ORIGINAL RESEARCH

Comparative Study on Fracture Resistance of Endodontically Treated Tooth in relation to Variable Ferrule Heights using Custom Made and Prefabricated Post and Core

A.Meenakshi[1], S.Sureshkumar[2], Vinay Bharti[3], T.Maria Singam[4] , N.Sangeeta Meena[5], Priyanjali Paul[6]

1-Professor, Dept. of Prosthodontics, Tamilnadu Govt. Dental college & Hospital Chennai, India. 2,3,4,5,6-PostGraduate Student, Dept. of Prosthodontics, Tamilnadu Govt. Dental college & Hospital Chennai, India.

Correspondence to:
Dr. A.Meenakshi, PG student Professor, Dept. of Prosthodontics, Tamilnadu Govt. Dental college & Hospital Chennai, India.
Contact Us: www.ijohmr.com

ABSTRACT

Aim: This invitro study was conducted to evaluate the fracture resistance of endodontically treated teeth restored with different type of post with variable ferrule height. **Introduction:** Endodontically treated teeth had significantly different physical properties compared to vital teeth. In the instance of minimal remaining tooth structure, a foundation is required to retain the crown often with the placement of a post to provide retention for the foundation restoration. At one time post was thought to strengthen the remaining tooth,and was referred to as an "Intracoronal crutch" by Rosen.Furthermore, the ferrule effect reduces the wedging of tapered posts (or) bending forces during post insertion and helps to improve the marginal integrity of the fixed partial dentures. The majority of studies regarding the effectiveness of ferrule, support the need for at least 1.5mm of ferrule height. **Methods:** A total no. of 40 samples were made. The samples were broadly categorised into two main groups of A & B. These groups were further divided into 8 sub groups of A1,A2,A3,A4 & B1,B2,B3,B4 of 5 samples each.All the samples were subjected to fracture test at particular load with universal testing machine.The differences in fracture load between Group A & Group B are compared by paired student's T test and is highly significant at the level of 0.001%. **Results:** The result of this study revealed that the endodontically treated teeth samples restored with custom made cast post and core with different ferrule heights exhibit higher fracture resistance than prefabricated post with metal, core restored teeth samples. **Conclusion:** Comparatively the custom made cast post and core with variable ferrule height, especially 2mm ferrule showed significant fracture resistance than prefabricated post with metal core.The group restored with prefabricated post with metal core showed fracture between cementoenamel junction and remaining coronal tooth structure. By contrast, the samples restored with custom made cast post and core typically showed fracture at root.

KEYWORDS: Ferrule Effect, Post,And Core, Fracture Resistance

INTRODUCTION

The success achieved with esthetic restoration has resulted in increased patient demands for these treatments. Consequently, there has been a significant increase in the use of all ceramic crowns,with the core materials and endodontic posts.[1] Following endodontic therapy, teeth needed to be protected because of the risk of fracture particularly in the cervical region, which is continuously subjected to stress.[2]

It is well established that dentin undergoes change not only in its physical characteristics, but also in its physical properties with decrease in immature collagen levels. The hardness and shear resistance are markedly decreased .[3,4]

It is assumed that endodontically treated teeth are weaker and due to the loss of moisture which is given by the vital pulp they become more susceptible to fracture[5] ,which also produce a decrease in Young's modulus, and loss of residual tooth substance. Endodontically treated teeth often lack coronal tooth structure as a result of caries, previous restorations, trauma (or) endodontic procedures .

The quality and quantity of the remaining dentin is the deciding factor for the survival of the pulp less teeth[6]. To ensure functional longevity, endodontically treated teeth must have at least 5mm of tooth structure coronal to the crestal bone, 3mm needed to maintain a healthy soft tissue complex, and 2mm of coronal tooth structure incisal to the preparation finish line are necessary to ensure functional integrity.[7]

Any corono radicular restoration must meet the following conditions.

- The restoration must protect the tooth against the load placed on it by distributing the stress thought the supporting tissue.[8,9]
- It must ensure the retention and stability.[10]
- It must minimize any new loss of coronal and radicular substance during preparation.
- It must asses the prosthetic role of the teeth .[8,9]

The failure of the majority of restored pulpless teeth was reported to be prosthetic rather than biological.[11] The

How to cite this article:
Meenakshi A, Sureshkumar S, Bharti V, Singam TA , Meena NS, Paul P. Comparative Study on Fracture Resistance of Endodontically Treated Tooth in relation to Variable Ferrule Heights using Custom Made and Prefabricated Post and Core. Int J Oral Health Med Res 2016;3(1):68-74.

generally accepted explanation for the increased failure rate is the substantially decreased structural integrity of the tooth because of the removal of tooth structure during endodontic dowel space preparation and cavity preparation .

