ejpmr, 2021,8(6), 455-463

SJIF Impact Factor 6.222

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 2394-3211

EJPMR

"INVITRO EVALUATION OF FRACTURE RESISTANCE OF PREFABRICATED SINGLE AND DOUBLE UNIT POST AND CORE SYSTEMS IN MAXILLARY ANTERIOR TEETH."

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Article Received on 11/04/2021 **Article Revised on 01/05/2021** **Article Accepted on 21/05/2021**

ABSTRACT

The fracture resistance of post-endodontic restorations with prefabricated post depends on their ability to resist masticatory load. The double unit prefabricated post and core system involves, placement of rigid post and, core build-up with less rigid material. Concentration of high stress is observed in transitional area between a rigid and a less rigid material leading to failure. Recently a prefabricated post and core system with a single material is available. The study evaluated the fracture resistance and mode of failures of single and double unit post and core systems. **Methods:** Decoronation of 44 human extracted maxillary central incisors was done at a level 2mm incisal to cementoenamel junction. The samples were instrumented with rotary Pro Taper universal system. Sectional obturations were done and randomly divided into two groups. Group I: Double unit post and core. (D.T. Light-Post X-RO)(BISCO) Group II: Single unit post and core. (Edelweiss Post and Core system). The samples were subjected to constant load under a Universal testing machine. Data were subjected to Independent t test for Statistical analysis. The mode of failures of both post and core systems were evaluated under Stereomicroscope. **Results:** The Mean values of fracture resistance of Group I & II were 420.54 & 289.17 N, respectively. In Group I, 77% of the fractures were favourable. In Group II, 95% of the fractures were favourable. **Conclusion:** Both systems presented sufficient fracture resistance. D.T. Light group showed better performance compared to Edelweiss group. Edelweiss group showed more favourable fractures compared to D.T. Light post group.

KEYWORDS: Edelweiss, Fracture Resistance, Postendodontic restoration, prefabricated post.

INTRODUCTION

The ultimate goal of endodontic treatment is to maintain the tooth as a functional unit. The survival and success of postendodontically treated teeth depend on their ability to resist masticatory load and prevent reinfection. Endodontically treated teeth (ETT) are potentially fragile than vital teeth against masticatory forces and may fracture more easily.[1] So often, the endodontically treated teeth are restored with full veneer crowns.

For many years post and core systems are used as the primary material for the final restoration of ETT that have lost their coronal tooth structure. Posts augment retention and resistance feature for the core material in badly mutilated ETT. Posts have been advocated to strengthen weakened endodontically treated teeth against intraoral forces within the radicular dentin. Frequently, a core is fabricated to retain the final restoration.[2] Posts and cores can be custom-made or prefabricated. Many dentists prefer to use prefabricated post systems because they are more practical, less expensive, and, in some situations, less invasive than customized post and core systems.[3]

The prefabricated post and core system's most popular technique involves selection and placement of post followed by core build-up. Assif and Gorfil reported that when root canal treated teeth restored with posts and cores, stresses were concentrated at the coronal third of the root, especially at the materials' interfaces with different moduli of elasticity.[4] Restoring the teeth using materials with similar elastic modulus to dentin appears advantageous due to the reduced risk of root fracture.[5]

Cohesive failure of the core restoration was also described and was due to the flexure of the post inducing stress on the composite resin core. The establishment of reliable bonds at the root, post, and core interfaces are critical for the clinical success of a post retained restoration. Many investigators have reported that the design and the material of the post and core affect the fracture resistance of endodontically treated teeth restored with post-and-core systems.[3] The formation of a biomechanical functional system (monoblock) allows for a better distribution of stress along the root, minimizing the rate of adhesive and cohesive failure.[6] Hence, there is a need for a prefabricated post and core system with a single material.

The elastic modulus of prefabricated quartz fibre post is closer to dentin than that of any metal post but this post requires a core build up with different material (Double unit post and core) and core is prone for fracture.[7] There is a concentration of high stress with increased forces in the transitional area between a rigid and a less rigid material, especially by lateral force. Due to the stresses induced by flexure of post, the core material can develop cohesive failure. Hence reliable adhesive bonds have to be established between post, core and root dentin. To avoid root fractures, a post with a modulus of elasticity similar to that of dentin is indicated which helps distribute the stress of occlusal load in a uniform pattern.[8,9] The type of failure determines whether the tooth can be repaired or not.

Hence, when restoring a badly broken down endodontically treated tooth, a prefabricated single unit post-core avoiding the interface between the post and the core, with high strength is required.

The Edelweiss post and core system claims that it's prefabricated posts have good biomechanical and physical properties. Edelweiss single unit post and core is a novel single unit composite post and core which can be modified according to the remaining tooth structure's requirement with an actual monoblock effect.[10] The literature available on this system is scanty. Therefore, this study aimed to evaluate the fracture resistance of endodontically treated maxillary central incisors restored with prefabricated single unit post and core system (Edelweiss post and core) and prefabricated double unit post and core system (D.T. Light Post X RO, BISCO).

The null hypothesis tested was that there are no differences in the fracture strength and failure pattern of teeth restored with prefabricated single unit post and core system and prefabricated double unit post and core system.

