EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 1493:1500, April, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 11-03-2023 • Accept Date : 03-04-2023 • Available online: 10-04-2023 • DOI : 10.21608/edj.2023.199395.2483

FRACTURE RESISTANCE OF FOUR DIFFERENT TYPES OF CAD/CAM LITHIUM DISILICATE ENDOCROWNS

Amr Abd-Elaziz Shebl Kassem *, Mohamed Desouky Mohamed * *and* Tarek Abd-Elhameed Abd-Elhameed *

ABSTRACT

Aim: To assess fracture strength of CAD-CAM fabricated molars endocrowns restoring endodontically treated molars using different types of litium disilicate blocks. **Materials & methods:** A maxillary first molar tooth was prepared to receive an all-ceramic endocrown, scanned with primescan intraoral scanner. A STL file was transferred to Formlabs 3D-printer to print twenty-eight resin dies. One die was scanned with primescan and twenty-eight lithium disilicate endocrowns were milled with Cerec MC X5 milling machine. Endocrowns were grouped into four groups (n=7); Group EC (IPS. Emax CAD), group CT (Cerec Tessera), group IL (GC Initial LiSi CAD) and group AM (Amber Mill). Endocrowns were bonded using Panavia F2.0 adhesive resin cement. Endocrowns were tested for fracture strength using a universal testing machine at a crosshead speed of 1 mm/min. Data were analyzed by one way ANOVA and Post Hoc Tests at p £ 0.05. **Results:** There was a significant statistical difference between mean fracture strength of all groups where group CT showed the highest mean fracture strength followed by groups EC and AM then Group IL. **Conclusions:** Tested lithium disilicate endocrowns showed different fracture strength means but all were within the clinically acceptable range.

KEYWORDS: Lithium disilicate, Endocrowns, Fracture strength, Bonding, CAD/CAM.

INTRODUCTION

The restoration of badly broken down endodontically treated teeth is one of the clinical challenges in dentistry. This is due to structural discontinuity resulted from extensive caries, fractures or cavity preparations in non-vital teeth.[1]

The traditional approach for restoring endodontically treated teeth is to build up the tooth with a post and core having similar physical properties to that of dentin then covering the tooth with a full-coverage crown with a ferrule.[2-4] Studies have concluded that sufficient ferrule effect is essential to increases the fracture resistance of treated teeth.[5,6]

* Lecturer, Department of Crown and Bridge, Faculty of Dentistry, Suez-Canal University, Ismailia, Egypt.

However, such type of restorations always weaken the root and increase the risk for root fracture.[7,8] Moreover, preparation of a molar for a post and core can lead to root perforation.[9,10] Also, there are limitations to the use of posts, that includes root anatomy, presence of dilacerations and short roots. These limitations have led clinicians to search for other alternative, which is the adhesive restorations.[11,12]. A macroretentive design is not a demand if there is sufficient tooth structure for bonding of an adhesive restoration. [1]

Endocrown is an adhesive restoration uses the internal surfaces of the pulp chamber to get the retention of the restoration.[13] So, the pulp canals walls and coronal tooth tissues that are removed for post and crown preparations are preserved.[14] Also, teeth without ferrule and interocclusal space for both core and crown can be restored with endocrown restorations.[15] Another advantage of endocrowns is that number of steps, due to use of different materials such as post, core and crown, are reduced.[14] It has also been reported that stresses that are presented at the interfaces of different materials with different moduli of elasticity may cause root fracture but this does not happen with endocrowns.[16,17]

Endocrowns has showed good retention, stability and, mechanical performance together with reduced stress on dentine and cement.[18,19] Also, computer-aided design/computeraided manufacturing (CAD/CAM) technology, which provides the possibility for chair-side design and fabrication of endocrowns.[20]

Lithium disilicate CAD/CAM ceramics are considered from the best materials used in dentistry. They provide superior esthetics with reasonable strength.[21,22] They were traditionally presented in a softened state to facilitate milling then crystallized and glazed in a furnace to increase their strength. Recently, new fully crystallized lithium disilicate CAD/CAM ceramics have been presented in a way that decreases the chair side time as they do not need further heat treatment after milling, just polishing only.[22]

Several studies were conducted to observe different preparation designs of endocrowns[23-25] but researches that evaluated effect of the used materials, effect of manufacturing technology and type of milling either hard or soft on performance of endocrowns are subtle.

