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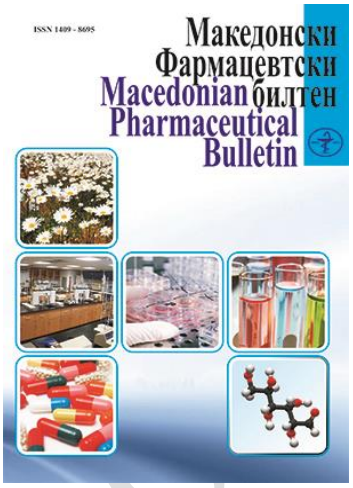

Title: Comparative evaluation of internal and marginal fit in zirconia crowns fabricated from digital and conventional impression methods

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Comparative evaluation of internal and marginal fit in zirconia crowns fabricated from digital and conventional impression methods

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Abstract

The accuracy of the internal and marginal fit of crowns is an important criteria for the clinical quality, success and durability of prostheticdental restorations. Inadequate fit of crowns is potentially harmful to the prepared tooth and the periodontium. It allows the penetration and adhesion of oral bacteria that cause secondary caries, gingival irritation and hypersensitivity. Aesthetics, fracture resistance and marginal accuracy are the main determinants of dental crowns. Therefore, the main objective of this study is to determine the internal and marginal accuracy of all-ceramic crowns.

In this *in vitro* study, two groups of zirconia crowns were fabricated using different impression techniques: digital and conventional impression technique. The precision of the crowns was measured microscopically at nine standardized points, after which a statistical processing was used to obtain the required results. Digital impression was found to be more precise than conventional, and crowns from the digital impression/zirconia group had lower values, i.e. they fitted the prepared tooth more precisely.

Keywords: zirconium crowns, digital/conventional impression, marginal/internal fit.

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Introduction

Advances in ceramic material science lead to improvements in the physical properties and aesthetics of all-ceramic restorations, and make frequent use of these restorations. For many years, dentists research whether and how crowns fit (Demir et al., 2014), because apart from the aesthetic role, a very important criteria are the internal and marginal fit, which plays an important role in the accuracy and success of the crowns (White et al., 1994). According to McLean and von Fraunhofer (1971), a clinically acceptable marginal gap between the dental crown and prepared tooth should be 120 μm.

Dental impressions are one of the key steps for a successful prosthetic restoration and they can greatly affect the accuracy of the restoration. All stages of prosthetic restoration manufacturing play a role in the accuracy of the restoration. Impressions can be taken with the widely used elastomeric, silicone, materials and digital impressions. The comparison between digital and conventional impression techniques is very current in the literature (Yuzbasioglu et al., 2014).

Dental digital impressions are becoming increasingly popular because they simplify the impression process, result in greater accuracy, reduce the time of the patient visit, and allow a digital connection to the dental laboratory. Digital impressions do not involve the discomfort of taking a conventional impression from the patients mouth, and the 3D digital models are highly precise and accurate. The scanned surfaces can be immediately sent to the dental laboratory for fabrication process. These impressions increase patient comfort, reduce the possibility of error, and reduce the time it takes to complete a case (Holland et al., 2008).

Conventional impression method is a critical component in the fabrication of fixed prosthetic restorations. Conventional impressions such as polyvinyl siloxanes or polyethers are a complicated procedure for both the dentist and the patient. Factors that reduce the accuracy of conventional impressions can include: incorrect tray size, bleeding from the gums, inadequate sulcus retraction, limitations in the hydrophilicity of the material, short working phase, patient movement, tearing and deformation of the impression upon removal from the mouth, dimensional instability, required disinfection, and inadequate pouring (Christensen, 2005). One study reported that more than 89% of

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impressions sent to a dental laboratory were unsatisfactory, with one or more errors (Samet et al., 2005).

The increasing demand for highly aesthetic dental crowns has contributed to the increase in the use of dental ceramics for both, the anterior and posterior regions of the oral cavity. The use of zirconia has increased in recent years due to its aesthetics and biocompatibility. It has excellent mechanical properties that make it more commonly used than other ceramics in restorative dentistry (Blatz , 2002) . Zirconium oxide is used as the core of the future crown. Although there are several types of zirconia, three are most commonly used in dentistry: yttrium-stabilized tetragonal zirconia (Y-TZP), magnesium-stabilized partial zirconia (Mg-PSZ), and aluminum-stabilized zirconia, and all of them have high fracture resistance and biocompatibility.

