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ORIGINAL RESEARCH

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Comparative Evaluation of Fracture Strength of Different Types of Composite Core Build-up Materials: An *in vitro* Study

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ABSTRACT

Aim: The aim of the study was to evaluate the fracture strength of three types of composite core build-up materials. The objectives were to study and evaluate the fracture strength and type of fracture in composite core build-up in restoration of endodontically treated teeth with or without a prefabricated metallic post.

Materials and methods: A total of 60 freshly extracted mandibular premolars free of caries, cracks, or fractures were endodontically treated and restored with composite core build-up with prefabricated metallic posts cemented with resin luting cement (group I) and without a post (group II). This was followed by a core build-up of 10 teeth each with three different types of composite materials: Hybrid composite, nanocomposite, and ormocer respectively. The samples were mounted on polyvinyl chloride block and then loaded in the universal load frame at 90° to the long axis of tooth. The fracture strength of the samples was directly obtained from the load indicator attached to the universal load frame.

Results: Analysis of variance (ANOVA) test revealed that teeth restored with post exhibited highest fracture strength (1552.32 N) and teeth restored without post exhibited lowest fracture strength (232.20 N). Bonferroni's test revealed that values for hybrid composite (Z-100, 3M ESPE) with post, nanocomposite (Z-350, 3M ESPE) with post, ormocer composite (Admira-VOCO) with post, and nanocomposite (Z-350, 3M ESPE) without post were not significantly different from each other.

Conclusion: Teeth restored with post and core using hybrid composite yielded the highest values for fracture strength. Teeth restored with ormocer core without post exhibited the lowest values. Teeth restored with nanocomposite core without post exhibited strength that was comparable with hybrid composite core but higher than that of ormocer.

Clinical significance: Mutilated endodontically treated teeth can be prosthetically rehabilitated successfully by using adhesive composite core build-up along with post to meet anatomical, functional, and esthetic demands.

Keywords: Bonferroni's test, Hybrid composite, *In vitro* study, Nanocomposite, Ormocer.

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INTRODUCTION

Prosthetic rehabilitation of root canal-treated mutilated teeth poses a great challenge to the prosthodontist. Biologic, esthetic, and functional demands have to be met while restoring the mutilated teeth.[1] Various techniques and special considerations are needed for prosthetic rehabilitation of root canal-treated teeth to promote the endurance, as they have inadequate coronal tooth structure.[2]

The deficient coronal tooth structure makes retention and stability of subsequent prosthetic rehabilitations more challenging. It also promotes the incidence of prosthetic failures. Higher risks of fracture are seen in root canal-treated than in vital teeth due to lack of moisture content and adequate sound tooth structure. Full coverage fixed crowns are usually recommended in many clinical situations to maintain function and esthetics.[1-3] Following root canal treatment, post and core build-ups are usually recommended to prevent dislodgement of fixed crown prosthesis and enhance the resistance to fracture of the teeth.[4,5] The prefabricated post with composite coronal build-up is usually recommended due to simplicity, low invasiveness, and minimal complications.[6] Composite resin, glass ionomer, cast metal alloys, dental amalgam, etc., have been recommended for coronal build-up after completion of root canal treatment. Resin composites have shorter setting time, are easier to manipulate, and have adequate mechanical and physical properties. Glass ionomer cements are hydrophilic and have low fracture strength, and sensitivity to moisture. Cast metal core build-up requires multiple settings, prolonged treatment time, and is technique-sensitive. Dental amalgam shows inadequate initial tensile and compressive strengths, long setting time and cannot be used in severe coronal tooth portion damage conditions. Hence, most preferred material for core build-up is composite.[7-11] When composite resin core build-up is done with proper bonding techniques, it provides an indispensable bond in the prosthetic rehabilitation of root canal-treated teeth.[12] Composite restorations aid in better esthetic outcomes. According to studies by Manning KE, Yli DC, Yu HC, Kwan EW, composite resin core build-up materials have hardness and fracture toughness similar to tooth structure and have fracture strength and bond strength higher than amalgam.[12] After understanding the advantages of composite core build-up material over other core build-up materials, a need was felt to find out the most accurate core build-up material among recently introduced various composite core build-up materials and their efficiency in the presence and absence of post. With this in mind, this *in vitro* study was carried out to evaluate and compare the fracture strengths of various types of composite coronal build-up materials along with prefabricated metal post and without post.

