ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 6, Issue – 3, May - 2023, Page No. : 195 – 207

A comparative evaluation of fracture resistance of three types of post and core systems in endodontically treated anterior teeth: An in- vitro study

[1]Dr Aditya Narayanan, Senior lecturer, Department of Conservative Dentistry and Endodontics, The Oxford Dental College and Hospital, Bangalore.

[2]Dr Ritika Pundir, Senior Lecturer, NSVK Sri Venkateswara Dental College and Hospital, Bangalore.

[3]Dr Qurat ul Ain, Senior lecturer, Department of Conservative Dentistry and Endodontics, The Oxford Dental College and Hospital, Bangalore.

[4]Dr Durga Devi Dasari, Senior lecturer, Department of Conservative Dentistry and Endodontics, The Oxford Dental College and Hospital, Bangalore.

[5]Dr Shari Devarajan, Senior lecturer, Department of Conservative Dentistry and Endodontics, The Oxford Dental College and Hospital, Bangalore.

Corresponding Author: Dr Aditya Narayanan, Senior lecturer, Department of Conservative Dentistry and Endodontics, The Oxford Dental College and Hospital, Bangalore

Citation of this Article: Dr. Aditya Narayanan, Dr Ritika Pundir, Dr Qurat ul Ain, Dr Durga Devi Dasari, Dr Shari Devarajan, "A comparative evaluation of fracture resistance of three types of post and core systems in endodontically treated anterior teeth: An in- vitro study", IJDSIR- May - 2023, Volume – 6, Issue - 3, P. No. 195 – 207.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

The purpose of this study was to compare fracture resistance between different post and core systems like custom Ni-Cr alloy cast post, prefabricated glass fiber post with composite build-up, and when a single unit edelweiss post and core system was used. For this study, forty-eight freshly extracted maxillary central incisors with similar root lengths approximately 12 mm measured from apex to cementoenamel junction extracted for orthodontic and periodontal purposes were selected. The teeth were divided into 4 groups and were subjected to root canal treatment and obturated with gutta-percha all the teeth were decoronated except the control group and were mounted in acrylic blocks. For three experimental groups, post space preparation was done and teeth were restored with cast post (Ni-Cr alloy) and core Group 2 (n=12), Glass fiber post, (Medicept self-post) with composite core with size 2 core former Group 3 (n=12), and post and core single unit (Edelweiss post system) Group 4 (n=12) using adhesive resin cement for all the experimental groups.

The Control group 1 samples were selected with intact coronal structures and normal composite access restoration with ideal crown preparation was done. All the samples were subjected to a load of 0.5 m/min at 130° until fracture occurred. The fracture resistance of the specimen was measured using a universal testing machine and the data was analysed.

The fibre post group displayed the maximum fracture resistance (828.53 N) among the experimental groups cast post and core (587.64 N) and there was no statistical difference between edelweiss post and core (447.92 N) and the control group (450.3 N).

The fracture resistance of fibre post system is more than all the groups, therefore, providing better stress distri bution of compressive forces in anterior endodontically treated teeth. There was no significant difference between the fracture resistance of the control group and the edelweiss post and core unit.

Keywords: Glass Fiber Post, Edelweiss Post And Core Single Unit, Fracture Resistance, Dental Dowels.

Introduction

A standard method of restoring a mutilated tooth when undergoing endodontic treatment is to use a post and core, onto which a full crown is cemented. The excessive removal of dentine caused by the crown preparation and the access cavity preparation further makes the tooth prone to fracture. [1]

The fracture susceptibility of teeth restored with posts may be related to factors such as the amount of remaining tooth structure, which provides resistance to the fracture of the tooth, as well as the characteristics of the post, such as the material composition, modulus of elasticity, diameter, and length. [2]

Endodontic posts can be pre-formed and custom made; metallic and non-metallic: stiff and flexible and aesthetic and non-aesthetic. The disadvantage of resin composite core bonded to a fiber-reinforced post is that additional clinical time is spent at the chairside in the fabrication of the core and possible cohesive failure of the bond between the composite core material and the post surface. [3]

To overcome this disadvantage of placing a separate core, recently Edelweiss Dentistry, Austria has intro duced prefabricated tooth-coloured post and composite core with high dense laser sintered composite material which has a modulus of elasticity similar to that of dentin. Thus, the present study was conducted to compare the fracture resistance of endodontically treated teeth restored with different post-core systems like custom Ni-Cr alloy cast post, prefabricated glass fiber post with composite build-up, edelweiss post and core system.

Materials and Methods

For this study, forty-eight freshly extracted maxillary central incisors with similar root lengths approximately 12 mm measured from apex to cementoenamel junction extracted for orthodontic and periodontal purposes were selected. The teeth were divided into 4 groups. The canal patency was determined by passing the size 15K file and then the working length was established. The root canal shaping was performed up to the number 50 K file using the crown down technique. During instrumentation, the canals were irrigated with 2.5% sodium Hypochlorite solution and 17% EDTA. The obturation was performed using Gutta-percha and AH26 plus resin sealer with cold lateral condensation technique.

