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Original Article

In vitro evaluation of the fracture strength of all-ceramic core materials on zirconium posts

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ABSTRACT

Objective: For most endodontically treated teeth, tooth-colored post-core systems are preferable for esthetic reasons. Therefore, improvements in material strength must also consider tooth colored post-core complexes. The objective of this study was to evaluate the difference in tooth colored post–core complex strengths. **Materials and Methods:** A total of 33 human maxillary central incisor teeth were used for this study, with three groups of 11 teeth. Three different methods were used to fabricate all-ceramic post-core restorations: zirconia blanks, Cerec 3D-milled to one-piece post-core restorations (Test Group 1); feldspathic cores (from feldspathic prefabricated CAD/CAM blocks) adhesively luted to CosmoPost zirconia posts (Test Group 2); and IPS Empress cores directly pressed to CosmoPost zirconia posts (Test Group 3). All-ceramic crowns from feldspathic ceramic were constructed using a CAD/CAM system (Cerec 3D) for all specimens. The post-core complexes were tested to failure with the load applied at 45° angled relative to the tooth long axis. The load at fracture was recorded. **Results:** The maximum fracture strength of the milled zirconia cores (Test Group 1) was 577 N; corresponding values for the milled feldspathic cores (Test Group 2) and the pressed cores (Test Group 3) were 586 and 585 N, respectively. Differences were not statistically significant at $P < 0.05$ ($P = 0.669$). **Conclusions:** All-ceramic cores adhesively luted on zirconia posts and one-piece all-ceramic zirconium post–core structures offer a viable alternative to conventional pressing.

Key words: All-ceramic crown, all-ceramic post-core, one-piece post-core, zirconium post-core

INTRODUCTION

Endodontically a treated tooth with extensive loss of tooth structure exhibits a higher risk of fracture than vital teeth. In such cases, the post-core method is used in dental practices. Different types of posts are inserted in root canals to support and strengthen the restoration. For this purpose, titanium, gold-plated, chrome–nickel or gold-cast posts, ceramic pre-fabricated posts have been used. Because, there is a wide variety of post–core restoration technologies and materials, there is no consensus regarding the most appropriate option for post-core systems.[1] Some studies support casted post-cores while others support tooth-colored prefabricated posts.[2,3] Esthetic considerations favor tooth-colored posts in the anterior maxillary region, where all-ceramic crowns are used.[4-7]

Metal ceramic crowns have been used for decades in prosthetic dentistry. Non-precious alloys have poor dark reflection under gingiva and marginal adaptation is worse than with all-ceramic crowns.[8] The esthetic properties of ceramic crowns are preferable in the anterior region for prosthetic treatment. Light-conducting, fiber and all-ceramic posts[9] are available for restorations in more esthetically demanding areas.

Christel *et al*.[10] investigated zirconium posts introduced by the end of the 1980's and reported that they have high fracture and bending strength.

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Composite and ceramic cores can be constructed on zirconium posts. Composite resin core materials currently used for prefabricated posts inserted into endodontically treated teeth can be easily and quickly applied. Compared with pre-fabricated metal posts, lower bond strengths have been reported for composite resin core materials bonded to zirconium posts.[4,11] This result is related to the smooth surface of the zirconia posts, which prevents macromechanical and micromechanical retention from the composite resin core materials. For this reason, ceramic plug-compatible cores are preferred for use with zirconium posts.[12] There are different methods for preparing ceramic post-core systems: the core can be constructed separately and adhesively, luted to post and tooth, a one-piece post-core complex can be constructed using computer-aided design and computer-aided manufacturing (CAD/CAM) techniques and the core can be constructed using a heat-pressed technique.[13]

The purpose of this study is to evaluate the fracture strength differences in different all ceramic post combinations. The null hypothesis to be tested was that the types of all-ceramic post-cores do not affect the fracture strength results of the all-ceramic post core systems.

MATERIALS AND METHODS

A total of 33 human maxillary central incisors free of cracks, caries and fractures were selected for the study. Three groups of 11 specimens were formed. To ensure an even distribution of the size of teeth within the specimen groups, we select teeth randomly distributed into Test Groups. Groups were consisted of Cerec 3D milled zirconia blanks to one-piece post-core restorations, adhesively luted feldsphatic cores (from feldspathic prefabric cad/cam Blocks) to zirconia posts (CosmoPost; Ivoclar, Schaan, Liechtenstein), pressed IPS Empress cores directly to zirconia posts and named as groups 1, 2, 3, respectively. Distribution of Test Groups was pointed out in Table 1.

