THE PUBLISHING HOUSE
OF THE ROMANIAN ACADEMY

PROCEEDINGS OF THE ROMANIAN ACADEMY, Series A,
Volume 18, Number 4/2017, pp. 345–352

MARGINAL AND INTERNAL FIT OF PARTIAL-RETAINER CAD/ CAM ZIRCONIA FIXED DENTAL PROSTHESES

Adrian CANDEA, Anca JIVANESCU, Marius LERETTER, Mihai ROMINU

"Victor Babes" University of Medicine and Pharmacy of Timisoara, 9 Revolutiei Blvd., 300070, Timisoara, Romania
Corresponding author: Anca Jivanescu, E-mail: ajivanescu@yahoo.com

Abstract. The aim of this study was to evaluate the marginal and internal adaptation of partial retained fixed dental prostheses milled from semi-sintered zirconia blocks. Standardized preparations for retainers were performed on abutment teeth of a typodont maxillary model. Two preparation designs were considered in this study: occluso-proximal preparations and palato-buccal preparations, following two axes of insertion for the restorations – a vertical axis and a transversal one. The assessment of the marginal and internal adaptation was carried out using the cement replica technique and image-processing software was used for the measurements. The results were statistically analyzed using ANOVA ($\alpha = 0.05$). Within the limitations of this study, zirconia inlay-retained fixed partial dentures showed an average marginal and internal fit within clinically acceptable limits.

Key words: preparation design, zirconia fixed partial denture, marginal and internal fit, CAD/CAM computer aided design/computer aided manufacturing, PRFDP-partial retained fixed dental prostheses.

1. INTRODUCTION

Single missing tooth situations can be approached in several ways [1]. The traditional/conventional prosthetic treatment requires circumferential preparation of the abutment teeth adjacent to the gap in order to receive full crown retainers. Tooth preparation for an all-ceramic crown demands 63–73% tooth hard tissue removal and a major risk of pulpal and periodontal reactions [2–7].

Today, dentistry focuses upon preservation and biological aspects rather than upon the surgical approach of the dental treatment. Due to the continuous development of dental materials and adhesive techniques, minimally invasive therapeutic alternatives are becoming widespread [5]. When implant therapy is neither possible nor indicated, fixed dental prostheses (FDP) with minimally-invasive retainers (partial crowns, inlays, onlays, wings) may be a valid alternative [1–3].

From the great variety of materials used with CAD/CAM (computer aided design/computer aided machining) technology, yttria stabilized polycrystalline tetragonal zirconia possesses superior mechanical properties, displaying high flexural strength, resistance to traction and compression and high fracture toughness [8, 9]. Several authors state that all-ceramic zirconia-based restorations provide a promising alternative to restorations with metal framework [8, 9], showing excellent clinical performance on medium- and long-term observation time [9–11].

Marginal discrepancies have a negative impact on the clinical success of a fixed dental prosthesis. Most authors agree that marginal openings below 120µm are clinically acceptable [9, 11, 2–15], although some authors consider clinically acceptable marginal openings below 100µm [16].

The present study investigates the marginal and internal fit of all-ceramic partial-retainer fixed dental prostheses(PRFDP), made with the Lava CAD/CAM system (3M ESPE, Seefeld, Germany), comparing two preparation design for inlay-retained fixed partial dentures, in order to evaluate their suitability for clinical use. The study compares minimally-invasive standard inlay-retained fixed dental prostheses with occluso-cervical insertion axis to a new design of minimally-invasive partial-retainer fixed dental prostheses with palato-buccal insertion axis.

2. MATERIALS AND METHODS

A maxillary typodont (Frasaco, Tettnang, Germany) with missing second premolars was used as the model for this in vitro experiment. Standardized preparations for the retainers were performed by the same operator on the abutment teeth of the model.