Group 1 (Control group), where only the access cavities were filled with composite followed by crown preparation of 2 mm from the incisal edge to the cervical margin. In Group 2 (Custom Ni-Cr alloy cast post with core) post space preparation of 8.5mm was done. Wax pattern fabrication was done using the indirect method, the custom Ni-Cr alloy cast posts were luted with resin cement. In Group 3(Glass fiber post with composite core build-up) post space preparation of 8.5mm was done, posts were luted with resin cement and a core of 4 mm height was built up with core build-up material using a size 2 core former. In Group 4(Edelweiss post and core) post space preparation of 8.5mm was done, posts were luted with resin cement, then post cemented teeth were stored in saline solution at ambient temperature and placed in acrylic moulds.

The specimens were then mounted on a universal testing machine and a compressive load of 0.5mm/min at 130 degrees will be applied to the long axis of the tooth until a fracture occurred. The fracture resistance was measured and the data analysis was carried out.

Results

Table 1: Fracture resistance values (N)

Sample	Group 1 (Control)	Group 2 (Cast post and core)	Group 3 (Fibre post)	Group 4 (Edelweiss post and core unit)
1	250.77	176.5	660.02	277.31
2	757.47	348.97	757.89	281.35
3	402.98	789.46	1053.58	262.73
4	161	621.98	1117.35	579.08
5	727.89	192.78	911.48	643.6
6	463.08	398.5	221.49	582.47
7	650.46	926.95	452.84	255.87
8	266.21	663.67	416.1	320.39
9	323.97	730.95	649.79	561.81
10	373.17	648.4	1830.23	524.07
11	565.21	832.97	873.19	534.89
12	461.33	720.57	998.31	551.48

Table 2: One- way ANOVA comparing mean fracture resistance values (N)

Groups	N	Minimum	Maximum	Mean	S. D	P-value
Natural tooth	12	161.00	757.47	450.30	192.24	0.004*
Cast post	12	176.50	926.95	587.64	249.11	
Fibre post	12	221.49	1830.23	828.52	417.81	
Edelweiss	12	255.87	643.60	447.92	152.24	

One-way ANOVA indicated a significant difference in mean fracture resistance between the cast post and fibre post groups ($p<0.004$).

There was no significant difference in fracture resistance between the edelweiss and control group.

Table 3: Inter-group comparison of the maximum force between the groups using post hoc Bonferroni test

Sample	Mean diff	p-value
Natural tooth V/s Cast post	-137.347	1.000
Natural tooth V/s Edelweiss	2.374	1.000
Natural tooth V/s fibre post	-378.220	.009
Cast post V/s Edelweiss	139.721	1.000
Cast post V/s Fibre post	-240.881	.215
Edelweiss V/s Fibre post	-380.600	.008

The fracture resistance of the control group and edelweiss post and core is similar, and the difference is not significant compared with each other. However, the difference in fracture resistance with cast post and fibre post was statistically significant.

Figures

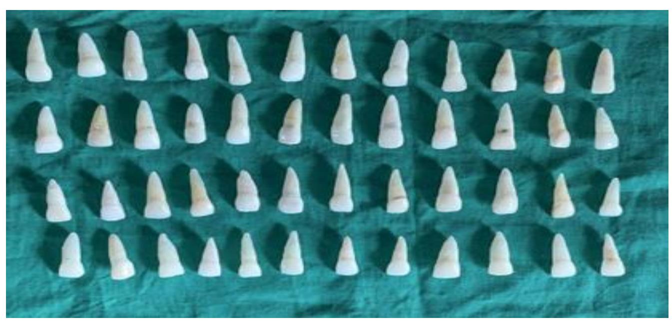


Figure 1: Forty-eight maxillary central incisors

Figure 2: Decoronated samples of group 2,3 and 4

Figure 3: Control group after root canal and crown preparation

Figure 4: Cast post and core (Group 2)

Figure 5: Post-placement (Group 3) Fibre post

Figure 6: Post-placement in (Group 4) Edelweiss Post and core.

