Comparison of Fracture Resistance of Three Recent Esthetic Post and Core Systems with Cast Metal Post and Core to Compressive Loading - An in vitro Study

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Abstract: ***Introduction**: The primary function of a post is to provide retention for a core, which is essential for the longevity of restorations placed on endodontically treated teeth. With the increasing use of anterior all ceramic restorations to meet the aesthetic needs; there is a need for tooth colored posts and cores that are as good as if not better than their metallic non-aesthetic metal counterparts. **Aim**: To determine and compare the fracture resistance of three recently introduced esthetic post and core systems with a cast metal post and core to compressive loading using a clinically related test method. **Materials and Methods**: Forty maxillary central incisors were selected, sectioned and their roots endodontically treated and assigned to 4 experimental groups (n=10). The cast metal post and core (CMPC) served as control group. The other groups were zirconium dioxide post and ceramic core group (ZCER), zirconium dioxide posts and composite core group (ZCOM) and glass fiber post and composite core group (GFCOM).The post spaces were prepared, posts were seated and cores were formed. A compressive load was applied to the inclined surface on each specimen until failure occurred and measured in Newtons. Data were analysed by One-way Analysis of Variance (ANOVA) and intergroup comparison was done using Tukey's Post Hoc test. **Results**: CMPC and ZCER groups exhibited the highest fracture resistance and the values were: 680.6 N and 630.03 N respectively. ZCOM group exhibited fracture resistance greater than GFCOM but less than ZCER and CMPC. Conclusion: CMPC and ZCER groups were found to be more fracture resistant than the ZCOM and GFCOM group. Aside from its desirable esthetic properties,the ZCER group demonstrated high resistance to fracture.*

Keywords: Composite resin, root canal therapy, Glass fibre post, fracture resistance, post and core technique

1. Introduction

Endodontic therapy has provided dentistry the ability to retain teeth that just a few decades ago would have been extracted without hesitation. When there is substantial loss of coronal tooth structure due to caries, trauma or both, a post and core is often required to retain a definitive restoration.[1,2]

A post is usually placed in an attempt to strengthen the tooth.[4,5,6] However, in vitro and in vivo studies have demonstrated that a post cannot reinforce endodontically treated teeth.[7,8,9]Posts are required for supporting a core foundation when there is insufficient clinical crown remaining.[10,11,12]

Although cast post and core foundations are the gold standard for endodontically treated teeth, due to their superior physical properties and proven clinical effectiveness[13] yet its mechanical properties may increase the risk of root fracture.[14]Moreover, the esthetic properties of these materials are compromised since the gray-colored post is visible through overlying translucent all-ceramic restorations, especially in patient with a high lip line, cast metal post and core foundations may result in esthetic problems.[15]

In the recent times, there has been a tremendous increase in the use of all ceramic crowns, particularly for anterior teeth because of their superior natural appearance compared to metal ceramic restorations.[16] Both the declining acceptance of cast post and core restorations as well as patients interest in dental esthetics has resulted in the development of esthetic posts, especially Glass Fiber and Zirconia Ceramics. These increase the transmission of light within gingival tissues and underlying root, enhancing the esthetics. Being metal free materials, they also annihilate the potential hazards of corrosion and allergic hypersensitivity.[17]

Glass fibers such as silica or quartz reinforced epoxy resin posts have low modulus of elasticity similar to that of dentin. This property has been reported to reduce the risk of root fracture. [18, 19]Glass fiber reinforced posts also have the advantage of easy removal if endodontic re-treatment is required. [19, 20] These can be used with various composite resin core build-up materials.

A prefabricated zirconia ceramic post system has been introduced to satisfy esthetic needs presented by endodontically treated anterior teeth. The translucency of all ceramic crowns can be successfully maintained with the use of ceramic post and core materials. Also, amelioration in adhesive porcelain bonding systems have accelerated the trend toward the use of ceramic core materials. Many dentists prefer to use prefabricated post systems because they are more practical, less expensive and in some situations less invasive than customized post and core systems. They also save time and can provide satisfactory results. [21, 22, 23]

The purpose of this in vitro study was to determine and compare fracture resistance of three esthetic post and core systems, Zirconia post and Ceramic core, Zirconia post and Composite core and Glass Fiber post and Composite core with cast posts under compressive loading.