2.1. Preparation Design

Two preparation designs were considered as follows: occluso-proximal preparations in the right quadrant and palato-buccal preparations in the left quadrant, following two different axes (a vertical occluso-cervical axis and a transversal palato-buccal axis). The first preparation design has the following characteristics: height of the horizontal cavity = 2mm, isthmus width = 2mm, width of proximal cavity = 3.5mm, height of the proximal cavity = 3.5mm. The palato-buccal preparation has the following reduction amount: bucco-palatal width = 5mm, cervico-occlusal height = 2mm, palatal reduction with a 0.5mm chamfer for a height of 3mm. Diamond rotary instruments were used for the preparation (Jota AG, Rüthi, Switzerland). The margins of the preparations were clearly defined and all the internal angles and edges were rounded.

After the preparation, ten impressions were taken by the same operator with vinylpolysiloxane (Express XT, 3M ESPE, Seefeld, Germany), using a one-step technique. Standard metal impression trays (Hi-Tray Metal , Zhermack, Italy) were used to carry the impression material.

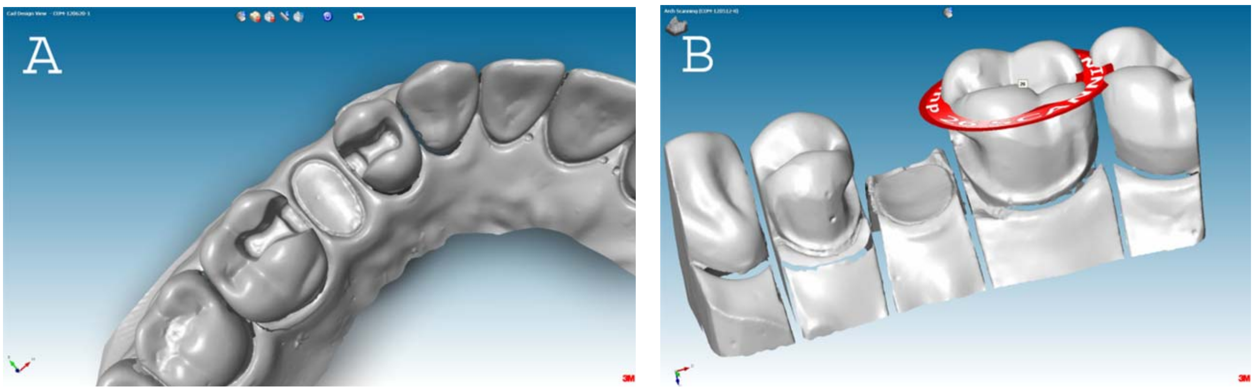

Fig. 1 – The digital model of the prepared abutments for the vertical (A) and transversal (B) axis.

2.2. Manufacturing process

The impressions were poured in a class IV die stone (Thixo-Rock, Bredent, Senden, Germany) and the same technician prepared each of the ten stone models. The models were scanned using Lava Scan ST (3M ESPE, Seefeld, Germany), thus resulting in digital models. (Fig. 1). For each of the ten digital models, two zirconia fixed partial dentures (corresponding to the two preparation designs) were designed using Lava Design CAD 7.2 software (3M ESPE, Seefeld, Germany) (Fig. 2). A standardized protocol was used (full contour modeling, virtual cement layer of 25μm and connector size of 9–12mm^2).

Lava Plus semi-sintered zirconia blocks were milled and the restorations immersed into Lava Frame Shade (3M ESPE, Seefeld, Germany) for 2 minutes. The milled blocks were then left to dry at room temperature. The process of sintering to full density was completed in the Lava Therm oven for 10.5 hours at 1450 °C. Adjustments were performed under 6X magnification (Mantis, Vision Engineering, Surrey, England) using Presto Aqua II (NSK, Tokyo, Japan) handpiece and code red rotary instruments (NTI, Kahla, Germany). Individualization was achieved using Lava Plus shades and pigments (3M ESPE, Seefeld, Germany). Following this process twenty three-unit zirconia PRFDPs were made, ten for each group.