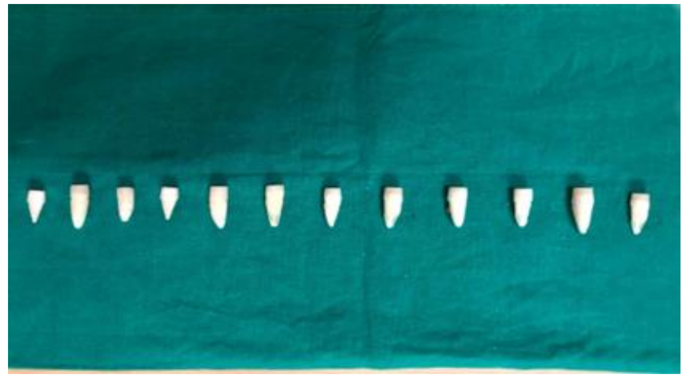


Figure 7: Core build-up in Group 3

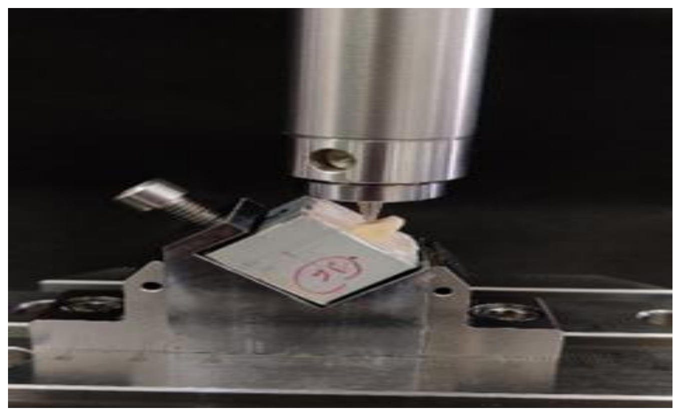
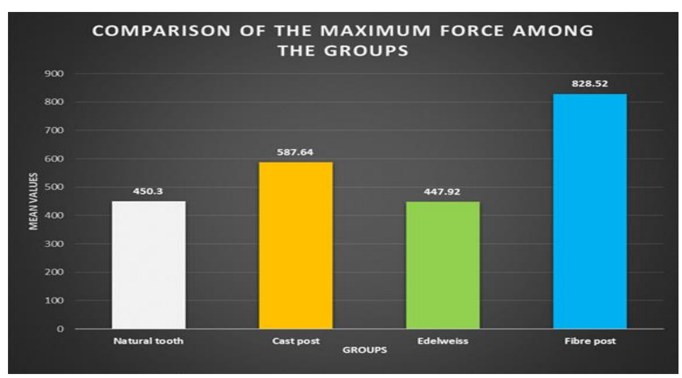
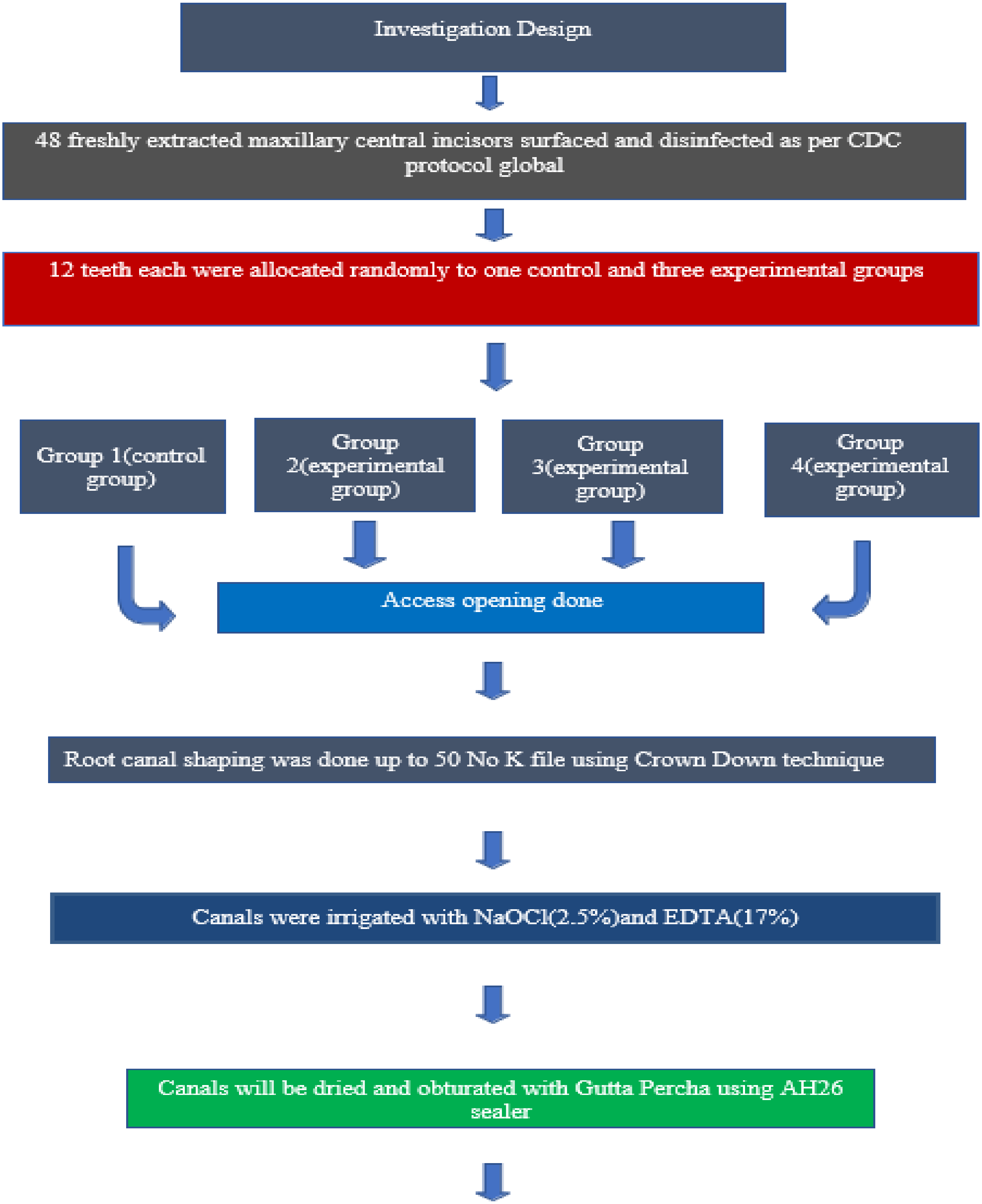


