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## **ABSTRACT** **of the dissertation for the degree of Doctor of Philosophy**

### **EVALUATION OF THE APPLICATION EFFICIENCY OF ZIRCONIUM CROWNS**

Specialty : 3226.01 - Dentistry

Field of science: Medicine

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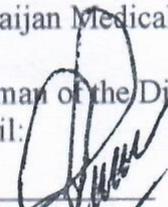
**Baku – 2022**

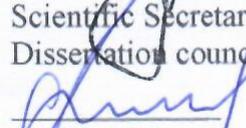
The dissertation was completed at the Department of Orthopedic Dentistry of the Azerbaijan Medical University.

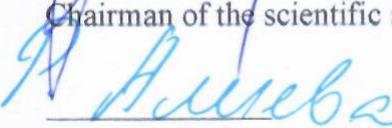
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## GENERAL DESCRIPTION OF THE RESEARCH

**Relevance of the topic** . The aesthetics, biocompatibility and high durability of zirconia crowns have made zirconium-based restorations popular. Due to computer-aided design and manufacturing (CAD / CAM) technology the ideal Zircon coping / framework for not only single-use but also multilevel restorations has been produced<sup>1</sup>.

Mechanical durability and long-term clinical results are important factors in the selection of zirconia crowns. A number of researchers have reported a gap between the crown and tooth in vitro and in vivo<sup>2,3</sup>. A large gap can lead to cement dissolution and plaque build-up, marginal leakage, secondary caries and ultimately crown damage. A clinically acceptable marginal gap is noted within 120 microns or 0.12 mm<sup>4,5</sup>.

The high initial durability and fracture toughness of zirconia are due to the physical property of partially stabilized zirconia, known as "transformation hardening"<sup>6</sup>.

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<sup>1</sup>S-R.Ha, S-H.Kim, J-B.Lee [et al.].Effects of coping designs on fracture modes in zirconia crowns: Progressive load test / *Ceramics International*, - 2016. 42:6, - p. 7380-7389.

<sup>2</sup>F.Ricci tiello, M.Amato,R.Leone [et al.]. InvitroEvaluation of the Marginal Fit and Internal Adaptation of Zirconia and Lithium Disilicate Single Crowns: Micro-CT Comparison Between Different Manufacturing Procedures / *Open Dent J*, -2018. 12, - p. 160-172.

<sup>3</sup>R.Sorrentino, C.O.Navarra, R.DiLenarda [et al.]. Effects of finish line design and fatigue cyclic loading on phase transformation of zirconia dental ceramics: a qualitative micro-Raman spectroscopic analysis / *Materials*, - 2019. 12, - p. 6.

<sup>4</sup> R.Rai, S.A.Kumar, R.Prabhu [et al.] Evaluation of marginal and internal gaps of metal ceramic crowns obtained from conventional impressions and casting techniques with those obtained from digital techniques / *Indian J Dent Res*, - 2017. 28: 3, - p. 291-297.

<sup>5</sup>M.Rödiger, A.Heinitz, R.Bürgers [et al.].Fitting accuracy of zirconia single crowns produced via digital and conventional impressions - a clinical comparative study / *Clinical Oral Investigations*, -2017. 21: 2, - p. 579–587.

<sup>6</sup> Al-Baadani A.H. Evaluation of internal adaptation of full contour zirconia crowns versus veneered zirconia crowns: In vitro study / *International Dental & Medical Journal of Advanced Research*, - 2016.2, - p. 1–6.

Marginal fit and internal adaptation are decisive factors in increasing restoration longevity. Newer and more economical CAD / CAM systems have been introduced, requiring better marginal fit and adaptation of all ceramic crowns. CAD / CAM systems include matrix scanning or tooth preparation and milling<sup>7</sup>.

Although zirconia has excellent mechanical properties, its opaque white color and insufficient transparency require a glass cladding on the porcelain frame to achieve a natural appearance and acceptable aesthetics<sup>8</sup>. However, cracking or shredding of porcelain lamina has been reported to be a serious complication of these restorations. Possible causes of porcelain lamina cracking are: differences in coefficient of thermal expansion (CTE) between framing and porcelain, porcelain capping, porosity, poor wetting of the lamina, defects in lamina, inadequate framing to support porcelain plywood, overload and fatigue<sup>9</sup>.

Prosthetic accuracy can be influenced by several variables, such as restorative materials, manufacturing procedures, framework, cementation techniques, and aging<sup>10</sup>. A marginal mismatching can result in the exposure of the oral fluid to the cement, causing it to dissolve. Consequently, marginal discrepancies increase percolation (oozing) of bacteria, food, and oral contamination, potentially causing secondary caries, endodontic inflammation, and periodontal disease<sup>11</sup>.

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<sup>7</sup> M.BankoğluGüngör, A.Doğan, B.TurhanBal [et al.]. Evaluation of marginal and internal adaptations of posterior all-ceramic crowns fabricated with chair-side CAD/CAM system: an in vitro study / *ActaOdontolTurc*, - 2018. 35:1, - p. 1-8.

<sup>8</sup> S.R.Habib, M.G.AIAjmi, M.Al.Dhafyan [et al.]. Effect of Margin Designs on the Marginal Adaptation of Zirconia Copings/*ActastomatologicaCroatica*, - 2017. 51(3), - p.179-187.

<sup>9</sup> L.O.Pedroche, S.R.Bernardes, M.P.Leao [et al.] Marginal and internal fit of zirconia copings obtained using different digital scanning methods / *Braz. oral res.*, - 2016. 30 (1), - p. 1-13.

<sup>10</sup> Nakazawa, K. Surface properties of dental zirconia ceramics affected by ultrasonic scaling and low-temperature degradation / K.Nakazawa, K.Nakamura, A.Harada [et al.] // *PLOS ONE*, - 2018. 13, - p. 1-18.