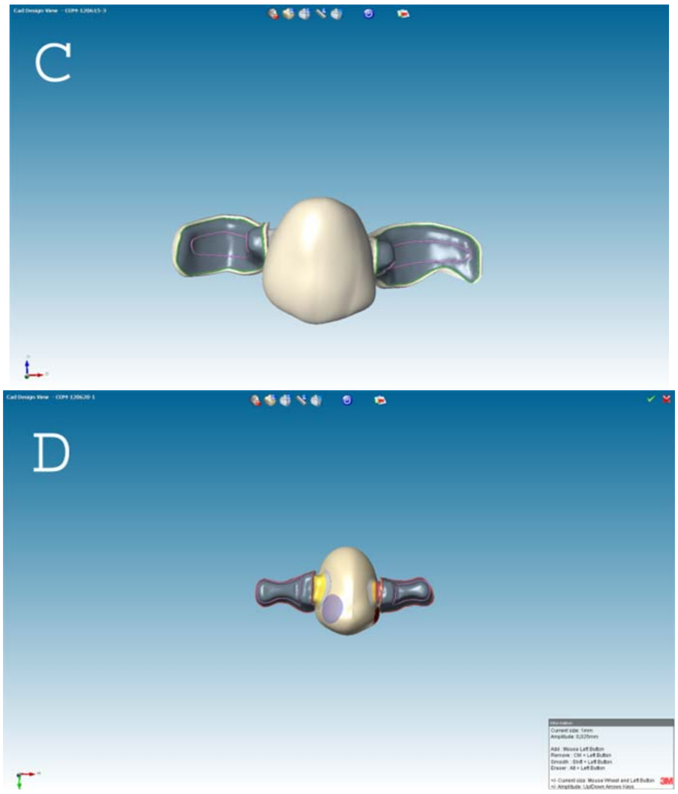

Fig. 2 – The design of the two partial-retained fixed dental prostheses.

2.3. Microscope examination

Light body silicone (Fit Checker II, GC, Tokyo, Japan) was injected on the preparations of the typodont model, and then each of the twenty PRFDPs was seated on the abutments under finger pressure, reproducing the clinical situation of the luting process (Fig. 3). After the setting of the light body silicone, stabilization was achieved using a regular body silicone (Express XT Regular Body, 3M ESPE, Seefeld, Germany). Standardized mesio-distal sections of the silicone replicas were obtained with the aid of a razor blade, parallel to the axis of the restoration, following the vertical axis for the first group, respectively the transversal axis for the second group. The width of the light-body silicone replica was considered to represent the fit of the restoration.

Further on, the measurement points were defined. One hundred points/ abutment/ section were considered. Measurement points were defined with two marginal values per section analyzed for the assessment of the marginal fit (marginal cervical and marginal occlusal for the vertical axis group and 2 points for the marginal buccal and marginal palatal for the transversal axis group. In order to assess the internal fit of the restorations all the 100 points/section were analyzed.

Fig. 3 – The final restorations and the corresponding sectioned silicone replicas.

For each restoration, two silicone replicas were obtained. In this manner, two values were obtained for each measurement point, corresponding to the two silicone replicas of each PRFDP. An average value was calculated for every one of the defined points/restoration. Following the described technique for each group of ten zirconia PRFDPs, the gaps between the restoration and the abutments were measured.

In addition photos of the silicone replicas were obtained with the aid of a stereomicroscope (Zeiss Stemi 2000 with CL 1500 ECO illuminator, Carl Zeiss Microscopy GmbH, Jena, Germany) linked to a photo camera (Canon EOS 550D, Japan) through a camera adapter (T2-T2 DSLR 1.6x, Carl Zeiss Microscopy GmbH, Jena, Germany) at 1.25 magnification (Fig. 4).

