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FRACTURE RESISTANCE OF DIFFERENT ESTHETIC POST AND CORE MATERIALS AND ASSESSMENT THEIR MODE OF FAILURE

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ABSTRACT

Purpose: This in vitro study measured fracture resistance of different esthetic post and core materials and compare their modes of failures.

Statement of problem: Increase esthetic demand and patient awareness have encouraged development of esthetic post and core systems. Translucency of ceramic restorations is accompanied by marked decrease in alumina content that may affect mechanical properties.

Methods:40 extracted human central incisors were used in this study. Teeth were randomly divided into 4 groups of 10 each: group 1:Translucent Zirconia(TZ);group 2:High Translucency IPS E.Max (T-IPS); group 3:Polymer Infiltrated Ceramic (Vita Enamic) (PIC) and group 4: Control group (C), teeth were endodontically treated with no posts and cores. Posts and cores were processed according to manufacturer instructions cemented to teeth with adhesive resin cement; then specimens were mounted to acrylic resin blocks, attached to Instron universal testing machine, and loaded with a crosshead speed of 0.5 mm/min, until fracture. Types of failures were also recorded in different groups. Data were statistically analyzed using 1-way analysis of variance (ANOVA), and Scheffe test made pairwise comparison ($\alpha = 0.05$).

Results: TZ group showed the highest fracture resistance (454 .4±41.6 N). T-IPS showed higher results(360.4±35.7N) than PIC(300.9±35.6 N) and control(276.7±32.5 N) and the two latter groups were not significantly different from each other $P < 0.001$.As regard mode of failure TZ showed 80% non-restorable type, T-IPS 40%,PIC 50% and control group showed 20% non-restorable type respectively.

Conclusions: Regarding fracture strength and mode of failure, High Translucent IPS-E Max post and core can be an alternative treatment method when compared with other techniques.

INTRODUCTION

In 1989, Geller and Kwiatkowsky [1] introduced cast glass ceramic post and core material in order to maintain color and translucency of pulpless teeth. This treatment modality achieved perfect esthetics but has low mechanical properties due to brittle nature of glass ceramics[2].

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Different methods for fabricating esthetic posts and cores have been evolved and the use of CAD-CAM systems for construction of cores to be combined with prefabricated posts additionally, completely milled posts and cores have been described in different literature (3,4,5).

Technique of milling zirconia post and core has been described by Awad ,Marghalani (6), Streacker and Geissberger (5). The authors used computer-aided design and computer-aided manufacturing (CAD-CAM) technology to fabricate yttrium-tetragonal zirconium polycrystal ceramic posts.

In anterior region, because of esthetic problems, prefabricated esthetic post systems such as lithium disilicate, polymer infiltrated ceramic and zirconia are generally preferred. The clinical success of these materials depends on severity of clinical factors, but fracture resistance is a critical issue. However, as the bending resistance of a post depends on its diameter and physical properties, it is essential to have a basic knowledge concerning the mechanical properties of individually selected post (7).

In large, non circular or tapered canals, post systems that rely on the use of a cylindrical prefabricated post may not achieve the intimate adaptability of the post to the canal, possibly compromising the retention of the post (6).

When these factors are assessed, a custom made milled posts and cores would be an alternative treatment option in some clinical cases. Butz et al (8) reported that survival rates and fracture strengths of prefabricated zirconia posts with composite cores are significantly lower, so this combination are not recommended for clinical use. Bittner et al (9) reported an advantage that single piece post and core systems avoid potential core delamination by eliminating interfaces between the post and the core. Additionally, one research study reported that core construction technique was a decisive factor in survival rate of zirconia post (10).

Dowel material plays a crucial role in the biomechanical performance of endodontically treated teeth. Numerous experimental and finite element studies have shown the relevance of post designs, including length, diameter and material, on the strength of restored teeth (11). Endodontic posts can be preformed or custom made, metallic or nonmetallic, stiff or flexible and esthetically or non-esthetically (12).

Tooth structure remaining after endodontic therapy exhibits irreversibly altered physical characteristics. Changes in collagen cross linking and dehydration of the dentin result in 14% reduction in strength and toughness. The internal moisture loss is approximately 9% and is greater in anterior than posterior ones. This combined loss of structural integrity, loss of moisture and loss of dentin toughness compromises endodontically treated teeth [13].

The greatest bite force was found in the first molar region, whereas at the incisors it decreased to only about one third to one fourth that in the molar region. In previous studies, mean values for the maximal force level in the molar region have reached 847N [14]. For the incisal region, bite force values ranging from 108 to 299N have been reported [15]. Men often achieve significantly greater bite forces than women [16].