<sup>11</sup> Cunali, R.S. Marginal and Internal Adaptation of Zirconia Crowns: A Comparative Study of Assessment Methods / R.S.Cunali, R.C.Saab, G.M.Correr [et al.] // *Brazilian Dental Journal*, - 2017. 28(4), - p. 467-473.

Despite the long-standing use of alloys and ceramics as fixed and removable restorative materials, questions on their behavior in the oral cavity still remain. These materials come into close and prolonged contact with the gums and oral mucosa and are proved to cause inflammation in these tissues.

Thus, although zirconia is considered to be a reliable material, restorations with zirconia crowns are not problem-free. Therefore, there is a need for studies on the ultimate fit of anatomical contoured zirconia crowns made applying the CAD / CAM system and the state of the oral cavity with zirconia crowns.

### **Object and subject of research**

The object of the study was 101 patients having carious teeth and absence of teeth, defects in previously installed crowns, traumatic injuries and unsatisfactory aesthetic appearance requiring orthopedic dental treatment.

The subject of the research is prosthetics with zirconium crowns and evaluation of their treatment in dynamics.

### **The aim of the study**

To study the clinical characteristics of fixed zirconium dioxide crowns and to evaluate the quality of restorations according to modern criteria.

### **Research objectives**

1. To characterize the condition of the periodontium and marginal periodontium in pre and post- installation period of zirconium crowns.
2. To study the clinical characteristics of two-layer and monolithic crowns based on zirconium dioxide, taking into account the gingival/periodontal biotype.
3. To assess the marginal fitness with traditional two-layer zirconium dioxide crowns fixed to incisors and canines.
4. To assess marginal fitness and absolute marginal divergence of single monolithic zirconium dioxide crowns made applying the CAD / CAM system and fixed on premolars and molars.
5. To evaluate the quality of restorations according to the United States Public Health Service (USPHS) criteria and the effectiveness of orthopedic treatment with zirconia crowns.

## **Research methods**

Using a periodontal probe, the state of the marginal periodontium and the gingival/periodontal biotype were determined.

Dental indices: OHI-S (Green, Wermillion 1964), PMA (Parma C., 1960), Mülleman-Cowell (1981) have been used.

CAD / CAM technology, including casting, scanning, three-dimensional modeling (3D) and programming, milling, sintering were used for restorations.

The United States Public Health Service (USPHS) criteria have been applied.

The statistical software package Microsoft Office Excel, Statistica 6.0 and S. Holm method were used to correct the statistical result.

## **The main theses for the defense**

1. Fixation of zirconium crowns does not lead to the impairment of the periodontal condition.
2. The minimum marginal gap of two-layer restorations is noted at the marginal position and the maximum - in the occlusal region.
3. Marginal gap of premolars in relation to incisors, lateral incisors and canines is reduced. In molars, the marginal gap is significantly lower statistically than in central incisors, lateral incisors and canines.
4. In a 3-year follow-up period, the highest A score according to the USPHS was obtained with two-layer and monolithic restorations for such characteristics as secondary caries and fracture. The survival rate for two-layer restorations was found to be 100%; for monolithic restorations - 97.9%.

## **Scientific novelty**

The clinical characteristics of two-layer and monolithic crowns based on zirconium dioxide in patients with different gingival biotypes have been studied.

The marginal adaptation of two-layer crowns with a zirconium framework to the anterior teeth and to the single monolithic crowns fixed on the chewing teeth have been evaluated.

Data on the quality of the restorations assessed according to modern criteria have been obtained.

## **Theoretical and practical significance**

The study revealed that the application of the two-layer ceramic crowns with a zirconium framework and monolithic zirconium restorations provides satisfactory results.

Evaluating the results of orthopedic treatment with zirconium crowns enables to identify their fixed prosthetics' positive and negative aspects.

**Approbation.** The main points of the dissertation were reported and discussed at: a scientific congress dedicated to the 90<sup>th</sup> anniversary of the Azerbaijan Medical University and the 80<sup>th</sup> anniversary of higher pharmaceutical education in Azerbaijan "Modern problems of pharmacy" (Baku-2021), as well as at a scientific conference called "Scientific dialogue. Medical issues" (Russia, Saint Petersburg, 2019) and X International scientific-practical conference: "Global science. Development and novelty" (Munich, Germany, 2019).

The main aspects of the research are set out at an expanded meeting of the Department of Orthopedic Dentistry with the participation of employees of others specialized dental departments of the Azerbaijan Medical University (18.06.2021, protocol №1), discussed at the scientific seminar of the Dissertation Council ED2.05 operating at Azerbaijan Medical University (11.11.2021, protocol №12).

**Implementation of research results.** The results of this study introduced into the practice of the dental clinic of AMU, as well as into the educational process at the department of prosthodontics dentistry.

**The name of the organization where the dissertation has been accomplished.** The research work was carried out at the department of prosthodontics dentistry of the Azerbaijan Medical University, on the basis of the Dental Clinic and SRC of AMU.

**Published works.** Based on the results of the dissertation, 12 scientific works were published, 8 of which are articles and 4 are theses, including 3 articles and 2 theses in foreign publishing houses.

**Dissertation structure and volume.** The dissertation is written on 165 pages containing 17 tables, 17 graphs, 1 figure, 4 photos, an

introduction (8.765 characters), a literature review (44.388), a chapter on material and methods (18.116), 3 chapters of our own research (31.292 + 48.347 + 31.468), a conclusion (21.258), conclusions (3.385), practical recommendations (0.496), a bibliography containing 200 sources and a list of abbreviations.

## **THE CONTENT OF THE WORK**

### **Material and research methods.**

The research work on revealing the effectiveness of monolithic and two-layer zirconium crowns was carried out in the period of 2018 -2020.

The examined group included the patients of the Orthopedic Department of the Azerbaijan Medical University. The patients submitted their written consent for participation after being acquainted with the aim of the research.

The study was carried out in accordance with the principles of the Helsinki Appeal of the World Medical Association “Recommendations for the physicians engaged in biomedical research with human participation”.