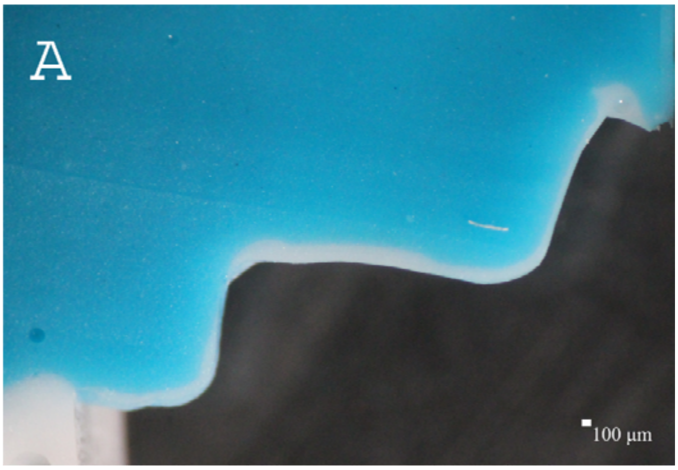

Fig. 4 – Optical microscope photos of the silicone replicas.

Imaging computer software was used for the measurements. First, the area corresponding to the cement layer was selected, cut and calibrated using Adobe Fireworks CS6 (Adobe, USA). Then, it was imported in custom-made image software (Dental Map – Image Processing) (Fig. 5). The results of the image processing were automatically exported in Office Excel (Microsoft, USA) to be analyzed. Each measurement was obtained and recorded by the same examiner.

Fig. 5 – Calibrated processed images **A.** Group I, **B.** Group II, **C.** Dental Image Processing software.

2.4. Statistics

The statistical analysis was performed using Office Excel for Windows (Microsoft Office 2010, Microsoft, USA). The minim, maxim, medians, averages and standard deviations were calculated for every location (marginal cervical, internal, marginal occlusal, marginal buccal, internal and marginal palatal) and every abutment. One-way analysis of variance (ANOVA) was chosen to examine the differences of fit between the two groups of PRFDPs at a 5% level of significance.

3. RESULTS

The results are presented in Table 1. For the vertical axis group of PRFDP (I), the average marginal cervical gap was of 59.8 ± 13μm for the mesial retainer, 56 ± 12.4μm for the distal retainer, 61.9 ± 12.2μm for the mesial retainer, and 47 ± 14.7μm for the distal retainer. The average internal gap was 120.7 ± 60.4μm for the mesial retainer and 121.8 ± 58.2μm for the distal retainer.

For the transversal axis group of PRFDP (II), means and standard deviations were recorded as follows: the average marginal buccal gap 114 ± 14.7μm for the mesial retainer, 137.2 ± 22.6μm for the distal retainer, marginal palatal gap was of 91.3 ± 23.8μm for the mesial retainer and 89.7 ± 31μm for the distal retainer. The average internal gap was 147.8 ± 40.4μm for the mesial retainer and 190.7 ± 49μm for the distal retainer.

The average marginal gap width was of 56.2 ± 13.8μm for the first group (I) and 108 ± 30.2μm for the second group (II). The average internal gap width was 121.3 ± 59.3μm for the first group (I) and of 169.2 ± 49.8μm for the second group (II).

Table 1

Average marginal and internal gap widths, standard deviations, minima, maxima and medians for each location

Design	Abutment tooth	Location	Average/ STDEV	Minimum	Maximum	Median
Group I	Upper Right First Premolar	Marginal cervical	59.8 ±13	42	77	62.5
		Marginal occlusal	61.9±12.2	42	79	64.5
		Internal	120.68±60.4	12	272	110
	Upper Right First Molar	Marginal cervical	56±12.4	40	77	52.5
		Marginal occlusal	47.1±14.7	22	72	49.5
		Internal	121.85±58.2	20	253	118
Group II	Upper Left First Premolar	Marginal buccal	114±14.7	96	141	110
		Marginal palatal	91.3±23.8	57	130	92.5
		Internal	147.78±40.42	45	283	141
	Upper Left First Molar	Marginal buccal	137.2±22.66	107	184	131
		Marginal palatal	89.7±31.1	34	130	93.5
		Internal	190.67±49.07	34	298	195

The ANOVA test indicated statistically significant differences between the groups regarding both the marginal ($p \ll 0.001$) and the internal fit ($p \ll 0.001$). – see Table 2.