Conversely, it has been shown that providing coronal coverage significantly increases the stiffness of the remaining tooth. Several retrospective studies have reported that adequate coronal coverage following endodontic treatment resulted in decreased in tooth loss. Consequently, a large number of endodontically treated teeth particularly those that have undergone extensive tooth destruction are restored with crowns to provide the required coronal coverage.[12,13]

Opinion has since changed, rejecting the notion that a tooth is strengthened by incorporation of dowel (post). Despite the potential detrimental effects, dowels are still indicated to retain a foundation.

Restoring endodontically treated teeth is a challenge aspect involving varied treatment options. When there is an insufficient clinical crown remaining, cast post and core restoration is the gold standard for endodontically treated teeth.[12]

The most popular systems used when there is coronal tooth structure loss because they can save the time and can provide satisfactory results.[14]

The ferrule effect is been given importance in the recent years. A ferrule has been described a key element of tooth preparation when using a post core.[13] Sorensen et al. suggested that a ferrule or more specifically the ferrule effect can be defined by a 360-degree metal collar surrounding parallel walls of dentin and extending coronally to the shoulder of the preparation.

It is generally accepted restorative strategy to include a ferrule in the design of the tooth preparation when a endodontically treated teeth is resorted using a post and core and then restoring with crown.[15]

The availability of 2 mm of coronal tooth structure between the shoulder of the crown preparation and tooth-core junction provides ferrule effect which increases fracture resistance and preventing further dislodgment of the post.[16] It has also been confirmed that the ferrule effect improves resistance to dynamic occlusal loading, maintains the integrity of the artificial crown retainer, and reduce the potential of concentration of stress at the junction of post and core.

Aim of this In Vitro Study are:

- To evaluate the fracture resistance offered by endodontically treated teeth restored with custom cast post.
- To evaluate fracture resistance of endodontically treated teeth restored with prefabricated post with metal core.
- To ascertain and compare fracture resistance of teeth restored with custom cast post with variable ferrule height and teeth without ferrule.
- To ascertain and compare fracture resistance of teeth restored with prefabricated post with variable ferrule height and teeth without ferrule.
- To compare fracture resistance of teeth restored with custom cast post and prefabricated post with variable ferrule heights.

MATERIALS AND METHODS

This study was done to measure the influence of variable ferrule height on fracture resistance of endodontically treated teeth restored with custom cast post and prefabricated post with core.

MATERIALS USED IN THIS STUDY:

Equipments:

S.No	Instrument	Brand, Manufacturer
1.	Reamer	MANI INC, TOCHIGI, JAPAN.
2.	k- files	MANI INC, TOCHIGI, JAPAN. I
3.	Hand piece	Ka vo, Brazil.
4.	Burs	Sofu kit. Brazil.
5.	Vernier caliper	Aerospace, India.
6.	Induction casting machine.(Fig.1)	Bego, Germany. 1
7.	Universal testing machine.(Fig.2)	Lloyd, United Kingdom. 1

Fig 1: Induction Casting Machine

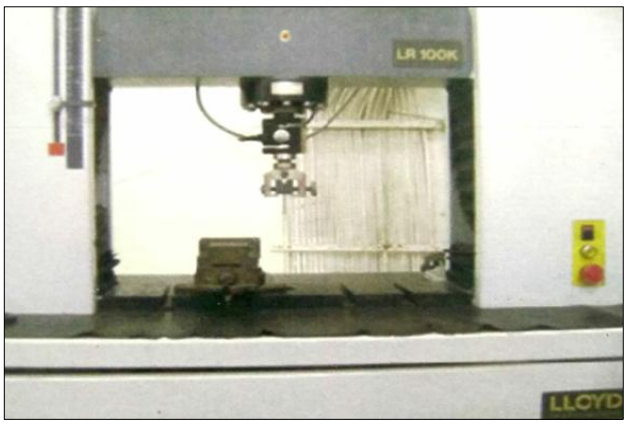

Fig 2: Universal Testing Machine

Materials:

S.No	Material	Brand, Manufacturer
1.	Gutta percha points	Dentsply, China.
2.	Zinc oxide eugenol cement	Samit, Faridabad.
3.	Inlay wax	Gc, Tokyo, Japan.