MATERIALS AND METHODS

Materials used

Freshly extracted mandibular premolars,10% formalin (Fisher Scientific, Mumbai, India), 5.25% sodium hypochlorite (Dentpro, Mumbai, India), 3% hydrogen peroxide (Bhandari Labs, Ujjain, India), normal saline (Tech tonics, Kamla, Nagpur, Maharashtra, India), epoxy resin sealer cement (MM-Seal, Micro Mega, France), gutta-percha obturating material (Dentsply, Ballaigues, Switzerland), prefabricated metal posts (para post, Coltene and Whaledent, USA), resin luting cement (Relyx Unicem, 3M ESPE, Germany), and composite core build-up materials: (1) Hybrid composite (Z-100, 3M ESPE, Germany), (2) nanocomposite (Z-350, 3M ESPE, Germany), and (3) ormocer (Admira, VOCO, Germany).

Methodology

Selection of Teeth

A total of 60 freshly extracted mandibular premolars free of caries, cracks, or fractures were selected for this study. Hard and soft deposits present on the surface were cleaned using hand scaling instruments. The teeth during study were stored in 10% formalin solution which has fungicidal properties. Radiographs of the selected teeth were made to exclude the possibility of presence of resorption, or obstructions within the root canal system. The selected teeth were measured mesiodistally and buccolingually using calipers. This was done so that the teeth of similar dimensions could be evenly distributed between test groups.

Group I (with post):

- 10 endodontically treated teeth restored with hybrid composite (Z-100, 3M ESPE) resin core along with metallic post.
- 10 endodontically treated teeth restored with nanocomposite (Z-350, 3M ESPE) resin core along with metallic post.
- 10 endodontically treated teeth restored with ormocer (Admira-VOCO) resin core along with metallic post.

Group II (without post):

- 10 endodontically treated teeth restored with hybrid composite (Z-100, 3M ESPE) resin core only.
- 10 endodontically treated teeth restored with nanocomposite (Z-350, 3M ESPE) resin core only.
- 10 endodontically treated teeth restored with ormocer composite (Admira-VOCO) resin core only.

Access openings of the 60 teeth samples were prepared with the help of round diamond point (No. 4 Mani, Japan). No 15 stainless steel K-files (Dentsply, Maillefer, Ballaigues, Switzerland) were used to establish patency of the canal. A barbed broach was used to remove the pulpal tissues. Sodium hypochlorite solution (5.25%) was used as a root canal irrigating agent. The clinical working length was kept 2 mm short of the anatomical canal length. All the specimens were handled using latex gloves and held in moist gauze during instrumentation to prevent from getting dehydrated. Root canal preparation of the teeth was completed with K files from No. 15 to No. 50.

Fig. 1: Samples after decoronation

Fig. 2: Decoronated teeth with core build-up

Frequent recapitulation maintained the patency of canal. The canal was dried for obturation. Epoxy resin sealer cement was mixed as per the manufacturer's guidelines. After coating the canal with sealer, obturation was done with the selected master cone up to full working length. Endodontic spreaders (Dentsply, Maillefer, Ballaigues, Switzerland) were then used to create space for accessory cones. Secondary cones No. #30, #20, and #15 were used for lateral condensation. The obturation of the sample teeth was completed following the same standardized procedure. A hot burnisher was used to seal the orifice with gutta-percha. The samples to be prepared were standardized with respect to tooth dimensions, post and core dimensions, and position in the mounting. All the teeth from groups I and II were cut 2 mm cervical to cementoenamel junction (CEJ) (Fig. 1). The 2 mm tooth structure that remained coronal to the CEJ helped to simulate the ferrule effect, which is instrumental in protecting the tooth from fracture. A shoulder finish line of width 1.5 mm was made around the coronal tooth structure. Gutta-percha was then removed from the root using peeso reamers no. 1 to 5 (Mani, Japan) sequentially. The post space was thus prepared to a uniform dimension of 1.5 mm diameter to a length of 9 mm within the root and 2 mm above the root which equals a total post length of 11 mm. Standardization was achieved using a rubber stopper placed at 11 mm length of the peeso reamer. The canal was irrigated off the debris. This procedure leaves back a minimum of 4 to 5 mm of gutta-percha in the root canal, which is advocated by researchers.[12] The canal was then predrilled for access post. The access post drill was then used to create the actual post space and the final position was checked using the access post as a gauge. The post was then cut to a length of 11 mm with a diamond point so that 2 mm protruded out of the tooth coronally. After the preparation of canal space, resin luting cement was mixed as per standard guidelines and applied to the post space and to post. Posts were seated with uniform pressure and light cured. In group II, the teeth were sectioned as earlier mentioned and gutta-percha removed till 2 mm below the CEJ. A prefabricated core former template was used for the core build-up. The material was dispensed and condensed into the preformed matrix and light cured for 20 seconds per surface. The core former template was then removed from the hardened core. The core was then modified if necessary according to the standardized core dimensions (Fig. 2). A depression of 1 mm diameter was made with a round bur, approximately in the center of the occlusal surface of the core build-up for standardizing the point of load application during fracture strength test. A polyvinyl chloride plastic block was used for mounting the teeth. Autopolymerizing acrylic resin was packed into the block. A single tooth was mounted up to the cervical finish line maintaining its long axis perpendicular to the floor (Fig. 3). Once set, the specimens were ready for testing of fracture strength. The specimens had to be loaded along the long axis of the tooth. Polyvinyl chloride plastic block was milled in such a way that when the specimen block was placed on it, the tip of the plunger contacted the 1 mm depression on the occlusal surface of