Table 2

One-way ANOVA on the measurement location factor (AveMW I, AveMW II)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AveMW I	10	562	56.2	44.16389
AveMW II	10	1080.5	108.05	289. 667

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13442.11	1	13442.11	80.67755	**4.53697E-08**	4.413873419
Within Groups	2999.075	18	166.6153			
Total	16441.19	19				

4. DISCUSSION

The adequate marginal and internal adaptation is one important factor to be considered regarding the prognosis of a fixed dental prosthesis [–19].

There is evidence that excessive internal fit discrepancies of fixed restorations may lead to reduced fracture resistance [20, 21] and failure of the veneering porcelain [11, 14], because a large thickness of the cement layer decreases the flexural strength of ceramics [22]. There is also evidence that a thick resin cement layer implies higher water absorption, negatively affecting the mechanical properties of the fixed restorations [23].

Also, a deficient marginal fit leads to plaque retention and consequently to secondary caries, pulpitis, gingivitis, periodontitis [17–19]. However, few studies have been conducted on the internal fit of all-ceramic partial-retainer fixed dental prostheses, and the direct influence of the internal fit upon the strength and consequently upon the prognosis of this treatment method. Marginal openings below 120µm are considered clinically acceptable by most of the authors [9–11, 12–15]. An internal space of 50–100µm has been considered acceptable regarding the properties of the resin cements [24] but some researchers consider acceptable also an internal space of 200–300µm [25]. In a study on the clinical fit of all-ceramic three-unit FPDs using the replica technique, Reich et al. reported values of 80±50µm for the marginal gap, 132 ± 89µm for the mid-axial gap, 195 ± 118µm for the axio-occlusal transition gap, respectively 215 ± 109µm for the occlusal gap [26].

The present study revealed a highly significant difference between the groups regarding both the marginal ($p \ll 0.001$) and the internal fit ($p \ll 0.001$) – see Table 2).

The average marginal gap width recorded in the present study was of 56.2 ± 13.8µm for the first group (I) and 108 ± 30.2µm for the second group (II). The values of the average marginal gap were inferior to the acceptable gap size of 120µm, reported by most of the authors [17, 18, 27]. Also, the values recorded for the first group (I) were lower than those recorded by Reich et al. in a similar study investigating Lava FPDs retained on full-crowns [26].

Addi *et al*. reported values of the internal fit of 208 ± 85µm for IPS Empress inlays, 260 ± 84µm for Opc inlays and 230 ± 68µm for Denzir inlays [28]. In another study, Audenino et al. reported values of the overall fit of 85 ± 32µm for Colorlogic, 53 ± 21µm for IPS Empress, 129 ± 11µm for Celay Direct and 140 ± 6µm for Celay Indirect [29].

The values of the internal fit in the first group (I) were 120.68 ± 60.4µm for the mesial retainer, respectively 121.85 ± 58.18µm for the distal retainer. Gap widths were generally smaller at the margins and at the axial walls and larger at the shoulder of the proximal box and at the floor of the preparations. The values of the internal fit in the second group (II) were 147.78 ± 40.42µm for the mesial retainer, respectively 190.67 ± 49.07µm for the distal retainer. The average internal gap width was 121.3 ± 59.3µm for the first group (I) and of 169.2 ± 49.8µm for the second group (II), lower than the values recorded by Addi [28], but higher than those recorded by Audenino [29] for all-ceramic inlays as single restorations. Both previous studies [28, 29] used 7 points/section for the measurement of the internal fit. The present study used 100 points/section for the measurement of the internal fit.

The limitation of this study consist in the fact that, similar to previous studies, only one mesio-distal section was taken into account for each zirconia PRFDP, which might reflect neither the marginal, nor the internal fit of the restoration as a whole.

An important aspect to be considered is that the fit is influenced by the different flow properties of the resin cement and the silicone paste [18]. Tsitrou *et al*. reported that the marginal gap values for the resin cement were lower than those obtained with the silicone replica technique, probably due to the better flow properties of the composite resin cement [27].

