Ann Med Res 2021;28(2):267-74

Annals of Medical Research
DOI: 10.5455/annalsmedres.2020.03.202

Original Article

Fracture strength of endodontically treated teeth restored with novel CAD/CAM ceramic post systems

Dogu Omur Dede[1], Ersan Celik[1], Ayca Tulga[1], Evren Sariyilmaz[2], Fatih Cakici[2], Elif Bahar Cakici[2], Cigdem Kahveci[1]

[1]Department of Prosthodontics, Faculty of Dentistry, Ordu University, Ordu, Turkey
[2]Department of Endodontics, Faculty of Dentistry, Ordu University, Ordu, Turkey

Abstract

Aim: The purpose of this study was to investigate the fracture strength (FS) and fracture types of endodontically treated teeth that restored with CAD/CAM made novel ceramic posts.

Materials and Methods: Seventy human maxillary central incisors were selected, endodontically treated and expanded to 1.8 mm diameter with leaving of 2-3 mm canal filling. The teeth were randomly divided into 7 post restoration groups (n=10); a glass fiber post system as control (GFbr), monolithic zirconia (GMzr), lithium disilicate (GLds), zirconia-reinforced lithium silicate (GZr_Lds) ceramics, nanoparticle-filled (GRmc_Cer), resin nano-ceramic (GRmc_Lu), and polymer-infiltrated (GRmc_En) resin matrix ceramic groups. Then composite cores were build-up, crown restorations fabricated, and incubated in a water bath (37 ± 1^0C, 24 hours). A dynamic load was applied at 135° to the long axis of each specimen with a crosshead speed of 1 mm/min. FS and fracture types (favorable-catastrophic) were recorded. The FS values were statistically analyzed with one-way ANOVA and Tukey HSD tests (α=.05).

Results: While the FS values of GMzr (365.62 ± 28.52 N) was significantly higher than GFbr (261.07 ± 24.51 N), all other groups (167.09-191.64 N) significantly lower, according to the Tukey HSD (P<.05). Catastrophic fractures were observed only for GMzr.

Conclusion: The results of this study suggest that the novel CAD/CAM ceramic materials substantially be suitable for the rehabilitation of severely damaged teeth with composite resin core build-up in the anterior region. However, only the monolithic zirconia post restorations may be more durable than the glass fiber post systems.

Keywords: CAD/CAM; ceramics; post restoration; fracture strength; fracture type

INTRODUCTION

When the tooth structure severely damaged as a result of dental caries, traumas, physiological or pathological erosion, intra-extra coronal restorations must be performed in a most aesthetic and functional manner (1-5). Root canal support with post restorations are used to rebuild the tooth structure, increase the retention and support the coronal restoration, in such cases with compromised tooth structure (>50% damaged of coronal tooth structure) (5-10). It has been reported that the endodontically treated teeth were not only showed higher fracture rates than the vital teeth (6,11) but also they have higher survival rates in cases of supporting with post-core restorations (5,9,10,12). The cast gold post-core restorations have been indicated as the "gold standard" for rehabilitating the severely damaged and endodontically treated teeth (2,10). However, the prefabricated post systems with custom-made composite resin or amalgam buildup combination have been increasingly popular, because of the easier, controllable, cost-effective and less time-consuming application procedures (6,9). The clinical performances of cast metal and prefabricated post-core restorations have been evaluated in a previous study and the success rates reported as 87% and 92 % after 6 years of follow-up respectively (2).

Most of the prefabricated post systems comprise of a noble metal or gold-plated base metal alloys. However, the unaesthetic appearance of these metal prefabricated post systems leads to controversial results in cases where the aesthetic background color is important (2,6,9-13). The dark appearance of a metal post-core restoration restricts the potential usage with ceramic restorations in the

Received: 5.03.2020 **Accepted:** 27.04.2020 **Available online:** 18.02.2021
Corresponding Author: Dogu Omur Dede, Department of Prosthodontics, Faculty of Dentistry, Ordu University, Ordu, Turkey,
E-mail: dt_dogu@hotmail.com

anterior region (1,12,13). The biomechanical properties of a post material have been indicated as important as the physical factors in matters of choosing the post system, which should be similar to dentin structure without stress concentration (2,3,6,9,14). Until recently, many types of fiber-reinforced prefabricated post systems, which have highly successful results in terms of aesthetic, biomechanical properties with significantly reduced failure rates, have been introduced including polyethylene, polyamide carbon or glass fiber (1,3,4,9,10,15). On the other hand, fiber-reinforced post systems have better corrosion, fatigue resistance, the option of easy removal from the root canal (3,10). Fiber-reinforced post systems contain a high volume percentage of continuous carbon or silica-based fibers embedded in the polymer matrixes, usually the epoxy resin (3,6,10,16). The main disadvantage of fiber-reinforced post systems is originated from poor adhesion of fiber bundle to the polymer matrixes. It has been reported that the differences in the thermal expansion coefficients of the fiber and polymer matrix might lead to residual stresses development at the fiber-matrix interface during thermal fatigue conditions (16). This interfacial zone may not only be affected by thermal but also by mechanical and hydrolytic fatigue conditions. The fatigue conditions probably cause degradation on the biomechanical features and the physical integrity of the fiber-reinforced post systems resulted with the failing of long-term clinical performance of the restoration (4,9,10).