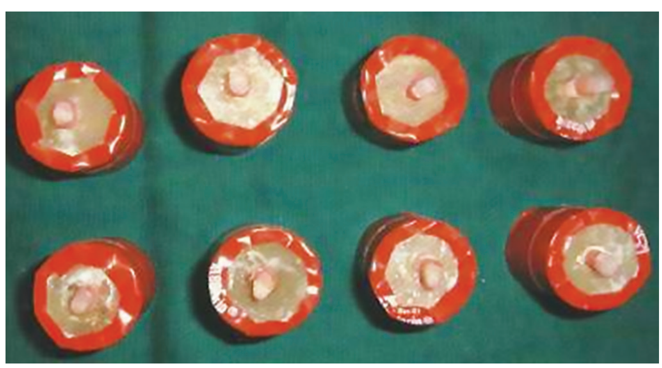

Fig. 3: Samples mounted in rings after core build-up

Fig. 4: Sample testing in load frame

the sample at an angle of 90°. The fixture was attached to the base of the universal load frame (Fig. 4). The loading of the samples was done with a crosshead speed of 01 mm/min till the appearance of visible sign of fracture, or a clear-cut debonding of the post and core. The fracture strength of the samples was directly obtained from the load indicator attached to the universal load frame. The fractured samples were removed out of the acrylic block and evaluated for region of fracture. Statistical analysis of the data obtained was done.

RESULTS

The 60 samples prepared were loaded in the universal load frame at right angle to the tooth. After the appearance of visual sign of fracture, the loading was stopped. The force that the tooth can maintain till the fracture was recorded as the peak fracture. The null hypothesis in this study was that all samples irrespective of the type of restoration they receive have no change in fracture resistance. Statistically speaking, it is inferred that all sample means are equal and there is no difference between them. The alternate hypothesis in case the null hypothesis gets rejected is that the sample means are different and this difference is caused due to the mechanical properties of restorative materials. The ANOVA test was carried out for analyzing the difference between two test groups simultaneously. The ANOVA test revealed that teeth restored with post exhibited highest fracture strengths (1552.32 N) and teeth restored without post exhibited lowest fracture strengths (232.20 N) (Table 1).

Individual groups were compared with each other using the Bonferroni test. The multiple comparison test was carried out to analyze the difference between the fracture strength in pairs.

The test results indicated that values for hybrid composite (Z-100, 3M ESPE) with post, nanocomposite (Z-350, 3M ESPE) with post, ormocer composite (Admira-VOCO) with post, and nanocomposite (Z-350, 3M ESPE) without post were not significantly different from each other. However, ormocer composite (Admira-VOCO) without post showed statistically significant difference compared with hybrid composite (Z-100, 3M ESPE) with post and nanocomposite (Z-350, 3M ESPE) with post.

Hybrid composite (Z-100, 3M ESPE) without post showed a statistically significant difference compared with hybrid composite (Z-100, 3M ESPE) with post (Table 2).

