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Original Article

Evaluation of the Fracture Resistance of Computer-aided Design/Computer-aided Manufacturing Monolithic Crowns Prepared in Different Cement Thicknesses

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ABSTRACT

Introduction: The purpose of this study was to evaluate the fracture resistance of monolithic computer-aided design/computer-aided manufacturing (CAD/CAM) crowns that are prepared with different cement thickness. **Materials and Methods:** For this investigation, a human maxillary premolar tooth was selected. Master model preparation was performed with a demand bur under water spray. Master die was taken to fabricate 105 epoxy resin replicas. The crowns were milled using a CEREC 4 CAD/CAM system (Software Version, 4.2.0.57192). CAD/CAM crowns were made using resin nanoceramic, feldspathic glass ceramic, lithium disilicate, and leucite-reinforced ceramics. Each group was subdivided into three groups in accordance with three different cement thicknesses (30, 90, and 150 μm). Crowns milled out. Then RelyX™ U200 was used as a luting agent to bond the crowns to the prepared samples. After one hour cementations, the specimens were stored in water bath at 37°C for 1 week before testing. Seven unprepared and unrestored teeth were kept and tested as a control group. A universal test machine was used to assume the fracture resistance of all specimens. The compressive load (N) that caused fracture was recorded for each specimen. Fracture resistance data were statistically analyzed by one-way ANOVA and two-factor interaction modeling test ($\alpha = 0.001$). **Results:** There are statistically significant differences between fracture resistances of CAD/CAM monolithic crown materials ($P < 0.001$). It is seen that cement thickness is not statistically significant for fracture resistance of CAD/CAM monolithic crowns ($P > 0.001$). **Conclusions:** CAD/CAM monolithic crown materials affected fracture resistance. Cement thickness (30, 90, and 150 μm) was not effective on fracture resistance of CAD/CAM monolithic crowns.

KEYWORDS: *Cement thickness, fracture resistance, monolithic computer-aided design/computer-aided manufacturing crowns*

INTRODUCTION

Many patients request tooth-colored restorations, since to nonveneered metal, crowns are often incorporated with esthetic limitations.[1] Fracture resistance is one of the most significant criteria for longtime performance of dental restorations.[2] Ceramics are brittle and have low tensile strength and fracture toughness due to the presence of inherent flaws within the material.[3] Numerous techniques have been developed in an attempt to overcome this problem and to allow the use of all-ceramic restorations on posterior teeth.[4,5] This may be ascribed to the optimized fabricating conditions that computer-aided design/computer-aided manufacturing (CAD/CAM) materials undergo resolving the risk of void and volume defects.[6,7] Besides, to prevent disadvantages of ceramic restorations, composite resins are used for indirect esthetic restorations.[7]

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As CAD/CAM gets more popular, machinable versions of esthetic materials have been introduced.[8] These materials have a fracture strength value that should resist occlusal loads (150–665 N).[9] The fracture strengths of CAD/CAM materials ranging from 772.3 N for machinable feldspathic ceramics to 1000 N for zirconia machined crowns.[10,11] Machinable ceramics are more homogeneous and stronger than conventional sintered porcelain.[12] Machinable ceramics has been investigated many times.[7-11,13] Clinical studies have reported that the longevity of ceramic restorations is better than of composite resin crowns.[14-17] However, other reports have shown that the behavior of teeth with ceramic and composite resin crowns is similar.[10,18,19]

Fracture resistance of all-ceramic restorations is strongly dependent on the support materials. In addition, preparation design, dentin thickness, cement type, and thickness can be influential factors. The film thickness of the cement affects directly the long-term clinical success. While determining the film thickness of the cement, the mixing technique, the rate, and the heat are as much important as the clinician's experience of the material. As a result, in real clinical situations, the actual cement thickness depends on the experience of the clinician and the material used.[20,21]

The purpose of this study was to evaluate the fracture resistance of monolithic CAD/CAM crowns which were made of resin nanoceramic, feldspathic glass ceramic, lithium disilicate, and leucite-reinforced ceramics that were prepared in different cement thicknesses.

The hypothesis was that significant differences would be found according to fracture resistance among the materials which were used for complete crowns and no significant differences would be found between crowns that prepared in different cement thicknesses.

