COMPARATIVE EVALUATION OF MICROLEAKAGE OF ANTERIOR ENDOCROWN VS CUSTOMIZED POST IN RESTORING CASES OF PERMANENT UPPER CENTRALS WITH WIDE FLARED ROOT CANAL

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Abstract

This is an invitro study is to compare the performance of innovative technique of adhesive anterior endocrown compared to the customized fiber post in restoration of flared root canal in a human permanent upper central incisor.

Material and Methods: 40 extracted upper central incirors are decapitated, endotreated, and artificially flared to resemble wide root canal situations. Samples are divided into 2 groups (I) Anterior Endocrown, (II) customized post and core, each group is further subdivided into 2 groups A and B. group A is subjected to Thermocyclic loading, group B used as control. All samples are immersed in 2% methylene blue dye for 24 h and sectioned to investigate dye leakage.

Results: Groups subjected to loading (IA and IIA) showed more leakage with a significant difference compared to non-loaded groups (IB and IIB). Anterior endocrown groups showed more leakage than customized post and core groups but was significant in loaded groups.

Conclusion: anterior endocrown is a viable option for treating wide flared root canal but Glass fiber post stands out as the gold standard for practice.

Keywords: Anterior Endocrown, customized post.

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1. INTRODUCTION

Restoration of teeth following endodontic treatment will always remain a challenge. Tooth structure lost due caries, non-carious lesions, trauma or endodontic access complicate the procedure. Substantial loss of tooth structure jeopardizes the retention of the coronal restoration and thus the use of radicular post to gain retention for the coronal restoration is necessary.

Single rooted upper maxillary teeth are the most traumatized teeth especially in adolescents[1,2], in this early stage of tooth development the trauma causes pulp necrosis and halts complete root formation resulting in incomplete root formation and/or wide flared root canal with or without open apex and thin walls[3].

The main problem with wide root canals is the need to reinforce the thin remaining dentin thickness[4] and minimize root fracture. The use of fiber post was advocated to strengthen the roots weakened due to caries and/or endodontic treatment5, but the bond may fail over the years due to fluid leakage from apical foramina and lateral canals over the years[6].

Upper maxillary centrals with single canals are usually wider cervically than most fiber post systems, this necessitates the modification of the post by adding composite 5 to the post or by adding auxiliary posts[7]. Custom ceramic posts or customized posts are used but the use of metal posts was disregarded due to their known disadvantages mainly the objectionable esthetics[8] and increased incidence of vertical root fracture[7] and interfering with the diagnosis of vertical root fracture by CBCT[9].

The main disadvantages of the custom-made ceramic post included the difficult technique and multiple visits. The glass fiber ready-made posts simplicity made them a daily practice. The positive impact of glass fiber post and core is evident in several studies such as the study by **Pang et al.**[10] that showed glass fiber post-and-core restoration significantly enhances the fracture resistance of flared root canals. Some even went as far as to consider it to the gold standard when it comes to treatment of flared root canals, this could be illustrated in the study by **Beltagy**[11].

On the other hand, Gomes G.M. et al12 pointed out to the problem of lack of adaptation and

recommended using anatomic posts. Rayyan [13] useda smart dentine substitute to reinforce weakened roots or a combination of flowable composite resin and fiber post to reinforce weak roots. The glass fiber post will need to customized to improve the fit in the wide root canal.

The choice for a ceramic material for custom-made ceramic post was lithium disilicate ceramic. The ceramic material shows a compressive strength of 360-400 MPa, sufficient to withstand dental applications. The lithium disilicate is indicated for crowns, three unit anterior bridges, partial crowns, molar endocrown, venners[14] and implant superstructure15. One of the great merits of this material is bondability and its well-known for its adhesive strength[16].

In 2010, **Culp et al.** [16], reviewed the uses of the lithium disilicate ceramic suggesting that more innovative designs could be made out of this material owing to its strength, bondability, availability of different processing techniques, and being able to use it in a monolithic form. The lack of need for a veneering material was advantageous compared to zirconia, thus core-veneer bond strength was no more a matter of concern.

Dental laboratories utilize lost-wax technique to generate lithium disilicate ceramic crowns. This technique cope better with errors in preparation and atypical design better than CAD/CAM systems[17]. The bonding of ceramics allowed for more innovative ideas involving preparation techniques and uses in different situations for example endo laminate.

