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RESEARCH ARTICLE

EVALUATION OF GLASS FIBRE POST WITH VARYING FERRULE LENGTHS

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ABSTRACT

Statement of problem: The presence of ferrule is hypothesized to protect the tooth from wedging stresses in post restored teeth. Restoration design must provide enough strength to restoration and to abutment teeth to resist occlusal forces. It is important to evaluate the optimum ferrule length in various post and core restorations that must be incorporated in endodontically treated teeth to increase its fracture resistance.

Purpose: The purpose of this study was to evaluate the effect of different length of ferrule on fracture resistance and mode of failure of endodontically treated teeth restored with two different post systems, including glass fibre post and composite system and Ni-Cr cast metal post and core system.

Methods: Eighty freshly extracted human maxillary central incisors were endodontically treated. Teeth were randomly divided into two groups of 40 teeth each. Each group was further subdivided into four subgroups of 10 teeth each depending upon the length of ferrule preparation i.e., 0mm, 1mm, 2mm and 3mm. The Group A was restored with glass fiber-reinforced post and composite resin core (GFRP) and the Group B was restored with Ni-Cr cast post and core (CP). All the specimens were loaded to fracture using a universal testing machine and mode of failure was recorded by visual inspection. Data were statistically analyzed.

Results: The mean fracture resistance was found to be highest at ferrule length of 2mm in both groups.

Conclusions: This *in vitro* study demonstrated that the optimum ferrule length required is 2mm.

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INTRODUCTION

Endodontically treated teeth where substantial tooth structure has been lost as a result of dental caries and previous restorations have a guarded prognosis at the outset. This makes retention of subsequent restorations more problematic and increases the likelihood of fracture of the tooth during functional loading because of desiccation or premature loss of moisture supplied by vital pulp (Ng *et al*., 2006). Successful restoration of endodontically treated teeth requires an effective coronal seal, protection of the remaining tooth, restored function and acceptable aesthetics (Stankiewicz and Wilson, 2002). The endodontically treated teeth, particularly those that have undergone extensive tooth destruction are restored with crowns to provide the required coronal coverage (Tan *et al*., 2005). Post is used as reinforcing element and aids in supporting a core foundation when there is an insufficient clinical crown (Dikbas *et al*., 2007).

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The most important factor to consider in the restoration of the prosthodontic restoration of endodontically treated teeth is the post preparation material and a design that reduces the chances of root fracture (Kaur *et al*., 2012). The usage of "ferrule effect" is another approach for strengthening the tooth having post and core (Stankiewicz and Wilson, 2002). The ferrule exerts its effect by balancing the functional lever forces, limiting the wedging action of tapered posts, protecting the integrity of the cement seal and resisting torsional forces (Zhi-Yue and Yu-Xing, 2003). The fracture resistance of endodontically treated teeth depends upon the amount of coronal tooth structure available for preparation of ferrule. However, Saupe *et al*. (1996) showed that there was no significant difference in fracture resistance between post and core restorations that used a ferrule and restorations without a ferrule. Therefore, the present in vitro study aimed to compare and evaluate the fracture resistance of endodontically treated teeth restored with two different post-systems i.e., Glass fibre post and composite resin core and custom made cast post and core with variable ferrule length. From the results, the optimum ferrule length required providing maximum fracture resistance to endodontically treated teeth restored with the two post and core systems was inferred.

MATERIALS AND METHODS

Eighty intact maxillary central incisor teeth having coronal length of approximately 10 mm and minimum root length of 13 mm were selected. The teeth were cleaned for any root deposits and stored in artificial saliva at room temperature until used for study. Endodontic treatment of the selected teeth was completed as A#15-50 using rotary instrumentation and conventional step back technique and each canal was obturated by lateral condensation technique using gutta-percha cones (Akkayan, 2004; Dikbas *et al*., 2007). The endodontically treated teeth were randomly divided into two groups i.e., Group A and Group B of 40 teeth each. Teeth in Group A was restored with glass fibre-reinforced post (RelyX^{TM} 3M ESPE US) and composite resin core (Paracore, Coltene) and teeth in Group B was restored with custom made Ni-Cr cast post and core (Wirolloy, Bego Germany). Depending upon different ferrule length preparation i.e., 0mm, 1mm, 2mm and 3mm, each group was further subdivided into four subgroups of 10 teeth each. Thus subgroups A_0, A_1, A_2, A_3 and B_0, B_1, B_2, B_3 were formed based at varying length of ferrule preparation. All the prepared teeth were decoronated horizontally at CEJ perpendicular to long axis of teeth in subgroup A_0 and B_0. For subgroups A_1, A_2, and A_3 in Group A and B_1, B_2 and B_3 in Group B, the prepared teeth was decoronated to flat plane at a height of 1mm, 2mm and 3mm incisal to cementoenamel junction to incorporate ferrule of height 1 mm, 2 mm and 3 mm respectively. The dimensions were checked with the help of a graduated periodontal probe (William's probe).