Tooth-colored ceramic prefabricated post or custom-made post-core systems also preferable in favor of high esthetic expectations, especially with the all-ceramic restorations in the maxillary anterior region (1,12,14). Zirconia posts have been introduced by the end of the 1980s, which have high fracture strength (FS), toughness, and chemical stability than the cast or fiber-reinforced post systems (12,10,17-19). However, the higher flexural strength, elastic modulus and the stiffness of the zirconia material (20) may cause unfavorable force distribution and catastrophic vertical-deep root fractures (6,10,12,21). The removing difficulties from the root canal and insufficient bonding capacity to composite resin core buildup materials are the other disadvantages of this post system (6,10,12).

The impressive developments on the Computer-Aided Design / Computer-Aided Manufacturing (CAD/CAM) technology and accompanying new restorative materials have been already begun to change the producing techniques with providing high quality, aesthetic restorations in also a chairside approach (10,22). One of the most popular CAD/CAM restorative material of lithium disilicate (Lds) and recently presented zirconia-reinforced lithium silicate (Zr_Lds) ceramics not only exhibits similar optical features with the natural dentition but also have the strong bonding capacity to the tooth structure and sufficient mechanical properties (10,23,24) Lds ceramics have high FS due to dispersed lithium disilicate crystals inhibits crack formation in the glass matrix and thus the manufacturer recommends its use for inlays, onlays, anterior or posterior crowns, and implant-supported crowns (23). While these materials are already being used as core material with zirconia post systems (CosmoPost; Ivoclar Vivadent AG), their performance as a monolithic post or post-core restoration has not been evaluated. The resin matrix ceramics (RMC) materials have been recently developed to combine the physical and mechanical advantages of ceramics and improved flexural properties and low abrasiveness of composite resin materials (22,25). The RMC's are biocompatible materials with a similar modulus of elasticity to the dentin tissue, which may show fewer crack propagations and better stress distribution than almost all other ceramics (10,26,27).

It has been expected that an ideal post material must have not only close physical but also mechanical properties such as elastic modulus, compression stress, and thermal expansion parameters to the dental tissues (9,16,28). According to the outcomes of the current literature, ideal post material still remains a controversial issue. The purpose of this in vitro study was to investigate the fracture strength and fracture modes of endodontically treated maxillary central incisors that restored with CAD/CAM made ceramic and RMC posts compared with a glass fiber post system. Care was taken to standardized the geometries and dimensions of tested post restorations. The null hypothesis of this study was that the FS of restored teeth would not differ with the type of post restorations.

MATERIALS and METHODS

This study was approved by the Clinical Research Ethics Board of the Ordu University with grant no: 2015/11-02. Seventy freshly extracted human maxillary central incisor teeth in similar dimensions with a straight root canal without any cracks, caries, restoration, and no shorter roots than 10 mm were selected for the present study. The external debruises on the teeth were removed with a scaler and stored in a 0.1% thymol solution throughout the study.

The anatomic crown of the teeth was sectioned horizontally to the long axis at the 2 mm coronal to the most incisal point of cementoenamel junction (CEJ), with the use of water-cooled diamond bur (SWS Dental SA) on the air turbine at 300000 rpm. A butt shoulder finish line preparation has been performed, with a wall convergence of 6 degrees, on the remaining crown portion throughout the CEF in the high of 2 mm and width of 1 mm. The remaining root canals were prepared instrumentally with the Reciproc system (VDW) up to size R50 (50.05) under copious 5% sodium hypochlorite (NaOCl) irrigation solution (Wizard) at a working length (1mm from the apical foramen). Silicone stoppers were utilized for controlling the working length of the files. After the mechanical preparations were finished, root canals flushed with 5mL of 17% ethylenediaminetetraacetic acid (EDTA) and 2 mL distilled water, respectively. Root canals were dried with paper points (Diadent). Then the root canals were obturated with laterally condensed gutta-percha (VDW) and a resin sealer (AH 26; DeTrey).

The 8 mm coronal part of gutta-percha filler was removed for each tooth using a peeso-reamer canal drill set (VDW) with leaving of 2-3 mm canal filling in the apical portion. Then the root canals were expanded to a width of 1.8 mm using a root canal drill set of a glass fiber post system (Cytec Blanco; Hahnenkratt GmbH) along with the irrigation of 0.5% NaOCl solution. Then the teeth were divided into 7 groups randomly (n=10) according to the post groups.