Materials and methods

In this *in vitro* study, a phantom jaw model was used, where teeth were prepared. The preparation method is standardized in this type of study: a chamfer finishing line with a width of 1 mm, 6o conicity of the prepared tooth, 1.5 mm removal of tooth substance from the axial and 2 mm from the occlusal side. Then, the impression technique was obtained .

The conventional impression was performed in two stages with condensation C-silicones, Xantopren/Optosil system (Kulzer GmbH). The first stage was with a heavy body silicone mass with a dough-like consistency, with polymerization time of 5 min, while the second was a correction phase, with a low-viscosity silicone mass, light body, with polymerization time of 5-6 minutes. Impressions were taken with standard tray and it was poured with dental stone to make a working model.

The dental stone working models obtained by casting conventional impressions were used for scanning, designing, machining and milling zirconium blocks to obtain fifteen zirconium crowns.

The production of these digital impression crowns began with scanning the models using a scanner (Open Technologies, Italy), based on instructions data for each tooth individually. The camera of this scanner allows 5-axis scanning, and a precision of up to five microns. The prepared tooth, antagonists and bite were scanned.

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The scanner transferred the data to software (Exocad, Germany). First, the material that should be milled was determined, as well as the color from which the crowns would be produced. The system determined the finishing line, as well as the gap, which was 40 μm. This gap was on the entire crown except for the finishing line. The thickness of the crowns was 1 mm.

The intraoral impression scanner works on the basis of the emission of visible blue light from light-emitting diodes (LEDs). By emitting these wavelengths, a series of images and a 3-D model are formed. The scanner should be 10-15 mm away from the teeth.

To make the digital impression, a contrast spray was first applied in a thin layer, Apollo di speed spray. This layer was applied to the teeth that were scanned on the phantom model in order to be visible and recognizable for the optical scanner. After the system checked the surfaces and approved this data in the form of a file, it was sent to the production center. These data, 3D models, were used to design and manufacture fifteen crowns. According to this design, data was sent to the CAM cutting machine and the processing of the zirconium blocks begins. This machine cuts and mills the blocks in 5 axes in space.

The manufactured crowns were 23% larger than required, a dimension that is expected to contract during the sintering process. Sintering was performed in a furnace at a temperature of 1450 ^{o}C for 8 hours.

After the crowns were fabricated, their internal and marginal fit were examined. The replica technique was the method used for their testing (Trifkovic et al., 2012). This technique is a method that uses a low-viscosity silicone mass to fill the interior of the crowns and place them on the prepared tooth. This thin silicone layer was a replica of the cement layer, and its thickness was measured microscopically at nine reference points (Fig. 1).

Fig. 1

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Results and discussion

The study examined 30 fabricated crowns, which were divided into two groups using two impression methods:

I. Digital impression using Apollo DI, Sirona, (Sirona Dental Systems GmbH, Germany) intraoral digital scanner.

II. Conventional two-phase impression method using polyvinyl siloxanes (Zhermarck, condensation, C silicones) and standard trays.

The crowns of each group were divided into two groups:

IA Digital impression/CAD/CAM of zirconia crowns (read further: Digital impressions/zirconia);

IID Conventional impression/CAD/CAM of zirconia crowns (read further: Conventional impressions/zirconia);

Table 1

The average values of the P1 points at marginal space from the digital impression/zirconia group were the lowest and were 0.110±0.080, in the range 0.000 to 0.322, while the average values of the P1 points at marginal space for conventional impression/zirconia were 0.251±0.200, in the range 0.085 to 0.669.

The average values of the P9 points at marginal space in the digital impression/zirconia group were the lowest and were 0.080±0.200, in the range 0.000 to 0.234, while the average values of the *P9 points* at marginal space in the *conventional impression/zirconia group* were 0.210±0.100, in the range 0.064 to 0.514 (Table 1).

The difference registered between the average values for point *P1* and *P9* in the marginal space between digital and conventional impressions according to the Mann-Whitney U test was statistically significant at $p<0.05$. in both groups (Table 2) .

Table 2 and 3

The average values of the P2 points at internal fitting in the digital impressions were lowest in the digital impressions/zirconia group as 0.076±0.030, in the range 0.033

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to 0.118, and the average values of the P2 points at internal space in the conventional impressions/zirconia group as 0.159±0.080, in the range 0.079 to 0.323. The remaining internal fitting points are shown above in Table 3.