Polymer infiltrated ceramic(Vita Enamic) eliminates many of the drawbacks associated with traditional dental ceramics by combining resin and nano-technologies.Nano ceramic particles are embedded in a highly cross-linked resin matrix (80 % wt Nano ceramic and 20 % wt resin) (17). Resin nanoceramic has lower modulus of elasticity than brittle glass ceramic materials and porcelain fused to metal veneering porcelain and allowed absorption of chewing forces and decrease stresses falling on restoration, this is especially advantageous for crowns over implant (17).

The purpose of this in vitro study was to compare the fracture resistance of different esthetic post and core systems produced with different fabricating techniques and materials. Null hypothesis of this study was that different fabricating techniques and materials would not affect the fracture resistance of post and core systems or fracture mode.

MATERIALS AND METHODS

Fourty freshly extracted maxillary central incisors with intact crown and apices were collected and stored in 0.1 thymol solution after extraction. Stereomicroscope was used to examine the roots and ensure absence of cracks or fractures. Mean root length from cervical line to root apex was 13.0±1 mm.

30 samples were resected 1mm coronal to cemento-enamel junction using a double sided diamond (Degussa AG, Frankfort, Germany) disk at low speed hand piece under copious water coolant.

Decoronated samples were endodontically treated,working length was measured by deduction 1mm from length recorded with # 15 K files. All samples were instrumented using M two NiTi rotary files up to size 40/0.4 at working length. Files were used to full length of each root canal.

Root canals were irrigated with 5 ml of 2.5% NaOCl solution using 30 gauge needle, dried with corresponding absorbent paper points and obturated with lateral condensation technique using size 40 gutta-pecha as a master cone. Epoxy resin sealer was used in all tested groups (AH 26, De Trey, Zurich, Switzerland).

Cervical external surface of resected teeth were machine milled (Degussa AG, Frankfurt ,Germany) to standardize the preparation, core dimension and obtain 5 mm diameter to root face for all tested samples.

10 samples serving as control group are merely restored with composite resin Z 250 (3M ,ESPE) sealing access opening after root canal treatment.

Specially designed Teflon mold (Fig.1) was machine milled in order to hold the tooth in its block with their long axis at 130°in relation to load applicator of testing machine. Block was cylindrical in shape with 3 cm in diameter and 5 cm in length and central hole 10mm in diameter.

All samples were embedded in an autopolymerizing acrylic resin perpendicular to long axis of root. Post space was adjusted at a length of 13mm and diameter 1.4 mm. The length was obtained by initially removing the gutta percha with a Gates Glidden drill (Mani Inc.,Tochigi-Ken, Japan) up to size 3 (Fig.2).

All 40 samples were randomly divided into 4 groups consisting of 10 teeth each. Samples were divided into the following groups:

Group 1 (TZ): Translucent Zirconia.

Group 2 (T-IPS): High Translucency IPS E-Max.

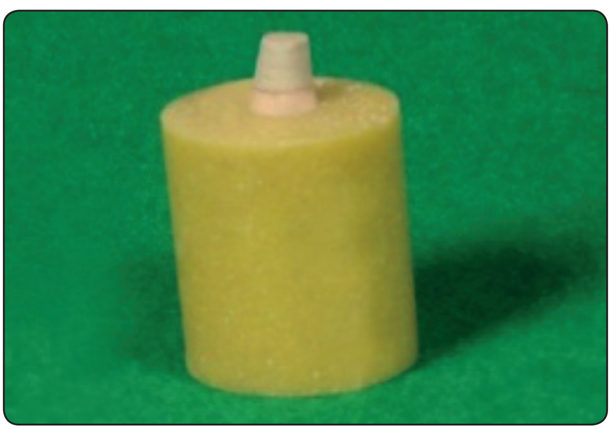


Fig. (1) Acrylic mold.

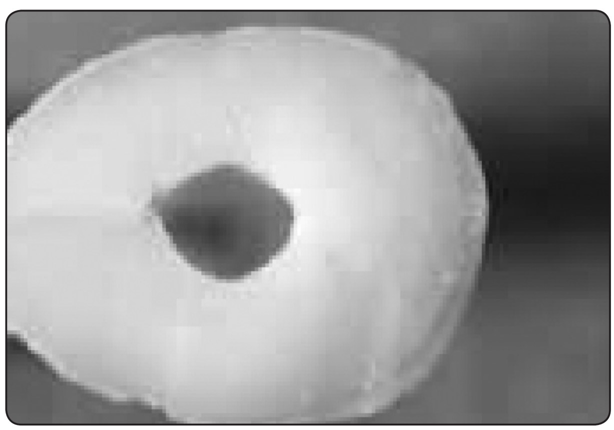


Fig. (2) Sample after post preparation.