MATERIALS AND METHODS

Ethical approval was obtained from Atatürk University for this study (27.09.2013/10); a human maxillary premolar tooth was selected for this investigation. Calculus and residual periodontal tissues were removed with a scaler; the tooth was cleaned with powder. It was stored in 0.1% thymol solution. Master model preparation was performed with 1 mm wide shoulder which was done by bur optionally under water spray [Figure 1]. The angle of convergence of the walls was 12 degrees. Vinyl polysiloxane (3M ESPE, St. Paul, USA) impression of the finished master die was taken to fabricate 105 epoxy resin replicas. All specimens were mounted with their long axis in cylindrical molds using an autopolymerizing acrylic resin.

The crowns were milled using a CEREC CAD/CAM system (Software Version, 4.2.0.57192). Preparations were firstly coated with a titanium oxide-based agent (CEREC powder VITA, Zahnfabrik, Germany), and digital impressions were taken by an intraoral camera (Bluecam). Crowns were milled out. The cutting diamond burs were changed after milling 10 crowns, and the milling unit was calibrated using the CEREC calibration kit. Ceramic thickness for each crown was standardized.

Four CAD/CAM materials were used. Monolithic fully anatomical crowns of 2.0 mm occlusal dimension without veneer were produced. They were randomly divided into five groups ($n = 21$): (1) monolithic crowns were prepared with feldspathic glass ceramic (Cerec), (2) with lithium disilicate ceramic (e.max), (3) with leucite-reinforced ceramic (Empress), and (4 and 5) with resin nanoceramics (Lava and Enamic) [Table 1]. Each group was subdivided into three groups according to three different cement thicknesses. Seven unprepared and unrestored teeth were kept and tested as a control group (G_6).

Before cementing, the internal surface of all crowns was etched for 60 s using 4.9% hydrofluoric acid (Ceramics Etch, Vita) and was thoroughly rinsed and dried. Then, RelyX™ U200 was used as a luting agent to bond the crowns to the prepared samples. The mix was applied to the intaglio surface of each crown. When crowns cemented with adhesive cement, they were held in position for 3 min with finger pressure. Excess cement was removed from the margins, and then, they were polished with flexible discs (Sof-lex). A 22 N static load was applied for 5 min with a loading apparatus. One hour after cementations, the specimens were stored in water bath at 37°C for 1 week before testing.

Seven unprepared and unrestored teeth were kept and tested as control group.

A universal test machine was used to assume the fracture tests of all specimens (control and test groups). The specimens were firmly retained to the test machine. A static compressive axial load was applied to the central occlusal surface of ceramic crown at a crosshead speed of 1 mm/min through a 3.5 mm diameter steel ball.

The compressive load was centered on the central groove of each crown so that the load was applied to the triangular ridges of both facial and palatal cusps. The compressive load (N) that caused fracture was recorded for each specimen [Figure 2].

Statistical analysis

The load data for the CAD/CAM crowns were entered into the statistical package SPSS v. 17. Fracture resistance data were analyzed by one-way ANOVA and two factors with interaction modeling test ($\alpha = 0.001$). To determine the similar subgroups, Duncan's multiple comparison test was used ($\alpha = 0.05$).

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RESULTS

Mean fracture resistances and Standard deviations of the monolithic crowns that were prepared in different cement thicknesses are shown in Table 2.

From highest to lowest, the fracture resistance of the tested materials is e.max > control > Enamic > Lava > Cerec > Empres [Figure 3].

It was observed that the highest fracture resistance was determined in e.max monolithic crowns (30 µm cement thickness) and the lowest fracture resistance was determined in Empres monolithic crowns (90 µm cement thickness) [Figure 4].