The purpose of this in vitro study was to assess the fracture resistance of CAD-CAM fabricated endocrowns restoring endodontically treated molars using different types of lithium disilicate blocks. The null hypothesis was that there is no difference in the resistance to fracture between the endocrowns fabricated from the different tested materials.

MATERIALS AND METHODS

This study was approved by research ethical committee of Faculty of Dentistry- Suez Canal University (n.543 /2022).

Samples Preparation

An extracted sound human maxillary first molar tooth was selected for this study. Tooth preparation was done under air water spray. Occlusal reduction was ended 2 mm above cervical line. The internal cavity was free from any undercuts and its axial walls were aligned with an internal taper of 8°–10° having a cavity margin wall (90° butt margin) of 2 mm thickness (figure 1). Depth of the intracoronal cavity was 4 mm measured from the floor of the cavity to the internal cavity margin.

Digital scanning was performed for the prepared tooth using an intraoral scanner (Primescan, Dentsply Sirona, USA). Acquired data was saved as standard tessellation language (STL) files and transferred to a 3D printer (Formlabs Form 2, USA) to print 28 prototyped resin dies.

Endocrowns Construction

One of the printed dies was selected and scanned using an intraoral scanner (Primescan, Dentsply Sirona, USA). Then, a STL file was transferred to

CAD software CEREC InLab SW 16.1 Software. The design of the endocrown restorations was obtained by the software. 28 endocrowns were milled using Cerec MC X5 milling machine. Endocrowns were divided into four groups (n=7) according to used material type; Group (EC) for lithium disilicate (IPS. Emax CAD, Ivoclar Vivadent, Lichtenstein), group (CT) for advanced lithium disilicate (Cerec Tessera, Dentsply Sirona, USA), group (IL) for fully crystallized lithium silicate (GC Initial LiSi CAD, GC, Japan) and group (AM) for nano lithium disilicate (Amber Mill, HASSBIO, Korea). Group (EC), group (CT) and group (AM) endocrowns were fired for crystallization and glazing in a compatible ceramic furnace (Programat P310, Ivoclar Vivadent, Germany) following their manufacturer instructions. Then, lithium polishing kit (IPS e.max Chairside Adjustment and Polishing System; Brasseler, USA) was used for finishing and polishing of all endocrowns.

Endocrowns Bonding

Endocrowns were fitted on their corresponding dies, cleaned and dried. Each group of endocrowns was cemented after etching of the bonding surfaces of the endocrowns using hydrofluoric acid gel 9.5% (Porcelain etch, Ultradent Products, UT, United Stated) following the manufacturers recommendations. The bonding surfaces were silanized by a primer (Porcelain silane, Ultradent, USA) and left for 60 seconds then air dried for 5 seconds. Endocrowns were bonded using dual-cure adhesive resin cement (Panavia F2; Kuraray Dental, Japan). They were seated on the corresponding dies by static finger pressure, then loaded axially with a static load of 3 kg. using a specially designed device, followed by initial light-curing for 1-2 seconds to remove the excess of cement, then each surface was photopolymerized for 20 seconds. Samples were kept in distilled water at 37 ^{0}C.

Testing procedure

Each endocrown was subjected to static load to fracture using a universal testing machine (TIRA test 2805, Tira GmbH, Germany) with a loadcell of 5 Kg and a stainless-steel ball (5 mm in diameter) was applied vertically perpendicular to the occlusal plane and centered on the occlusal surface of the endocrown (figure 2). Force was applied with a cross-head speed of 1 mm/minute until failure. The load at failure manifested by an audible crack and was confirmed by a sharp drop at the load-deflection curve recorded using a computer software. The maximum force to produce fracture was recorded in Newtons (N). The fracture surfaces of all samples were examined under a stereomicroscope (Olympus, Japan) at a magnification of X20.