Group 3 (PIC): Polymer Infiltrated Ceramic (Vita Enamic).

Group 4 (Control): Sound teeth were endodontically treated and access opening were sealed with composite resin Z250 (3M, ESPE).

According to previous studies[27,30], impression of post and core spaces were taken with C type light and heavy viscosity silicone based impression material (Zeta Plus; Zhermack, Badia Polesine, Italy) mixed and applied inside root canals .

After taking the impressions, dies were prepared and scanned by laser in laboratory for acquiring and transmitting informations. Full Digital impressions were made with an extra-oral scanner (inEos X5; Sirona, Germany) to generate virtual models. Special software (in Lab SW 4.2.1.61068, Sirona Dental Systems, Bensheim, Germany) was used to design the post and core restorations.

According to manufacturer instructions 10 Vita Enamic Blocks (VITA Zahnfabric; Bad Sackingen, Germany) and 10 Lava Plus High Translucency Zirconia (3M ESPE) were processed in milling unit (MC XL, Sirona Dental systems, Bensheim, Germany) (Fig.5). 10 HT ingots IPS e.max (IVOCLAR VIVADENT) were prepared and after spruing, investing and burn out of posts and cores patterns, heat-pressing from Zirconia-enriched glass-ceramic at 900^0C and 5 bar pressure in a hot press furnace and fully cristallized (Programat P300, Ivoclar Vivadent, Schaan, Liechtenstein) according to manufacturer instructions.

All samples were luted with Panavia 21 (Kuraray Noritake Dental Inc. Japan) resin cement following manufacturer instructions and stored in distilled water at 37˚C for 24 hours before testing.

Specimens were mounted in a specially designed attachment (Fig.4) to hold and fix specimens during load application to ensure that force from testing machine crosshead speed of 0.5mm /min was applied at 130˚to the long axis of the root. Fracture resistance test was applied using a universal testing machine (Fig. 4) All restorations were loaded until catastrophic failure occurred and the testing machine automatically recorded the fracture force (Newton).

All fractured specimens were classified as restorable or not restorable. This was judged on the basis of whether fractures were located above cement enamel junction or extended apically (non-restorable). As shown in (Table 2) and Graph (2).

SPSS version 22.0 was used for data management. Mean, standard deviation and range described fracture resistance. One way ANOVA made comparisons between groups and Scheffe test made pairwise comparisons. Fisher exact test compared independent proportions. P value always 2 tailed and significant at 0.05 level.

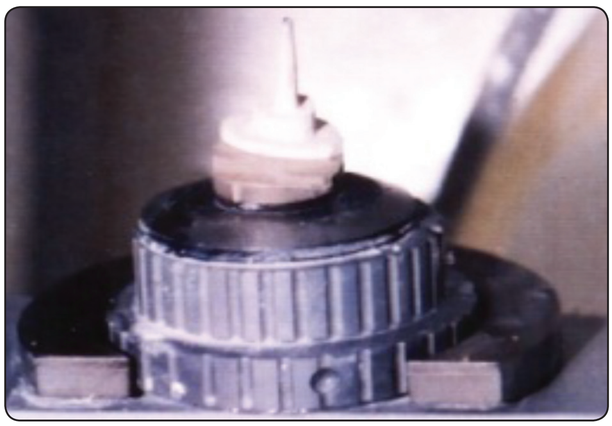


Fig. (3) Milled post and core

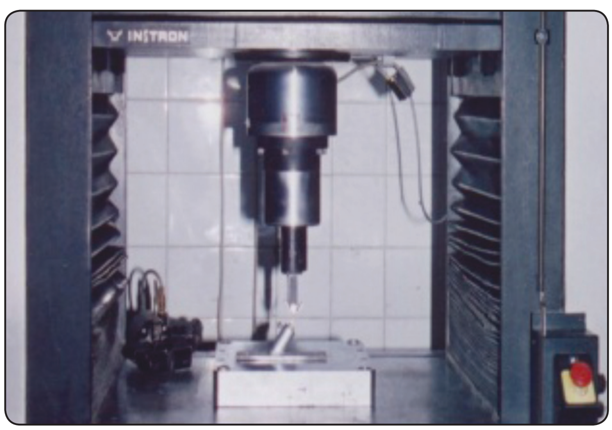


Fig. (4) Universal testing machine, Instron, England.