One of the most commonly preferred size (in the diameter of 1.8 mm and in the length of 14 mm) of the glass fiber post system (GFbr) for maxillary central incisor teeth, was admitted as the control group. The original length (20 mm) of the glass fiber posts (Cytec Blanco) were sectioned to reduce in the length of 14 mm from the apical end with a water-cooled diamond bur. In order to standardize the dimensions of all post groups, the digital fabrication procedures of CAD/CAM post specimens have been conducted using one specimen of the GFbr. This specimen has been scanned by a dental laboratory scanner (5 Series; Dental Wings Inc) and the 3D image transformed into STL (Standard Tessellation Language) data format for completing digital post design (DWOS CAD; Dental Wings Inc). Then the post restorations were manufactured with a 5-axis milling machine (HSC 20 Linear; DMG MORI) using appropriate CAD/CAM blocks listed in Table 1. After the milled post restorations were separated from the blocks, the GLds and GZr_Lds specimens were crystallized, and the GMZr specimens sintered according to the manufacturer's introductions.

Table 1. The post materials (composition), manufacturers and lot numbers of the test groups.

Group	Material (Composition)	Manufacturer	Lot Number
GFbr	Cytec Blanco; glass fiber post system (60% glass fiber, 40% epoxy resin matrix)	Hahnenrratt GmBH,	027656
GMZr	In Coris TZI; high-translucent monolithic zirconia block (99% ZrO_2-HfO_2-Y2$0_3$, <.5% Al_2O_3, <.5 %SiO_2)	Sirona Dental Systems	2014211887
GLds	IPS e.max CAD; lithium disilicate-reinforced glass-ceramic block (SiO_2-Li_2O-K_2O-MgO-P_2O_5-Al_2O_3)	Ivoclar Vivadent	U49077
GZr_Lds	Vita Suprinity; zirconia-reinforced lithium silicate glass-ceramic (SiO_2-Li_2O-K_2O-P_2O_5-Al_2O_3-ZrO_2-CeO_2)	Vita Zahnfabrick	47610
GRmc_Cer	Cerasmart; nanoparticle-filled RMC block (71 wt% SiO_2-barium glass, 29 wt% UDMA, DMA, Bis-MEPP)	GC Dental Products	1410071
GRmc_Lu	Lava Ultimade; nanoparticle-filled RMC block (80 wt% SiO_2-ZiO_2, 20 wt% Bis-GMA, UDMA, Bis-EMA, TEGDMA)	3M ESPE	3314A2
GRmc_En	Vita Enamic; polymer-infiltrated hybrid RMC block (86 wt% SiO_2-Al_2O_3-Na_2O-K_2O-B_2O_3-ZrO_2-CaO, 14 wt% UDMA, TEGDMA)	Vita Zahnfabrick	68251
GRmc_En	Vita Enamic; polymer-infiltrated hybrid RMC block (86 wt% SiO_2-Al_2O_3-Na_2O-K_2O-B_2O_3-ZrO_2-CaO, 14 wt% UDMA, TEGDMA)	Vita Zahnfabrick	68251

UDMA: Urethane dimethacrylate; DMA: Dodecyl dimethacrylate; Bis-MEPP: 2, 2-Bis (4-methyacryloxypolyethoxyphenyl) propane; Bis-GMA: Bisphenol-A-glycidyl methacrylate; Bis-EMA: Bisphenol-A-ethoxylate glycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate

Prior to the luting procedure, all CAD/CAM post specimens were abraded with 30 µm silica-coated aluminum oxide (Al_2O_3) airborne particles (CoJet; 3M Espe) for 15 s at a pressure of 2,5 bar from a distance of 10 mm using an intraoral sandblaster (Prophyflex 3; KaVo Dental GmbH). A 3-methacryloxypropyltrimethoxysilane (ESPE Sil; 3M ESPE) coupling agent was applied onto the CAD/CAM posts with single used brushes and waited for 5 min to dry. The coronal dentin surfaces were etched 35 % orthophosphoric acid (Scotchbond etchant; 3M Espe) for 15 seconds, rinsed and air-dried slightly. A self-etch bonding agent (Clearfill SE Bond 2; Kuraray Co Ltd) was applied onto the posts, root canals and coronal dentin surface using micro brushes for 10 seconds. Then all post specimens were cemented with dual-polymerizing adhesive resin cement (Panavia SA; Kuraray Co Ltd) according to the manufacturer's instructions. The cement was injected directly into the root canal using needle tube applicator, and the posts were quickly seated into the root canals under finger pressure. The excess cement was partially light-cured for 5 seconds in order to easily be removed, and the remainder was light-polymerized for 40 seconds.