Group A (GFR) special drills supplied with the kit, were used to prepare post space, leaving 3 mm apical seal in the root canal. Prepared post space was evaluated with the radiograph. (GFRP), the prefabricated glass fiber posts were cemented with adhesive resin cement (3M) ESPE. Then it was light cured for 40 sec to achieve complete polymerization. Core build up was done with (Paracore, Coltene). The preformed polyester matrix was filled with the core build up material placed on the specimen. Each increment was light cured for 60 sec. It was finished to the final core height of 6 mm and bucco-lingual and mesio-distal dimensions corresponding to that of the tooth, with the help of composite finishing kit. For Group B (CP), Peeso reamers (#1-6, Mani Japan) were used to prepare the post space. Wax pattern for cast post and core was prepared. Paper pin was roughened and dipped in molten blue inlay wax and inserted into the canal. Incremental addition of wax was done to make a post pattern. The core was built up to achieve a desired core height of 6 mm, and bucco-lingual and mesio-distal dimensions 1.5 mm less than to the corresponding total bucco-lingual and mesio-distal dimensions of the specimen. The post and core wax pattern was sprued and invested. Casting was done with Ni-Cr alloy (Wiron-99, Bego, USA) and casting of post and core were obtained and finished. The cast post was placed in the canal to check its fit and was cemented with adhesive resin cement. The cementation of GFRP was done in a similar way. Then core build up done and finished with the help of composite finishing kit. Crown pattern were prepared with blue inlay wax and then casting is done in Ni-Cr alloy (Wiron-99, Bego, USA). The castings were retrieved and finished .The cementation of crown was done with adhesive resin cement. The root surface of each specimen was coated with a layer of Addition silicone Type I- regular viscosity, polyvinyl siloxane impression material to simulate periodontal ligament (Zhang *et al*., 2015). The teeth were embedded in chemical cure acrylic resin with mid-facial extent of the CEJ located 2 mm coronal to the flat surface of acrylic resin and held under digital pressure until material was set (Evangelinaki *et al*., 2013). The specimens were tested using the Universal Testing Machine (Tinius Olsen H50KS). A metal jig was fabricated having the provision for holding acrylic resin block that oriented the specimen at an angle of 135 degree to the load application tip of the attachment tool. The load was applied on the palatal surface of cast crown, 3mm from incisal edge, at an angle of 135^0 to the long axis of the root at crosshead speed of 2mm/min until failure occurred (Sendhilnathan and Nayar, 2008) (Fig. 1). Mean failure load in Newton was calculated using one-way ANOVA and Tukey's post-hoc test. The level of significance for the present study was fixed at 0.05. Each sample was then removed from the acrylic resin block and mode of failure was noted.

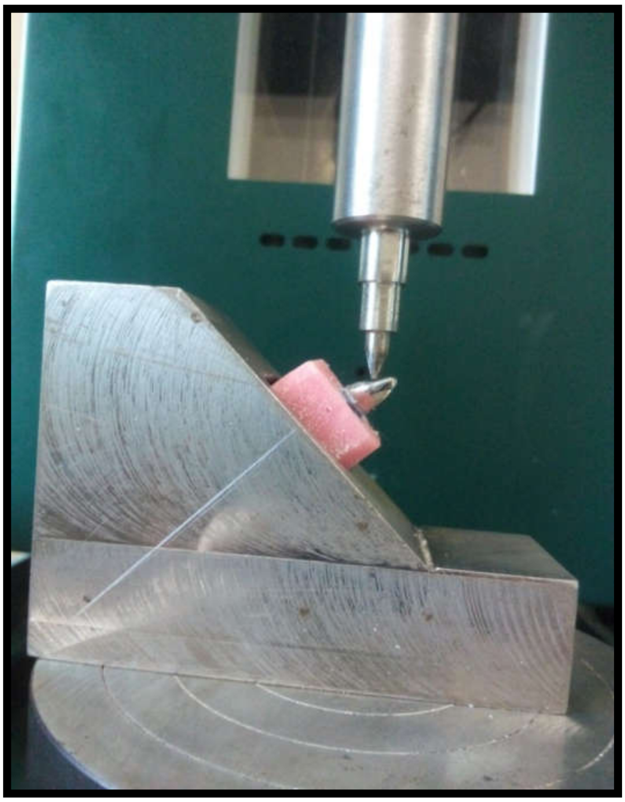

Fig 1. Load application on tooth at 135^0 along the long axis of the tooth sample