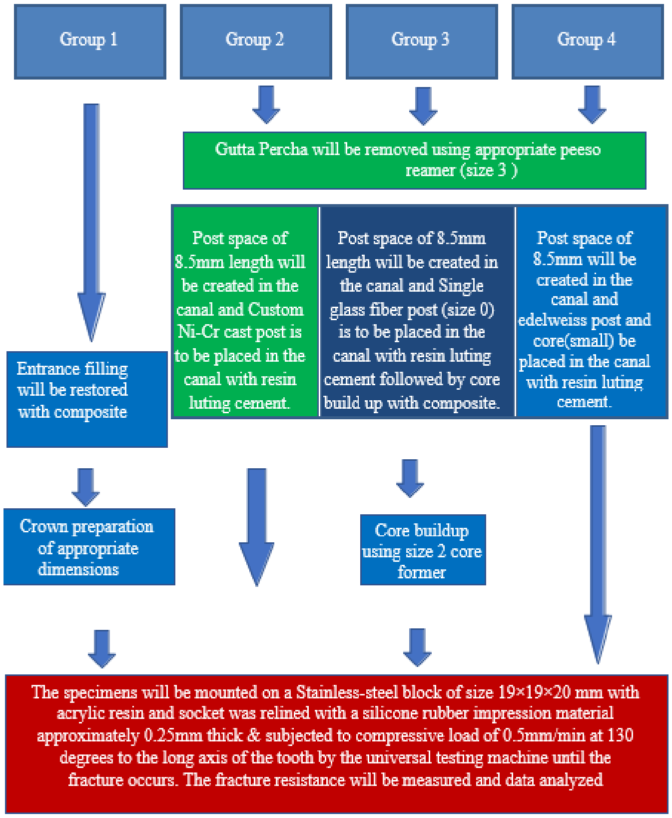
Figure 8: Testing samples under Universal Testing Machine



Graph 1:


Investigation Design
48 freshly extracted maxillary central incisors surfaced and disinfected as per CDC protocol global
12 teeth each were allocated randomly to one control and three experimental groups
Group 1(control group)
Group 2(experimental group)
Group 3(experimental group)
Group 4(experimental group)
Access opening done
Root canal shaping was done up to 50 No K file using Crown Down technique
Canals were irrigated with NaOCl(2.5%)and EDTA(17%)
Canals will be dried and obturated with Gutta Percha using AH26 sealer

Graph 2:



Graph 3:

Discussion

The present study was done to compare the fracture resistance of endodontically treated anterior teeth restored with different post and core systems like custom Ni-Cr alloy cast post, prefabricated glass fiber post with composite build-up, and when a single unit edelweiss post and core system was used.

The 48 maxillary anterior teeth used for the study were extracted and stored in saline solution at ambient temperature. An intracanal post is often required for the restoration of endodontically treated teeth. The decrease in fracture resistance of endodontically treated teeth is attributable to various factors.

They include extensive loss of tooth structure due to dental caries, previous restorations or fractures, loss of water from the dentinal tubules, age changes in the dentine, the effect of endodontic irrigants and medicaments, and the effect of bacterial interaction with the dentine. Thus, maintaining the structural integrity of post endodontically restored teeth by conserving the bulk of dentine has been advocated. A post system should ideally exhibit a fracture resistance higher than the average masticatory forces. Post material and fracture of roots also have a definite link. [1]

Peroz et al in 2005 described the lost tooth structure as Class I when access preparation with all 4 axial cavity walls is remaining. Class II describes the loss of 1 cavity wall, commonly known as the mesio-occlusal (MO) or the disto-occlusal (DO) cavity. Class III represents a MOD cavity with 2 remaining cavity walls. Class IV describes 1 remaining cavity wall, in most cases the buccal or lingual wall, and Class V describes a decoronated tooth with no cavity wall remaining. The minimal thickness of the cavity wall as a determining factor for the resistance to functional loads of the crown-root complex is considered as 1 mm. [2]

Hard tissue with thicknesses below this level cannot be prepared for full crowns. A thickness greater than 1 mm provides an amount of hard tissue sufficient to stabilize the core material even after crown preparation. The minimal height of a cavity wall capable of providing a sufficient ferrule effect is 2 mm.