A composite resin core (Clearfill Core; Kuraray Co Ltd) was built up to constitute a total abutment height of 6 mm measured from the buccal CEJ. The composite-core was prepared using a water-cooled diamond bur by following the existing ferrule preparation for each specimen. Then digital impressions of prepared teeth were obtained using a dental laboratory scanner (5 Series) and the design of single tooth incisor crown restorations completed using special software (DWOS CAD) in identical dimensions. Crown restorations were sintered from a Cobalt-Crome (Keramit NP-S; Nobil-Metal SpA) metal powder by using a direct metal laser sinter (DMLS) machine (EOSINT M 270; EOS GmbH). Full metal crown restorations were subjected to a secondary heating procedure for 4 hours in the temperature ranges of 450-900 ^{0}C to relieve stress. After finishing and polishing procedures the crowns were luted with dual-polymerizing adhesive resin cement (Panavia SA; Kuraray Co Ltd) according to the manufacturer's instructions (Figure1).

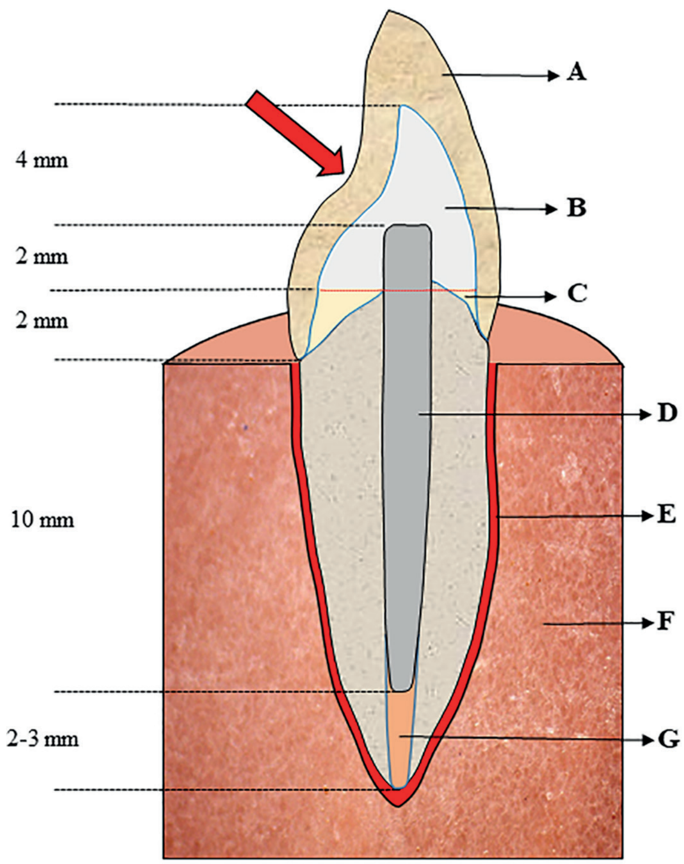

Figure1. The dimensions and the schematic picture of a specimen mounted in the acrylic resin block: Full-metal crown restoration (A), composite resin core (B), remaining crown dentine tissue (C), post-restoration (D), wax layer simulating the biological range (E), acrylic resin block (F), remaining gutta-percha filling (G)

The root surface of all specimens, below the 2 mm apical of CEJ, was covered with a 0.1mm thick layer of wax to simulate the biological range. Then the specimens were perpendicularly embedded in the auto-polymerizing acrylic (Meliodent; Kulzer Gmb) blocks and incubated in a 37±1 ^{0}C water bath for 24 hours prior to fracture testing.

The acrylic blocks were connected in a universal testing machine (Autograph AGS X; Shimadzu Co) using a stainless-still mold that allowed loading of 135 degrees to the long axis of tooth lingually (Figure 2). These angulation has been indicated as the calculated contact angle of Class I occlusion between the maxillary mandibular incisor teeth (2,6). The specimens were loaded at a head speed of 1 mm/min until fracture occurred and data (Newton=N) recorded. In addition, the fracture types (modes) have been recorded and they were classified as favorable (restorable) or catastrophic (non-restorable).

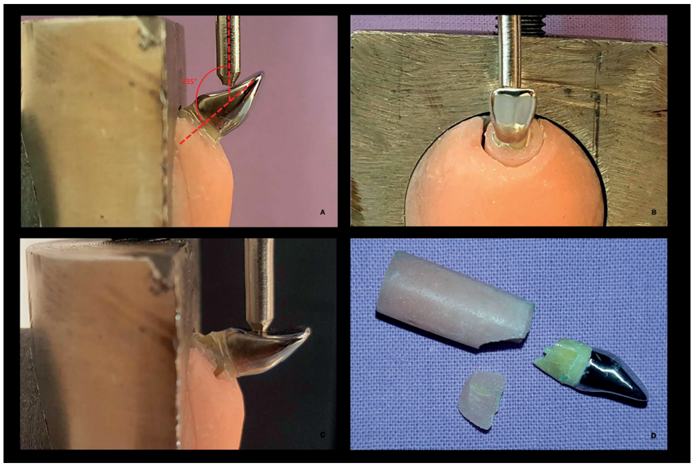

Figure 2. The connected specimen in a universal testing machine loading of 135 degrees to the long axis of tooth lingually (A, B) at a head speed of 1 mm/min until fracture occurred (C, D)