A total of 101 patients were examined, 43 (42.6%) of them were men and 58 (57.4%) were women. The age ranged from 24 to 47 years, the average age was  $34.9 \pm 3.77$  years. Criteria for study inclusion criteria were: written consent form for participation in the study; incisors and canines requiring orthopedic treatment; first or second molar, first or second premolar, requiring a monolithic restoration with / or without endodontic therapy. Criteria for exclusion from the study were :age under 18; severe periodontitis, bruxism; deep bite; pregnancy, feeding period; severe somatic diseases. Caries was revealed in 41 (40.6%), traumatic injury to the teeth - in 14 (13.9%), the absence of certain teeth - in 20 (19.8%), the unsatisfactory aesthetic appearance of the teeth in- 16 (15.8%) and defects of previously installed crowns - in 10 (9.9%) patients. Among examined, the orthognathic appearance was found in 79 (78.2%), distal bite in 9 (8.9%), and a straight bite was observed in 2 (2.0%) patient, mesial bite- in 3 (3.0%), deep bite- in 6 (5.9%), cross bite - in 1 (1.0%), open

bite - in 1 (1.0%). Thick biotype was determined - in 84 (83.2%), thin biotype - in 17 (16.8%) patients.

Monolithic crowns were installed in 76.2% of cases; two-layer zirconia crowns in 23.8% of cases. Totally, 24 classic zirconium crowns were installed on the anterior teeth, of which 11 (45.8%) crowns were installed on the incisors, 8 (33.3%) on the lateral incisors and 5 (20.8%) crowns on the canines. (group I)

Restoration with monolithic zirconium crowns were performed in 77 patients in the molar and premolar areas. A total of 98 crowns were installed in the group II: 42 (42.8%) monolithic zirconium crowns on the upper jaw, 22 of them were fixed on the premolars, and 20 restorations- on the molars. 56 (51.0%) crowns were installed on the lower jaw, 26 crowns of them were installed on premolars and 30 crowns on molars. At the same time, 59 (76.6%) patients had 1 crown, 15 (19.5%) - 2 crowns, 3 (3.9%) - 3 crowns.

The success of fixed crowns was assessed in 7-10 days and in 6, 12, 18, 24 and 36 months.

During clinical examination the condition of the marginal periodontal tissues was assessed using a periodontal probe with an interval of 0.25 mm. At the same time, the depth of the periodontal sulcus, the presence or absence of a periodontal pocket, gingival recession and the degree of the gingival margin compliance were determined.

The biotype of the gums has also been determined in the patients. To identify the type of gums, a periodontal probe was inserted into the periodontal sulcus from the vestibular side to the connective tissue attachment. If the probe tip was visible in the lumen, the gingival biotype was considered thin; otherwise, the gingival biotype was considered thick.

The periodontal condition was assessed by a simplified oral hygiene index (OHI-S, Green, Wermillion, 1964), papillary-marginal-alveolar index (PMA, Parma, 1960, The Muhlemann-Cowell Index (1981).

Plaque volume was determined using OHI-S (Oral Hygien Indices - Simplified). The buccal surface of the 16, 26 teeth, the vestibular surface of the 11 and 31 teeth and the lingual surface of the

36 and 46 teeth have been investigated. While determining this index, subsidiary dyes were not applied. Plaque was assessed according to criteria.

The results were evaluated in points: <0.6 (low score) - good quality of hygiene; 0.7 - 1.6 points (average score) - satisfactory quality of hygiene; 1.7-2.5 points (high score) - unsatisfactory quality of hygiene; more than 2.6 points (very high) - poor quality of hygiene.

To determine PMA, the Schiller-Pisarev solution (iodide-potassium solution) was used, which was applied to the gum with a cotton ball. The color of the gums varies from light brown to dark brown, indicating the intensity of the inflammation. The results were assessed as follows: up to 30% - mild gingivitis; 30-60% - moderate gingivitis; more than 60% - severe gingivitis.

Periodontal bleeding index reveals initial inflammatory changes.

Muhlemann-Cowell index was determined to assess the degree of bleeding of the gingival sulcus while probing 0.2 mm or under pressure on the periodontal papilla.

All patients had undergone X-ray examination. Orthopantomography was used, since it is the most informative method to X-ray the state of periodontal tissues.

The preparation of the teeth and the corresponding schemes met all the requirements. The circumferential, axial and occlusal contraction of the prepared teeth was modified to the number of the tooth that needed the crown. Preparation of teeth for classic two-layer zirconia crowns was carried out so that the minimum thickness was from 1.0 to 1.5 mm or an incisor reduction being from 1.8 to 2.0 mm, a visible and continuous circumferential chamfer with a reduction of at least 0.5 mm at the edge of the gums. The horizontal and vertical preparation of the tooth had an angle of approximately 5 ° and there was no chamfer. All edges of the incisor were rounded off.

For each crown, marginal gap and absolute marginal mismatch were measured. All measured data were averaged basing on four positions: edge, rounded shoulder, axial wall, and occlusal area. It should be noted that the marginal mismatch is the perpendicular distance from the prepared model to the inner surface of the frame; axial or axial wall is the distance in the middle axial wall between the

inner surface of the frame and the prepared tooth; The middle occlusal wall is the distance in the occlusal region between the prepared tooth and the inner surface of the frame.

The United States Public Health Service (USPHS) criteria were used to evaluate the single crowns at baseline and re-appointments.

Marginal gap and absolute marginal divergence were measured according to the recommendations of J.R. Holmes et al. (1989).