2. Methodology

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics Shri Sai Dental College,Vikharabad.

Fourty extracted human permanent central incisors extracted for periodontal reasons were taken for this study with similar dimension; teeth were cleaned of any debris, calculus. Teeth selected for study was free of any defects like caries & restoration. The teeth were disinfected according to CDC guidelines.

These fourty teeth were divided into 4 groups depending on the type of post & core material used:
Group 1: Cast Metal post and core (CMPC)
Group 2: Zirconia posts and Ceramic core (ZCER)
Group 3: Zirconia posts and Composite core (ZCOM)
Group 4: Glass Fiber posts and Composite core (GFCOM)

The coronal aspect of each tooth was resected perpendicular to the long axis and 1mm incisal to the cementoenamel junction, with a diamond coated disc (Horico) mounted in a straight handpiece (NSK, Japan). Labiolingual and mesiodistal measurements of the sectioned tooth surfaces were made with a digital vernier calipers (Aero space, China).The roots were endodontically instrumented to the apex using protaper rotary instruments (Dentsply,Maillefer) till F3 and obturated with protaper GP points (Dentsply,Maillefer) using ZOE sealer.

Procedure for fabricating standardized cores:

To obtain standardized cores, a wax pattern was fabricated from casting wax (SK Dental waxes, Bombay) which had 6.5mm diameter base, 7.3 mm diameter cervicoincisally and 6.2mm buccolingually. Impression of the wax pattern was taken with rubber base impression material (Exaflex). Then dies were made from the impression material. Polyvinyl material was vacuum pressed on these dies. In this way a hollow matrix was fabricated which had the same dimensions as that of the wax pattern. The base of the matrix was fitted flush to the sectioned tooth surfaces. Then 1 mm of the matrix was cut at the open end so that it acted as an inlet for the placement of composite resin.

Procedure for preparation of forty samples: For all the groups the post spaces were enlarged with pesso reamers no 2 and 3 (MANI CE 0197 Prime Dental Products PVT LTD) initially to a depth of 9mm. The final enlargements were accomplished with the 1.4 mm diameter drills that were specifically given with 1.4mm zirconia posts (Cosmoposts,IvoclarVivadent) and 1.4mm GF posts (Bioloren,Ammdent). All the posts had 1.4mm diameter and were sectioned to a standard length of 13mm using carbide fissure bur and high speed airotor handpiece The length of the posts was 4 mm from the finish line into the core. In groups 2, 3 and 4 all the post spaces were etched using 37% orthorphosphoric acid (3M ESPE), for 30 sec and bonding was done using a bonding agent (3M ESPE) polymerized for 20 sec. Cementation was done using dual curing resin luting agent(Kerr,Orange,CA).

Group 1: A direct technique was used. The post pattern was fabricated using inlay wax. For the core part, the polyvinyl matrix was placed on the tooth, resin wax (Leva) was injected in to the matrix and polymerized. After polymerization, the matrix was removed from the molded core. Then the entire pattern was retrieved from the root, invested and cast. The cast post and core systems were then cemented into the roots using GIC.

Group 2: Posts were seated into the prepared post space. Polyvinyl matrix was placed on the tooth surface, resin wax was then injected in to the matrix and polymerized for 20 sec to form the core. Matrix was then removed and retrieved post and core foundations from the roots were invested with a phosphate bonded investment (Deguvest). Wax was eliminated from the invested units in a pre heated furnace (Unident) (800˚C for 45 minutes). Cores around zirconia posts were prepared using ceramic ingots (e-max, Ivoclarvivadent) heat-pressing process (975˚C for 45 min.) in a heat pressing furnace (Ivoclarvivadent). The formed ZCER foundations were then cemented into the post spaces.

Group 3: After etching and bonding,posts were cemented in to the prepared post spaces. The matrix was seated on the sectioned tooth surface and composite core material (Z350, 3M ESPE) was placed in 2mm increments and polymerized for 20 sec. After polymerization, the matrix was removed from the molded cores.