All teeth were stored at room temperature in a 0.9% serum physiologic solution. All roots were covered with wax (Dipping Wax, Bego, Germany) under 2 mm below the cement enamel junction (CEJ) for generating periodontal space. The teeth were embedded in 2 cm × 2 cm × 5 cm molds in auto-polymerizing acrylic resin (Vertex, Vertex Dental and The Netherlands). To simulate a human periodontium, wax layer of roots were changed with a 0.1 mm thick layer of light-body silicone (Elite HD + Light Body Normal Setting, Zhermack, Italy) after embedding process.

Table 1: Distribution of Test Groups

Test group	Post structure	Core structure
Test 1 group	Milled zirconium post	Milled zirconium core
Test 2 group	Pre-fabricated zirconium post	Milled feldspathic core
Test 3 group	Pre-fabricated zirconium post	Heat-pressed IPS cosmo core*

*Manufactured from IPS empress ingot compatible for pressing with zirconium posts

The clinical crowns were cut 2 mm coronal to the most incisal point of the CEJ. All teeth were prepared under water cooling with high speed hand piece until 1 mm shoulder finish line was formed with 1 mm diameter diamond fissure bur (Diatech, Coltene/Whaledent, Switzerland).

All specimens were submitted to conventional root canal therapy, root canals were enlarged to size 40 (Dentsply Maillefer, Ballaigues, Switzerland) and rinsed with 2.5% sodium hypochlorite. Root canal filling was carried out by lateral condensation with gutta-percha (Sure Dent Corporation, Korea) and eugenol-free sealer (AH plus, Dentsply, Germany). Specimens were waited 2 weeks in formol solution for root canal therapy maturity. Then, temporary filling material on the canal entrance removed and teeth submitted to Peeso Reamer (No: 1) and then drilled with 1.4 and 1.7 steel drills in the CosmoPost set. Gutta percha was removed from the root canals with a Peeso Reamer, leaving 3 mm of root canal filling in the apical portion. Subsequently, the root canals were enlarged to receive endodontic posts using a tapered number 2 drill (ISO 90) from the CosmoPost kit.

Impression of the specimens was made with silicon material (Elite HD Putty Soft ve Light Body, Italy) and CosmoPost impression metal. Hard Stone (Moldano, Heraeus Kulzer, Germany) mixed in vacuumed mixer (EasyMix Vacuum Mixer, Bego Dental, USA) following manufacturers' instructions.

In Test 1 group, root portion of the impressions were dusted with titanium oxide (TiO_2, Cerec Propellant, Vita Zahnfabrik, Germany). Optic impression was made inCerec 3D inEos (extraoral scanner). Post-core structures [Figure 1] suitable for root-canal space were produced from prefabricated zirconium blocks (InCoris Zirconium Blocks, Sirona dental systems Gmbh, Bensheim, Germany) for constructing 6 mm core structure from CEJ.

While forming Test 2 group, we benefit from the correlation technique, which is one of the three techniques (replication, dental data base, correlation) using in Cerec 3D CAD/CAM system when shaping the restoration. In correlation system, you must record the form of the restoration, which you want to form in the milling machine. We designed the form of the restoration with wax and introduce it to the system. By this way, we will produce the wanted restoration from ceramic.

In Test 2 group, 1.7 mm diameter zirconium posts placed to hard Stone models of the specimens, then modelation (crown wax, medium-hard) was carried out for forming cemento enamel 6 mm core structure. We lubricate the post before modelation for removing post from the modelation and we want to monitorize the hole in the middle of the modelation. This hole powdered with TiO_2 and optic impression was carried out by the software of the inEos [Figure 2]. Core structures having holes in the middle produced from Cerec feldspathic blocks (Sirona Cerec Blocks, Bensheim, Germany). The irregularities around the hole were straightened by 1 mm diameter cylindrical diamond bur under water cooling.

For Test 3 group, cosmoposts were inserted into specimens; then modelation was done 6 mm from cementoenamel junction (Finesse All-Ceramic Inlay Wax, Ceramco, UK). After removal of the post-core structure from the root canal, structures were formed from IPS Cosmo following the manufacturer's instructions.

The posts with the core patterns were subsequently sprue and invested (IPS Empress Investment, Ivoclar). After the burnout and preheating process, the core was heat-pressed with a zirconia-enriched glass ceramic (Empress-Cosmo, Ivoclar) at 900°C and 5 bars. Investment was removed, all surfaces were carefully air-abraded and the posts-cores were prepared for cementation with resin cement.

In all groups, zirconium post parts were abraded with Al_2O_3 particles (S-U Austral, Schuler Dental, Germany). Root canals were abraded % 37 orthophosphoric acids (Ultra-etch, Ultradent) for 15 min. After the abrasion process specimens washed for 10 s and dried for 5 s with air spray and paper points consecutively. (Sure-endo, Sure Dent Corporation, Korea) All canals were pre-conditioned with a self-etching primer for 5 s (ED-Primer, Kuraray) then polymerized 10 s with halogen light source (Hilux, Benlioğlu Dental, Ankara) and the posts were cemented using a dual-polymerizing resin cement (RelyX adhesive resin cement [ARC], 3M ESPE, Germany).