4. Prefabricated post Mani EG posts. Tochigi. Japan.
5. Autopolymerizing resin Dentsply, Gurgaon, India.
6. Wiralloy Bego, Germany.
7. Glass Ionomer cement. Gc Fuji, Japan.
8. Silicon impression material Aquasil, Dentsply, Germany

METHODOLOGY:

1- Selection of teeth,
2- Root canal preparation,
3- Post space preparation,
4- Grouping of samples,

Group A- custom cast post and core with sub groups of variable ferrule height (Al- 0 mm, A2- 1mm, A3- 1.5 mm, A4- 2mm)

Group B- prefabricated post and core with sub groups of variable ferrule height (Bl- 0 mm, B2-1 mm, B3- 1.5 mm, B4- 2mm)

5- Ferrule preparation for both group A & B,
6- Pattern fabrication,
   - Group A- Pattern fabrication for customized cast post.
   - Group B- Pattern fabrication for prefabricated post and core.
7- Investing and casting
8- Cementation
9- Acrylic block preparation
10- Preparation of metal core for receiving porcelain fused metal crown.
11- Custom made acrylic jig preparation,
12- Testing of specimens.

Selection of Teeth: A total number of forty recently extracted maxillary canines with similar root lengths of 15mm to 16mm measured from the apex to the cemento enamel junction were selected from maxillary canines extracted for periodontal disease.

The teeth were cleaned and stored in distilled water at room temperature. Teeth were selected for this study were examined to eliminate the root surface carious lesions, fissures and had not previously been subjected to endodontic therapy

Preparation of Root Canal: Each canal was prepared to within 1mm of radiographic apex with a standard master apical file #20.

Master apical files of 3 larger sizes #25, #30, #35 were used for further preparation of the canal. The root canal of each tooth was instrumented with a conventional step back technique.

The canals were irrigated with 2.5% sodium hypochlorite solution throughout the preparation and dried with paper points.Using lateral condensation every canal was obturated with gutta percha points and zinc oxide eugenol cement as a root canal sealant.

Preparation of Space For Endodontic Post: After two weeks, post preparations were made. Specimens of both groups custom made and prefabricated ‘ were prepared with reamer, starting from number l to 5 with slow speed handpiece, to remove 9mm of gutta percha apical to the cemento-enamel junction from each filled canal, leaving 4mm as apical seal.

Grouping of Samples: After post space preparation, forty teeth were grouped into 2 major groups of custom made cast post with core (group A) and prefabricated post with metal core (group B). Both group A and group B are further divided into four sub groups with variable ferrule height.

Ferrule Preparation [Fig-3]: Ferrule preparations for both groups A and B are same.

Fig-3: Ferrule Preparation

-For Group A1 & B1 - (0 mm / No ferrule),[Fig-4a] the removal of coronal aspects of the tooth at the cementoenamel junction perpendicular to the long axis of the tooth was performed by using high speed handpiece with flat end was tapering diamond. No coronal dentin was remaining above the Cemento enamel junction.

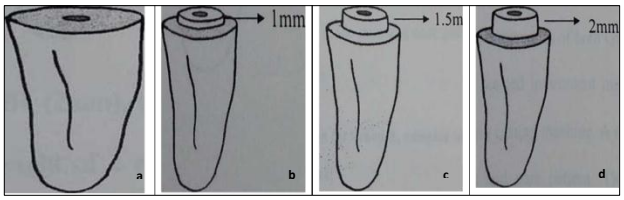

Fig-4a,b,c,d Different Ferrule Heights for Different Groups. 4a- 0mm/ No ferrule for Groups A1 & B1, 4b- 1mm ferrule for Groups A2 & B2, 4c- 1.5 mm ferrule for Groups A3 & B3, 4d- 2mm ferrule for Groups A4 & B4

-For the groups A2 and B2 (1mm),[Fig-4b] to obtain a flat plane coronal to cementoenamel junction the coronal structure was reduced at a height of 1 mm circumferentially. The ferrule height was standardized by customized probe having the measurement of 0.5,1.0, 1.5, 2.0 mm.