To take the imprint, the gum was displaced with Ultrapak retraction sutures # 00 and # 000 (Ultradent, USA). The 2 retraction sutures were placed as follows: first suture # 000 and then suture # 00. The impression was made using vinyl polysiloxane material (Aquasil Ultra LV; Dentsply, York, PA, USA). Thereafter, later models were scanned with a scanner (3Shape D700, Holmens Kanal 7, Copenhagen, Denmark). The crowns were designed using 3Shape software for dental research. The model was first processed in the Zenotec CAM Wieland Dental system, then loaded onto a CNC Wieland Select milling machine (Wieland Dental, Pforzheim, Germany). A Zenostar translucent disk blank (Wieland, Oakville, ON, Canada) was used as a block. The sintering process was carried out in an oven Wieland cube . The staining and glazing was completed with the IPS e.max stain system. In the process, temporary acrylic crowns (Structur 2 SC; Voco GmbH, Cuxhaven, Germany) were placed in patients prior to the installation of the final ones, 7 days after the imprinting phase.

All teeth were prepared according to the manufacturer's recommendations (rounded shoulder edge), the sharp corners being rounded .Marginal gap and absolute marginal divergence were measured according to the recommendations of J.R. Holmes et al. [1989]. Margin gap is defined as the perpendicular distance from the edge of the restoration to the tooth surface. The absolute marginal divergence is the distance between the restoration margin and the preparation line. Along the rounded boundaries of the work piece, the measured point was determined by expanding the main contours of the matrix and drawing the angle bisector.

USPHS criteria were used to evaluate single crowns at baseline and re-appointments. Color, marginal fit, marginal discoloration,

secondary caries, surface texture, severe fractures were assessed. The restoration according to Alpha and Bravo categories was considered to be successful.

Statistical processing of the results was carried out using the software package Microsoft Office Excel, Statistica 6.0. A descriptive analysis was done according to modified USPHS criteria to evaluate the restoration and the restoration results. The arithmetic mean and mean deviation were calculated. To compare the two groups of patients, Student's t- criteria were applied. The statistical data were corrected by S.Holm method . All analyses were performed at the level of confidence.  $p < 0.05$ .

### **Research results**

#### **Clinical Evaluation of Zirconia Crowns at Various Stages of the Research**

After the crown fixation, the 1 and the 11 group patients were revealed to have increasing OHI-S level at all stages of the observation period and this level was assessed to be average. In the 1 group patients, the greater amount of plaque than in group II was stated , but with no statistically significant difference. A dynamic study of the PMA and Mulleman-Cowell index also showed no statistically significant difference between the groups. Inflammation of the marginal gums assessed by 2 points was noted in 19.8% of cases, being in group I - 11.9%, in group II - 7.9% of cases. Consequently, gingival condition was relatively better in patients with monolithic zirconia crowns. ( Table1).

In the 1 group patients with a thick gingival biotype, the average value of the OHI-S index was  $1.24 \pm 0.36$  points, in patients with a thin biotype -  $1.27 \pm 0.30$  points, in the 11 group patients, respectively,  $1.16 \pm 0.37$  points and  $1.19 \pm 0.33$  points.

In the 1 group patients with thick and thin biotype, the average value of the PMA index was  $6.96 \pm 1.81\%$  and  $7.37 \pm 2.79\%$ , in group II -  $6.89 \pm 2.07\%$  and  $7.21 \pm 1, 26\%$  respectively. The average value of the Müllemann-Cowell index in group I patients with a thick biotype was  $0.45 \pm 0.15$  conv. units, in patients with a thin biotype -

0.46 ± 0.12 conv. units, in group II patients respectively, 0.44 ± 0.15 conv. units. and 0.45 ± 0.12 conv. Units.

**Table 1.**

**The frequency of inflammation in periodontitis according to the value of PMA in patients of groups I and II.**

Research period	Degree of inflammation	I group (n=24)	II group (n=77)
before fixation	no staining	17/70,8	40/51,9
	Mild degree	5/20,8	28/36,4
	medium degree	2/8,3	9/11,7
After 7 days.	No staining	7/29,2	33/42,8*
	Mild degree	13/54,2	35/45,4
	medium degree	4/16,7	9/11,7*
After 6 month.	No staining	13/54,2	32/41,5*
	Mild degree	7/29,2	36/46,7*
	medium degree	4/16,7	9/11,7*
After 12 month.	No staining	12/50,0	33/42,8
	Mild degree	8/33,3	35/45,4
	medium degree	4/16,7	9/11,7*
After 24 month.	No staining	10/41,7	30/39,0
	Mild degree	7/29,2	39/50,6*
	medium degree	7/29,2	8/10,4
After 36 month	No staining	10/41,7	30/39,0
	Mild degree	7/29,2	39/50,6*
	medium degree	7/29,2	8/10,4

**Note:** in the numerator, absolute. values, in the denominator%; \* - statistical significance of differences between groups (p <0.05-0.01)

The average OHI-S index in group 1 patients with a thin biotype was higher by 2.4 % than that with a thick gingival biotype . PMA index by 5.6%, Mulleman index by 2.2% respectively.

The average OHI-S index in the 11 group patients with a thin biotype was 2.5% lower than that with a thick gingival biotype. The average value of the PMA index in patients with a thin biotype was 4.4% higher. the average value of the Mullemann index in patients with a thick and thin biotype did not differ. It was found that the patients with thin biotype are more prone to gingival recession. ( Table 2).