The aim of the study is to compare invitro performance of innovative design of adhesive anterior endocrown to the customized fiber post in restoration of flared root canal in a human permanent upper central incisor.

The null hypothesis is that both restorations show no significant difference in microleakage following construction nor following thermomechanical cyclic loading.

2. MATERIAL AND METHODS

- **Study design**

This is an invitro study, 40 samples are divided into 2 groups and further divided into 2 subgroups.

	Samples restored by Anterior Endocrown (I)	**Samples restored by customized post and core and a crown (II)**
Samples subjected to artificial thermomechanical cycling (A)	**(IA) N=10**	**(IIA) N=10**
Control group (B)	**(IB) N=10**	**(IIB) N=10**

A) Sample preparation:

Forty human maxillary central incisors were used for this study. Teeth were collected from outpatient clinic of oral surgery department, faculty of Dentistry, Minia University. Ethical approval for the use of extracted human teeth was obtained in accordance with guidelines from research ethics committee approval of faculty of Dentistry, Minia University.

The selected teeth were stored in 0.9% normal saline at room temperature until time of use. The root surfaces of selected teeth were cleaned with ultrasonic scaler (*Woodpecker, Guilin, P.R.China*) to remove any hard deposits adhering to root surface. The teeth were then immersed in 5.25% sodium hypochlorite solution (NaOCl) for 30 minutes to remove any soft tissue debris that were present on root surface. The selected teeth were radiographically examined from the buccal and mesial view to exclude any roots having abnormalities such as root fracture, pulp stone, and internal root resorption.

The roots of teeth were embedded in a mold containing epoxy resin. After 24 hours the mold was deconstructed. The epoxy resin covered the roots of the teeth up to 2mm apical to the cemento-enamel junction. The epoxy blocks are finished using sand paper.

Samples are stored in saline for 24h. at 37c, after which samples were decapitated at 3mm above the C.E.J. using a cutting metal disc under coolant. After decapitation, all samples were examined by magnifying loupes (3.5 X) for any cracks or fractures. Any sample that showing root cracks or enamel cracks were discarded. Sample was examined radiographically to make sure it contained a single root canal. All samples should contain a single canal otherwise discarded.

All samples received endodontic treatment. After decapitation, access to pulp chamber was achieved by high-speed round bur (*Dentsply Maillefer, Ballaigues, Switzerland*). Patency of the canals was verified by inserting a #15 K-file (*Dentsply Maillefer, Ballaigues, Switzerland*) into the root canal by watch-winding motion until the tip was visible at the apical foramen. Working length was determined by subtracting 1 mm from this measurement.

The root canals were instrumented with rotary files (*Micro Méga, Besançon, France*) under irrigation with normal saline, followed by using manual stainless-steel files in a reciprocating handpiece up to size #80. Following root canal cleaning and shaping, all samples were obturated by gutta percha in continuous wave compaction technique.

c) Post space preparation

All samples were prepared using pressodrill burs in ascending order of size. The goal of this step is thinning the remaining dentin to leave 1mm thickness of dentin and leave 5mm of gutta percha apical to the preparation. The preparation should be flared from apical to cervical. All steps of the post space preparation were performed under coolant. The depth from the cavo-surface margin should be set at 7mm ± 1mm. The depth of the post preparation was checked

using a periodontal probe. The internal line angles were rounded and smoothened using finishing stones. Preparation of the remaining part of the coronal tooth structure will done by a tapered with round end diamond stone. The finish line will be placed just above the C.E.J. and following its configuration. The finish line geometry will be deep chamfer of thickness 1mm. A ferrule of 2mm height above the C.E.J. is created. The preparation is finished using fine grit diamond. Any sharp line angles will be rounded.

By the end of preparation, all samples should bear the following criteria:

i. 1mm thickness deep chamfer finish line
ii. 2 mm ferrule above the C.E.J.
iii. Flat incisal top
iv. Apical 5 mm of the canal obturated by gutta percha
v. Flared post space leaving a minimum of 1mm thickness of dentin

The samples were divided to 2 groups according to the type of restoration it will receive Group 1: Lithium disilicate anterior endocrown (AE) and **Group2:** Fiber post customized by flowable composite and heat pressed lithium disilicate crowns (CFP)

Group I: Lithium disilicate anterior endocrown

Group I samples received an in direct intra canal wax pattern. The canals were lubricated by a separating medium, impression of the root canal and the preparation was done with a circular perforated tray of comparable size to the specimen in use, the impression material of choice was addition silicone impression material (*ZhermackSpA, Italy*), the light material was injected into the post space using the narrow tips, a plastic post was placed immediately following the light body impression material injection to support the light material. The plastic post was previously prepared by roughening and creating undercuts to retain the impression material.