-For the groups A3 and B3(1.5 mm),[Fig-4c] the coronal tooth structure was reduced to a flat plane at 1.5mm of height coronal to cementoenamel junction circumferentially, the ferrule height was standardized by customized probe having the measurement of 0.5,1.0,1.5,2.0 mm.

-For the groups A4 and B4 (2mm),[Fig-4d] the reduction of coronal tooth structure was done at 2mm of height in a flat plane to cementoenamel junction circumferentially,

the ferrule height was standardized by customized probe having the measurement of 0.5,1.0,1.5, 2.0 mm.

Pattern Fabrication

- Pattern fabrication for Group A,[Fig-5] samples includes the sub groups A1, A2, A3, and A4. A direct method was used to fabricate custom made post and core patterns by using green colored inlay wax.

Fig-5: Pattern fabrication for Custom Made Cast Post

- Pattern fabrication for Group B,[Fig-6] samples includes the sub groups Bl, B2, B3, and B4.

Fig 6: Pattern fabrication for Prefabricated Post And Metal Core

The canals were restored with prefabricated stainless steel, parallel sided serrated posts with tapered end. Above the prefabricated post the core pattern was made with green colored inlay wax.

Investing And Casting Of Patterns: After the pattern fabrication, the samples of both Group A & Group B were invested with phosphate bonded investment material wiro west, and casting done by using induction casting machine. A nickel chromium alloy was used to cast the post and core pattern. The samples were finished by using metal trimming and polishing kit.

Cementation: Type 1 glass ionomer cement was used to cement the post and core in the prepared root canals of the tooth samples. The luting cement was mixed according to the manufacturer's instructions and introduced into each root canal with a lentulo spiral drill, on a low speed hand piece.

Cement was placed over the post surface and seated under finger pressure. Excess cement was removed and each specimen was returned to storage in distilled water.

Preparation To Receive Porcelain Fused Metal Crowns: All the specimens were prepared with a flat end tapered diamond bur in a high speed handpiece with water spray. Specimens were prepared to receive complete crowns with shoulder finish lines with 1 mm wide by using flat end tapered diamond. The finish lines of all the specimens were placed at the level of Cementoenamel junction.

After preparation of specimen, a special tray was made by using autopolymerizing resin. An impression was made by using putty and low viscosity vinyl polysiloxane impression material. Then impression was poured with TYPE 4 gypsum product. The die stone models were removed from the impression after complete setting of them.

Wax pattern were made for metal coping on the model using green colored inlay wax. Then the wax patterns were sprued, invested, and cast in Ni-Cr alloy.

After casting, sprues were removed by using carborundum disk, and then the metal coping surface was finished with aluminum oxide stone. The thickness of the coping around 0.3mm-0.5mm was maintained. The coping is now ready for placement of porcelain.

An opaque porcelain is used to mask the metal color and to give restoration its basic shade. The opaque porcelain is applied in 2 layers and fired as per the manufacturer’s instruction.

After this, the dentin porcelain was mixed to a creamy consistency with distilled water or the manufacturer's recommended liquid. Then it was applied over the opaque porcelain with a sable brush or small spatula, after the enamel porcelain was applied over the dentin porcelain and completed the full contour of restoration. Then it was fired under vacuum.

Finally, the porcelain fused to metal crowns were finished and then subjected for glazing. All the crowns were cemented to the teeth samples with TYPE I glass ionomer cement.

Preparation Of Acrylic Block: The root surfaces of teeth samples were marked 2 mm below the CEJ and covered with 0.6 mm thick tin foil. These teeth samples were then embedded in an acrylic mold having the dimensions of 40 mm height and 28 mm diameter with an internal hole in the center to accommodate the teeth samples.

The teeth samples were placed along their long axis in the center of the mold using a dental surveyor, and kept in cold water bath during polymerization of the resin. After the first signs of polymerization, teeth samples were removed from the resin blocks, and tin foil spacers were removed from the root surface.

Silicone base impression material was injected into the acrylic resin blocks and teeth were reinserted into the resin blocks. A standardized silicone layer is formed over root surface to simulate periodontal ligament.

Custom Made Acrylic Jig Preparation [Fig 7]: A custom made jig, which would fit exactly in the retaining arm of the universal testing machine, was made from the rectangular block of acrylic. This was designed to hold the samples at 135 degree to the proposed loading. It was to orient all the specimens in the universal testing machine at 135 degree angulation.