**Table 2.**

**Values of parodontal indices in patients with different biotypes in the study groups during the examination period**

Indices	Research period	I group (n=24)		II group (n=77)	
		Thick biotype (n=18)	Thin biotype (n=6)	Thick biotype (n=66)	Thin biotype (n=11)
OHI-S	Before treatment	0,81±0,20	0,84±0,14	0,78±0,25	0,82±0,12
	after 7days	0,85±0,17	0,90±0,12	0,81±0,27	0,84±0,15
	6 month.	1,07±0,28	1,09±0,34	1,0±0,33	1,03±0,20
	12 month.	1,26±0,40*	1,27±0,29*	1,17±0,38*	1,20±0,40*
	24 month.	1,43±0,42*	1,49±0,28*	1,34±0,42*	1,38±0,40*
	36 month.	1,58±0,51*	1,61±0,49*	1,50±0,45*	1,52±0,50*
PMA, %	Before treatment	6,0±1,77	6,01±1,24	6,0±1,32	6,0±1,27
	after 7days	6,20±1,70	6,58±2,20	6,16±2,01	6,33±1,14
	6month.	7,04±1,97	7,31±1,08	6,88±2,17	7,12±1,11
	12month.	7,10±1,62	7,37±0,88	6,91±2,22	7,30±2,0
	24month.	7,14±1,46	7,65±1,79	7,13±2,31	7,57±2,05
	36month.	7,32±2,30	7,96±1,03	7,35±1,62	7,74±1,12
Mulleman-Cowell, conv. units.	Before treatment	0,54±0,14	0,55±0,10	0,54±0,17	0,56±0,11
	after 7 days	0,61±0,22	0,62±0,14	0,60±0,19	0,60±0,14
	6 month.	0,51±0,16	0,52±0,13	0,52±0,17	0,52±0,15
	12 Month.	0,39±0,11*	0,40±0,12*	0,37±0,13*	0,40±0,10*
	24 Month.	0,39±0,13*	0,39±0,10*	0,40±0,12*	0,40±0,11
	36 month.	0,36±0,12*	0,39±0,13	0,33±0,12	0,33±0,09

**Note:** \* - statistical significance of differences between indicators with the initial indicator (after 7 days) (p <0.05)

**The condition of the gingival margin in patients after orthopedic treatment by zirconium crowns.**

The dimensions of the marginal gap in two-layer restorations varied from 68.0 to 133.0 mcm on average  $98.80 \pm 18.44$  mcm. In 8.3% of cases, marginal fit was determined in the range of 68-80 microns, in 37.5% of cases, in the range of 81-100 microns and 101-120.0 microns, respectively, in 16.7% of cases - in the range of 121-133 microns. The average marginal discrepancies in the margin, in rounded shoulder, in axial wall and occlusal area were 61.5 mcm, 90.8 mcm, 106.7 mcm and 146.2 mcm, respectively. The minimum and maximum marginal deviation was observed in the position of the edge ( $61.5 \pm 14.7$  mcm) and the occlusal area ( $146.2 \pm 32.9$  mcm).

There was no statistically significant difference in the marginal fit between the incisors and canines.

At the marginal point, the divergence in the central incisors ranged from 69.4 to 111.4 microns; in the lateral incisors, from 68.2 to 110.2 microns; in canines from 69.1 to 104.8 microns.

In the rounded shoulder position, the divergence for the central incisors, lateral incisors and canines varied between 22.6 - 82.7 mcm; 27.5 - 82.0 mcm; and 24.4 - 84.2 mcm, respectively.

In the position of the axial wall, the magnitude of the divergence varied from 75.4 to 138.8 mcm in the incisors; from 76.1 to 158.7 mcm in the lateral incisors and from 76.0 to 128.3mcm in the canines.

In the occlusal region, the values for the central incisors ranged between 107.5 - 182.0 mcm; for the lateral incisors, 110.4 - 172.2 mcm and for the canines, 114.2- 166.7 mcm.

When measuring the marginal gap in 98 monolithic restorations, the mean value was determined to be  $90.6 \pm 20.71$ mcm, the average value of the absolute marginal divergence -  $164.90 \pm 22.28$  mcm.

The marginal gap for premolars and molars averaged  $90.8 \pm 18.96$  microns and  $89.14 \pm 21.0$  microns, respectively; the absolute marginal divergence for premolars and molars was  $165.82 \pm 19.95$  mcm and  $163.11 \pm 22.37$  microns, respectively.

The value of the marginal gap in the upper jaw premolars was 3.7% higher than in the lower jaw ones. For upper and lower jaw molars, the marginal gap did not differ. Measurement of the absolute

marginal gap showed that both premolars and molars did not differ in size.

The index of the marginal gap for monolithic crowns on premolars ranged from 70.2 to 110.8 microns; on molars, from 69.6 to 104.0 microns. At the same time, the marginal gap ranging from 84 to 100 mcm was found to be more common. In 23 (47.9%) of 48 crowns on premolars, the marginal gap was determined to range from 84 - 100 mcm; in 16 (33.3%) crowns, from 70,2 - 83 microns. In 9 (18.8%) prosthetic teeth, the marginal gap ranged from 101 - 110.8 microns.

Measurement of the marginal gap in the prosthetic molars revealed the interval frequency of 79.2 - 90.6 mcm. In 28 (56%) of the 50 installed monolithic crowns on molars, the marginal gap was determined ranging in 79.2 - 90.6 microns. In 14 (28.0%) crowns, the marginal gap varied in the range of 69.6 - 78.0 mcm and in 8 (16.0%) crowns, in the range of 91–104.0 mcm. The absolute marginal gap in premolars fluctuated in the range of 130.5 - 198.6 microns, and this range mainly being 151 - 177.2 microns. The fluctuations of absolute marginal gap in 17 (35.4%) crowns were 130.5 - 150.4 mcm; in 20 (41.7%) crowns, 151.0 - 177.2 mcm and in 11 (22.9 %) crowns, 178.0 - 198.6 microns. The absolute marginal gap for molar crowns fluctuated in the range of 132- 194 mcm. The indicator for interval of 132.0 - 150.0 mcm was determined in 28.0% of cases (n = 14); 152.0 - 176.0 mcm interval was noted in 46.0% of cases (n = 23); interval ranging from 177.0 - 194.0 mcm was revealed in 26.0% of cases (n = 13) .

Measurement of the absolute marginal fit of the crowns on molars showed a statistically significant frequency of the absolute marginal gap from 152 to 176 mcm. The absolute gap from 152.0 to 176.0 microns was more common than 132.0-150.0 microns and 177.0-194.0 microns by 43.48% (p <0.05) and 39.13% ( p <0.05), respectively.