Fig. (1): Prepared tooth with 90° butt margin(occlusal view)

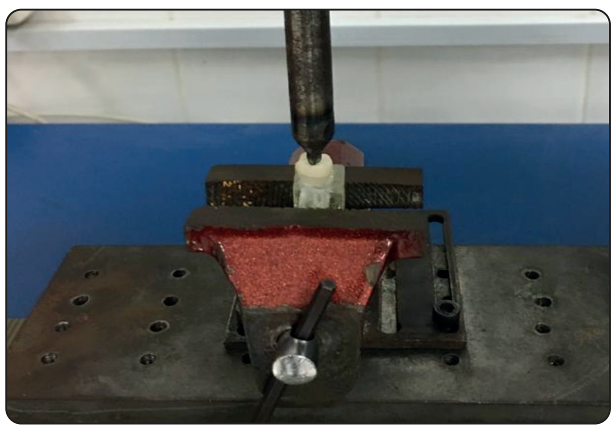

Fig. (2): Universal testing machine for frecture resistance testing

TABLE (1): Mean and standard deviation (SD) in Newton of fracture resistance for the tested groups.

Group	Group (EM) E-max CAD	Group (CT) Cerec Tessera	Group (IL) GC Initial LiSi CAD	Group (AM) Amber Mill	p-value
Mean ± SD	1483.76 ± 150.34 a	1911.32 ± 168.40 b	1112.48 ± 110.89 c	1430.11 ± 100.39 a	<0.001*

Significance level p ≤ 0.05 **** Statistically significant*** ***Means with similar letters are not significantly different.***

Statistical Analysis

Data was analyzed using IBM SPSS software package version 20.0. (SPSS Inc., USA). Numerical data was described as mean and standard deviation Data was explored for normality using Kolmogrov-Smirnov test and Shaprio-Wilk test. One way analysis of variance (ANOVA) test for comparison between each 2 groups was done using Post Hoc Test (Tukey). A p-value ≤0.05 was considered statistically significant.

RESULTS

The mean and standard deviation (SD) values of fracture resistance in Newton for the four groups are represented in table 1

There was a significant difference statistically in mean fracture resistance between the four tested groups (P<0.001) where group CT showed the highest mean fracture resistance (1911.32 ± 168.40 N) and group IL showed the lowest one (1112.48 ± 110.89 N). However, there was no significant statistical difference in mean fracture resistance between group EC (1483.76 ± 150.34 N) and group AM (1430.11 ± 100.39 N) (P=0.06).

DISCUSSION

Endocrown is considered an option for restoring endodontically treated tooth due to the advancements in adhesive dentistry.[26,27] Ceramic endocrowns were reported to be suitable for molars more than Premolars. This is related to the more surface area inside the pulp chamber of molars available for bonding in comparison to premolars and that enhance endocrowns retention given by the adhesive cement.[28] This was the reason for the use of a molar tooth in the present study.

The present study did not use natural teeth for fracture resistance testing. Using natural prepared teeth can lead to a variability in the fracturetest results compared with the used 3D printed dies. Difference in natural teeth dimensions and quality of their surface for bonding are variables that can affect the results of test. [1] Use of 3D printed dies with the same dimensions of preparation, the same surface quality for bonding could standardize the conditions in the current study. Furthermore, using 3D printing excluded the human variations of dies formation by pouring an elastomeric mold with epoxy resin that usually leads to errors in the formed dies.[29]

Also, endocrown dimensions was designed with the Cerec software. This could permit the milling of all endocrowns with the same size, axial and occlusal details thus allowing the standardization of load application point for all of them.

In the current study, there was no simulation of the periodontal ligament. It was found that the thickness of the silicon artificial ligaments is larger than that is found clinically. This thickness cannot be standardized and that can result in uncontrolled movements of the samples during fracture test. Furthermore, it was concluded that there was no difference in fracture resistance when using artificial periodontal ligaments or not under a static load.[1]

The choice of dual-cure adhesive resin cement in the current study was related to the endocrowns materials used as the light used for curing cannot pass through the ceramic to reach the deep areas for cement curing. So, chemical curing can complete the cement polymerization in these deep areas.[30]

Seating of the endocrowns on the dies was standardized using a specially designed cementation device, which allowed static placement of 3 Kg load during the seating procedure to exclude any human variations in pressure. This load was chosen as recommended by Rinke et al. (1995) [31] and Groten and Probester (1997) [32] to avoid the danger of damaging the ceramic crowns.

Differences in composition, manufacturing techniques, crystals content and crystallization parameters vary between different lithium disilicate CAD/CAM ceramic materials, and this is reflected not only in the different microstructure of these materials but also in their mechanical and clinical performance.[33]

The null hypothesis was rejected as there was a significant statistical difference among the fracture resistance values of tested lithium disilicate types of endocrowns.