During the light body injection, an assistant was mixing 2 equal loads of the putty consistency of the addition silicone impression material, the putty was placed in the tray and placed over the specimen. After 3 minutes, the material achieved final setting and was removed. The impression was inspected for any impression errors, if any found the impression was redone, if not the impression was considered acceptable and proceeded for the next stage.

The impression tray boxing was done using pink wax to form a mold that supports gypsum pouring, grade IV gypsum was mixed according to manufacturer instructions and poured over the impression over a vibrator and left to set overnight.

The resultant cast was checked to be free from errors, the post space was lubricated by a separating material and checked by periodontal probe to be fee from undercuts, duralay powder and liquid were mixed according to the manufacturer instructions, when the mix reached the dough stage it was loaded on a plastic post that was previously dipped in the duaralay liquid to allow for better bonding to the mix. The loaded plastic post was inserted in the previously lubricated post space, this part was difficult and had to be continuously checked and more duralay was added till the post space is reproduced, further additions are needed to form the crown part of the anterior endocrown.

After finishing the wax pattern, a sprue was added and the wax pattern will be invested and pressed in a pressing furnace. Using a lost wax technique, a lithium disilicate anterior endocrown will be constructed. The endocrown will be checked for insertion and marginal integrity. If it is considered acceptable, the endocrown will be cemented to the post space using adhesive resin cement after etching and priming of the ceramic surface according to the manufacturer instructions.

Group II: Fiber post customized by flowable composite and heat pressed lithium disilicate crowns.

For group II samples, fiber posts will be used, size of the fiber post should allow for a room of at least 1mm between canal walls and the post. The post will be customized to size using flowable resin composite bonded to the post by universal bond and light cure applied. The customized post will be cemented by dual cure adhesive resin cement according to the manufacturer instructions. The core will be built by dual cure resin composite core building material. The core will be prepared to receive an anterior lithium disilicate ceramic crown. Crown will be fabricated using a direct wax pattern which will later be invested and pressed into a lithium disilicate ceramic crown

e) Sample testing

Samples of group I (Lithium disilicate Anterior Endocrown) & II (customized Post & core, Lithium disilicate crown) were further subdivided into two sub groups. Subgroup A and Subgroup B.

Subgroup A is subjected to Thermomechanical cyclic loading procedures for laboratory testing of dental restorations. Samples of groups IA and IIA are subjected to thermal cycling, the number of cycles used was 1200 cycles. Dwell times were 25 seconds in each water bath with a lag time 10 s. The low-temperature point was 50C). The high temperature point was 55 0C.18

Mechanical aging was performed using a programmable logic-controlled equipment, the newly developed four stations multimodal ROBOTA chewing simulator integrated with thermo-cyclic protocol operated on servo-motor.

ROBOTA chewing simulator which has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each of the chambers consists of an upper Jackob's chuck as hardened steel antagonist holder that can be tightened with a screw and a lower plastic

sample holder in which the specimen can be embedded.

The specimens were embedded in Teflon housing in the lower sample holder. A weight of 10 kg which is comparable to 98 N of chewing force was exerted. The test was repeated 118000 times to clinically simulate the 1 year chewing condition, according to previous studies[19].

Microleakage testing

Then the crowns were then immersed in 2% methylene blue solution. The specimens were then embedded in the clear auto polymerizing acrylic resin following standardized technique using custom made metal jig.

The standardized method for sectioning was followed and the sectioning of the specimens was done buccolingually through the middle of the prepared specimen using diamond blade attached to die cutting machine following the grooves on the surface of the resin.

Each tooth part was viewed under a stereomicroscope at 30x magnification to assess the penetration of the dye from the external margin and the images were captured and transferred to a IBM personal computer equipped with the Image-tool software (Image J 1.43 U, National Institute of Health, USA) and the length of the penetration was recorded.

All data were recorded and tabulated. The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution

Independent sample t-test was used to compare between two groups in non-related samples. Two-way ANOVA test were used to test the interactions between different variables.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

3. RESULTS

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The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

I) Effect of cyclic loading:

For both restorations, thermomechanoical cyclic loading showed a marked effect. There was a statistically significant difference between (Control) and (Tested) groups where ($p<0.001$).