Figure 1: Master model

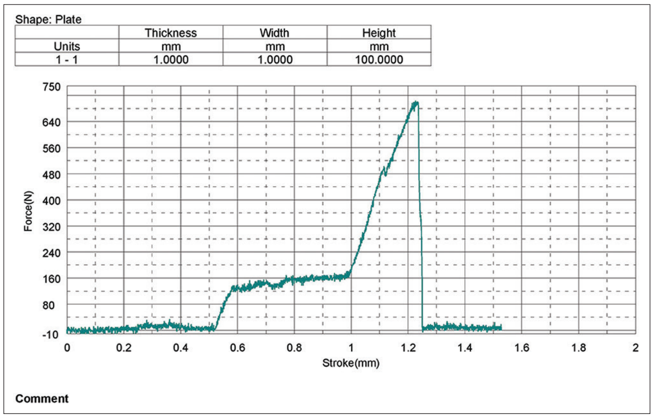

Figure 2: A graphic that is obtained during the fracture testing

Table 1: The content of the materials

Commercial name	Manufacturer	Structure	Content (%wt)	Indications
CEREC blocs	SIRONA	Feldspathic	SiO_2 56-64	Single-tooth restoration
CEREC blocs PC			Al_2O_3 20-23 Na_2O 6-9 K_2O 6-8 CaO 0.3-0.6 TiO_2 0.0-0.1	Superstructure
IPS empress CAD	IVOCLAR	Leucite-reinforced ceramic	SiO_2 60-65 Al_2O_3 16-20 K_2O 10-14 Na_2O 3.5-6.5 Other oxids 0.5-7.0 Pigments 0.2-1.0	Single-tooth restoration
IPS e.max CAD	IVOCLAR	Lithium disilicate ceramic	SiO_2 57-80 Li_2O 11-19 K_2O 0-13 P_2O_5 0-11 ZrO_2 0-8 ZnO 0-8 Al_2O_3 0-5 MgO 0-5	Single-tooth restoration
Lava Ultimate	3M ESPE	Resin nanoceramics	Ceramic (80%) Resin (20%)	Single-tooth restoration
Enamic	VITA	Resin nanoceramics	Ceramic (86%) SiO_2 58-63 $Al_2O_3$20-23 Na_2O 6-11 K_2O 4-6 B_2O_3 0.5-2 CaO <1 TiO_2 <1 Polimer (14%) PMMA	Single-tooth restoration

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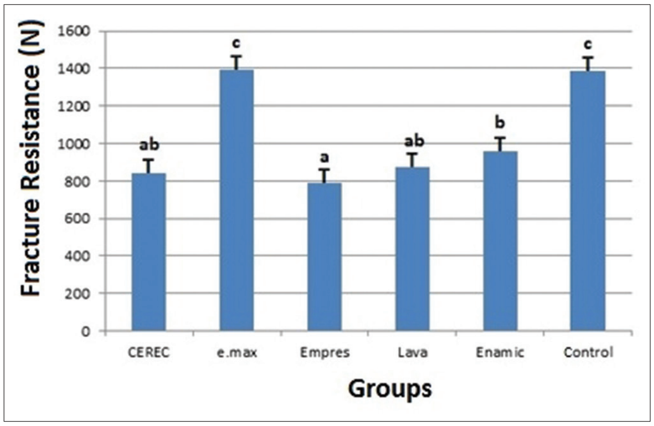

Figure 3: The mean fracture resistance of the test materials and control group

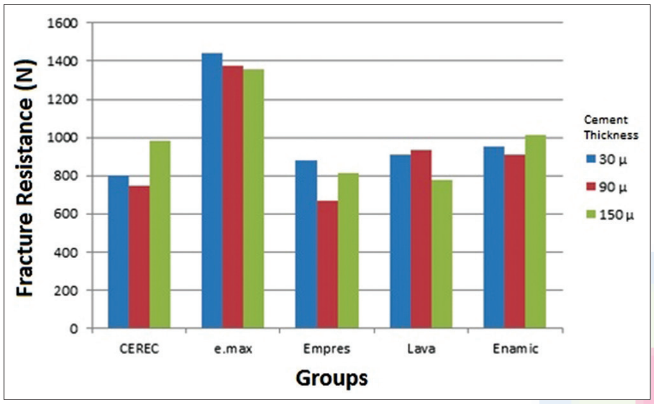

Figure 4: The fracture resistance of the monolithic crown materials in respect of the cement thickness

Table 2: The mean fracture resistance values of the groups (n=7)

Material	Cement thickness (µm)	Mean
Cerec	30	801.79±153.79
	90	745.18±220.23
	150	982.59±153.66
e.max	30	1443.30±167.78
	90	1372.77±161.47
	150	1354.91±220.85
Empres	30	881.16±78.70
	90	670.63±40.64
	150	812.18±146.58
Lava	30	907.14±62.65
	90	933.48±158.96
	150	778.57±104.74
Enamic	30	950.89±123.11
	90	910.71±102.30
	150	1012.50±122.24

Empres, Cerec, and Lava are similar among each other; Cerec, Lava, and Enamic are statistically similar among each other too. Control and e.max is similar statistically ($\alpha > 0.05$).