The significant difference of fit between the groups investigated might be the result of a higher permanent deformation in the left quadrant upon removal of the impression – palatal-buccal preparations and cervical-occlusal axis of removal. A solution to the problem could come from a recent study which concluded that Lava zirconia CAD/CAM frameworks fabricated from digital impression using Lava COS system displayed a better internal fit than those obtained using conventional impression [30].

It should to be considered that the values of the marginal and internal gaps recorded in the present study may be higher when compared to data from other *in vitro* studies, because the present study follows the steps of clinical applications.

5. CONCLUSIONS

Within this study's limitations, Lava Zirconia PRFDPs demonstrated an average marginal and internal fit within accepted limits, thus being suitable for clinical use. The statistical analysis revealed significant differences between minimally invasive PRFDPs with an occluso-cervical insertion axis and PRFDPs with a palato-buccal insertion axis regarding both the marginal and the internal fit.

In order to obtain an ideal fit, it is recommended to use digital impression for PRFDPs with palato-buccal insertion axis.

The clinical significance of this study comes from the fact that, regarding their fit, these conservative metal-free restorations can be considered a viable alternative to the traditional, more invasive, full-crown-retained fixed dental prostheses, with respect to the principles of aesthetic and minimally invasive dentistry.

ACKNOWLEDGMENTS

This study was supported by the "BddcAEC" project from the strategic grant POSDRU/88/1.5/S/63117 of the Ministry of National Education, Romania.

REFERENCES

1. MONACO C., CARDELLI P., OZCAN M., *Inlay-retained fixed dental prostheses: modified designs for a completely adhesive approach*, J. Can. Dent. Assoc., **77**, b86, 2011.
2. MONACO C., KREJCI I., BORTOLOTTO T. *et al*., *Marginal adaptation of 1 fiber-reinforced composite and 2 all-ceramic inlay fixed partial denture systems*, Int. J. Prosthodont, **19**, pp. 373–82, 2006.
3. BORTOLOTTO T., MONACO C., ONISOR I. *et al*., *In vitro assessment of single-retainer tooth-colored adhesively fixed partial dentures for posterior teeth*, Int. J. Dent., 101095, 2010.
4. Keulemans F., De Jager N., Kleverlaan C.J. *et al*., *Influence of retainer design on two-unit cantilever resin-bonded glass fiber reinforced composite fixed dental prostheses: an in vitro and finite element analysis study*, J. Adhes. Dent., **10**, pp. 355–64, 2008.
5. THOMPSON M.C., THOMPSON K.M., SWAIN M., *The all-ceramic, inlay supported fixed partial denture. Part 1. Ceramic inlay preparation design: a literature review*, Aust. Dent. J., **55**, pp. 120–7, 2010.
6. WOLFART S., LUDWIG K., UPHAUS A. *et al*., *Fracture strength of all-ceramic posterior inlay-retained fixed partial dentures*, Dent. Mater, **23**, pp. 1513–20, 2007.
7. EDELHOFF D., SORENSEN J.A., *Tooth structure removal associated with various preparation designs for posterior teeth*, J. Prosthet. Dent., **87**, pp. 503–9, 2002.