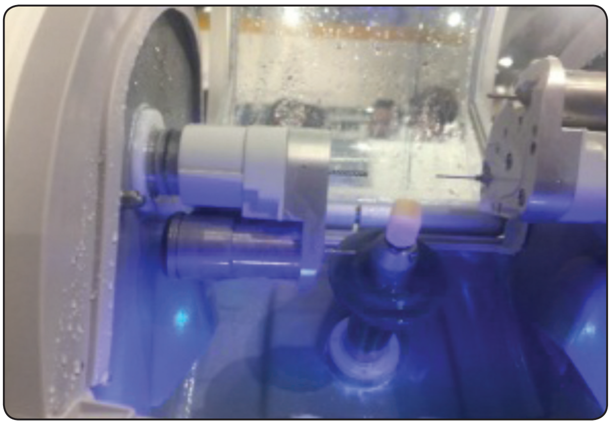


Fig. (5) Milling Chamber.

ESULTS

Table (1) and graph (1) showed comparison of fracture resistance (Newton) among study groups.

Group 1 (TZ) showed significantly higher fracture resistance than other groups. Group 2 (T-IPS) showed higher results than group 3, 4 and the latter 2 groups were not significantly different from each other.

TABLE (1) Comparison of fracture resistance (Newton) of study groups

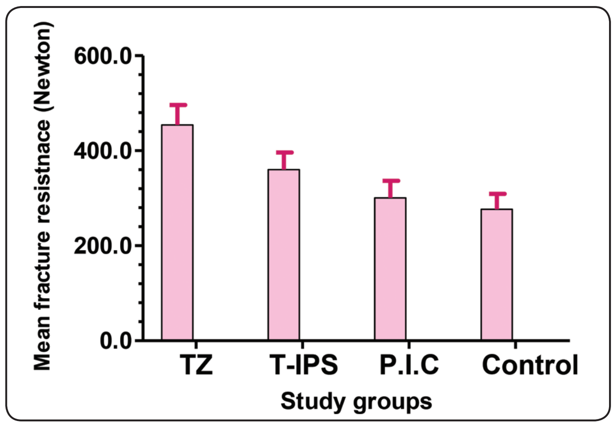
Study. groups	Mean	Std. Deviation	Minimum	Maximum
TZ	454.40 **(a)**	41.68	378.00	504.00
T-IPS	360.40 **(b)**	35.74	308.00	408.00
PIC	300.90 **(c)**	35.66	244.00	361.00
Control	276.70 **(c)**	32.57	224.00	322.00

P value <0.001, for groups sharing the same letter they are not significantly different

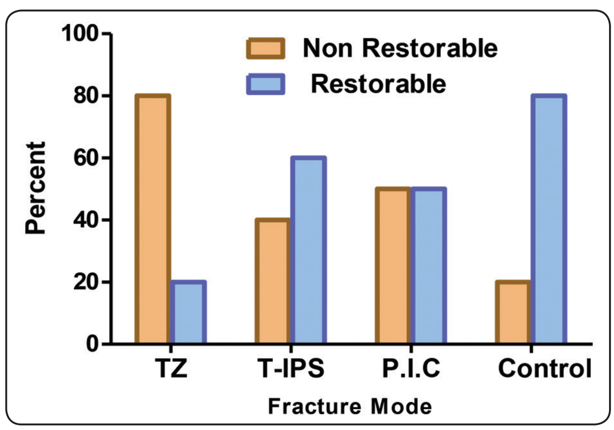
TABLE (2) Comparison of fracture mode percentage in different groups.

		Fracture mode			
		Non Restorable		Restorable	
		No	(%)	No	(%)
Study. groups	TZ	8	80.0%	2	20.0%
	T-IPS	4	40.0%	6	60.0%
	P.I.C	5	50.0%	5	50.0%
	Control	2	20.0%	8	80.0%

P value = 0.07 , not significant



Graph (1) Comparison of fracture resistance of different groups.



Graph (2) Comparison of fracture mode percentage in different groups.

Statistical Methods: SPSS version 22.0 was used for data management. Mean, standard deviation and range described fracture resistance. One way ANOVA made comparisons between groups and Scheffee test made pairwise comparisons. Fisher exact test compared independent proportions. P value always 2 tailed and significant at 0.05 level.

DISCUSSION

Zirconium Dioxide showed a higher resistance to fracture than E –Max and Polymer Infiltrated Ceramic restorations, this is attributed to the very high modulus of elasticity of Zirconium Dioxide due to densely sintered yttria-tetragonal zirconia polycrystal (y-TZP) and its ability to prevent crack propagation [(23)].

Results of this study emphasize the paramount impact of modulus of elasticity of foundation restorations on either fracture resistance or mode of fracture. It is possible to predict fracture resistance of a substance from the strength between individual bonds between the atoms in the material, the values of strength obtained by such a prediction are typically 10% of modulus of elasticity. The interatomic or intermolecular forces of the material are responsible for the property of elasticity [(19-20)].