Horizontal, vertical, and oblique fractures were seen in coronal build-up, post, and tooth structure. Post and core separations from teeth were also seen. Some fractures were a combination of above all. The fractures were classified into two types. They are:

1. Restorable or simple fractures: These fractures were in the coronal portion of tooth (Fig. 5).
2. Nonrestorable or complicated fractures: These fractures were in the root portion of tooth (Fig. 6).

Table 1: Analysis of variance test for all groups

	n	*Mean*	*Standard deviation*	*Standard error*	*95% confidence interval for mean*		*Minimum*	*Maximum*
					Lower bound	*Upper bound*		
Hybrid composite core with post (Z-100, 3M ESPE)	10	1149.47920	264.417948	83.616297	960.32599	1338.63241	752.640	1552.320
Hybrid composite core without post (Z-100, 3M ESPE)	10	823.59980	232.089557	94.896650	549.92866	979.27094	232.200	1340.640
Nanocomposite core with post (Z-350, 3M ESPE)	10	1027.75120	218.672552	69.150332	871.32228	1184.18012	682.080	1340.640
Nanocomposite core without post (Z-350, 3M ESPE)	10	925.79620	130.895773	41.392878	832.15900	1019.43340	705.600	1105.440
Ormocer composite core with post (Admira-VOCO)	10	948.38640	196.928657	62.274309	807.51213	1089.26067	686.784	1317.120
Ormocer composite core without post (Admira-VOCO)	10	733.26920	103.097620	32.602330	659.51761	807.02079	554.288	921.984
Total	60	924.88033	250.722317	32.368112	860.11189	989.64878	232.200	1552.320

Table 2: Multiple comparison Bonferroni test for all groups

(I) Group	*(J) Group*	*Mean difference (I–J)*	*Standard error*	*p-value*	*95% confidence interval for mean*	
					Lower bound	*Upper bound*
Hybrid composite core without post (Z-100, 3M ESPE)	Nanocomposite core with post (Z-350, 3M ESPE)	−263.15140	95.626356	0.121	−556.85838	30.55558
	Nanocomposite core without post (Z-350, 3M ESPE)	−161.19640	95.626356	1.0	−454.90338	132.51058
	Hybrid composite core with post (Z-100, 3M ESPE)	−384.87940*	95.626356	0.003	−678.58638	−91.17242
	Ormocer composite core without post (Admira-VOCO)	31.33060	95.626356	1.0	−262.37638	325.03758
	Ormocer composite core with post (Admira-VOCO)	−183.78660	95.626356	0.898	−477.49358	109.92038
Nanocomposite core with post (Z-350, 3M ESPE)	Hybrid composite core without post (Z-100, 3M ESPE)	263.15140	95.626356	0.121	−30.55558	556.85838
	Nanocomposite core without post (Z-350, 3M ESPE)	101.95500	95.626356	1.0	−191.75198	395.66198
	Hybrid composite core with post (Z-100, 3M ESPE)	−121.72800	95.626356	1.0	−415.43498	171.97898
	Ormocer composite core without post (Admira-VOCO)	294.48200*	95.626356	0.049	0.77502	588.18898
	Ormocer composite core with post (Admira-VOCO)	79.36480	95.626356	1.0	−214.34218	373.07178
Nanocomposite core without post (Z-350, 3M ESPE)	Hybrid composite core without post (Z-100, 3M ESPE)	161.19640	95.626356	1.0	−132.51058	454.90338
	Nanocomposite core with post (Z-350, 3M ESPE)	−101.95500	95.626356	1.0	−395.66198	191.75198
	Hybrid composite core with post (Z-100, 3M ESPE)	−223.68300	95.626356	0.346	−517.38998	70.02398
	Ormocer composite core without post (Admira-VOCO)	192.52700	95.626356	0.736	−101.17998	486.23398
	Ormocer composite core with post (Admira-VOCO)	−22.59020	95.626356	1.0	−316.29718	271.11678
Hybrid composite core with post (Z-100, 3M ESPE)	Hybrid composite core without post (Z-100, 3M ESPE)	384.87940*	95.626356	0.003	91.17242	678.58638
	Nanocomposite core with post (Z-350, 3M ESPE)	121.72800	95.626356	1.000	−171.97898	415.43498
	Nanocomposite core without post (Z-350, 3M ESPE)	223.68300	95.626356	0.346	−70.02398	517.38998
	Ormocer composite core without post (Admira-VOCO)	416.21000*	95.626356	0.001	122.50302	709.91698
	Ormocer composite core with post (Admira-VOCO)	201.09280	95.626356	0.602	−92.61418	494.79978
Ormocer composite core without post (Admira-VOCO)	Hybrid composite core without post (Z-100, 3M ESPE)	−31.33060	95.626356	1.000	−325.03758	262.37638
	Nanocomposite core with post (Z-350, 3M ESPE)	−294.48200*	95.626356	0.049	−588.18898	−0.77502
	Nanocomposite core without post (Z-350, 3M ESPE)	−192.52700	95.626356	0.736	−486.23398	101.17998
	Hybrid composite core with post (Z-100, 3M ESPE)	−416.21000*	95.626356	0.001	−709.91698	−122.50302
	Ormocer composite core with post (Admira-VOCO)	−215.11720	95.626356	0.429	−508.82418	78.58978
Ormocer composite core with post (Admira-VOCO)	Hybrid composite core without post (Z-100, 3M ESPE)	183.78660	95.626356	0.898	−109.92038	477.49358
	Nanocomposite core with post (Z-350, 3M ESPE)	−79.36480	95.626356	1.000	−373.07178	214.34218
	Nanocomposite core without post (Z-350, 3M ESPE)	22.59020	95.626356	1.000	−271.11678	316.29718
	Hybrid composite core with post (Z-100, 3M ESPE)	−201.09280	95.626356	0.602	−494.79978	92.61418
	Ormocer composite core with post (Admira-VOCO)	215.11720	95.626356	0.429	−78.58978	508.82418