Fig 7: Custom Made Apparatus

Testing Of Specimens [Fig 8]: Each specimen was placed in custom made apparatus that allowed the specimen to be positioned at 45 degree to the buccal/lingual axis.The specimens were put through loading at this orientation in a universal testing machine. The load was measured in Newtons (N).

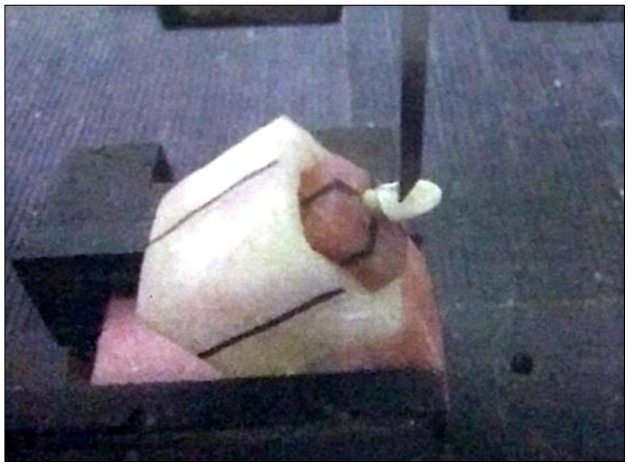

Fig 8: Orientation of the teeth samples to the Testing Machine

Each specimen was embedded in a self-cured acrylic resin block which is 2mm apical to the margins of porcelain fused to metal crown,and in a universal testing machine it's then loaded at 135 degrees from long axis at a crosshead speed of 1.0mm/minute until fracture.Static loading tests were performed on each specimen until failure (crack without a complete fracture).

RESULTS

This study was conducted to evaluate the fracture resistance of endodontically treated teeth restored with prefabricated post and custom cast post with variable ferrule heights.A total no. of 40 samples were made. The samples were broadly categorised into two main groups of A & B. These groups were further divided into 8 sub groups of A1,A2,A3,A4 & B1,B2,B3,B4 of 5 samples each.

All the samples were subjected to fracture test at particular load with universal testing machine.

The differences in fracture load between Group A & Group B are compared by paired student's T test and is highly significant at the level of 0.001%.[Table:1]

Sub Group	Fracture load of Group A		Fracture load of Group B		P value
	Mean	SD	Mean	SD	
1	728.08	25.84	558.64	12.99	<0.001**
2	760.06	18.49	635.12	16.66	<0.001**
3	812.70	44.49	725.78	15.50	<0.003**
4	838.46	32.61	755.76	11.26	<0.003**

** Differences are statistically Significant at the 0.001 level

Table 1: Paired t-tests for paired samples

DISCUSSION

Dentists frequently restore teeth that have been endodontically treated.The restoration of endodontically treated teeth which have weakened roots require special; attention because of function and aesthetics.

Post and core are commonly advocated method to replace the lost coronal tooth structure and to provide retention and resistance of the final restoration. A number of materials are available for this purpose. Materials currently available for posts are cast alloys, prefabricated stainless steel alloys, prefabricated glass ceramic post, prefabricated carbon fiber post and custom made post produced intraorally by cast metal or composite.

For better performance of the post, the dimension of the post and certain physical characteristics of materials such as strength and modulus of elasticity, are important with respect to preservation and fracture strength of the tooth structure.[17]

In others words, the diameter of post should be minimized, but it is sufficient to resist functional forces. Materials with high modulus of elasticity showed more resistant to distortion and distributed loads more evenly.

Materials currently used often for cores are cast metal, amalgam, composite resin, and glass ionomer[18], The selection of core material should be based on the

capabilities of transmitting functional forces efficiently. Some characteristics of core materials should be considered are modulus of elasticity, compressive strength, tensile strength, yield strength,and stability. The prefabricated steel post and cast metal post core can maintain the necessary physical characteristics within the relative narrow canal.

Regardless of the cement or post type used, restored endodontically treated teeth should have sufficient coronal tooth structure to incorporate the principle of a ferrule, which will improve the fracture resistance and thereby the longevity of the restoration.[19] A ferrule is afforded by the complete crown providing a bracing effect when it is placed over the tooth structure or core foundations.