Polymer Infiltrated Ceramic consist of 80 % ceramic and 20 % composite resin with nano-technology, it is neither a resin composite nor a pure ceramic but a combination ,demonstrating a non brittle and fracture resistant nature [(21-22)].

Post material plays a crucial role in the biomechanical performance of endodontically treated teeth. Numerous experimental and computational studies have shown the relevance of post designs, including length, diameter and material, on the strength of restored teeth [(23)]. Endodontic posts can be preformed or custom made, metallic or nonmetallic, stiff or flexible and esthetically or non-esthetically pleasing [(24)].

Custom-made metal posts and cores are widely used in clinical practice because of their superior properties [(25)], but they have disadvantages, such as a high modulus of elasticity, increasing possibility of unrestorable fractures of remaining tooth structure [(26)].

Bittner et al state that the clinical performance of restorations machined by CAD-CAM provides a post and core with durability, adaptability to the canal and adequate esthetics [(27)]. CAD-CAM system used in this study is the CEREC system [(28)]. Streacker , Geissberger [(29)] and Bittner [(30)] used the CEREC In Lab technique for fabricating single piece zirconia post and core. Dayalan et al [(31)] found a 3.5% error in milling of posts. This could be an error in milling or due to inability of scanner to record fine details of the scanned patterns. In indirect technique, after making the impression, a physical model (die) was prepared and scanned by laser in laboratory for acquiring and transmitting information.

Strub et al [(32)] found that fracture strength of zirconia posts combined with prefabricated glass ceramic crowns are 1,494.5 ± 333.5 N, and 463.3 ± 46.2 N for zirconia posts and cores without crown. In another in vitro study, mean fracture loads (503 N) for zirconia ceramic posts with composite resin cores, and 521 N for zirconia ceramic posts and cores [(33)]. In the present research zirconia posts and cores demonstrated the best fracture resistance values when compared with other test groups(454 .4±41.6 N) . Explanation for the different fracture strength values obtained in these studies may be due to different materials. Strub et al [(32)] and Heydecke et al [(33)] used completely restored teeth and tested the prefabricated zirconia posts and cores, while Friedel and Kern [(34)] reported that fracture values were changed when the posts and cores were restored with crowns.

Beck et al [(27)] reported that the superior performance of prefabricated zirconia posts than custom made may be explained by the fact that these posts were industrially machined from wrought material consisting of hot isostatically pressed zirconia. Similarly, in this study, custom-made zirconia posts and cores were first milled with a milling unit from prefabricated presintered zirconia blocks. After this procedure, the completed test specimens were sintered in dental laboratory. This can be a critical factor in mechanical properties of restorations; therefore, the expected decreased in fracture strength values of the test specimens were drawn.

In this research, when the failure type was assessed, the majority of the fractures in group 1 occurred in apical half of the root, and it was unrepairable as previously mentioned in a study by Heydecke et al [(33)], this can be attributed to the fact that zirconia posts had the highest modulus of elasticity among the post types tested. This high modulus of elasticity of zirconia posts and its difference from the tooth can create catastrophic failure, which could be a limitation for this treatment method.

The cementing process is a critical factor in clinical success of posts and cores, as previously mentioned in the literature. Friedel and Kern [(34)] reported that when the phosphate monomer in Panavia 21 was used for bonding to zirconia posts a higher bond strength was achieved than when using conventional resin composites .

Another limitation of this in vitro study was cyclic loading, which was not used for this study, and may affect the results, because dental materials may behave differently with cyclic loads in compare to increasing loads to failure. Additionally, as with any in vitro study, a final limitation was the fact that it could not completely simulate in vivo conditions.

Results of this in vitro study support rejection of the null hypothesis that different fabricating techniques and materials would not affect the fracture resistance of post and core systems and type of fracture.

CONCLUSIONS

Within the limits of this study ,the following conclusions were drawn:

1- Tranclucent Zirconia had significantly the highest fracture resistance than other groups.

2- High Translucency Lithium Disilicate showed higher fracture resistance than Polymer Infiltrated Ceramic and Control group and the two latter groups were not significantly different from each other.

3- Translucent Zirconia showed 80 % non-restorable fractures, Translucent Lithium Disilicate 40%, Polymer Infiltrated Ceramic 50 % and Control group 20 % non-restorable fractures respectively.

CLINICAL IMPLICATIONS

Regarding fracture resistance and mode of failure, High Translucency IPS-E Max post and core can be an alternative treatment method when compared with other techniques.

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