*The mean difference is significant at the 0.05 level

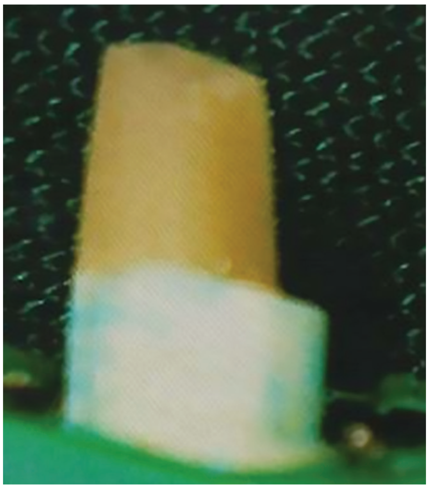

Fig. 5: Sample with salvageable fracture

Fig. 6: Sample with nonsalvageable fracture

DISCUSSION

The long-term success of prosthetically rehabilitated teeth with root canal treatment depends mainly on the adequacy, efficiency, and material aspects with which they have been restored. They may withstand the masticatory load only if they have minimal conservative access opening, no features of break down or fracture, and no resorption. However, scientific literature has advocated that endodontically treated teeth are more susceptible to fracture than vital teeth.[13,14] A post and core build-up is critically needed to provide adequate support, stability, foundation structure, and retention to crown/extra coronal restoration in root canal-treated teeth and also to enhance resistance to fracture of the teeth. However, it should not have any adverse effects on the load-bearing ability of the endodontically treated teeth. Engineering principles indicate that the anatomical and physiological integrity of endodontically treated teeth is dependent on the intrinsic quality and quantity of sound dentinal tissues and the integrity of the anatomic form. In endodontically treated teeth, these factors are compromised and hence, they may not perform to their fullest capacity similar to vital tooth.[15,16] Protection of such a weakened tooth is enhanced by an extra coronal restoration. Many times, the remaining sound dentin may not be adequate enough to support a crown. This is when the coronal tooth portion build-up is indicated since it provides a secure substructure which is critically essential for the long-term success of the prosthetic restoration.[17] The post and core systems available in market have their own advantages and drawbacks. On using post and core build-up for restoration of mutilated endodontically treated tooth, many types of failures have been observed, such as failure of cementation, wedging, perforation, and vertical and horizontal splitting of teeth. Also, the procedure is time consuming and expensive. To overcome all the above problems, many alternative techniques for restoration and reinforcement of endodontically treated teeth have been advocated in the literature.[14,15] Amalgam has been used as a coronal and radicular build-up material successfully.[18] However, it is not very esthetic for anterior teeth. Composite resins have also been used for the fabrication of cores very effectively.[19-21]

In view of the problems in restoring endodontically treated teeth, despite the advances in material science and technology, this *in vitro* study was designed to compare the fracture strength of composite resin core build-up with metal post and without post. In this study, 60 human mandibular premolars were selected. An attempt was made to establish the criteria for exclusion of teeth. This was done by measuring the mean dimensions of root length, external diameter at different levels from the apex, and choosing only those teeth which approximated the mean value in their dimensions. All such selected teeth were endodontically treated.