II) Effect of design:

i) Control:

There was no statistically significant difference between (IB) and (IIB) where ($p=0.863$).

The highest mean value was found in (Anterior Endo-crown) group with higher leakage, while the least mean value was found in (Post and Core) group with lower leakage.

ii) Tested:

There was a statistically significant difference between (IA) and (IIB) where ($p=0.008$).

The highest mean value was found in (Anterior Endo-crown) group with higher leakage, while the least mean value was found in (Post and Core) group with lower leakage.

Table (1): The mean, standard deviation (SD) values of leakage of different groups.

Variables	Leakage				
	I		II		p-value
	Mean	SD	Mean	SD	
A	872.06	80.94	790.92	86.35	**0.008***
B	542.25	83.51	534.83	95.38	**0.863ns**
p-value	**<0.001***		**<0.001***		

Means with different small letters in the same column indicates significant difference, means with different capital letters in the same row indicates significant difference

*; significant ($p<0.05$)

Figure (1): Bar chart representing leakage for different groups

4. DISCUSSION

The emergence of newer material dictates the innovation of new preparation designs; this will always be the case. Patients with traumatized anterior teeth and flared root canals were a serious challenge even to the skilled prosthodontist, on one hand esthetics is the patient priority, the weak rook wall on the hand jeopardies longevity, the pulp death hindered the continuation of dentin formation.

An endocrown is a 1-piece restoration developed for endodontically treated teeth, this was made possible by the advances in adhesive dentistry that allows bonding of a ceramic material to the tooth structure possibly reinforcing the weak tooth structure while retaining and restoring the coronal portion without jeopardizing the esthetic outcome in favor of mechanical advantages.

This study consists of two parts: an invitro part and a clinical part. Both were needed to better understand the how this design works and if the proposed intervention was of value to the flared root canal cases.

The use of upper central incisors as specimen was justified by numerous research that show that these teeth in specific are more likely to be affected by trauma in a young age. (1,2,20–23) Thus are the perfect example for a tooth with flared root canal.

The specimen was extracted from adults thus the root canal needed to be modified to simulate the flared root canal, this was done by over-instrumentation of the specimen during root canal preparation procedures. Rotary files were used in successive order to widen the canals to a size of #40/0.4 taper. This was the widest file on the market.

Over enlarging was done by manual files to a minimum of ISO#60. Copious irrigation was used. During obturation, Lateral condensation technique was avoided to prevent buildup of stresses in the flared canal (10), continuous wave obturation technique by EQ-v® packing device was used instead.

The use of a ferrule design the anterior endocrown was justified as this was advocated as being the design superior to fiber post in a study by Carvalho M24, which proved the superiority of ferrule designs to non-ferrule designs and fiber posts.

In the present study, the two control untested groups showed non-significant difference in the dye penetration but the CGFP group showed slightly better results, the higher dye penetration which equates to higher microleakage. Since none of the steps were done in conditions simulating the intraoral environment, impressions, post cementation, were

done in the outside dry environment that rarely resembles the harsh intraoral condition.

The slight non-significant difference could be attributed to difference in design of both restorations. The sample size could limit the outcome. Several studies compared both designs in terms of fracture resistance[25,13], or using finite element analysis studies[26], however to the best of our knowledge no studies comparing anterior endocrown and fiber post regarding microleakage could be found by any of the researchers. Further studies are needed to approve or disapprove these results.

The effect of thermomechanical cycling loading on the results of the microleakage is significant in both groups ($P<0.001$), samples restored by anterior endocrown and customized post groups, this result is in accordance to several studies that experimented with endocrowns, such as the study by **Elashmawy Y**. and **Elshahawy W**., their study involved endocrowns constructed from 4 different material (Lithium disilicate, PEEK, Polymer infiltrated resin, zirconia) and following thermomechanical cyclic loading all groups showed significant change in marginal gap.

In a similar study by **Taha et al**[27], thermomechanical cycling resulted in significant difference in marginal adaptation regardless of the material tested, the study of **Rosentritt et al**[28] study showed that lateral forces are more detrimental than vertical forces regarding the marginal integrity.

The deterioration of margin quality was explained by the study of **Rocca et al**[29] to be due the effect of the aqueous medium, thermal stresses and occlusal loading on the resin bonding interfaces.