In Test 1 and Test 3 group, post-core structure was intact and cemented entirely. IPS Cosmo core related with Test 3 group and feldspathic core related with Test 2 group were applied hidrofloric acid (IPS Ceramic Etching gel, Ivoclar Vivadent, Liechtenstein) 30 s and silane agent (ESPE-sil, 3M ESPE, Germany) because of glass content. In Test 2 group, post-core structure was separate, by this way when post cemented to the root canal core was cemented to post at the same time. All posts were cemented with RelyX ARC.

After cementation, excess cement was cleaned and all optical impressions were made with Cerec 3D inEos. 33 similar crowns were fabricated from an all-ceramic material (CerecBloks, Bensheim, Germany) in the same dimensions with the help of software by CAD/CAM technique. The crowns were adhesively luted with RelyX ARC in accordance with the manufacturer's instructions.

Figure 1: Aspect of Test 1 group specimen before milling

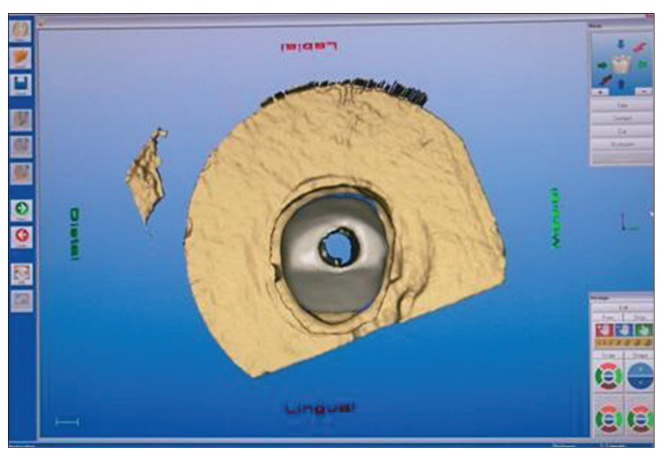

Figure 2: Aspect of Test 2 group in the software

Specimens were subjected to thermo-cycling (Water Bath, Nüve Sanayi Malzemeleri, Türkiye) for 6000 cycles (5-55°C, 20 s dwell time). A compressive load was applied to the posts at 45° to the long axis of the tooth, at a crosshead speed of 1 mm/min, 4 mm from the incisal edge. Failure detection was set at a 10% loss of the maximum applied force. Fracture load was recorded for all specimens randomly distributed into Test Groups [Table 2]. One-way analysis of ANOVA was used to determine the significance of the failure loads between groups.

RESULTS

There was not any missing specimen during thermocycling. Most of the fractures occurred where the static load was applied to the specimen. In Test Group 1, cervical teeth fractures were observed in nine specimens. In one specimen, both post-core and root fractures were observed and in the other specimen, only a crown fracture occurred. In Test Group 2, fractures were observed in cervical regions of the teeth for eight specimens, whole crown cracks occurred in two specimens, post-core and root fractures were observed in two specimens and only a core fracture was observed in one specimen. In Test Group 3, cervical crown fractures were observed in seven specimens, whole crown cracks occurred in three specimens; one of the four specimens that showed a post-core fracture also showed a root fracture. Fractures observed after static loading were recorded and classified according to the area where the fracture occurred [Table 3].

The results were statistically evaluated by one-way ANOVA analysis. The fracture strength values observed after static loading were recorded [Table 2]. The maximum fracture strength values for Test Groups 1, 2 and 3 were 577, 586 and 585 N, respectively [Figure 3]. There was no statistical difference ($P = 0.669$, $P > 0.05$) among the groups.

DISCUSSION

With the rejection of the null hypothesis, one-piece zirconium post-core systems have no mechanical advantages over other aesthetic post-core solutions.

In the current study, some of the specimens had large standard deviations. One possible explanation is that the study used extracted human teeth. Human teeth are commonly used for *in vitro* testing of post restorations. The sizes and shapes of the root canals and/or the texture and properties of the inner surfaces of the root canals may have differed. Differences among the specimens were the result of anatomic variation and specimen preparation, which replicated clinical reality.[14] Several other studies have used human teeth within these limitations and reported meaningful results.[15,16] Dentinal changes can be caused by variation in water content, pulpal condition before tooth extraction, patient age and dentin composition. These dentinal changes can affect elasticity, thereby changing the fracture pattern during loading.