Fracture strength test results of the present study showed that Cerec Tessera group of endocrowns had the highest mean fracture strength among the tested groups of endocrowns. This could be attributed to the different microstructure of this ceramic material than that of the other tested materials. According to the manufacturer, Cerec Tessera has a special microstructure in which 0.5 µm long lithium disilicate crystals are embedded in a glassy matrix together with 0.2–0.3 µm platelet like lithium alumino silicate crystals (Li0.5Al0.5Si2.5O6) known as virgilite. During firing of the crowns, more virgilite crystals are formed. These crystals together with the lithium disilicate crystals might create high tensile strength and stop crack propagation and that could increase the endocrowns fracture strength. [34]

On the other hand, GC Initial Li Si crowns had the lowest mean fracture strength among the tested groups of endocrowns. According to the manufacturer, this fully crystallized lithium disilicate ceramic material is comprises of lithium aluminosilicate glass ceramic that is reinforced with lithium disilicate. Its microstructure reveals fine-grain needlelike lithium disilicate crystals with sizes of 0.3 µm surrounded by glass matrix particles. In spite of the advantage of decreasing chair side time when using this type of CAD/CAM ceramics as it does not need further heat treatment after milling but this could lead to processing and handling damage due to the difficulty for the milling burs to mill these endocrowns from fully crystallized blocks with the possibility of creating some microcrack lines that might lead to their low fracture resistance. [35]

However, there was no significant statistical difference in mean fracture resistance between Emax CAD and Amber Mill groups of endocrowns. These could be rendered to the similar crystal content of both materials. According to manufacturer's information, E.max CAD has a composition of 59% LiSi2O5, 33% glass, and crystal sizes of 2 to 4 µm while Amber Mill presents 46.1% LiSi2O5, 33.7% and crystal sizes size of 0.2 µm.[36]

There is a difference in the crystal size between the tested materials as Amber Mill has the smallest crystals size among the four tested materials but a recent study on lithium silicate glass–ceramics reported that both Amber Mill and E.max had higher lithium disilicate content than that of Initial LiSi which could lead to the high fracture resistance of their endocrowns when compared with Initial LiSi ones.[36,37,38]

In addition, Amber Mill and E.max endocrowns were crystallized after milling so microcracks that are present in blocks or that may have occurred during milling might have disappeared after heat treatment.[22]

Results of the current study are in accordance with those of El-Damanhoury et al.[20] and Taha et al.[13] On the other hand, El ghoul et al [39], Dartora et al [40] and Gresnigt et al.[41] reported higher mean fracture resistance values for E-max endocrowns than that of the present study. The different results between the studies may be because of the differences in any test method such as crosshead speed, type of load application device, ball diameter, whether endocrowns were bonded to natural teeth or resin dies, type of tooth and cementation technique.

Finally, it was reported that the clinical masticatory force ranges from 600 N to 800 N or even exceed these values for bruxer patients in the molar region of the mouth. [42,43,44] Results of the present study showed that the load needed to fracture any of the tested endocrowns was greater than that present clinically.

CONCLUSIONS

Within the limitation of the present study, the following conclusions can be stated:

1. Cerec Tessera endocrowns were the most resistant to fracture among the tested lithium disilicate ones.
2. Initial LiSi CAD endocrowns were the least resistant to fracture among the tested lithium disilicate ones.
3. Tested lithium disilicate endocrowns withstood normal masticatory forces range in the molar area.

Limitations of the study:

One of the limitations of the current study was the use of one type of cement. Using more than one cement can provide different results. Effect of fatigue, thermocycling and different depths of pulp chamber extensions of endocrowns on their fracture strength was not assessed. Furthermore, the applied force in the present study had one direction and speed but this is not the condition clinically.