It is important to include this step to carefully simulate all clinical parameters. Teeth receiving post and core restorations are always root canal-treated which also causes loss of tooth structure to some extent. As this could influence the result, the endodontic treatment was mandatory to obtain reliable results. Obturation was done using gutta-percha with eugenol-free root canal sealer, since eugenol can delay the curing of composite resin. Some researchers have proposed that eugenol inhibits polymerization of composite resin cement.[22] Hence, noneugenol root canal sealer was used in the obturation step. Root canal space was prepared using the peeso reamers and calibrated drills provided with the prefabricated post system. This was done to ensure maximum adaptation of the post to the canal walls, thus maximizing retention and resistance form of the post preparation and limiting the luting agent thickness to just filling any space present between the post and the tooth. It is extremely important that the prosthodontic restoration on endodontically treated teeth should be able to sustain masticatory forces. Fracture strength greatly influences the selection of core build-up materials. Core build-up materials must withstand unfavorable forces due to masticatory movements and parafunction movements. A normal chewing force of 35 to 70 N with a frequency of 1.66 Hz is seen intraorally. The maximum bite force during clenching as measured with intraoral strain gauge gnathodynamometer averages 162 pounds in the range of 55 to 280 pounds (25–121 kg). There appears no correlation of biting force either to age or sex. The weakest biting force of 55 lb occurred in a 20-year-old tall healthy man, wherein, on palpation, his masseter muscles were small, and a maximum biting force of 200 lb was seen in a 17-year-old girl. In group I, teeth restored with posts, all three core materials showed 100% nonsalvageable fractures, but the fractures occurred at a much higher value than normal biting force. In group II, teeth restored with hybrid composite (Z-100, 3M ESPE) showed 30% salvageable fractures and 70% nonsalvageable fractures, nanocomposite (Z-350, 3M ESPE) showed 20% salvageable fractures and 80% nonsalvageable fractures, and teeth with ormocer (Admira-VOCO) material showed 30% salvageable fractures and 70% nonsalvageable fractures.

This indicated that teeth treated with only core build-up and with tooth structure of 2 mm above the CEJ can fracture in a repairable manner. In the current study, crowns were not placed on the coronal build-ups. Thus, the occlusal surfaces of the coronal build-ups were subjected to a compressive load. It has avoided any errors in the result in variations in material structure, shape, length, and thickness. It allows accurate evaluation of structural integrity and fracture resistance of post and core build-ups.[10]

The surface texture and surface energy affect the optimum integrity of different materials. Hence, adhesive resin luting cement was applied to the post prior to cementation and also prior to coronal tooth structure build-up to promote optimum bonding between the post head and the coronal build-up. It also supports the fact that the adhesive luting agent has significant strengthening effect on the post retention.[6]

The results are consistent with the results obtained by Kern et al[23] who concluded from their study that posts do reinforce the core materials under externally applied loading.

CONCLUSION

Within the restrictions of this study, the under-mentioned conclusions were drawn:

- Teeth treated with post and core using hybrid composite yielded the highest values for fracture strength (1149.4792 N).
- Teeth restored with ormocer core without post exhibited the lowest values (733.26920 N).
- Teeth restored with nanocomposite core without post exhibited strength that was comparable with hybrid composite core, but higher than that of ormocer.
- A statistically significant difference was recorded between
  - Hybrid composite core without post and hybrid composite core with post
  - Nanocomposite core with post and ormocer core without post
  - Hybrid composite core with post and ormocer core without post
- Teeth restored with post exhibited high mean fracture strength than without post, i.e., post helped in reinforcing the core materials.
- Significant number of samples restored with post and without post showed nonrestorable factures.
- Teeth restored with the different core materials within groups, i.e., within group I with post and within group II without post, showed no significant result.

CLINICAL SIGNIFICANCE

Mutilated teeth can be restored successfully by using post and core build-up using adhesive composite core build-up materials to meet the functional and esthetic demands. Rehabilitation of endodontically treated mutilated teeth with adhesive resin core along with post enhances the life span of the teeth by improving the fracture strength.

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