Data were statistically analyzed. Firstly, the Levene Homogeneity test was used for evaluating the normal distribution of the variables. The test showed the normal distribution of variables (P =.052). One-way analysis of variance (ANOVA) and Tukey HSD tests were used to compare the FS of the groups. The fracture types were analyzed with a nonparametric chi-square test and the correlation between fracture types, and FS was compared with Kendall's tau_b correlation analyses. All the computational work was performed by means of SPSS 20.0 V statistical software (SPSS Inc.) and significance evaluated at P<.05 for all tests.

RESULTS

According to the One-way ANOVA, the post type compared in our study was found to be effective on the FS (P<.001) (Table 2). The mean FS values (N), standard deviations (SS) and Tukey HSD multiple comparison test results of the test groups were shown in Table 3. In this table, the statistical comparisons were given by letters, there was a statistical difference observed between different letter coded groups according to the Tukey HSD test (P<.05).

The FS value of the GMZr group (365.62±28.52 N) was significantly higher than the other groups (P<.001). The FS of the GFbr group (261.07±24.51 N) was the second higher value which was also statistically different from the remaining post groups (P<.05). However, there was no significant difference observed between the remaining post groups (P>.05).

Table 2 The effects of post type variable on the FS values according to one-way ANOVA test

Variable (source)	df	Sum of squares	Mean squares	F	P
Between groups	6	304272.117	50712.020	68.126	.000*
In groups	63	46896.463	744.388		
Total	69	351168.580			

*Significantly different at P<.05.

Table 3. Mean FS values (N), standard deviations (SS) and Tukey HSD multiple comparison test results of the post groups

Group	FS	SS	Differences*
GFbr	261.07	24.51	b
GMZr	365.62	28.52	c
GLds	187.27	19.86	a
GZr_Lds	191.64	17.68	a
GRmc_Cer	191.54	25.29	a
GRmc_Lu	167.09	31.15	a
GRmc_En	174.71	38.47	a

*The Tukey HSD test results are given by letters and a statistical difference observed between differently coded groups (P<.05)

When the fracture types were analyzed according to the Pearson Chi-Square test, statistically significant differences determined among the test groups (P<.001). It was shown in Table 4 that only 3 specimens of the GMZr group had catastrophic (non-restorable) fractures which were located at the cervical third of coronal to mid-third of root surface with oblique direction. Favorable fractures were observed for all other specimens and most of these fractures started at the cervical third of coronal and finished at the cervical third of root surface with oblique direction. However, the fracture line of RMC post specimens was usually restricted at the coronal tooth tissue (Figure 3).

As a result of Kendall's tau b correlation analyses, the coefficient of correlation between FS and fracture types was statistically significant (P=.004, r2=0.288), indicating that these 2 variables were slightly correlated.

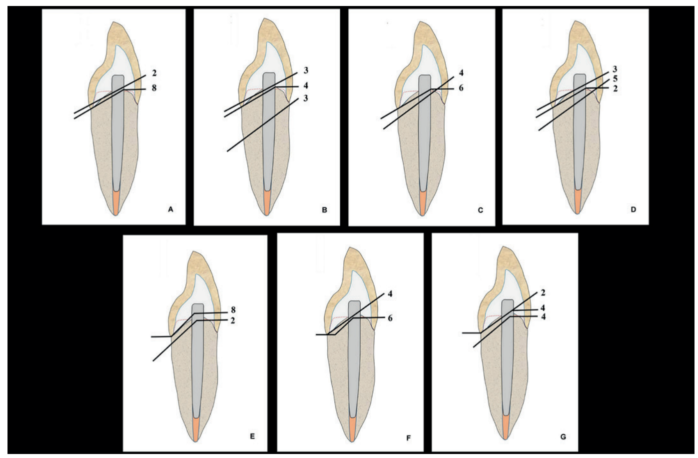

Figure 3. The localization and frequencies of fractures in tested post groups. The fractures started at the coronal and finished at the cervical third of root surface were assumed as favorable; below were assumed as catastrophic. A, GFbr; B, GMZr; C, GLds; D, GZr_Lds; E, GHbr_Cer; F, GHbr_Lu; G, GHbr_En.

Table 4. The fracture type summaries of the test groups.

Fracture type	GFbr	GMZr	GLds	GZr_Lds	GRmc_Cer	GRmc_Lu	GRmc_En
Favorable	10	7	10	10	10	10	10
Catastrophic	0	3	0	0	0	0	0
Total	10	10	10	10	10	10	10

DISCUSSION

In this study, endodontically treated maxillary incisors were restored with various novel CAD-CAM post and composite resin core materials, and the FS and fracture modes were evaluated after storage in a water bath for 24 h. From the results of this study, the null hypothesis has been rejected.