The minimum value of the marginal gap in both premolars and molars was determined in the axial wall and the maximum value - at the edge. In premolars at the marginal point, the discrepancy ranged from 82.5 to 110.8 microns, on average  $96.8 \pm 16.3$  mcm; in molars it

ranged from 72.1 to 104.0 microns, on average  $94, 5 \pm 30.2$  mcm. There was no significant difference in the mean value of the divergence at the measured points for premolars and molars. The gap in the rounded shoulder in premolars averaged  $93.7 \pm 21.1$  mcm, fluctuating in the range of  $78.8 \pm 103.4$ mcm. The average clearance for the finish line molars with rounded shoulder was  $92.4 \pm 18.1$  mcm, ranging from 82.0 to 98.6 mcm. At the axial point, the mean value of the gap in premolars and molars was  $79.7 \pm 20.8$  mcm and  $82.0 \pm 16.0$  mcm respectively; in the occlusal region ,  $89.9 \pm 17.6$  mcm and  $89.4 \pm 19.7$  microns respectively.

Overall, monolithic zirconia crowns coincide to clinically acceptable criteria.

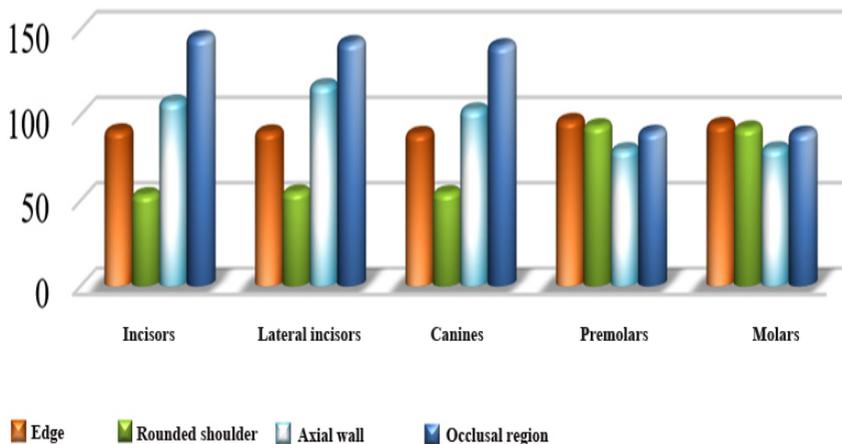
Comparative analysis between the groups showed that the gap from the marginal point in different groups of teeth did not vary. At the same time, the size of the gap in premolars' finish line with a rounded shoulder exceeded this indicator in incisors, lateral incisors and canines by 43.01% ( $p < 0.05$ ), 41.3% ( $p < 0.05$ ) and 41, 73% ( $p < 0.05$ ), respectively.

The index of the marginal gap in the molars' finish line with a rounded shoulder was higher than in incisors by 42.21% ( $p < 0.05$ ); in lateral incisors by 40.48% ( $p < 0.05$ ); in canines by 40.91% ( $p < 0.05$ ) (graph 1).

In all-ceramic zirconia crowns placed on premolars and molars, the marginal divergence in the axial wall statistically was significantly lower. Comparative analysis revealed a decrease in the marginal gap in premolars' axial wall relative to incisors by 35.01% ( $p < 0.05$ ); to lateral incisors by 47.05 ( $p < 0.05$ ); to canines by 29.2%. A similar marginal gap reduction was observed between premolars and molars with anterior crowns in the occlusal region. The gap in the occlusal region of premolars was lower than incisors, lateral incisors and canines by 61.51% ( $p < 0.01$ ); 58.29% ( $p < 0.01$ ); and 56.28% ( $p < 0.01$ ), respectively. In molars, the gap in the occlusal region was lower than in incisors, lateral incisors and canines by 62.42% ( $p < 0.01$ ); 59.17% ( $p < 0.01$ ) and 57.16% ( $p < 0.01$ ), respectively.

**Graph 1.**

**The results of measuring the marginal gap in different groups of teeth**



**Results of the clinical evaluation for zirconia restorations according to USPHS criteria**

According to the color matching characteristics, 24 restorations were assessed by the highest A score for the crowns during the following study periods: in 7-10 days and in 6 and 12 months. The examination in 18 months showed that 21 (87.5%) crowns responded to indicator A. After 24 and 36 months, the number of the restorations were 18 (75.0%) and 17 (70.8%). During examination in 18 months, it became apparent that 3 (12.5%) crowns were slightly different in shade and transparency from the adjacent tooth, while being in normal shade range corresponding to B indicator. Further studies showed that in 24 and 36 months period, 6 (25,0 0%) and 7 (29.2%) restorations, respectively, corresponded to the B indicator. Thus, throughout the entire 3-year period, a successful restoration in terms of color matching was stated.(Table 3)

**Table 3.**

**Evaluation results for anterior tooth restorations  
(I group) during the survey**

Criteria	Indicator	Research terms of the restoration					
		initial, n=24	after 6 month n=24	after 12 month., n=24	after 18 month., n=24	after 24 month., n=24	after 36 month., n=24
Color matching	A	24 (100%)	24 (100%)	24 (100%)	21 (87,5%)	18 (75,0%)	17 (70,8%)
	B	-	-	-	3 (12,5%)	6 (25,0%)	7 (29,2%)
	C	-	-	-	-	-	-
Anatomical shape	A	24 (100%)	24 (100%)	24 (100%)	24 (100%)	23 (95,8%)	20 (83,3%)
	B	-	-	-	-	1 (4,2%)	4 (16,7%)
	C	-	-	-	-	-	-
Discoloration of the edge surface	A	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-
Edge integrity	A	24 (100%)	24 (100%)	24 (100%)	23 (95,8%)	22 (91,7%)	20 (83,3%)
	B	-	-	-	1 (4,2%)	2 (8,3%)	4 (16,7%)
	C	-	-	-	-	-	-
Secondary caries	A	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-
Surface texture	A	24 (100%)	24 (100%)	21 (87,5%)	21 (87,5%)	20 (83,3%)	19 (79,2%)
	B	-	-	3 (12,5%)	3 (12,5%)	4 (16,7%)	5 (20,8%)
	C	-	-	-	-	-	-
Fracture	A	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)	24 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-