No post is needed in cases with at least 2 axial cavity walls remaining. A post should be inserted if only 1 cavity wall is remaining and when there is no cavity wall remaining, but a ferrule of 2 mm is needed to provide a lower risk of root fracture. [2]

Cast post and core system

Historically, the most commonly used post and core system were cast metal posts. They remained as the treatment of choice in post endodontic situations to date for most dentists. However, they fail twice as often as prefabricated metal posts, and may also result in catastrophic root fractures. [3]

Glass fiber post system

The glass fiber post contains pre-stretched silanized glass fibers bonded by methacrylate or epoxy-polymer matrix with a high degree of conversion and a highly cross-linked structure that binds the fibers. [4] The fibers offer strength and stiffness, while the polymer matrix transfers forces to the fibers and also protects them from the moisture of the oral environment. [5] The fibres contribute stiffness and strength to the usually elastic matrix. Epoxy resins and Bis GMA are usually used as resin-based materials for dental fiber posts. E- (electrical application) and S- (stiff, strong) glass fibers have become the most commonly used reinforcing fibers. Glass fibers stretch uniformly under stress to their breaking point and on the removal of the tensile load short of breaking point, the fiber returns to its original length. These posts have excellent Esthetic properties, flexural and fatigue strength, and a modulus of elasticity similar to that of dentin. The modulus of elasticity of FRC posts provides elevated shock resistance, weaken ing of vibration effect, shock absorption, and augmented fatigue resistance. [6] Glass fiber posts are easy to handle allowing one- visit therapy. They have excellent bio com patibility and are of low cost. They can be retrieved easily during retreatment.

A study done by Érico Braga Franco et al 2014 evaluated the influence of glass fiber post and cast post on the fracture resistance of endodontically treated teeth and concluded that for teeth restored with glass fiber posts, the failure occurred at the junction between the composite resin core and the post. Cast post, though having significantly greater fracture resistance than glass fiber posts had more catastrophic fractures. [5].

On Esthetic considerations, the cast metallic post can result in discoloration and shadowing of the gingiva at the cervical aspect of the tooth. Moreover, they require two appointments with added laboratory fee. [7]

Thus, for the current study glass fiber post (Medicept self-post) is a high-quality, translucent glass fiber resin post system, that has a double conical shape of the post which provides a greater diameter in the coronal portion and the apical region of the post for maximum stress distribution which displays greater modulus of elasticity than dentin while bending It is a great alternative for Esthetic, metal-free restorations. [8]

Its available in various sizes size 0(1.00mm), size 1(1.30mm), size 2(1.60mm), size 3(1.80mm), size 4(2.00mm). The post used in this study is size 0(1.00mm). For the other group, the recently launched single unit Edelweiss post and core system was used. These post and core units claim to have better physical properties than the fiber post.

Features of Edelweiss post & core system single unit

The Edelweiss POST & CORE system is a laser sintered nanohybrid composite monobloc. The posts have a conical shape for perfect post space adaptation. The translucency of the fibre free post, supported by the lens design, allows uninterrupted light transmission for complete poly merization of the luting cement resulting in a single monobloc between the adhesive layer and com posite post. This is supposed to avoid the wedging effect. The core has a similar feel to that of the natural tooth and makes handling easier. [9]

It is manufactured by selective laser sintering (SLS) by additive manufacturing (AM) process for fabricating three- dimensional (3D) objects by adding powdered materials layer-by-layer according to computer-aided design (CAD). Laser sintering of the material results in a homogenous, inorganic, and high gloss laser vitrified post surface which is then fused with a sintered and thermally tempered (300°C) dynamic composite core.

This produces an optimal integration between function and esthetics. The aesthetic property is unique because a translucent post is attached to an opaque built-in core.

Since the post and core is a homogenous Monoblock the manufacturer claims that there is no possibility of debonding of the core from the post. Light transmission throughout the full length of the post is enhanced by the post's translucency because of the vitrified glass-like layer on the surface which enhances the optical pro perties. This ensures complete polymerization of the luting cement. They claim that its strength is similar to that of lithium disilicate and its glasslike surface has similar optical properties to those of ceramics which benefits the clinician. [10,11]

Its flexural modulus is 20 GPa like Dentin (15 – 20 GPa), flexural strength is 200MPa and compressive strength of 550MPa, surface hardness is 95HV and the post and core system are radio-opaque. Edelweiss post and core single unit are available in 7 forms: upper anterior, upper premolar, upper molar, lower anterior, lower premolar, and lower molar, and also a universal post without the core. The post and core system used in this study is of the maxillary anterior with a post length of 8.5mm an apical diameter of 1.0mm.