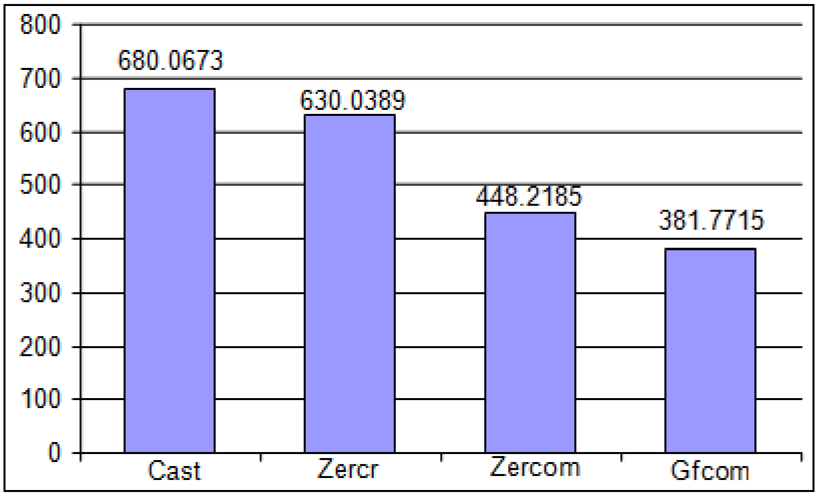
Group 4: Following etching and bonding posts were cemented into the prepared post spaces. The matrix was placed on the sectioned tooth surface and composite was placed in 2mm increments and was then polymerized for 20 sec. After polymerization, the matrix was removed from the molded cores.

Loading Procedure
Following thermal cycling (5000 cycles between 5˚C and 55˚C with a dwell time of 30 second) a universal testing machine (Shimadzu, Japan) was used to apply a constant compressive load at a crosshead speed of 1mm/min, at a 130º angle to the long axes of the test specimens, until failure occurred. The tip of the loading bar was positioned to contact the centre of the palatoincisal surface at an angle of 90ºC. The force at failure was measured in Newton. All the data were analyzed by One-way Analysis of Variance (ANOVA) and intergroup comparison done with Post Hoc Tukey test. A 95% confidence level was used for the ANOVA test. Results showed that there was significant difference in the fracture resistance values obtained with different groups ($p<0.05$).

3. Results

Graph 1 represents the mean values obtained by calculating the fracture resistance values of the four post and core systems after compressive loading and the values are 680.0673, 630.0389, 448.2185 and 381.7715 respectively. CMPC and ZCER groups exhibited the highest resistance fracture and the values are: 680.6 N and 630.03 N respectively. ZCOM exhibited fracture resistance greater than GFCOM but less than ZCER and CMPC. GFCOM group showed the least resistance to fracture to compressive loading. CMPC group exhibited 7 root fractures out of 10 specimens. There was also post dislodgement in 5 specimens. In ZCER group, there were 4 root fractures, 3 post fractures and 5 core fractures. In ZCOM group, there was no root fractures but 3 post fractures and 5 core fractures. In GFCOM group, no root fracture was seen but there were 5 post fractures and 6 core fractures.

Graph 1:



Graph 1

(Fig 1): represents the mean values obtained by calculating the fracture resistance values of the four post and core systems after compressive loading.

4. Discussion

A combination of proper coronal restoration and endodontic treatment is mandatory for the long-term success of a restored endodontically tooth.[20] Posts have evolved immensely as a postendodontic restoration since their first use in as early as the 1700s.

As a result of caries, previous restorations, trauma or endodontic procedures, endodontically treated have minimal coronal tooth structure. The quantity of coronal and root dentin that remains after root canal treatment and post space preparation plays an important role in prolonging the life of the tooth and restoration. [24] This present study attempted to test fracture resistance of three new esthetic post and core systems to compressive loading.

Cast metal post were the traditional and most promising formula for restoration of badly broken endodontically treated teeth. However, they come along with the primary drawback of affecting the aesthetic outcome of the treatment since they have been used with all-ceramic crowns. They are known to provide a metallic hue which is unacceptable in treating the anterior aesthetic zones of oral cavity. They are also associated with catastrophic fractures of root[25,26], corrosion and allergies to the component metals. So there was a need for newer alternatives in this era of increased awareness of aesthetics.

