implants. The minimum of 2 mm in thickness of the keratinized tissue (TKT) and in height of the keratinized tissue (HKT) is required for implant uncovering without subepithelial connective tissue grafts (SCTG) or free gingival grafts (FGG).[8] The precision of lasers (small cut width) during implant uncovering allows minimal interference in AG.

Lasers in dentistry have many advantages, not only from the dentist's viewpoint but also the patient's. The combined use of Er:YAG and diode lasers will undoubtedly increase in the future. Within the limitations of the present study, it was concluded that Er:YAG laser application in implant bed preparation and diode laser employment in implant uncovering may represent a promising alternative to conventional surgical protocols. However, the authors unambiguously agree that the use of lasers is not flawless. Therefore, further clinical studies on a larger group of patients are required to evaluate their clinical limitations and long-term results.

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