Effect of the ferrule on fracture resistance of tooth

In the present study, the samples were decoronated 2mm above the cementoenamel junction in experimental groups. A ferrule is composed of parallel walls of dentin from the crown's margin extending coronally to the fractured part of the tooth. [12]

Studies have demonstrated that a minimum ferrule height of 1.5-2 mm shows improvement in the longevity of endodontically treated teeth restored with post and core and also provides better fracture resistance. [12]. It is stated that the glass fiber post and a built-up core concentrated stresses at the cervical level hence, the stress distribution to dentin in this region is higher. However, when the ferrule effect exists, the fiber post has less tendency to bend. [13]. Considering the height of the ferrule some studies showed that the presence of a ferrule of 1.5 to 2 mm height was more important for fracture resistance than the post type or post design as the tooth with a cervical ferrule presents a coronal displacement of the fulcrum line, decreasing the effect of flexion (bending moment) and protecting the specimen. [14]

Root canal treatment procedure

The canal patency was determined by passing the size 15K file and then the working length is established. The root canal shaping was performed up to the number 50 K file using the crown down technique. During instru mentation, canals were irrigated with 2.5% sodium hypochlorite solution and 17% EDTA. The obturation was performed using Gutta-percha and AH26 plus resin sealer with cold lateral condensation technique. In this study, the post space preparation was done 24 hours after obturation considering the setting time of the AH Plus sealer and by the studies done by Maddison and Zakaria Sen et al, Bourgeois and Lemon et al and Abramovitz et al. [15]

Post space preparation

Studies have shown that post space preparation results in weakening of the tooth structure and increase the probability of tooth fracture due to the formation of cracks and defects that can cause stress concentration. [16] Thus, the post-insertion should not be accomplished at the cost of sacrificing radicular dentin. [17]

A study conducted by Shurooq S. Abdulrazzak et al 2013 tested the fracture resistance of endodontically treated maxillary central incisors with different post lengths and three different ferrule heights. They con firmed that endodontically treated teeth with the presence of a ferrule were superior in the prevention of tooth fracture under a static load regardless of the post length. Results indicated that increasing the ferrule height significantly increased the fracture resistance of endodontically treated teeth. The most reasonable explanation given by them is that when the amount of remaining dentine increases, it allows for redistribution and dissipation of large forces. Besides, more coronal dentine structure forms a more stable foundation for the post and core with greater resistance to rotation could be achieved. The study also found no significant differences between the mean failure loads for the three post lengths used in each of the three ferrule height groups. These findings may be because the effect of ferrule was masking the effect of post length. It was also confirmed that the ferrule length was more important than the post length in terms of enhancing the fracture resistance of crowned teeth and increasing the post length did not significantly increase the fracture resistance of endo dontically treated teeth restored with prefabricated glass fiber posts. [18]. According to traditional teachings, a minimum of 3 to 5 mm of gutta-percha should remain in the apical portion of the root to maintain an adequate seal. A study by Abramovitz et al. in 2001 demonstrated that 3 mm of gutta-percha provides an unreliable apical seal, therefore, 4 to 5 mm is recommended. [19]

In this present study after 24 hours, Gutta Percha was removed using size 3 peeso reamer from the coronal and middle using third of the roots creating an 8.5mm of post space length in the canals of all the three experimental groups to provide an apical 4-5mm of apical gutta-percha.

Etching & Bonding

In the current study, the total-etch system was followed by the previous studies by Goracci et al and Theodor et al. The post space and the remaining dentin were etched with 36% phosphoric acid. Further bonding was done by Prime & Bond® NT™ Nano-Technology Dental Adhesive. Prime & Bond ® NT™ is a light-cure self-priming dental adhesive designed to bond composite materials that combine primer and adhesive in a single container. The reduction of components and treatment steps simplifies use, maintaining superior bond strengths and protection against microleakage. Prime & Bond® NT™ Dual Cure bonding system used in the study includes the Prime & Bond ® NT™ and Self-Cure Activator components. [20]

Sialinization

Post adhesion in the root canal represents the weakest point of the restoration. Bonding of fiber posts to composite materials relies on the chemical interaction between the post surface and the resin material used for luting and building up the core. In an attempt to maximize resin bonding to fiber posts, several surface treatments have been recently suggested: 1. silanization and/or adhesive application; 2. acid etching, sandblasting and silica coating; 3. alternative etching techniques (treatments that combine both a micromechanical and a chemical component). [21] In this study, both the glass fibre post and edelweiss post and core were treated with a silane coupling agent by Angelus.

Cementation and Core build-up

In this study after the sialinization the posts were cemented with Maxcem Elite™ Universal Resin Cement (Kerr) by and core build-up with Lux core Z (DMG), using size 2 core former (PDP Rhos). The use of an adhesive resin cement allows the formation of a signifi cant chemical bond between the dentin and the post itself. [22]

Bonding between the fiber post and the root dentin creates a "monobloc" another factor that could contri bute to a better distribution of stress on the tooth. [23]

The dual-cure composite core material was selected because of its ability to bond to both the glass fiber post and tooth structure, and still be cured with the post where light activation within the root was not possible. A previous study showed that the micro-tensile bond strength of low viscosity core material to fiber-reinforced composite post is higher than conventional composites using the incremental technique. [24]

The use of such flowable composites minimizes the occurrence of bubbles and voids within the core or the core/post interface due to better integration with the fiber post. [25]