RESULTS

The mean fracture resistance was found to be highest at ferrule height of 2mm in both groups. The highest mean fracture resistance of group B was 999.40N at 2mm of ferrule followed 975.60N at 3mm, 685.7N at 1mm and 592.90N when no ferrule was incorporated in it. In group A highest fracture resistance was found to be 606.6N at 2 mm ferrule followed by 589.4N at 3mm ferrule, 422N at 1 mm and 310N when no ferrule was incorporated in it. The fracture resistance of group A and group B was shown in Table 1. The fracture resistance of group A was lower than the group B in their respective subgroups. In both groups there was significant increase in mean fracture resistance when ferrule length was increased up to 2mm. However, p-value > 0.05 was not significant when ferrule length was increased from 2mm to 3mm as shown in Table 2 & 3.

Table 1. Fracture resistance of various ferrule lengths in Group A restored with glass fibre post and composite core and group B restored with cast metal post and core

Ferrule length	N	Mean fracture resistance of group A	Mean fracture resistance of group B
0 mm	10	310	592.90
1 mm	10	422	685.70
2 mm	10	606.6	999.40
3 mm	10	589.4	975.60

Table 2. Multiple comparison of fracture resistance of various ferrule lengths in group A

		Mean Difference	p-value	95% Confidence Interval	
				Lower Bound	Upper Bound
0 mm	1 mm	-112.000*	.000*	-136.07	-87.93
0mm	2 mm	-296.600*	.000*	-320.67	-272.53
0mm	3 mm	-279.400*	.000*	-303.47	-255.33
1mm	2 mm	-184.600*	.000*	-208.67	-160.53
1mm	3 mm	-167.400*	.000*	-191.47	-143.33
2mm	3 mm	17.200	.236	-6.87	41.27

Table 3. Multiple comparison of fracture resistance of various ferrule lengths in group B

		Mean Difference	p-value	95% Confidence Interval	
				Lower Bound	Upper Bound
0 mm	1 mm	-92.800*	.000*	-121.12	-64.48
0 mm	2 mm	-406.500*	.000*	-434.82	-378.18
0 mm	3 mm	-382.700*	.000*	-411.02	-354.38
1 mm	2 mm	-313.700*	.000*	-342.02	-285.38
1 mm	3 mm	-289.900*	.000*	-318.22	-261.58
2 mm	3 mm	23.800	.126	-4.52	52.12

Table 4. Mode of failure in various ferrule lengths in group A

		group_A				Total
		0 mm	1 mm	2 mm	3 mm	
Complete debonding of crown post and core complex		4	3	1	0	8
		50.0%	37.5%	12.5%	.0%	100.0%
Crown cementation failure	Count	3	2	1	0	6
		50.0%	33.33%	16.66%	.0%	100.0%
Fracture of post	Count	3	4	3	4	14
		21.428%	28.57%	21.428%	28.57%	100.0%
Fracture of root		0	0	1	2	3
		.0%	.0%	33.33%	66.66%	100.0%
Core fracture		0	1	4	4	9
		.0%	11.11%	44.44%	44.44%	100.0%

Table 5. Mode of failure in various ferrule lengths in group B

	Group_B				Total
	0 mm	1 mm	2 mm	3 mm	
Complete debonding of crown post and	4	3	2	1	10
core complex	40%	30.0%	20.0%	10%	100.0%
Crown cementation failure	3	2	0	0	5
	60.0%	40.0%	.0%	.0%	100.0%
Fracture of post	0	0	0	0	0
	.0%	.0%	.0%	.0%	100.0%
Fracture of root	3	5	8	9	25
	12.0%	20.0%	32.0%	36.0%	100.0%
Core fracture	0	0	0	0	0
	.0%	.0%	.0%	.0%	100.0%

Mode of failure for GFRP group was predominantly complete debonding of crown post and core complex or post fracture whereas for CP group most of the failures were root fractures as shown in Table 4 & 5.