The difference registered between the average values for the internal fitting points between digital and conventional impressions according to the Mann-Whitney U test was statistically significant for $p<0.05$ at the points: P2, P4, P5, P6 and P8 (Table 4)

Table 4
Fig. 1 and 2

Comparison of the marginal and the internal fit of fixed dental restorations manufactured with digital and conventional impression methods shows that those manufactured with the digital impression method result with better fitting. Also, they have statistically significant smaller marginal and internal spaces than those made with the conventional impression method (Fano et al., 1992). These findings highlight the potential advantages of the so-called fully digital workflow (Cardelli et al., 2011). The results of this study present that the combination of digital impression and CAD/CAM zirconia manufacture the most precise dental crowns, with mean marginal space values of 0.110 mm at P1, and 0.080 mm at P9. These results are in accordance with the data of some published studies comparing digital and conventional impression methods (Syrek et al., 2010).

The marginal fit of these crowns was assessed by measurements at points P1 and P9 and comparison between IA (digital impressions/zirconia) and IID (conventional impressions/zirconia), and therefore, better marginal fit was shown by the IA group, i.e. CAD/CAM zirconia crowns obtained by digital impressions (Almeida et al., 2013) (Table. 1).

Our observations are in accordance with literature data that compared marginal fit between all-ceramiccrowns, CAD/CAM zirconia crowns manufactured with a digital intraoral camera and all ceramic crowns manufactured with polyvinyl siloxanes (conventional impressions).

The difference registered between the average values for points P1 and P9 on the marginal fit between digital and conventional impressions according to the Mann-Whitney U test was statistically significant at $p<0.05$ ($p=0.003$) (Table 2) .

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Table 3 represents the internal fit between IA and IID and digital impressions/zirconia group, and had a more precise internal fit than the IID group, i.e. conventional impressions/zirconia (Rathika et al., 2017). These measurements were also statistically significant, as shown above at Table 4.

Additionally, there are several reasons for the less precise fit of crowns obtained with conventional impression method, and the most important ones are: the numerous stages of manufacturing process, impression deformation, dimensional changes of impressions, and incorrect manipulation with the impression materials (Fano et al., 1992). In this sense, this is one of the main reasons for the digitalization in dentistry.

Conclusion

The clinical significance of this study are the findings that the combination of digital impression and CAD/CAM technology on zirconia crowns produces a clinically acceptable marginal fit that according to McLean and von Fraunhofer's estimate of a clinically acceptable marginal gap of 120 µm which protects patients from gingivitis, caries, periodontal disease and hypersensitivity. Despite this, technological improvements increased digitalization need to be carefully assessed for the specific situation of the work environment. Therefore, such technology requires frequent updates and/or upgrades that need to be actively monitored.

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Резиме

Компаративна анализа на внатрешното и маргиналното налегнување на цирконiумски коронки произведени со дигитално и конвенционално отпечатување

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Клучни зборови: цирконiумски коронки, дигитално/конвенционално отпечатување, маргинално/внатрешно налегнување.

Прецизноста на внатрешното и маргинално налегнување на коронките е важен критериум за клиничкиот квалитет, успех и долготрајност на протетичките реставрации. Несоодветното налегнување на коронките е потенцијално штетно за препарираниот заб и за пародонциумот, затоа што се овозможува навлегување и адхерирање на оралните бактерии кои предизвикуваат секундарен кариес, гингивална иритација и хиперсензитивност. Естетиката, отпорноста на фрактуртаа и маргиналната точност се главни детерминанти на денталните коронки. Затоа, како главна цел на оваа студија е да се испита внатрешната и маргинална точност на целосно керамичките коронки. Во оваа *in vitro* студија се изработија две групи на цирконiумски коронки добиени со различни методи на отпечатување: дигитално и конвенционално отпечатување. Прецизноста на коронките се мереше микроскопски во девет стандардизирани точки, по што со статистичка обработка се дојде до бараните резултати. Дигиталното отпечатување се покажа попрецизно од конвенционалното, и коронките од групата дигитални отпечатоци/цирконiум имаат пониски вредности односно најпрецизно налегнуваат на забното трупче.