Heydecke et al.[20] reported the main disadvantage of natural teeth is being comparatively larger in mechanical parameters, often leading to larger standard deviations .this has also been noticed in the present investigations that the variables in human teeth may enlisted as tooth conditions previous to the extraction, tooth age, tooth storage conditions, pulp status at the time of extraction, root anatomy, and root dimensions.[21]

In the present study, the custom made cast post and prefabricated post with metal core were used. This study revealed that increasing ferrule height significantly increased the fracture resistance of endodontically treated teeth restored with custom cast post and cores, which is in the order of O mm, 1mm, 1.5 mm, 2 mm. The prefabricated post with metal core comparatively showed lesser fracture resistance than custom made cast post.

Lyones and Baxandale[22] observed that the mean force applied on a maxillary canine was 215N. In the presence of Parafunctional loading that this force increased to 254.8N and the maximum force were between 343 and 362.6N. In the present study, the maximal force to induce fracture of teeth with a uniform 2mm ferrule was 835.5N for custom made cast post and 755.6N for prefabricated post with metal core. This observation leads to the conclusion that there is substantial benefit in providing a ferrule whenever possible.

The result of this study indicates the presence of remaining coronal tooth structure did influence the fracture resistance of tooth.The findings of this study are in harmony with Sorensen and Engelman, who found that 1 mm of remaining coronal tooth structure was able to resist compressive load.

Pereira et. al observed the teeth restored with prefabricated post with composite core with 2mm ferrule showed significantly higher fracture resistance of 745.3 N. This is due to larger amount of coronal tooth structure. The higher quantity of inorganic particles corresponds to the maximum resistance of compressive load, surface hardness and wear resistance.[23]

The present study showed prefabricated post with metal core surrounding the ferrule produce the better fracture resistance of 756 N at 2 mm ferrule height.

Schilling burg et al,[24] found that when a large amount of tooth structure loss is seen extending beyond the level of alveolar crest either due to caries or multiple fractures then the tooth cannot be restored until extraordinary measures been applied,even if a dowel core placed in the tooth, the root will remain susceptible to fracture unless the crown encircles the tooth apical to the core. The ferrule effect present around the tooth functions in protecting it from fracture by dowel from within, in fact if tooth structure is lost “only” to the level of epithelial attachment; it may be desirable to permit the access to enough tooth structure apical to the finish line to produce a ferrule effect. In the present study also confirm the presence of ferrule of 1.5 mm and 2mm reduces the fracture of root significantly ($p<.001$).

Pierrisnard et al.[2] in their finite element analysis noted that the cervical region of post-restored teeth were more susceptible to tensile loads increasing the risk of fracture in that area. Also many studies report the cervical third fracture as the major mode of fracture.

ZhiXue and YuXing also stated the apical root fracture being the common mode .In the present study it was seen that cervical root fracture was the predominant pattern and that it can be restored in most of the clinical situation. The tapering end post design showed more promising results and resulted in less number of apical root fractures.

In the present study crowns were placed over the experimental teeth samples before putting them through compressive testing to simulate the clinical conditions more precisely, similar comments were made by Heydecke et al.[20]

Thus, the present study showed that the increase in ferrule height increases the fracture resistance of teeth samples restored with both custom made cast post and prefabricated post with metal core and maximum fracture resistance attained at a ferrule height of 2 mm. The custom made cast post exhibited more resistance against the fracture when compared to prefabricated post and core.

SUMMARY

This in vitro study was conducted to evaluate the fracture resistance of endodontically treated teeth restored with different type of endodontically treated teeth restored with different type of post with variable ferrule height. A total number of forty recently extracted maxillary canines were selected for this study.

Teeth samples were divided into group A & B. Than group A restored with custom made cast post with core and group B restored with prefabricated post with metal core. Then these teeth samples were embedded in acrylic blocks. Above which porcelain fused metal ceramic crowns cemented with type I G.I.C.

After that, these teeth samples were subjected to universal testing machine at an angulation of 45 degree by using custom made acrylic apparatus for fracture testing.

The results were subjected to one way ANOVA and HSD TUKEY test to analyze the statistical significance.

The result of this study revealed that the endodontically treated teeth samples restored with custom made cast post and core with different ferrule heights exhibit higher fracture resistance than prefabricated post with metal, core restored teeth samples.