As a result of analysis, there are significant differences between CAD/CAM monolithic crown materials which were used in the current study ($P < 0.001$). Cement thickness is not significant for fracture resistance of CAD/CAM monolithic crowns statistically ($P > 0.001$).

DISCUSSION

The control teeth were collected from dental clinics over 1–3 months. For this reason, the fracture load of these teeth had naturally large variability.[7] The control teeth were showed the lowest mean fracture load although the values were not different from the monolithic crowns statistically.

Compressive strength studies of crown systems, within their limitations, give an idea for the load-bearing capacity in simulated clinical situations. The results of *in vitro* strength studies may give helpful information for the design of clinical studies, which have to give definitive answers.[10] All-ceramic crowns of all CAD/CAM monolithic crown materials which were used in the current study have appeared to exhibit sufficient strength values to allow clinical evaluation.

There are limitations of this *in vitro* study in terms of clinical situation. First, instead of prepared natural teeth, epoxy resin replicas were used as abutments, to have a standardized configuration of the experimental specimens. Epoxy resin was preferred because its elastic modulus was close to natural dentine.[22]

De Boever *et al*.[23] noted that standard occlusal forces vary between 45 and 68 N in region where chewing is made, i.e., premolar and molar teeth (10–15 pounds). However, occlusal load in individuals who have parafunctional movements such as bruxism can be 570 N in the anterior area and 910 N in the posterior area in average. Pröbster[24] in their study indicated that mastication happens by applying a force of 40 N and the maximum force can be 245–545 N. These values show that teeth and restorations can meet at very high forces in the oral cavity. Körber *et al*.[25] in their study indicated that single crowns should be resistant to 450 N fracture strength and bridges should be resistant to 500 N fracture strength in mouth. According to the findings of the present study, it is observed that the minimum fracture resistance value is 670.63 N, and the fracture resistance value that is identified for single crowns by Körber *et al*. is higher than 450 N. In the light of the available knowledge and the findings, it can be stated that full-ceramic systems that are prepared with CAD/CAM are appropriate for clinical use.

Carvalho *et al*.[8] examined the fatigue fracture resistance values of the feldspathic glass ceramic, lithium disilicate ceramic, and resin nanoceramic crowns prepared with

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CAD/CAM. They found out that the fracture resistance of lithium disilicate and resin nanoceramics was similar and the fracture resistance of feldspathic ceramic crowns was statistically lower ($P < 0.05$). Homaei *et al.*[12] determine the fatigue strength of lithium disilicate e.max CAD (LD) and polymer-infiltrated ceramic (PIC). The fatigue resistance of LD crowns on premolars was significantly higher than PIC crowns.

Clausen *et al.*[26] compared the fracture resistance of full-ceramic crowns and concluded that lithium disilicate ceramic (IPS e.max Press) crowns were more resistant than leucite-reinforced ceramic (IPS Empress Esthetic) crowns.

Bindl *et al.*[27] reported that the fracture resistance of lithium disilicate crowns was significantly higher than feldspathic and leucite-containing crowns.

In the present study, however, the fracture resistance of IPS Empress CAD crowns (787.99 N) was found to be lower than the fracture resistance of CEREC crowns (843.18 N), but it was stated that this difference was not statistically important. Although the fracture resistance of IPS Empress CAD crowns and 3M ESPE Lava Ultimate was found out to be statistically similar, the fracture resistance of Vita Enamic was found to be statistically different ($P < 0.05$). The mean fracture resistance values have changed between 787.99 and 1390.33 N.

The differences in the fracture resistance values in literature result from the differences in the test methods, die materials, bonding techniques, and cements used.

Tuntiprawon and Wilson[28] changed the cement thicknesses of jacket crowns (in the first group, one layer platinum foil; in the second group, two layers die spacer; and in the third group, four layers die spacer application) and studied the effect of this on the fracture resistance, and they found out that there was a statistical difference among the groups and that the fracture resistance got prominently lower when the cement thickness was increased above 70 µm.

Scherrer *et al.*[29] pointed out that the fraction resistance of the glass-ceramic samples that are cemented with zinc phosphate cement and that are machinable does not depend on the film thickness of the cement. They also indicated that when the thickness of the cement is 300 µm or more, the fracture resistance of the samples that are cemented with resin cement decreases significantly, and this decrease is statistically important. As a result, they represent that the fracture resistance of the machinable glass ceramics is not affected by the film thickness of the cement.