The FS of endodontically treated and restored teeth mostly depends on the dimensions, design, and material of the post, the remaining tooth tissue (8), location of the residual structure, ferrule (7), adhesive systems and factors that related with occlusion (4). In the present study, the FS and fracture type of the severely damaged teeth has been evaluated in terms of only the preferred post material variation. The dimensions, forms, surface characteristics of all tested post restorations have been standardized following with the same fabrication procedures. In order to standardize the dimensions of post restorations, all specimens have been milled as a replica of a glass fiber post using digital design and manufacturing technologies. Digital data of a glass fiber post specimen in the diameter of 1.8 mm and in the length of 14 mm has been acquisition by a dental laboratory scanner and the 3D images transferred as STL file to a CAD/CAM system to fabricated the ceramic post specimens from appropriate blocks. Furthermore, the same adhesive cementation, core and crown restoration fabrication process had been performed for each post group.

Occlusal forces and chewing stress have been distributed more uniform when the post and core restorations have similar elastic modulus to the dentin tissue (3,28). Related studies showed that the elasticity modulus of the fiber-reinforced post systems (~20 GPa) are more comparable to dentine (18 GPa) and thus demonstrates similar stress distribution patterns under external forces and increases the structural integrity (3,4,15). In addition, the fiber-reinforced posts easily removable from the root canal, when it cracked and the fracture type may generally be defined as favorable (3,5,10). Although fiber-reinforced post systems have good mechanical and physical features, there are some restrictions about their usage. Fiber-reinforced post systems prone to deformation under occlusal forces and mostly arose with neck fractures if they do not have sufficient rigidity (4,9,10). Furthermore, the lack of rigidity may be caused micro-movement of the core restoration, resulted with secondary caries, discoloration, periodontal problems and finally failure of the restoration (4). Nonetheless, the fiber-reinforced post systems are intensely suggested for the treatment of the severely damaged teeth and the research to reveal optimal post system has not been completed, yet. Therefore, a glass fiber post systems have been preferred as a control group in the present study.

The ceramics are one of the main restorative materials for dentistry, which have been preferred for many indirect restorations because of their superior properties like biocompatibility, integrity and ultimate optical properties for natural appearance (4,12-14). In this respect, zirconia demonstrated as the most suitable ceramic material for post restorations (14) has not only superior mechanical properties but also acceptable aesthetic properties, proved with many in vitro/vivo studies (2,6,10). However, the elasticity modulus of zirconia [200 GPa] is significantly higher than dentin tissue, which may cause improper force distribution, catastrophic fractures, and difficult to remove from the root canal (3,12,14). Furthermore, zirconia has an inadequate bonding capacity to other restoratives and tooth tissue either with using resin cementation techniques. The recently presented translucent monolithic zirconia, which may combine the mechanical superiorities and natural optical features, have been increasingly popular for several types of indirect restorations. The translucency of monolithic zirconia has been increased by some modifications, such as the production processes, sintering temperature and addition of coloring liquids (17-19). These modifications not only affect the optical features but also the mechanical and autocatalytic surface-transformation properties of zirconia (18). A full-contour fabricated zirconia restoration has an additional superiority that overcomes the chipping of veneering material (19). However, the performance and the mechanical properties of the monolithic zirconia post-core restorations have never been evaluated in clinical or laboratory studies before.

In the present study, the monolithic zirconia material has higher flexural strength with 600 - 1200 MPa and fracture toughness values (17,21) than other tested CAD/CAM ceramics. In parallel to this expectation, the FS values of the GMZr group was significantly higher than all other post groups, which also coincided with the results of related studies on zirconia post restorations (2,6,21). The fracture type of some GMZr specimens has been identified as catastrophic in contrast to all other post groups which were all favorable (restorable). In agreement with the results of previous studies, the stiffness and higher elastic modulus of the zirconia material may lead to less flexion in the post-cure unit and thus cause to non-favorable fractures of the teeth. On the other hand, the FS values of GMZr group (365.62 ± 28.52 N) were considerably lower than the FS values of restored teeth with zirconia post-cores in previous studies (2,4,6). In contrast to our study, the tested prefabricated fully sintered zirconia posts (Cerapost 232L12; Komet) were restored with composite resin (503 N) and heat-pressed ceramic (Empress-Cosmo; Ivoclar) (521 N) core materials in Heydecke et al.(2), The FS of same fully sintered zirconia post (Cerapost) material was evaluated by Pontious et al., and the much higher result reported for prefabricated ceramic (Ceracap; Komet) (1146.7±182.6 N) and custom-made ceramic (Cosmo; Ivoclar) (463.3±46.2 N) core groups (1). These variations may be mainly attributed to the weaker mechanical properties of tested monolithic zirconia material in the present study and also to the differences in the design, fabrication, cementation and the testing process between the studies.