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Table 1. Average values of marginal space of points P1 and P9 in both groups

	Average Mm	Confidence -95%	Confidence +95%	Number	Std.Dev.	Minimum mm	Maximum Mm
P1 IA	0.110	0.064	0.157	15	0.084	0.00	0.322
P1 IID	0.251	0.161	0.342	15	0.164	0.085	0.669
P9 IA	0.080	0.049	0.111	15	0.056	0.000	0.234
P9 IID	0.210	0.135	0.286	15	0.135	0.064	0.514

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Table 2. Mann-Whitney U test for point P1 and P9 of marginal space

	Rank Sum – Digital output/circuit.	Rank Sum – Conventional otput/circuit.	U	Z	*p-value*
P1	161.000	304.000	41.000	-2.945	0.003
P 9	145.000	320.000	25.000	-3.609	0.000

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Table 3. The average values of the points of internal fitting P2, P3, P4, P5, P6, P7, P8

		Average	Confidence -95%	Confidence +95%	Number	St. Dev	Minimum	Maximum
P2	IA	0.076	0.060	0.091	15	0.028	0.033	0.118
P2	IID	0.159	0.116	0.202	15	0.077	0.079	0.323
P3	IA	0.112	0.076	0.148	15	0.065	0.040	0.306
P3	IID	0.138	0.089	0.187	15	0.088	0.056	0.390
P4	IA	0.151	0.115	0.187	15	0.065	0.067	0.256
P4	IID	0.331	0.219	0.443	15	0.203	0.162	0.901
P5	IA	0.137	0.104	0.171	15	0.060	0.062	0.287
P5	IID	0.304	0.225	0.383	15	0.143	0.149	0.661
P6	IA	0.130	0.097	0.164	15	0.061	0.042	0.247
P6	IID	0.341	0.253	0.428	15	0.158	0.180	0.789
P7	IA	0.105	0.080	0.130	15	0.045	0.037	0.185
P7	IID	0.128	0.091	0.165	15	0.067	0.070	0.290
P8	IA	0.078	0.063	0.093	15	0.027	0.007	0.121
P8	IID	0.144	0.105	0.183	15	0.070	0.049	0.310

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Table 4. Mann-Whitney U test for P2, P3, P4, P5, P6, P7 and P8 points of internal fitting

Rank Sum – Digital output/circuit.	Rank Sum – Conventional otput/circuit.	U	Z	*p-value*
P2 154.500	310.500	34.500	-3.215	0.0013
P3 213.000	252.000	93.000	-0.788	0.431
P4 146.500	318.500	26.500	-3.546	0.000
P5 139.500	325.500	19.500	-3.837	0.000
P6 127.000	338.000	7.000	-4.355	0.000
P7 214.000	251.000	94.000	-0.747	0.455
P8 149.000	316.000	29.000	-3.443	0.000

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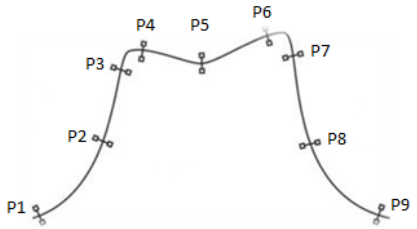

Fig. 1. Reference points at which the thickness of the silicone layer is measured (P1 and P9 - marginal space, P2, P3, P4, P5, P6, P7, P8 - internal fitting of dental crowns).