The low consistency of the core material (Lux core Z) makes it easier to lute the surface of the post, with less air contamination and superior bond strength. [25]

Mounting of the tooth samples in acrylic blocks

After the cementation of all the post systems in their respective groups all the samples were mounted on stainless steel blocks of 19×19×20 mm with acrylic resin and the socket was relined with a silicone rubber impression material. The use of rigid material to embed the extracted teeth may lead to distorted load values and possibly affect the mode of failure of the specimen. Therefore, an attempt was made in this study to simulate the periodontal ligament and surrounding anatomical structures by coating the roots with polyvinyl siloxane and then embedding the roots in acrylic resin. [26]

Fracture testing

The samples were subjected to a universal testing machine for determination of the fracture resistance the force was applied by measuring in the midline of the palatal slope from a point 4 mm from the start of palatal surface, at a rate of 0.5 mm/min at 130 degrees to the long axis of the tooth. The point of fracture was determined by a sudden drop of the applied force and that audible crack and the force was recorded in newtons.

Fracture resistance of glass fiber post with other FRC post has been already discussed in the literature, Though the studies show a good amount of fracture resistance of the fiber-reinforced post system, the literature also reveals the less fracture resistance of glass fiber post when compared to other metallic post systems such as the cast post and titanium post and also when compared to zirconia post. But all these post systems tend to cause a catastrophic fracture when subjected to load until failure which was comparatively less in the case of glass-reinforced post system. [27,28].

In this current study, the fracture resistance of cast post and core, glass fibre post with composite core, and edelweiss post and core were subjected to loading until fracture. The fracture resistance of the glass fiber group was the most as compared to edelweiss and cast post and core due to better distribution of forces according to the study by Verri et al. (2017), also found that the elastic modulus of the glass fiber posts was similar to that of dentin, resulting in a better stress distribution as compared to metal posts .[29] and as claimed by the manufacturer edelweiss post and core also has a flexural modulus is 20 GPa like Dentin (15 – 20 GPa), flexural strength is 200MPa and compressive strength of 550 MPa, surface hardness is 95HV but when the adhesive strength was compared to glass fiber post system there is a significant difference in the fracture resistance as studied by Pennacchio et al (2020). [30]

Anusavice et al recorded in their study that the maximum biting force is about 756N. [31] The fracture resistance values of the glass-reinforced fiber post were much higher than the expected maximum biting force stated by Anusavice in this study.

Limitations of the study

According to the study done by Asif et al 1993, a complete crown with a 2mm ferrule on the sound tooth structure changed the distribution of forces to the root and the post and core complex. In this study, the test loads were applied directly to the cores which were not restored with a complete crown. This was to exclude any external strengthening influence on the post and core foundation. If complete crown over the core were included in the study the results of this study may have been different. [16]. Another limitation of this study was that continually increasing static load was applied on the samples which are not the kinds of load in the oral cavity. A study under cyclic loading would have probably mimicked forces acting on the teeth in the oral cavity. [32] Furthermore, this is an in-vitro study. The performance of the material might be different in a clinical situation. A long-term clinical evaluation of the success of these materials in restoring the tooth to its natural strength will help in their comparison.

References:

1. Chauhan NS, Saraswat N, Parashar A, Sandu KS, Jhajharia K, Raba Diya N. Comparison of the effect for fracture resistance of different coronally extended post length with two different post materials. Journal of International Society of Preventive & Community Dentistry. 2019; 9(2):144.
2. Peroz I, Blankenstein F, Lange KP, Naumann M. Restoring endodontically treated teeth with posts and cores--a review. Quintessence international.2005 Oct 1; 36 (9).
3. Makade CS, Meshram GK, Warhadpande M, Patil PG. A comparative evaluation of fracture resistance of endodontically treated teeth restored with different post core systems-an an in-vitro study. The journal of advanced prosthodontics. 2011;3(2):90-5.
4. Kallio TT, Lastumäki TM, Vallittu PK. Bonding of restorative and veneering composite resin to some poly meric composites. Dent Mater. 2001.Jan;17(1):80–6.
5. Vallittu PK. A review of fiber-reinforced denture base resins. J Prosthodont.1996. Dec;5(4):270–6.
6. Richard Trushkowsky, Fiber Post Selection and Placement Criteria: A Review, Inside Dentistry, April 2008, Volume 4, Issue 4.
7. Kulkarni K, Godbole SR, Sathe S, Gotoorkar S, Jaiswal P, Mukherjee P. Evaluation of the Mode of Failure of Glass Fiber Posts: An In Vitro Study. International journal of scientific study. 2016 Mar 1; 3 (12):34-9.
8. https://www.mediceptdental.co.uk/pdf/Medicept_Brochure_CC_april-2018.pdf
9. https://www.edelweissdentistry.com/wpcontent/uploads/2018/02/EW_FactSheet_PostCore_EN.pdf
10. Singh, I., Shetty, R., Mehta, D., Lampl, S., & Chida, N. (2018). Prefabricated Laser Sintered Com posite Veneers and Occlusal Vertical Dimensions: Case Reports. The journal of contemporary dental practice, 19 11, 1417-1423.
11. Stankiewicz NR & Wilson PR (2002) The ferrule effect: literature review International Endodontic Journal 35 (7)575-581
12. Jotkowitz A & Samet N (2010) Rethinking ferrule—a new approach to an old dilemma British Dental Journal 209(1) 25 – 33
13. Joseph J & Ramachandran G (1990) Fracture resistance of dowel channel preparations with various dentin thickness Federation of Operative Dentistry 1(1) 32-35
14. Fontana PE, Bohrer TC, Wands Cher VF, Valandro LF, Lim berger IF, Kaizer OB. Effect of Ferrule Thickness on Fracture Resistance of Teeth Restored with