DISCUSSION

The results suggest that the fracture resistance and mode of failure of two groups does not have similar behavior under similar experimental study. The teeth restored in group B CP post showed higher mean fracture resistance than teeth restored in group I GFR post and these findings are similar to study done by Sreedevi and Sanjeev (2015). The cast post showed the higher mean fracture resistance because it reproduces the morphology of the post space leading to maximum adaptation to canal (Zhi-Yue and Yu-Xing, 2003) (Gluskin *et al*., 1995). In each group there was significantly increase in fracture resistance with increase of ferrule length from 0mm to 1mm because of the crown ferrule formation which provides resistance to dislodgement and prevents fracture by bracing the tooth. Sorensen and Engelman (1990), Loney *et al*. (1990), Isidor (1999) suggested that 1mm of coronal dentin above the shoulder significantly increased the failure threshold. When ferrule length is increased from 1mm to 2mm, there was significant increase in mean fracture strength due to increase in hugging action of metal crown due to increase in the surface area as 2mm was greater than 1mm as suggested by Philip LB (Tan *et al*., 2005). Further increase in ferrule length there is decrease in fracture strength. These results are consistent with those of previous studies which observed that ferrule length larger than 2mm was not able to resist the compressive load (Pereira *et al*., 2005). It is believed that cemented post acts as class I lever with fulcrum at cervical region of the post (Pilo *et al*., 2002; Pereira *et al*., 2006). Length of post inside the root should be greater than its length outside the root. This reduces the length of lever arm. If the length of crown ferrule is increased from 2mm to 3mm, the length of post outside the root increases. This increases the length of the lever arm which is responsible for increase in stresses inside the root. This in turn responsible for reduction in mean fracture resistance if teeth at 3mm ferrule length as compared to 2mm ferrule length. The hugging action of ferrule is there but lever action predominates at this length. Similar results of effect of increase in ferrule length were obtained in teeth restored in Group B and are in agreement with study done by Moksha Nayak (Moksha Nayak *et al*., 2010). The highest frequency of complete debonding of post and core complex was seen in A_0 group followed by B_0, A_1, B_1, B_2, A_2, B_3 and A_3. The highest frequency of crown decementation failures were seen in B_0, followed by A_0, B_1, A_1 and A_2. These failures suggest that complete debonding of post and core complex occurs at 0mm and 1mm ferrule length due to failure at the cement dentin interface that leads to loss of retention which causes complete debonding of crown post and core complex or crown cementation failure. Morgano and Brackett (1999) who reported that a flexible post may allow micromovement of core under occlusal load when ferrule is small or absent with resultant fracture of cement seal at crown margin. Libman and Nicholls (Libman and Nicholls, 1995) also reported similar results.

Fig. 2. Middle root fractures in CP post

Fig. 3. Cervical root fractures in GPRS post

Apart from this exclusive failures seen in Group A was fracture of restorative material and post fractures whereas in Group B there were fractures of middle root as shown in Fig 2. This can be explained by the fact that cast restorations have highest modulus of elasticity (220 GPa) as compared to glass fibre post (13-40 GPa), whereas the modulus of elasticity of dentin is (15-25 GPa). The high difference in modulus of elasticity as compared to dentine has resulted in increased root fractures in case of cast post and core system. Due to near comparable modulus of elasticity to dentin in case of glass fibre post, the incidence of root fracture are less and cervical root fractures occurs as shown in Fig 3. Stress concentration increased within post and core and resulting in post and core failures.

The frequency of post fractures were increased when ferrule length is less. Increasing ferrule length from 2mm to 3mm, the mode of failure was predominantly core fracture and root fracture. These results are supported by finite element analysis study done by Garhnayak and Parkash (Garhnayak *et al*., 2011). According to Abdalla and Alhadainy and Pereira, *et al*. (1996) (Moksha Nayak *et al*., 2010) the fracture of composite resin core when occlusal forces is applied may be a positive occurrence because it could be protective to the supporting root. Valle and Jefferson also concluded that the GFRP system showed complete debonding of crown post and core complex before any occurrence of root fracture (Pereira *et al*., 2014). Within Group B, at 0mm and 1mm ferrule length, majority of the specimen failed due to complete debonding of crown post and core complex and fracture of root. As the ferrule length was increased from 2mm to 3mm, the frequency of failures of root fracture increased because of increased stress concentration within the root.

Conclusion

Within the limitations of the study it can therefore be concluded that Group A (GFRP) system is better as its mode of failure is repairable. Retreatment is done by replacing by new post system but in group B (CP) system root fractures are always nonrepairable. Optimum ferrule length can be considered as 2mm as incidence of failures are less. Hence theoretically the need for ferrule is recommended, but in compromised cases where a good ferrule is not attainable, it might be desirable to restore a tooth with a glass fibre post rather than a metal post.

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