8. MANICONE P., ROSSI Iommetti P., RAFFAELLI L., *An overview of zirconia ceramics: Basic properties and clinical applications*, J. Dent., **35**, pp. 819–26, 2007.
9. KOMINE F., BLATZ M.B., MATSUMURA H., *Current status of zirconia-based fixed restorations*, J. Oral. Sci., **52**, pp. 531–9, 2010.
10. DELLA BONA A., KELLY J.R., *The clinical success of all-ceramic restorations*, J. Am. Dent. Assoc., **139 Suppl**, pp. 8S-13S, 2008.
11. BORBA M., CESAR P.F., GRIGGS J.A. *et al*., *Adaptation of all-ceramic fixed partial dentures*, Dent. Mater., **27**, pp. 1119–26, 2011.
12. BEUER F., AGGSTALLER H., RICHTER J. *et al*., *Influence of preparation angle on marginal and internal fit of CAD/CAM-fabricated zirconia crown copings*, Quintessence Int., **40**, pp. 243–50, 2009.
13. BEUER F., NAUMANN M., GERNET W. *et al*., *Precision of fit: zirconia three-unit fixed dental prostheses*, Clin. Oral. Investig., **13**, pp. 343–9, 2009.
14. SUBASI G., OZTURK N., INAN O. *et al*., *Evaluation of marginal fit of two all-ceramic copings with two finish lines*, Eur. J. Dent., **6**, pp. 163–8, 2012.
15. BINDL A., MÖRMANN W.H., *Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations*, J. Oral Rehabil., **32**, pp. 441–7, 2005.
16. FAHMY A.M., *Comparison of marginal fit between collarless metal ceramic and two all ceramic restorations*, J. Am. Sci., **8**, pp. 528–34, 2012.
17. BEUER F., AGGSTALLER H., EDELHOFF D. *et al*., *Marginal and internal fits of fixed dental prostheses zirconia retainers*, Dent Mater., **25**, pp. 94–102, 2009.
18. KOMINE F., IWAI T., KOBAYASHI K. *et al*., *Marginal and internal adaptation of zirconium dioxide ceramic copings and crowns with different finish line designs*, Dent. Mater. J., **26**, pp. 659–64, 2007.
19. MÖRMANN W.H., BINDL A., LÜTHY H. *et al*., *Effects of preparation and luting system on all-ceramic computer-generated crowns*, Int. J. Prosthodont., **11**, pp. 333–9, 1998.
20. TUNTIPRAWON M., WILSON P.R., *The effect of cement thickness on the fracture strength of all-ceramic crowns*, Aust. Dent. J., **40**, pp. 17–21, 1995.
21. REKOW E.D., ZHANG G., THOMPSON V. *et al*., *Effects of geometry on fracture initiation and propagation in all-ceramic crowns*, J. Biomed. Mater. Res. B Appl. Biomater., **88**, pp. 436–46, 2009.
22. SILVA N.R., DE SOUZA G.M., COELHO P.G. *et al*., *Effect of water storage time and composite cement thickness on fatigue of a glass-ceramic trilayer system*, J. Biomed. Mater. Res. B Appl. Biomater., **84**, pp. 117–23, 2008.
23.WETTSTEIN F., SAILER I., ROOS M. *et al*., *Clinical study of the internal gaps of zirconia and metal frameworks for fixed partial dentures*, Eur. J. Oral Sci., **116**, pp. 272–9, 2008.
24. MARTINS L.M., LORENZONI F.C., MELO A.O. *et al*., *Internal fit of two all-ceramic systems and metal-ceramic crowns*, J. Appl. Oral. Sci., **20**, pp. 235–40, 2012.
25. MÖRMANN W.H., BINDL A., LÜTHY H. *et al*., *Effects of preparation and luting system on all-ceramic computer-generated crowns*, Int. J. Prosthodont., **11**, pp. 333–9, 1998.
26. REICH S., WICHMANN M., NKENKE E. *et al*., *Clinical fit of all-ceramic three-unit fixed partial dentures, generated with three different CAD/CAM systems*, Eur. J. Oral. Sci., **113**, pp. 174–9, 2005.
27. TSITROU E.A., NORTHEAST S.E., VAN NOORT R., *Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM*, J. Dent., **35**, pp. 68–73, 2007.
28. ADDI S., HEDAYATI-KHAMS A., POYA A. *et al*., *Interface gap size of manually and CAD/CAM-manufactured ceramic inlays/onlays in vitro*, J. Dent., **30**, pp. 53–8, 2002.
29. AUDENINO G., BRESCIANO M.E., BASSI F., CAROSSA S., *In vitro evaluation of fit of adhesively luted ceramic inlays*, Int. J. Prosthodont., **12**, pp. 342–7, 1999.
30. ALMEIDA E., SILVA J.S., ERDELT K., EDELHOFF D. *et al*., *Marginal and internal fit of four-unit zirconia fixed dental prostheses based on digital and conventional impression techniques*, Clin. Oral. Investig. Mar., **18**, *2*, pp. 515–23, 2014.

Received July 22, 2015