a Glass Fiber Post or Cast Post. Operative dentistry. 2019 Jul 8.

15. Solano F, Hartwell G, Appel stein C. Comparison of apical leakage between immediate versus delayed post space preparation using AH Plus sealer. Journal of endodontics. 2005 Oct 1;31(10):752-4.

16. Singh V, Nikhil V, Bansal P. Induction of dentinal micro cracks during post space preparation: A com parative microcomputed tomography study. Journal of conservative dentistry: JCD. 2018;21(6):646

17. Stockton LW. Factors affecting retention of post systems: a literature review. The Journal of prosthetic dentistry. 1999;81(4):380-5.

18. Abdulrazzak SS, Sulaiman E, Atiya BK, Jamaludin M. Effect of ferrule height and glass fibre post length on fracture resistance and failure mode of endodontically treated teeth. Australian Endodontic Journal. 2014 Aug;40(2):81-6.

19. Abramovitz L, Lev R, Fuss Z, Metzger Z. The unpredictability of seal after post space preparation: a fluid transport study. J Endod on 2001; 27:292–5

20. http://www.dentsply.com.au/www/770/files/dfu-primeandbondnt.pdf

21. Salameh Z, Papacchini F, Ounsi HF, Goracci C, Task Andi E, Ferrari M. Adhesion Between Prefabricated Fiber-reinforced Posts and Different Composite Resin Cores: A Micro tensile Bond Strength Evaluation. 2006:113.

22. Borer RF, Briffo LA, Haddix JF. Effect of dowel length on the retention of 2 different prefabricated posts. Quintessence International. 2007;38(3).

23. Bacchi A, Dos Santos MBF, Pimentel MJ, Caetano CR, Sinhoreti MAC, Consani RLX. Influence of post thickness and material on the fracture strength of teeth with reduced coronal structure. Journal of conservative dentistry: JCD. 2013;16(2):139

24. Monticelli F, Goracci C, Grandini S, García-Godoy F, Ferrari M. Scanning electron microscopic evaluation of fiber post-resin core units built up with different resin composites. American journal of dentistry. 2005; 18 (1): 61- 5

25. Panitiwat P, Salimee P. Effect of different composite core materials on fracture resistance of endo dontically treated teeth restored with FRC posts. Journal of Applied Oral Science. 2017;25(2):203-10.

26. Singh V, Bogra P, Gupta S, Kukreja N, Gupta N. Comparative evaluation of fracture resistance of endo dontically treated teeth restored with resin fiber post and stainless-steel post: an in vitro study. Dental Journal of Advance Studies. 2015 Aug;3(02):080-4.

27. Abdelaziz KM, Keshk CK, Al-Mashhour OS, Alhudairy MA, Asiri MS, AL Shehri AM, Elshinawy MI. Fracture resistance of endodontically treated premolars with optimum and overprepared post spaces. International Journal of Contemporary Dental & Medical Reviews. 2018;2018.

28. Elshereksi NW, Ghazali M, Muchtar A, Azhari CH. Review of titanate coupling agents and their application for dental composite fabrication. Dental materials journal. 2017 Jul 28:2016-014.

29. Bhatnagar M, Tomer L, Saxena P, Singh A, Sharma V, Singh S. Evaluation of Clinical Performance of Cast Metal vs. Glass Fiber Posts in the Restoration of Endodontically Treated Teeth. Journal of Evolution of Medical and Dental Sciences. 2021 May 17; 10 (20): 14 96-501.

30. Pennacchio MC, Pontoriero DI, Ferrari M. Influence of different post's composition and shape on bond strength to radicular dentin. Journal of Osseo integration. 2020 Aug 27;12(3):209-14.

31. Anusavice KJ. In: Phillips' Science of Dental Materials. 10th ed. n Philadelphia: WB Saunders Co.;

1996.Mechanical Properties of Dental Materials (Chapter 4); pp. 49-7

32. Kulkarni K, Godbole SR, Sathe S, Gotoorkar S, Jaiswal P, Mukherjee P. Evaluation of the Mode of Failure of Glass Fiber Posts: An In Vitro Study. International journal of scientific study. 2016 Mar 1; 3 (12):34-9.