Regarding the results comparing leakage of the 2 groups that were artificially aged by thermomechanical cyclic loading, the Anterior endocrown showed more leakage compared to the customized post group with a statistically significant difference.

This finding is of utmost importance due to its clinical relevance as marginal integrity is a predictor regarding the long term success of a restoration30.

This result concurs the findings of other studies[27,28,31]. **Rosentritt et al**[28] study clearly showed that a stiff post transfers stresses to the weakest point of the restoration that is the cement interface, while a bonded post help dissipate the stresses evenly over the radicular walls. This partially explain the findings of this study, the anterior endocrown act as a stiff post which explains the difference yet it's bonded by the resin cement to the radicular walls.

The **Rocca et al**[31] study provides a useful insight to the post-crown system; this study used a scanning electron microscope with higher magnification, margin adaptation was divided into cement-dentin interface and cement-restoration interface. The artificial ageing affected more the margins of the endocrown than the post groups. Everything in accordance to this study expect that resin-ceramic interface showed higher gap values compared to resin-dentin interface.

5. CONCLUSION

Within the limitations of this study, it could be concluded that Anterior endocrown is a viable option but customized glass fiber post remains a gold standard for restoring wide flared root canal. Further studies involving higher magnification are recommended, further in vivo studies are needed before widespread adoption of the design.

6. REFERENCES

1. Petti S, Glendor U, Andersson L. World Traumatic Dental Injury Prevalence and Incidence, a Meta-Analysis - One Billion Living People Have Had Traumatic Dental Injuries. Vol 34.; 2018. doi:10.1111/edt.12389
2. H. El-Kenany M, M. Awad S, Hegazy S. Prevalence and Risk Factors of Traumatic Dental Injuries to Permanent Anterior Teeth among 8–12 Years Old School Children in Egypt. Vol 26.; 2016. doi:10.1016/j.pdj.2016.02.002
3. Singh RK S-BPSV, Kumar Singh R, Kumar Shakya V, et al. Interventions for managing immature permanent teeth with necrotic pulps. Cochrane Database Syst Rev. 2017;6(6):CD012709. doi:10.1002/14651858.CD012709.www.cochranelibrary.com
4. Zogheib LV, Pereira JR, do Valle AL, de Oliveira JA, Pegoraro LF. Fracture resistance of weakened roots restored with composite resin and glass fiber post. Braz Dent J. 2008;19(4):329-333. doi:10.1590/S0103-64402008000400008
5. Goncalves LA de A, Vansan LP, Paulino SM, Sousa Neto MD. Fracture resistance of weakened roots restored with a transilluminating post and adhesive restorative materials. J Prosthet Dent. 2006;96(5):339-344. doi:10.1016/j.prosdent.2006.08.030
6. Hashimoto M, Ohno H, Sano H, Kaga M, Oguchi H. In vitro degradation of resin-dentin bonds analyzed by microtensile bond test, scanning and transmission electron microscopy. Biomaterials. 2003;24(21):3795-3803. doi:10.1016/S0142-9612(03)00262-X
7. Li Q, Xu B, Wang Y, Cai Y. Effects of auxiliary fiber posts on endodontically treated teeth with flared canals. Oper Dent. 2011;36(4):380-389. doi:10.2341/10-283-L
8. Hegde M, B S. Esthetic posts - An update. MedindNic.in. Published online 2010:102-109.
9. Jakobson SJM, Westphalen VPD, Silva Neto UX, Fariniuk LF, Schroeder AGD, Carneiro E. The influence of metallic posts in the detection of vertical root fractures using different imaging