Zirconia is a metal with optimim properties for use in dentistry like superior toughness, strength, and fatigue resistance, in addition to excellent wear properties and biocompatibility, all similar to those of titanium.[27] It has a refractory index of 2.1-2.2. It is widely used along with ceramic veneering for anterior crowns. A shaded zirconia core is shown to result in better esthetics and greater natural appearance, similar to the chromatic dentin overlaid by translucent enamel.[28] Taner et al in 2006 [29] and Guido Heydecke et al in 2002[30]have suggested that zirconia posts with ceramic cores can be recommended as an alternative to cast posts and cores. If a chairside procedure is preferred, zirconia posts with composite cores can be used. Hence it is a newly sought after substitute for post restoration.

Another simpler alternative is glass fibre post available in prefabricated form. It has elastic modulus comparable to human dentin. It also offers good translucency and superior light transmission when used along with composite cores. However, it is not suitable for use in flared roots or thin-walled canals as more luting cement that may lead to inefficient bonding.[31] In such cases use of accessory glass fibres posts is suggested but if has shown little contribution in improving fracture resistance.[32,33]

In the present study the luting cement used is a resin based cement. It is known to provide superior retention of the post along with distribution of stresses from the post to the radicular dentin.

Also when fracture testing was done in the current study, load is applied at an angle of 130º angle to the long axes of the test specimens. We used this angle to mimic a normal clinical situation, in which the angle formed by the long axis of the mandibular central incisor to maxillary central incisor is 135°.[34]

In this study the highest fracture resistance was displayed by CMPC group. Similar result were obtained in an in-vitro study that determined and compared the fracture resistances of 3 recently introduced esthetic post-and-core systems with a cast metal post and core using a clinically related test method [29]. Though CMPC group exhibited the highest resistance to fracture, with esthetic dentistry gaining importance day by day, there is declining acceptance of cast post and core system. Spear F. in 1999, Turner CH in 1982, Soresen JA, Martionoff JT in 1984 have demonstrated that the most common cause of failure for cast posts and cores is post dislodgment, followed by root or post fractures. In the present study all the teeth restored with cast post and core systems showed root fractures as well as post dislodgement after testing. Recent studies suggest that the elastic modulus of the posts should be similar to that of root dentin to reduce the risk of root fracture [35]. Metal posts have a high modulus of elasticity, i.e., they have up to 20 times the value for dentin which is approximately 18 GPA, which causes force concentration in areas where the dentin wall is thin, which may increase the incidence of root fractures.[36,37]

In the present study ZCOM group displayed less resistance to fracture when compared to ZCER group and CMPC group, but more than GFCOM group. This can be attributed to the low strength of the composite material itself and less adhesion between the Zirconia and composite core. To enhance the bond between the post heads and the cores, adhesive resin luting agents can be applied to the post prior to forming the core. When a zirconia post is used with a direct composite core, a large stress bearing composite core should be avoided. Zirconia has a high modulus of elasticity, due to which forces are transmitted directly to the post/tooth interface without stress absorption. This may be the reason due to which some of the posts fractured in the present study.

Goldberg and Burstone reported that glass fiber reinforced post systems were composed of unidirectional glass fibers in the resin matrix that strengthened the structure of post without compromising the modulus of elasticity.[38] This low elastic modulus of GFCOM system follow the natural flexural movements of the tooth, reducing stress arising at the interfaces, enabling the restored system to mimic the mechanical behaviour of a natural tooth. In the present study teeth restored with GFCOM systems did not show any root fractures but had core or post fractures. This is in accordance with an in vitro study by Turker et al in 2015 who demontrated lowest fracture resistance for glass fibre post as compared to cast metal and zirconia posts.[39] Fractures obtained with fiber posts are reparable.[40]Use of resin luting cements for luting the post will improve adhesion of post material to the tooth. This will not only strengthen the root but also will improve fracture resistance of the tooth to masticatory forces. Application of adhesion of resin luting agent on to dowel head causes significant strengthening on the dowel head retention of the core materials.[41]Different surface treatments of prefabricated esthetic posts such as silanization, etching by hydrofluoric acid and sandblasting or airblasting with Al_2O_3 increase retentive strength of posts.[42] Similar results were shown by study done by Kumar et al [43] and Tariq et al [44] in which zirconia post had higher fracture resistance than glass fibre post.