It has been indicated in previous studies that the mean anterior bite forces in oblique direction were in the range of 100-200 N under any failure occurred (11,28). The FS value of GMZr (365.62±26.52 N) and GFbr (261.07±24.31 N) groups were significantly higher than these limits. The post restorations made of monolithic zirconia materials should be used as safety as glass fiber post material for the rehabilitation of severely damaged teeth with composite resin core build-up in the anterior region when considering FS successes. The second higher FS was observed in the GFbr group, which has lower elastic modulus (13.6 GPa) than not only the tested monolithic zirconia but also other ceramic materials. In spite of the higher FS values of GFbr, only restorable type of fractures was observed and this result may be explained with the lower elastic modulus, homogenous stress distribution and stress breaker characteristic of the glass fiber post material (6). These results are in agreement with the related studies (3-6,14,15) and will be concluded as the glass fiber post materials not only durable but also safe enough to restoring anterior teeth. However, in case of higher bite forces above the elastic limit of the post material and problems related to material fatigue may lead to irreversible damage to the teeth (4,9,10,16).

The reinforced glass ceramics such as the LDS or zirconia reinforces LDS with sufficient aesthetic and mechanical properties (23,24) attract a great deal of interest for clinical applications. The recently introduced zirconia reinforced LDS material combines the positive characteristics of zirconia and glass-ceramics (24). In the present study, while the FS values of GFbr and GMzr post groups were significantly higher than GZr_Lds (191.64±17.68 N) and GLds (187.27±19.86 N), no significant difference found between each other, according to the Tukey HSD. In a previous study, the FS values lithium di-silicate (470.8±428.2 N) and zirconia-reinforced lithium silicate (663.8±482.7 N) occlusal veneer restorations were found significantly higher than the FS results of the present study, which may be associated with the type, thickness of the materials and cementation technique (20). It will be concluded from the results of the present study that while the LDS and zirconia reinforced LDS post restorations may withstand the mean anterior bite force limits without any premature fracture but may not be durable as monolithic zirconia or glass fiber post restorations.

In restorative dentistry, RMC has been recently improved with CAD/CAM manufacturing. They have not only the physical and mechanical advantages of ceramics but also improved flexural properties and low abrasiveness of composite resins (5,22,25-27). The RMCs higher flexural strength (137 - 219 GPa) and modulus of resilience might be increased the resistance to crack propagation when compared with the regular ceramic materials. Furthermore, RMC materials have sufficient bonding capacity to the composite resin or cement materials (5,10,26). The present study brings new information about the use of RMC materials as CAD/CAM made post restorations. While the FS values RMC post groups were significantly lower than GMzr and GFbr, these values should also be clinically adequate when considering with the anterior bite force limits (100-200 N). The main advantage of RMC post restorations should be the lower elasticity modulus levels (3.48 - 40.06 GPa), which are more close to dentin tissue (17.7 - 29.8 GPa) and providing uniform stress distribution characteristic like fiber-reinforced post systems (5,22). The advantages (restorable) type of fractures, which have been observed for RMC post groups, may be associated with the superior mechanical properties of RMC materials that provide better stress distribution, in the present study. It has been shown in a previous study that the FS values of RMC materials significantly decreased after 7-day water storage and thermos-cycling procedures and this should be attributed to water absorption of resin matrix causing swelling of the network and reduction in the frictional forces between polymer chains (27).

In the present study, the FS and fracture types of endodontically treated and restored teeth with novel CAD-CAM ceramic materials have been evaluated in terms of identified features. However, these restorations should be evaluated using different post design, dimensions, and adhesive techniques. In addition, other mechanical properties like shear bond strength, flexural strength and fracture toughness of these materials should be evaluated as a post-core restoration. Although these post restorations are clinically designed to use with all-ceramic crown systems, full-metal crowns were fabricated in present study to maintain uniform stress distribution during testing procedures without any failure of the crown system. In this study, all samples have been incubated in a 37 ± 1 ^{0}C water bath for 24 hours. The long term success of these noble materials should be evaluated with future studies considering either dynamic, thermal or hydrolytic conditions with simulating of the oral environment.

CONCLUSION

Within the limitation of this study, the following conclusion should be drawn;

The CAD-CAM made monolithic zirconia post restorations should be more durable than glass fiber post systems in order to the rehabilitation of the severely damaged teeth with composite resin core build-up in the anterior region, considering fracture strength results. However, these post restorations involve more catastrophic fractures.

While the CAD-CAM made lithium disilicate or zirconia-reinforced lithium silicate post restorations should withstand the anterior bite force limits (200 N), not be durable as monolithic zirconia or glass fiber post systems.

The fracture strength performance of resin matrix ceramic post restorations was not successful enough in the maxillary anterior region in order to become an alternative option instead of the glass fiber post systems.