Rekow and Thompson[30] stated that the cement thickness can vary between 20 and 200 µm. However, to eliminate the disadvantages appeared due to low adhesion, the clinician and the technician should try to make up a cement layer that is as thin as possible.

Liu *et al.*[31] obtained two ideas from their study. The first idea is that 90 µm is the optimum cement thickness so as to minimalize the stress of the restoration crown. The second one is that the cement thickness is not a very important factor in maintaining the continuity of the full ceramics when the loading conditions are examined. In overloading conditions, the shearing stress will cause bonding failure of crown restoration. As a result, Liu *et al.*[30] noted that the optimal cement thickness is 90 µm and it can decrease the stress level in full-ceramic crowns; however, when it is compared to the loading conditions and the effect of cement modules, the cement thickness is considered to have inferior importance in the core and veneer stress.

Ai and Nagai[32] examined the effect of adhesion layer thicknesses that were defined as 20, 100, and 200 µm on the fracture toughness, and they reported that the fracture toughness was similar in 100 and 200 µm; however, it decreased slightly in 20 µm.

Prakki *et al.*[33] determined the cement thicknesses as 100, 200, and 300 µm for 1 and 2 mm-thick ceramic plates that were cemented on dentin with resin cement, and they used the ceramic plates that were not cemented as the control group. As a result, when the cement thickness was increased in 1-mm thick ceramic plates, the fracture resistance was increased as well. The cement thickness in 2-mm thick ceramic plates has not affected the fracture resistance.

In the present study, the effect of cement thicknesses determined as 30, 90, and 150 µm on the fracture resistance was found to be similar. Last of all, the null hypothesis was tested, which stated that cement thickness affects the fracture resistance of the CAD/CAM monolithic crowns and was rejected.

CONCLUSIONS

1. The fracture resistance of the materials used was identified, respectively, as: lithium disilicate crowns (IPS e.max CAD) > resin nanoceramic crowns (Vita Enamic >3M ESPE Lava Ultimate) > feldspathic crowns (CEREC blocs) > leucite crowns. The highest fracture resistance values were found out in lithium disilicate crowns ($P < 0.001$)
2. The effect of cement thicknesses which were determined as 30, 90, and 150 µm on the fracture resistance was found to be similar ($P > 0.001$)
3. Control group showed the highest fracture resistance values after the lithium disilicate crowns.

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In the way that natural teeth are used as the control group in different studies, metal-ceramic restorations that are still commonly used nowadays can also be preferred. The fracture resistance of CAD/CAM monolithic crowns can be compared to these restorations.

In addition, studies must go on the subject of fracture resistance of CAD/CAM monolithic crowns that are prepared with cement thicknesses of 150–300 μm and more.

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Conflicts of interest

There are no conflicts of interest.