In an in vitro study by Kuthukoti A et al in 2015, glass fibre post showed higher values of fracture resistance when compared to zirconia post.[45] The findings of current study are in contracdiction to this. The reason for this may be that they have tested fracture resistance without any core different from our study where we have core build up along with different post systems.

A recent study was performed by Kivanç BH , Görgül G where they compared fracture resistance of titanium posts, glass fiber posts, zirconia posts. They concluded that glass fiber post was more resistant to fracture than other groups; titanium posts showed the least resistance to fracture.[46]

Dilmener FT et al in 2006 conducted a comparative evaluation of fracture resistance of cast metal post-and-core, stainless steel post/composite-resin core, zirconium dioxide post/composite-resin core and zirconium dioxide post/ceramic core. They concluded that the cast metal post/core and zirconia post/ceramic core foundations were found to be more fracture resistant than the zirconia post/composite-resin core and stainless steel post/composite-resin core foundations. [47] The findings of present study are in accordance with this.

This present study demonstrated that the CMPC group exhibited high fracture resistance compared to other groups, but at the same time more incidences of root fractures is noted which could cause an irreversible damage to the tooth and necessitate extraction. ZCER group have shown incidence of root fractures, less than CMPC group but more than ZCOM group and GFCOM group with excellent aesthetics and leaves dentist with a scope of retreatment in case of post and core failure. ZCOM group and GFCOM exhibited fewer incidences of root fractures, though there was an incidence of post and core fractures, the failures were not irreversible. Since the fiber post has characteristics simulating natural dentinal structure and it acts as a shock-absorber, dissipating most of the stresses on the final restoration with only a small fraction being transmitted to the dentinal walls, it demonstrates favorable fractures.[48]

A recent in vitro study by Maroulakos G demonstrated that severely compromised endodontically treated teeth restored with bonded gold cast post and cores showed significantly higher fracture resistance when compared with titanium prefabricated post/composite resin core; and quartz fiber reinforced post/composite resin core. Also the primary mode of failure for gold cast post and cores and with titanium prefabricated post/composite resin core was root fracture, and for quartz fiber reinforced post/composite resin core was post debonding.[49] The findings of present study are in accordance with this.

However, zirconia posts fall short of the requirement that an ideal post should be easily removed when retreatment is needed, because it is nearly impossible to remove zirconia posts from the root canal when a failure occurs.[50] It is impossible to grind away a zirconia post, but removal of a fractured zirconia post by ultrasonic vibration has been found to cause temperature rise of the post and on the root surface.[51]

The major limitation of our study is that we are not able to simulate the various multidirectional forces present in the oral cavity in this in vitro setup of universal testing machine. Hence the results cannot be projected absolutely as similarly applicable in an vivo scenario.

The other factors that affect the fracture resistance of post restored endodontically treated teeth are post diameter, length, design and adaptability, amount of remaining root dentin, cement and method of cementation, core material and design, crown design and biocompatibility of post material.[52]

Thus there is a definite correlation between materials used for both the post and core component of restoration and fracture resistance of the restored endodontically treated teeth. Zirconia although fares well in providing the aesthetic value, fails in an ideal post with respect to physical properties like elastic modulus. Glass fibre posts seem both aesthetically and physically promising but are not suitable in every clinical situation.

5. Conclusion

Within the limitations of the present study, the following conclusions can be drawn:

The CMPC group and ZCER group were found to be more fracture resistant than the ZCOM group and GFCOM group. ZCOM exhibited fracture resistance greater than GFCOM but less than ZCER and CMPC. GFCOM group showed the least resistance to fracture to compressive loading. Aside from its desirable esthetic properties, the ZCER group demonstrated high resistance to fracture.

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