REFERRENCES

1. Chia-Yu Chang, Jau-Shing Kuo, Yang-Sung Lin, Yen-Hsiang Chang. Fracture resistance and failure modes of CEREC endo-crowns and conventional post and core-supported CEREC crowns. J Dent Sci 2009;4(3):110-117.
2. Bitter K, Kielbassa AM. Post-endodontic restorations with adhesively luted fiber-reinforced composite post systems: a review. Am J Dent 2007;20:353–360.
3. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, part I: composition and micro- and macrostructure alterations. Quintessence Int 2007;38:733–743.
4. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, part II: evaluation of fatigue behavior, interfaces, and in vivo studies. Quintessence Int 2008;39:117–129.
5. Sorensen JA, Engelman MJ. Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent 1990; 63: 529-536.
6. Magne P, Carvalho AO, Bruzi G, Anderson RE, Maia HP, Giannini M. Influence of no-ferrule and no-post buildup design on the fatigue resistance of endodontically treated molars restored with resin nanoceramic CAD/CAM crowns. Oper Dent 2014; 39: 595-602.
7. Heydecke G, Peters M. The restoration of endodontically treated, single-rooted teeth with cast or direct posts and cores: a systematic review. J Prosthet Dent. 2002;87(4):380–386.
8. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod. 2004;30(5):289–301.
9. Ferrari M, Vichi A, Grandini S. Efficacy of different adhesive techniques on bonding to root canal walls: an SEM investigation. Dent Mater 2001; 17: 422-429.
10. Krejci I, Mueller E, Lutz F. Effects of thermocycling and occlusal force on adhesive composite crowns. J Dent Res 1994; 73: 1228-1232.
11. Bindl A, Mormann WH. Clinical evaluation of adhesively placed cerec endo-crowns after 2 years: preliminary results. J Adhes Dent. 1999 Autumn;1(3):255-265.

12. Göhring TN, Peters OA. Restoration of endodontically treated teeth without posts. Am J Dent. 2003 Oct;16(5):313-317.

13. Taha D, Spintzyk S, Sabet A, Wahsh M, Salah T. Assessment of marginal adaptation and fracture resistance of endocrown restorations utilizing different machinable blocks subjected to thermomechanical aging. Esthet Restor Dent. 2018;1–9.

14. Kanat-ertürk B, Saridag S, Köseler E, Helvacioğlu-Yiğit D, Avcu E and Yildiran-avcu Y. Fracture strengths of endocrown restorations fabricated with different preparation depths and CAD/CAM materials. Dent Mater J 2018; 37(2): 256–265.

15. El-Damanhoury H, Haj-Ali R, Platt J. Fracture resistance and microleakage of endocrowns utilizing three CAD-CAM blocks. Oper Dent 2015; 40: 201-210.

16. 16. Zarone F, Sorrentino R, Apicella D, Valentino B, Ferrari M, Aversa R, Apicella A. Evaluation of the biomechanical behavior of maxillary central incisors restored by means of endocrowns compared to a natural tooth: A 3D static linear finite elements analysis. Dent Mater 2006; 22: 1035-1044.

17. Assif D, Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. J Prosthet Dent 1994; 71: 565- 567.

18. Valentina V, Aleksandar T, Dejan L, Vojkan L. Restoring endodontically treated teeth with all-ceramic endo-crowns - case report. Serbian Dent J 2008;55:54–64.

19. Biacchi GR, Basting RT. Comparison of fracture strength of endocrowns and glass fiber post-retained conventional crowns. Oper Dent 2012;37:130-136.

20. El-Damanhoury H, Haj-Ali R, Platt J .Fracture resistance and microleakage of endocrowns utilizing three CAD-CAM blocks. Oper Dent 2015; 40-2, 201-210.

21. Yuan JC-C, Barão VAR, Wee AG, Alfaro MF, Afshari FS, Sukotjo C. Effect of brushing and thermocycling on the shade and surface roughness of CAD-CAM ceramic restorations. J Prosthet Dent. 2018;119:1000–1006.

22. Lubauer J, Belli R, Peterlik H, Hurle K, Lohbauer U. Grasping the lithium hype: insights into modern dental lithium silicate glass-ceramics. Dent Mater. 2022;38:318–332.

23. Tribst JPM, Dal Piva AMO, Madruga CFL, et al. Endocrown restorations: influence of dental remnant and restorative material on stress distribution. Dent Mater. 2018;34:1466-1473.

24. Einhorn M, DuVall N, Wajdowicz M, et al. Preparation ferrule design effect on endocrown failure resistance. J Prosthodont. 2019;28(1): 237-242.

25. Hayes A, Duvall N, Wajdowicz M, Roberts H. Effect of endocrown pulp chamber extension depth on molar fracture resistance. Oper Dent. 2017;42(3):327-334.