Acknowledgments: The authors thank to the Scientific Research Project Council of Ordu University for the financial support by "AR-1527" numbered support project.

Conflict of interest : The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: The study was granted ethical approval by the Ethics Committee of Ordu University, (2015/11-02).

REFERENCES

1. Pontius O, Nathanson D, Giordano R, et al. Survival rate and fracture strength of incisors restored with different post and core systems and endodontically treated incisors without coronoradicular reinforcement. J Endod 2002;28:710-5.
2. Heydecke G, Butz F, Hussein A, et al. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent 2002;87:438-45.
3. Lamichhane A, Xu C, Zhang FQ. Dental fiber-post resin

base material: a review. J Adv Prosthodont 2014;6:60-5.
4. 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. Dent Mater J 2019;38:114-9.
5. Sary SB, Samah MS, Walid AZ. Effect of restoration technique on resistance to fracture of endodontically treated anterior teeth with flared root canals. J Biomed Res 2019;33:131-8.
6. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002;87:431-47.
7. Stankiewicz NR, Wilson PR. The ferrule effect: a literature review. Int Endod J 2002;35:575-81.
8. Maccari PC, Cosme DC, Oshima HM, et al. Fracture strength of endodontically treated teeth with flared root canals and restored with different post systems. J Esthet Restor Dent 2007;19:30-7.
9. Pereira JR, do Valle AL, Shiratori FK, et al. The effect of post material on the characteristic strength of fatigued endodontically treated teeth. J Prosthet Dent 2014;112:1225-30.
10. Bankoğlu Güngör M, Turhan Bal B, Yilmaz H, et al. Fracture strength of CAD/CAM fabricated lithium disilicate and resin nano ceramic restorations used for endodontically treated teeth. Dent Mater J 2017;36:135-41.
11. Ferrario VF, Sforza C, Serrao G, et al. Single tooth bite forces in healthy young adults. J Oral Rehabil 2004;31:18-22.
12. Ozcan N, Sahin E. In vitro evaluation of the fracture strength of all-ceramic core materials on zirconium posts. Eur J Dent 2013;7:455-60.
13. Dede DÖ, Armaganci A, Ceylan G, et al. Influence of abutment material and luting cements color on the final color of all ceramics. Acta Odontol Scand 2013;71:1570-8.
14. Ozkurt Z, Işeri U, Kazazoğlu E. Zirconia ceramic post systems: a literature review and a case report. Dent Mater J 2010 29:233-45.
15. Dikbas I, Tanalp J. An overview of clinical studies on fiber post systems. Scientific World Journal 2013;2013:171380.
16. Ray BC. Thermal shock and thermal fatigue on delamination of glass-fiber-reinforced polymeric composites. J of Reinforced Plastics and Composites 2005;24:111-6.
17. Zhang Y, Lee JJ, Srikanth R, et al. Edge chipping and flexural resistance of monolithic ceramics. Dent Mater 2013;29:1201-8.
18. Malkondu O, Tinastepe N, Akan E, et al. An overview of monolithic zirconia in dentistry. Biotechnology & Biotechnological Equipment 2016;30:644-52.
19. Carrabba M, Keeling AJ, Aziz A, et al. Translucent zirconia in the ceramic scenario for monolithic restorations: A flexural strength and translucency comparison test. J Dent 2017;60:70-6.
20. Elsayed A, Wille S, Al-Akhali M, et al. Effect of fatigue loading on the fracture strength and failure mode of lithium disilicate and zirconia implant abutments. Clin Oral Implants Res 2018;29:20-7.
21. Matsuzaki F, Sekine H, Honma S, et al. Translucency and flexural strength of monolithic translucent zirconia and porcelain-layered zirconia. Dent Mater J 2015;34:910-7.
22. Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. J Prosthet Dent 2015;114:587-93.
23. Fasbinder DJ, Dennison JB, Heys D, et al. A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. J Am Dent Assoc 2010;141:10-4.
24. Elsaka SE, Elnaghy AM. Mechanical properties of zirconia reinforced lithium silicate glass-ceramic. Dent Mater 2016;32:908-14.
25. Çelik E, Sahin SC, Dede DÖ. Shear bond strength of nanohybrid composite to the resin matrix ceramics after different surface treatments. Photomed Laser Surg 2018;36:424-30.
26. Chen C, Trindade FZ, de Jager N, et al. The fracture resistance of a CAD/CAM Resin Nano Ceramic and a CAD ceramic at different thicknesses. Dent Mater 2014;30:954-62.
27. Lauvahutanon S, Takahashi H, Shiozawa M, et al. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J 2014;33:705-10.
28. Varvara G, Perinetti G, Di Iorio D, et al. In vitro evaluation of fracture resistance and failure mode of internally restored endodontically treated maxillary incisors with differing heights of residual dentin. J Prosthet Dent 2007;98:365-72.