References

1. Seydler B, Rues S, Müller D, Schmitter M. *In vitro* fracture load of monolithic lithium disilicate ceramic molar crowns with different wall thicknesses. Clin Oral Investig 2014;18:1165-71.
2. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil 1999;26:582-93.
3. Homaei E, Farhangdoost K, Akbari M. An investigation into finding the optimum combination for dental restorations. JCARME 2016;6:1-9.
4. Harrington Z, McDonald A, Knowles J. An *in vitro* study to investigate the load at fracture of Procera AllCeram crowns with various thickness of occlusal veneer porcelain. Int J Prosthodont 2003;16:54-8.
5. AL-Makramani BM, Razak AA, Abu-Hassan MI. Evaluation of load at fracture of Procera AllCeram copings using different luting cements. J Prosthodont 2008;17:120-4.
6. Attia A, Kern M. Influence of cyclic loading and luting agents on the fracture load of two all-ceramic crown systems. J Prosthet Dent 2004;92:551-6.
7. Attia A, Kern M. Fracture strength of all-ceramic crowns luted using two bonding methods. J Prosthet Dent 2004;91:247-52.
8. Carvalho AO, Bruzi G, Giannini M, Magne P. Fatigue resistance of CAD/CAM complete crowns with a simplified cementation process. J Prosthet Dent 2014;111:310-7.
9. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM. Maximal bite forces in healthy young adults as predicted by surface electromyography. J Dent 2004;32:451-7.
10. Attia A, Abdelaziz KM, Freitag S, Kern M. Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns. J Prosthet Dent 2006;95:117-23.
11. Att W, Grigoriadou M, Strub JR. ZrO2 three-unit fixed partial dentures: Comparison of failure load before and after exposure to a mastication simulator. J Oral Rehabil 2007;34:282-90.
12. Homaei E, Farhangdoost K, Pow EH, Matinlinna JP, Akbari M, Tsoi JK. Fatigue resistance of monolithic CAD/CAM ceramic crowns on human premolars. Ceram Int 2016;42:15709-17.
13. Shahrbaf S, van Noort R, Mirzakouchaki B, Ghassemieh E, Martin N. Fracture strength of machined ceramic crowns as a function of tooth preparation design and the elastic modulus of the cement. Dent Mater 2014;30:234-41.
14. Dejak B, Mlotkowski A. Three-dimensional finite element analysis of strength and adhesion of composite resin versus ceramic inlays in molars. J Prosthet Dent 2008;99:131-40.
15. Khairallah C, Hokayem A. Long-term clinical evaluation of 2 dental materials used for the preparation of esthetic inlays. Odontostomatol Trop 2009;32:5-13.
16. Vanoorbeek S, Vandamme K, Lijnen I, Naert I. Computer-aided designed/computer-assisted manufactured composite resin versus ceramic single-tooth restorations: A 3-year clinical study. Int J Prosthodont 2010;23:223-30.
17. Magne P, Knezevic A. Influence of overlay restorative materials and load cusps on the fatigue resistance of endodontically treated molars. Quintessence Int 2009;40:729-37.
18. Ghazy M, El-Mowafy O, Roperto R. Microleakage of porcelain and composite machined crowns cemented with self-adhesive or conventional resin cement. J Prosthodont 2010;19:523-30.
19. Homaei E, Farhangdoost K, Tsoi JKH, Matinlinna JP, Pow EHN. Static and fatigue mechanical behavior of three dental CAD/CAM ceramics. J Mech Behav Biomed Mater 2016;59:304-13.
20. Kurtoglu C, Uysal H, Mamedov A. Influence of layer thickness on stress distribution in ceramic-cement-dentin multilayer systems. Dent Mater J 2008;27:626-32.
21. Pröbster L. Compressive strength of two modern all-ceramic crowns. Int J Prosthodont 1992;5:409-14.
22. Coelho PG, Calamia C, Harsono M, Thompson VP, Silva NR. Laboratory and FEA evaluation of dentin-to-composite bonding as a function adhesive layer thickness. Dent Mater 2008;24:1297-303.
23. De Boever JA, McCall WD Jr, Holden S, Ash MM Jr. Functional occlusal forces: An investigation by telemetry. J Prosthet Dent 1978;40:326-33.
24. Pröbster L. Survival rate of In-Ceram restorations. Int J Prosthodont 1993;6:259-63.
25. Körber KH, Ludwig K, Huber K. Experimental study of the mechanical strength of bridge frameworks for metalloceramics. ZWR 1982;91:50, 53-61.
26. Clausen JO, Abou Tara M, Kern M. Dynamic fatigue and fracture resistance of non-retentive all-ceramic full-coverage molar restorations. Influence of ceramic material and preparation design. Dent Mater 2010;26:533-8.
27. Bindl A, Lüthy H, Mörmann WH. Strength and fracture pattern of monolithic CAD/CAM-generated posterior crowns. Dent Mater 2006;22:29-36.
28. Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J 1995;40:17-21.
29. Scherrer SS, de Rijk WG, Belser UC, Meyer JM. Effect of cement film thickness on the fracture resistance of a machinable glass-ceramic. Dent Mater 1994;10:172-7.
30. Rekow D, Thompson VP. Engineering long term clinical success of advanced ceramic prostheses. J Mater Sci Mater Med 2007;18:47-56.
31. Liu B, Lu C, Wu Y, Zhang X, Arola D, Zhang D. The effects of adhesive type and thickness on stress distribution in molars restored with all-ceramic crowns. J Prosthodont 2011;20:35-44.
32. Ai H, Nagai M. Effect of the adhesive layer thickness on the fracture toughness of dental adhesive resins. Dent Mater J 2000;19:153-63.
33. Prakki A, Cilli R, Da Costa AU, Gonçalves SE, Mondelli RF, Pereira JC. Effect of resin luting film thickness on fracture resistance of a ceramic cemented to dentin. J Prosthodont 2007;16:172-8.