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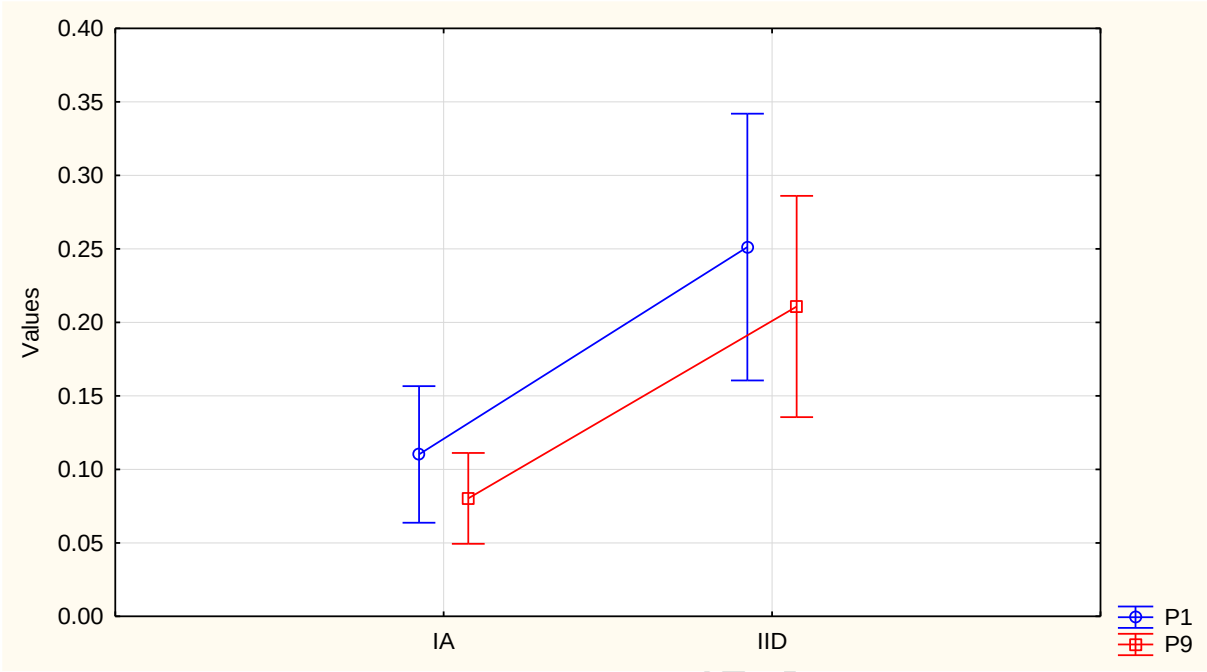

Fig. 2. Marginal fit at points P1 and P9 in groups IA and IID (digital impression/zirconia vs. conventional impression/zirconia).

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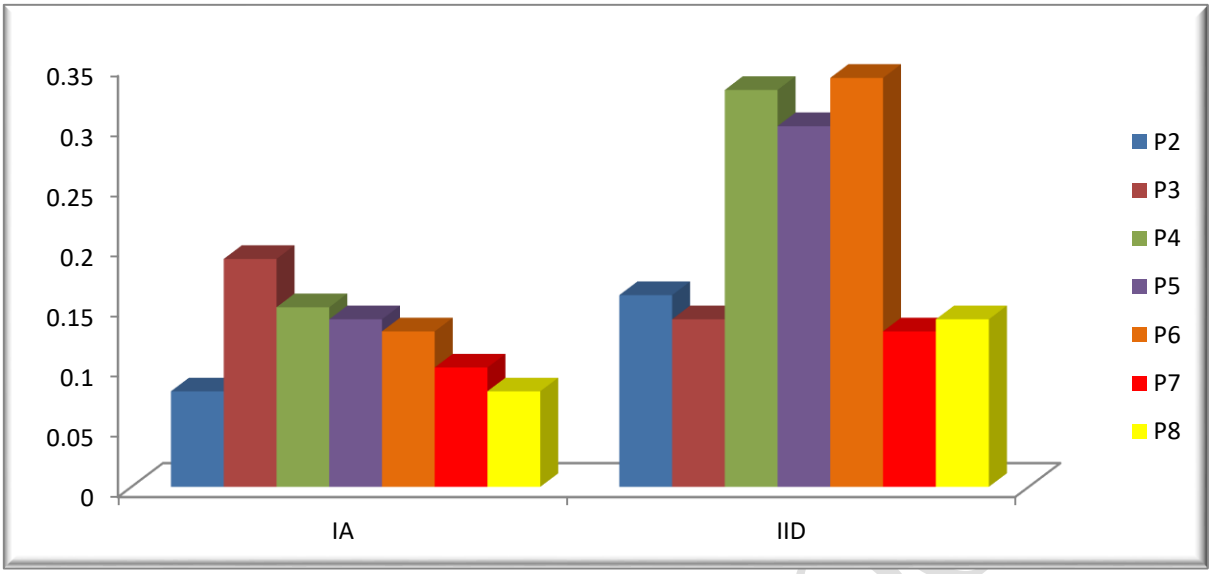

Fig. 2**.** Internal fitting at points P2, P3, P4, P5, P6, P7, P8 in IA and IID groups (digital impression/zirconia vs. conventional.impresion/zirconia).

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