**Table 4.**  
**Results of evaluating the restorations of the chewing teeth (group II) during the examination**

criteria	Indicator	Research terms of the restoration					
		initial,n=98	after 6 month n=98	after 12 Month., n=98	after 18 month., n=98	after 24 month., n=98.	after 36 Month., n=98
Color matching	A	98 (100%)	98 (100%)	98 (100%)	94 (95,9%)	93 (94,9%)	93 (94,9%)
	B	-	-	-	4 (4,1%)	5 (5,1%)	5 (5,1%)
	C	-	-	-	-	-	-
Anatomical shape	A	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-
Discoloration of the edge surface	A	94 (95,9%)	92 (93,9%)	94 (95,9%)	94 (95,9%)	94 (95,9%)	94 (95,9%)
	B	4 (4,1%)	4 (4,1%)	4 (4,1%)	4 (4,1%)	4 (4,1%)	4 (4,1%)
	C	-	2 (2,0%)	-	-	-	-
Edge integrity	A	98 (100%)	98 (100%)	98 (100%)	93 (94,9%)	93 (94,9%)	93 (94,9%)
	B	-	-	-	5 (5,1%)	5 (5,1%)	5 (5,1%)
	C	-	-	-	-	-	-
Secondary caries	A	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-
Surface texture	A	98 (100%)	96 (97,9%)	90 (91,8%)	98 (100%)	98 (100%)	91 (92,8%)
	B	-	2 (2,0%)	8 (8,2%)	-	-	7 (7,1%)
	C	-	-	-	-	-	-
Fracture	A	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)	98 (100%)
	B	-	-	-	-	-	-
	C	-	-	-	-	-	-

When assessing the marginal integrity of the restoration, 17 (70.8%) restorations were estimated with the highest point A. The remaining 7 (29.2%) crowns for the same characteristics were assessed with point B. At the same time, in the first 7-10 days after the restoration, as well as, during examination in 6 and 12 months, all restorations corresponded to the point A.

In 18 months, 95.8% of cases (23 crowns) were estimated by the highest point A; in 24 and 36 months this indicator was revealed to be 91.7% of cases (22 crowns) and 83.3% of cases (20 crowns). In 18 months, 1 restoration (4.2%) was assessed with point B ; in 24 and 36 months, 2 (8.3%) and 4 (16.7%) restorations were scored B, respectively.(Table 4).

The surface texture of all restorations was assessed with point A in the first days and in 6 months after the installation of two-layer zirconia crowns. In a year and a year and a half, 21 (87.5%) restorations were assessed with the highest point, respectively, and 3 (12.5%) crowns with a granular texture were rated as point B. In two years, 20(83.3%) restorations and by the end of the research period, i.e. in 3 years, 19 (79.2%) restorations were estimated with the highest point A. In these stages of the research, 4 (16.7%) and 5 (20.8%) crowns were assessed with point Bravo in 2 and 3 years, respectively.

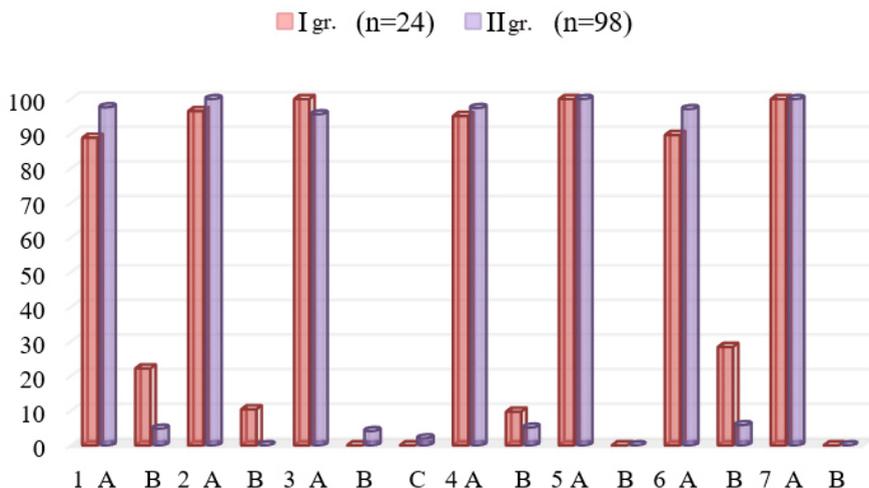
The deterioration of natural antagonist teeth averaged  $16.6 \pm 4.82\text{mcm}$  [8.2; 25.8 mcm] in 18 months, the indicator ( $p < 0.001$ ) statistically being significant compared to the initial (0 mcm). During the entire three-year research period, no case of tooth sensitivity was noted.

In 3-year follow-up period the highest point A was obtained both in group I and in group II according to the following characteristics: secondary caries and fracture (graph 2).

In terms of color matching, the highest point A was obtained on average for 88.8% and 97.6% of restorations in groups I and II, respectively.

According to the characteristics of anatomical shape, the highest point A was obtained on average by 96.5% and 100% of restorations, in groups 1 and 11, respectively. According to the characteristics of discoloration of the marginal surface, the highest point A was obtained

on average by 100% and 95.6% of restorations, respectively, in groups I and II. According to the characteristics of integrity of the edge, the highest point A was received on average by 95.1% and 97.4% of restorations, respectively, in groups I and II. According to the characteristics of surface texture, point A was determined on average in 89.6% of restorations in group I and in 97.1% of restorations in group II. Relatively better results were obtained with monolithic zirconia restorations, however, there were no statistically significant differences between the groups.



1 - color matching; 2 - anatomical shape; 3 - discoloration of the edge surface; 4 - marginal integrity; 5 - secondary caries; 6 - surface texture; 7 - fracture

**Graph 2. Average results of clinical evaluation of restorations during 3 years of follow-up according to USPHS criteria**

According to the USPHS criteria, marginal adaptation was assessed by point A (excellent) in 92.8% of cases (91 restorations); in 7.1% of cases (7 restorations) obtained point B (good).