26. Gohring TN, Peters OA. Restoration of endodontically treated teeth without posts. Am J Dent. 2003;16(5):313–317.

27. Lin CL, Chang YH, Pai CA. Evaluation of failure risks in ceramic restorations for endodontically treated premolar with MOD preparation. Dent Mater J. 2011;27(5):431–438.

28. Bindl A, Richter B, Mörmann WH. Survival of ceramic computer-aided design/manufacturing crowns bonded to preparations with reduced macroretention geometry. Int J Prosthodont 2005;18:219-224.

29. Dawood A, Marti BM, Sauret-Jackson V, Darwood A. 3D printing in dentistry. Br dent J 2015;219(11):521-529.

30. Menezes-Silva R, Espinoza C.A., Atta M.T., Navarro M.F., Ishikiriama S.K., Mondelli R.F. Endocrown: a conservative approach Braz Dent Sci 2016 Apr/Jun;19(2) 121-131.

31. Rinke S, Hüls A, and Jahn L. Marginal accuracy and fracture strength of conventional and copy-milled all-ceramic crowns. Int J Prosthodont 1995;8(4):303-310.

32. Groten M, and Pröbster L. The influence of different cementation modes on the fracture resistance of feldspathic ceramic crowns. Int J Prosthodont 1997;10(2):169-177.

33. Phark J.H., Duarte S. Microstructural considerations for novel lithium disilicate glass ceramics: A review. J Esthet Restor Dent. 2022;34:92–103.

34. Fasbinder DJ. CEREC Tessera Restorative Whitepaper. 2021. https:// assets.dentsplysirona.com/master/regions-countries/north-america/product-procedure-brand/cad-cam/CEREC-EN-US-document-Tessera-Clinical-WhitePaper_Final (2).pdf

35. GC. Initial LiSi Block Product Brochure. 2021. https:// www. gcamerica.com/products/digital/gc_initial_lisi_block/GCA_Initial_LiSi_Block_Brochure-digital.pdf

36. HASS Corporation. New Frontier of Lithium Disilicate-Based CAD/CAM Blocks & Disks. Amber Mill User Manual. https:// www.hassbio.com/common/download.php?fullpath=board/14/364_0.pdf&filename=%5BEN%5D+Amber+Mill_Manual_English.pdf

37. Ivoclar Vivadent. IPS e.max CAD - Scientific Documentation. 2011. https://www.ivoclarvivadent.com/en_US/downloadcenter/?dc=us&lang=en#search-info-210=106202%2C1&search-info-211=279006%2C1&search-info-212=106007%2C1&details=4857

38. Türksayar A.D., Demirel M., Donmez M. B. Optical properties, biaxial flexural strength, and reliability of new-generation lithium disilicate glass-ceramics after thermal cycling. J. Prosthodont. 2023;1–6.

39. El Ghoul W., Özcan M., Silwadi M.,Salameh Z. Fracture resistance and failure modes of endocrowns manufactured with different CAD/CAM materials under axial and lateral loading. J Esthet Restor Dent. 2019;1–10.

40. Dartora N.R., Maurício Moris I.C., Poole S.F., Bacchi A., Sousa-Neto M. D., Silva-Sousa Y.T. and Gomes E.A. Mechanical behavior of endocrowns fabricated with different CAD-CAM ceramic systems. J Prosthet Dent 2021; 125 (1): 117-125.

41. Gresnigt MM, Ozcan M, van den Houten ML, Schipper L, Cune MS. Fracture strength, failure type and Weibull characteristics of lithium disilicate and multiphase resin composite endocrowns under axial and lateral forces. Dent Mater 2016; 32:607-614

42. Zimmermann, M., Ender A., Attin T., Mehl A. Fracture load of three-unit full-contour fixed dental prostheses fabricated with subtractive and additive CAD/CAM technology. Clin. Oral. Investig. 2020, 24, 1035–1042.

43. Zimmermann M., Egli G., Zaruba M., Mehl A. Influence of material thickness on fractural strength of CAD/CAM fabricated ceramic crowns. Dent. Mater. J. 2017, 29, 778–783.

44. Waltimo, A., Könönen, M. A novel bite force recorder and maximal isometric bite force values for healthy young adults. Eur J Oral Sci 1993, 101, 171–175.