CONCLUSION

Within the limitation of this study,it can be concluded that;

- Increasing the ferrule height significantly increases($p<0.001$) the fracture resistance of endodontically treated teeth restored with both custom made cast post and core and prefabricated post with metal core.
- Comparatively the custom made cast post and core with variable ferrule height, especially 2mm ferrule showed significant fracture resistance than prefabricated post with metal core.
- The group restored with prefabricated post with metal core showed fracture between cementoenamel junction and remaining coronal tooth structure. By contrast, the samples restored with custom made cast post and core typically showed fracture at root.

REFERENCES

1. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent 2003; 89(4) 360-367.
2. Laurent Pierrisnard, Frederic Bohin, Patrick Renault, Michel, Barquins. Coron-radicular reconstruction of pulpless teeth: A \mechanical study using finite element analysis. J Prosthet Dent 2002; 88: 442-8.
3. Caputo AA, Standlee JP. Pins and posts-why, when and how. Dent Clin North Am 1976; 20, 299-311.
4. Naumann M, Preuss A, Rosentritt M. Effect of incomplete crown ferrules on load capacity of endodontically treated maxillary central incisors restored with fiber posts, composite build-ups, and all-ceramic crowns: An in vitro evaluation after chewing stimulation. Acta Odontol Scand 2006; 64(1) 31-36.
5. Carter JM, Sorensen SE, Johnson RR, Levis MS. Punch shear testing of Extracted vital and endodontically treated teeth, J Biomech 1983; 16: 841-8.
6. Tjan AH, Whang SB. Resistance to root fracture of post channels with various thicknesses of buccal dentin walls. J Prosthet Dent 1985; 53: 496-500
7. Spear F. When to restore, when to remove; the single debilitated tooth. Compad Contin Educ Dent 1999; 20- 316- 28.
8. Henry PJ, Bower RC. Post core system in crown and bridge work. Aust Dent J 1977; 22:46-52.
9. Waliszeweski KJ. Sabala CC.Combined endodontic and restorative treatment considerations.
10. Akkayan B. An in vitro study evaluating the effect of ferrule length on fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dowel systems. J Prosthet Dent 2004; 92(2) 155-1 62.
11. Pareira JR, Ornelas F, Conti RCR, do Valle, AL. Effect of a crown ferrule on the fracture resistance of endodontically treated teeth restored with prefabricated posts. J Prosthet Dent 2006; 95(1) 50-57.
12. Sorensen JA, Engelman MJ. Ferrule design and fracture resistance of endodontically treated teeth. J prosthet Dent 1990: 63: 529-36.
13. Tan PL, Aquilino SA, Gratton DG, Stanford CM, Tan SC, Johnson WT, Dawson D, In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 2005; 93(4) 331 - 336.
14. Torbjorner A,Fransson B,A literature review on the Prosthetic treatment of structurally compromised teeth, lnt J Prosthodont 2004; 17: 369-76.
15. Ichim I, Kuzmanovic DV, Love RM. A finite element analysis of ferrule design on restoration resistance and distribution of stress within a root. Int Endod J 2006; 39(6) 443-452.
16. Gegauff AG.Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns. J Prosthet Dent 2000; 84(2) 169-179.
17. Hunt PR, Gogamoiu D. Evaluation of post and core systems. J Esthet Dent 1996:8: 74-83.
18. Meng QF, Chen YM, Guang HB, Smales RJ. Effect of ferrule and increased crown length on the in vitro fracture resistance of premolars restored using two dowel and systems. Oper Dent 2007 Nov-Dee; 32(6):595-601.
19. Libman WJ, Nicholls JI. Load fatigue of teeth restored with case posts and cores and complete crowns. Int J Prosthodont 1995; 8: 155-61.
20. Heydecke G, Butz F, Hussein A, Strub JR. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent 2002; 87(4) 438-445.
21. Akkayan B, Gulmez T. Resistance to fracturc of endodontically treated teeth restored with different post systems. J.Prosthet dent 2002;87(4) 431-437
22. Lyons MF, Baxendale RH. A preliminary electromygraphic study of bite force and jaw-closing muscle fatigue in human subjects with advanced tooth wear. J Oral Rehabil 1990; 17: 311-8.
23. Bex RT, Parker MW, Judkins JT, Pelleu GB. Effect of dentinal bonded resin post-core preparations on resistance to vertical root fracture. J Prosthet Dent 1992; 67: 768-72.
24. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett Se. Fundamentals of fixed prosthodontics. 3rd Ed. Chicago: Quintessence Publishing Co; 1997. P.89.

Source of Support: Nil
Conflict of Interest: Nil