Thus, the results obtained show that monolithic zirconia crowns can be promising in terms of survival and clinical parameters.

Based on the results obtained, it can be concluded that monolithic zirconia restorations made using CAD / CAM technology are a viable option for restoring individual posterior teeth. This study found no fracture of the monolithic zirconium crown and a success rate of 97.4%. However, long-term, randomized controlled trials with a large sample of patients are required to adequately document the potential benefits of monolithic zirconia over other restorations. In this study, monolithic zirconia crowns showed excellent overall clinical survival in a variety of clinical evaluations. Based on observations over a 3-year period, it can be concluded that both fixed 2-layer and monolithic zirconia crowns are a promising option for prosthetics of premolars and molars.

Metal-ceramic restorations based on teeth have shown their success in long-term clinical observation and were considered the gold standard for metal-ceramic prostheses. However, the demand for metal-free restorations has led to a significant development of all-ceramic materials, which can now be considered a suitable alternative to porcelain-fused-to-metal restorations. We assessed the survival rate and outcome of technical and biological complications of 2-layer and monolithic zirconium dioxide crowns. after 3 years of installation. The survival rate of the zirconia crowns was high and some technical and biological complications were observed. We did not observe chips of veneering porcelain, which is the most common technical complication.

## CONCLUSIONS

1. The study revealed that the fixation of zirconium crowns did not lead to deterioration of the periodontal tissues. An index assessment of the state of the periodontium and gums showed no statistically significant difference in OHI-S, PMA and Mülleman-Cowell index between the groups with classic two-layer and solid zirconium restorations [1, 2,8].

2. The OHI-S, PMA and Müllemann index values in patients with a thin biotype and two-layer crowns are found to be slightly higher than those with a thick gingival biotype. In patients with a thin biotype after fixation of monolithic restorations, the OHI-S level was lower, the PMA index was higher, but the value of the Müllemann index in patients with a thick and thin biotype did not differ [3, 8].
3. The size of the gap in premolars' finish line with a rounded shoulder was higher than in incisors (43.01%,  $p < 0.05$ ), lateral incisors (41.3%,  $p < 0.05$ ) and canines (41.73%,  $p < 0.05$ ). The index of the marginal gap in molars' finish line with a rounded shoulder was higher than in incisors by 42.21% ( $p < 0.05$ ); lateral incisors by 40.48% ( $p < 0.05$ ); canines by 40.91% ( $p < 0.05$ ). In premolars, the marginal gap in the axial wall was reduced by 35.01% ( $p < 0.05$ ) relative to incisors; by 47.05% ( $p < 0.05$ ) relative to lateral incisors and by 29.2% relative to canines. The gap in the occlusal area of premolars is lower than that of incisors by 61.51% ( $p < 0.01$ ), lateral incisors by 58.29% ( $p < 0.01$ ) and canines by 56.28% ( $p < 0.01$ ). In molars, the gap in the occlusal area is lower than that of incisors, lateral incisors and canines by 62.42% ( $p < 0.01$ ); 59.17% ( $p < 0.01$ ) and 57.16% ( $p < 0.01$ ), respectively [5, 9, 10].
4. In 98 monolithic restorations, the average value of the marginal gap was  $90.6 \pm 20.71$   $\mu\text{m}$ ; the average value of the absolute marginal divergence was  $164.90 \pm 22.28$   $\mu\text{m}$ . The marginal gap of premolars and molars averaged  $90.8 \pm 18.96$  microns and  $89.14 \pm 21.0$  microns, respectively, the absolute marginal divergence was  $165.82 \pm 19.95$  and  $163.11 \pm 22.37$  microns, respectively. The gap in premolars' rounded shoulder averaged  $93.7 \pm 21.1$   $\mu\text{m}$ , fluctuating in the range of  $78.8 \pm 103.4$   $\mu\text{m}$ . The average gap for molars' finish line with rounded shoulder was  $92.4 \pm 18.1$   $\mu\text{m}$ , ranging from 82.0 to 98.6  $\mu\text{m}$ . At the axial point, The mean value of the gap in premolars and molars was  $79.7 \pm 20.8$   $\mu\text{m}$  and  $82.0 \pm 16.0$   $\mu\text{m}$ , respectively, at the axial point;  $89.9 \pm 17.6$   $\mu\text{m}$  and  $89.4 \pm 19.7$   $\mu\text{m}$  in the occlusal area [4, 6, 7].

5. It was estimated that in a 3-year follow-up period the highest point A was obtained with two-layer and monolithic restorations according to the following characteristics: secondary caries and fracture. In terms of color matching, the highest point A was obtained on average by 88.8% and 97.6% of two-layer and monolithic restorations, respectively. According to the characteristics of the anatomical shape, the highest point A was received on average by 96.5% of two-layer restorations and 100% of monolithic crowns. In terms of discoloration of the marginal surface, the highest point A was obtained on average by 100% and 95.6% of two-layer and monolithic restorations, respectively. In terms of marginal integrity, 95.1% of two-layer restorations and 97.4% of monolithic restorations were assessed with the highest point A on average. In terms of surface texture, 89.6% of two-layer restorations and 97.1% of all-ceramic zirconia restorations were noted to obtain point A on average. The survival rate for two-layer and monolithic restorations was determined to be 100%, and 97.9%, respectively [11].

## **PRACTICAL RECOMMENDATIONS**

1. It is recommended to determine the gingival biotype and include the information in the patient's diagnostic card before the restoration, since the biotype allows to get an idea on tissue processing and procedures to be applied in a particular situation as well as to be aware of the expected restoration result.
2. It is advisable every 6 months to monitor the quality of prosthetics and timely elimination of complications that might have arisen.
3. Ceramic crowns on CAD / CAM milled zirconia frames should be preferred for restorations.

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