Several authors have argued that crown placement when testing post-core restorations obscures the effects of different buildup techniques. A crown creates a ferrule effect when placed over a core buildup when the margins encircle a sound dentin collar. However, testing without a crown would not simulate a clinical situation. A cast crown with a ferrule has been shown to distribute forces to the post-core and root

Table 2: Recorded mean, standard deviation, minimum and maximum fracture loads of all groups

Groups	Mean (*N*)	Standard deviation (*N*)	Minimum (*N*)	Maximum (*N*)
Test Group 1	357.72	147.63	120.00	577.00
Test Group 2	383.54	119.79	205.00	586.00
Test Group 3	333.09	124.27	170.00	585.00
Total	358.12	128.68	120.00	586.00

Table 3: Specimens classified according to the area where fracture occurred

Groups (*n*=11)	Crown fracture		Post fracture	Core fracture	Root fracture
	Cervical	Whole crown			
1	9	1	1[a]	1[a]	1[a]
2	8	2	2[b]	2[b]+1	2[b]
3	7	3	4[c]	4[c]	1[c]

Superscribes infers that the specimen is the same one

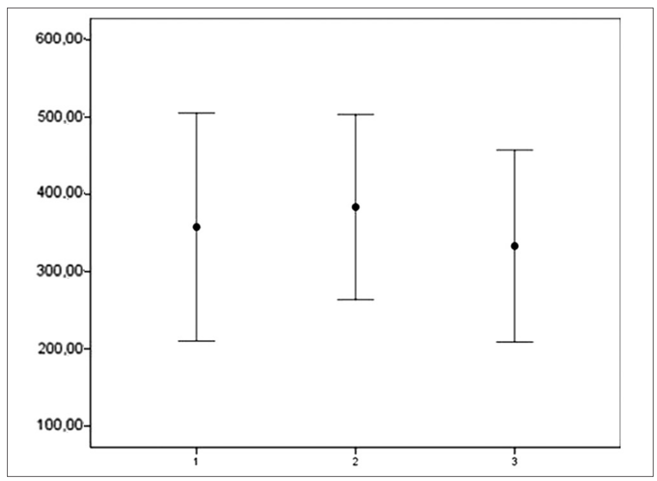

Figure 3: Graphic of statistical results (x: Test Groups, y: Newton)

more differently than forces applied directly to post or core.[17,18] Therefore, all samples in this study were restored with all-ceramic crowns for standardization and tested with complete-coverage crowns.

The ferrule height was constant around the periphery of the teeth.[19] Clinically, height normally varies around the circumference of a tooth. Furthermore, the finish line follows the coronal extension of the gingival tissue interproximally. However, the ferrule height and finish line were not considered for standardization of the specimens.

The fracture resistance was determined using a universal testing machine.[17,18,20,21] However, the universal testing machine did not reproduce oblique, torsional and lateral shearing forces produced during chewing. During testing, a single load increase was used at a constant angle and was applied over a small area on the artificial crown. However, masticatory forces are multidirectional and are applied repeatedly to a larger surface area.

Friedel and Kern[22] investigated the differences between the fracture resistances of groups consisting of prefabricated zirconia ceramic posts and resin composite buildup, zirconia ceramic posts and copy-milled alumina ceramic cores (two-piece technique) or copy-milled all-ceramic posts and cores made from a zirconia-reinforced glass-infiltrated alumina ceramic (one-piece technique). The mean fracture strength of the groups ranged from 205 to 522 N, which was consistent with our results. Prefabricated zirconia posts and resin composite buildup showed a statistically significant lower fracture strength after simulated chewing compared to teeth restored with prefabricated zirconia posts and alumina ceramic cores. The ceramic posts and cores made with the two-piece technique showed promising fracture strength under the tested conditions.

Bittner *et al.*[23] evaluated the fracture loads and failure modes of a gold-cast post-core as a control, one-piece milled zirconia post-core, prefabricated zirconia post with a heat-pressed ceramic core, titanium post and composite resin core and combined fiber/zirconia post with composite resin core. All systems showed sufficient mean load-to-failure values for anterior tooth restorations, including the recently developed one-piece milled zirconia post-core.

Jeong *et al.*[24] evaluated the fracture resistance of three groups: IPS Empress cores pressed directly to CosmoPost zirconia posts, IPS Empress cores adhesively luted to CosmoPost zirconia posts and In-Ceram zirconia blanks Celay-milled to one-piece post-core restorations. They concluded that all-ceramic cores adhesively luted on zirconia posts offer a viable alternative to conventional pressing.

CONCLUSIONS

Within the limitations of this *in vitro* study, we concluded that:

- Specimens in Test Group 2, consisting of a separate zirconium post and glass ceramic core structure, can be used as an alternative in post-core structures applied in the anterior region. It seems time consuming; beyond the cementation process is more demanding process than the other groups
- Post–core structures consisting of full zirconium ceramic material (Test Group 1) can also manufactured in the first appointment of the patient, but another call is needed because of the sintering process of zirconia
- Pressing ceramic onto a zirconium post is time consuming because of laboratory process
- Thus, each post-core system has advantages and disadvantages and a dentist may choose the method he or she prefers.

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