examinations. DentomaxillofacialRadiol. 2014;43(1):20130287. doi:10.1259/dmfr.20130287
10. Pang J, Feng C, Zhu X, et al. Fracture behaviors of maxillary central incisors with flared root canals restored with CAD / CAM integrated glass fiber post-and-core. 2019;38(1):114-119. doi:10.4012/dmj.2017-394
11. Ahmeda AA, , Mustafa M. Hassanb AIA. Microshear bond strength of universal adhesives to dentin used in total‐ etch and self‐ etch modes. Tanta Dent J. 2018;15:91-98. doi:10.4103/tdj.tdj
12. Gomes G, Monte-Alto R, Santos G, Fai C, Loguercio A. Use of a Direct Anatomic Post in a Flared Root Canal : A Three-year. Oper Dent. 2016;41-1:23-28. doi:10.2341/14-275-T
13. Rayyan MM. Comprehensive techniques for intraradicular rehabilitation of weakened anterior teeth. Compr Tech intraradiCularRehabil weakened anterior teeth. 2014;60(No.1):1289-1297.
14. IvoclarVivadent.
15. Lin WS, Harris BT, Zandinejad A, Martin WC, Morton D. Use of prefabricated titanium abutments and customized anatomic lithium disilicate structures for cement-retained implant restorations in the esthetic zone. J Prosthet Dent. 2014;111(3):181-185. doi:10.1016/j.prosdent.2013.07.013
16. Culp L, McLaren EA. Lithium disilicate: the restorative material of multiple options. Compend Contin Educ Dent. 31(9):716-720, 722, 724-725.
17. Neves FD, Prado CJ, Prudente MS, et al. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthet Dent. 2014;112(5):1134-1140. doi:10.1016/j.prosdent.2014.04.028
18. Morresi AL, D'Amario M, Capogreco M, et al. Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. J Mech Behav Biomed Mater. 2014;29:295-308. doi:10.1016/j.jmbbm.2013.09.013
19. Nawafleh N, Hatamleh M, Elshiyab S, Mack F. Lithium Disilicate Restorations Fatigue Testing Parameters: A Systematic Review. J Prosthodont Off J Am Coll Prosthodont. 2016;25(2):116-126. doi:10.1111/jopr.12376
20. Årtun J, Behbehani F, Al-Jame B, Kerosuo H. Incisor trauma in an adolescent Arab population: Prevalence, severity, and occlusal risk factors. Am J OrthodDentofacOrthop. 2005;128(3):347-352. doi:10.1016/J.AJODO.2004.06.032
21. Çelenk S, Sezgin B, Ayna B, Atakul F. Causes of dental fractures in the early permanent dentition: A retrospective study. J Endod. 2002;28(3):208-210. doi:10.1097/00004770-200203000-00016
22. Oliveira M, Corral C, Fraiz FC, Gugisch RC. Prevalence and Characteristics of crown fractures in permanent upper incisors from schoolchildren in a southern Brazilian city. 2007;43:4-8.
23. Dighe K, Kakade A, Takate V, Makane S, Padawe D, Pathak R. Prevalence of traumatic injuries to anterior teeth in 9-14 year school-going children in Mumbai, India. J Contemp Dent Pract. 2019;20(5):622-630. doi:10.5005/jp-journals-10024-2569
24. Carvalho MA De, Lazari-Carvalho PC, Cury AADB, Magne P. Accelerated fatigue resistance of endodontically treated incisors without ferrule restored with CAD / CAM endocrowns. Int J Esthet Dent. 2021;16(4):534-552.
25. Badawy AA El, Abd MH, Aziz E, Omar EA. Failure load of maxillary central incisor restored with CAD / CAM endocrown using different designs. Fail Load Maxillary Cent Incisor Restored with CAD/CAM Endocrown Using Differ Des. 2019;7(1):5-9. doi:10.12691/ijdsr-7-1-2
26. Zarone F, Sorrentino R, Apicella D, et al. 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(11):1035-1044. doi:10.1016/j.dental.2005.11.034
27. 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. J EsthetRestor Dent. 2018;30(4):319-328. doi:10.1111/jerd.12396
28. Rosentritt M, Sikora M, Behr M, Handel G. In vitro fracture resistance and marginal adaptation of metallic and tooth-coloured post systems. J Oral Rehabil. 2004;31(7):675-681. doi:10.1111/j.1365-2842.2004.01286.x
29. Rocca GT, Saratti CM, Poncet A, Feilzer AJ, Krejci I. The influence of FRCs reinforcement on marginal adaptation of CAD/CAM composite resin endocrowns after simulated fatigue loading. Odontology. Published online 2015. doi:10.1007/s10266-015-0202-9
30. Halawani S, Al-Harbi S. Marginal adaptation of fixed prosthodontics. Int J Med Dev Ctries. 2017;1(January):78-84. doi:10.24911/ijmdc.1.2.7
31. Rocca GT, Daher R, Saratti CM, et al. Restoration of severely damaged endodontically treated premolars : The influence of the endo-core length on marginal integrity and fatigue resistance of lithium disilicate CAD-CAM ceramic endocrowns. J Dent. 2018;68(February 2017):41-50. doi:10.1016/j.jdent.2017.10.011

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