MATERIALS AND METHOD

The study protocol was approved by the Institutional Review Board and Ethical Committee (IEC Ref No: VDC/IEC/2018/26).

Sample size calculation

Sample size calculation was done using G*Power software. The calculation was based on an effect size of 0.882, an alpha level of 0.05, a desired power of 80% with a degree of freedom of 1 for 2 sample groups. The desired sample size was 44.

Specimen preparation

Forty-four extracted human maxillary central incisors with a single root, single canal, and similar dimensions were selected. Samples were stored in 0.5% Chloramine solution at room temperature for less than two months.

All the specimens decoronated transversally with a double-faced carborundum disc at a level 2mm coronal to the cementoenamel junction. In each tooth, straight-line access to the root canal was made with Endo Access bur (Dentsply, USA) and established patency with 15K file (Mani, Japan). The working length (W.L.) was calculated by the visual method under 2.5X magnification (Dental operating microscope, LABOMED, PrimaDNT, USA) by inserting the 15k file (Mani, Japan) into the canal until it was first visible at apical foramen. The working length was established 1.0 mm short of this length. Did Biomechanical preparation using Nickle -Titanium rotary instruments Pro Taper universal system (DENTSPLY Tulsa Dental Corp) up to ISO size 50, with a rotational speed of 300 rpm and torque of 1.5 N/cm generated by the E-connect S Endomotor (Eighteeth, China).

During canal instrumentation, the canal irrigation between each instrument was done with 2 mL of 3% sodium hypochlorite (NaOCl, Prime Dental, India) using a syringe with a 27-gauge needle (R.C. Twents, Prime Dental, India). All canals were finally rinsed with 1mL of 17% Ethylenediaminetetraacetic acid (EDTA, R.C. help, Prime Dental, India) and followed by a final rinse with distilled water. All the canals were dried with paper points (Prime Dental Products Pvt Ltd). The canals were obturated with gutta-percha cones (Prime Dental Products Pvt Ltd) and sealer (A.H. Plus; DENTSPLY Intl) with a warm vertical compaction technique. The cones were heat seared and compacted, leaving 5mm of apical gutta-percha seal and a 10mm post space with Touch and Heat system (Sybron Endo). Investigator verified the quality of obturation with radiographs. Coronal preparation was standardized with a 1 mm shoulder finish line with flat end tapered diamond bur

(TF-12 DIA- burs, Mani, Japan) and a ferrule of 1.5 mm and the dentinal walls thickness was verified using a digital caliper with 0.01 mm accuracy (Insize Co, Ltd). Samples with less than 1 mm thickness were discarded and replaced.

The teeth were randomly divided into two groups of twenty-two each (n=22)
Group I - Double unit - post (D.T. Light- Post X-RO) (BISCO) and core composite resin.
Group II - Single unit post and core (Edelweiss Post and Core system).

Protocol for Group I
For all the samples in this Group, post space was refined using peesoreamers of sizes 1&2, and post space was enlarged using the corresponding post drill (#0.5) with the slow speed handpiece. Investigator verified the fit of each post in the root canal by radiographs. Acid etching of the post space was done using 37% phosphoric acid (Scotchbond etchant; 3M Dental Products) for 20 seconds. The post space was thoroughly rinsed for 10 seconds and dried with paper points. Two coats of Single bond adhesive (3M ESPE Adper) application was done with a thin brush inside the post space and light-cured for 20 seconds. RelyX Ultimate Adhesive Resin cement (3M ESPE) was mixed for 10 seconds and applied to the canal walls. The post surface was cleaned with alcohol, coated with Single bond adhesive (3M ESPE Adper) and light cured for 10 seconds. Post surface was coated with luting cement and inserted into the canal. Excess cement was removed and was light-polymerized for 40 seconds using a LED curing light (Woodpecker, China) at an intensity of 800 mW/cm^2.

The core was built using Nanohybrid composite resin (Filtek Z350 3M, ESPE, USA) by incremental technique. It was light-polymerized for 40 seconds using a LED curing device (Woodpecker, China) at an intensity of 800 mW/cm^2, according to the manufacturer's instructions. In Group I, teeth preparations were done, maintaining a height of 8 mm from incisal edge to cervical region (Fig.1).

Protocol for Group II
In Group II, after the tooth preparation, the post space preparation was done with a precision dental drill (Edelweiss post drill (size #1) as per the manufacturer's instruction. The post space preparation was done so that the remaining amount of Gutta-percha was 5mm and post length was standardized (10mm in radicular portion). Acid etching of the post space was done using 37% phosphoric acid (Scotchbond etchant; 3M Dental Products) for 20 seconds. The post space was thoroughly rinsed for 10 seconds and dried with paper points. Two coats of Single bond adhesive (3M ESPE Adper) application was done with a thin brush inside the post space and light-cured for 20 seconds. A single coat of Direct Veneer bond (EDELWEISS) was applied to the post and gently dried for 5seconds, and light-cured for 30 seconds outside the sample. The Edelweiss post and core cementation were done using RelyX Ultimate Adhesive Resin cement (3M ESPE). After the cementation of the post and core, preparation of tooth was done as required. In the Edelweiss post and core system, the core build-up is not required (Fig.2).

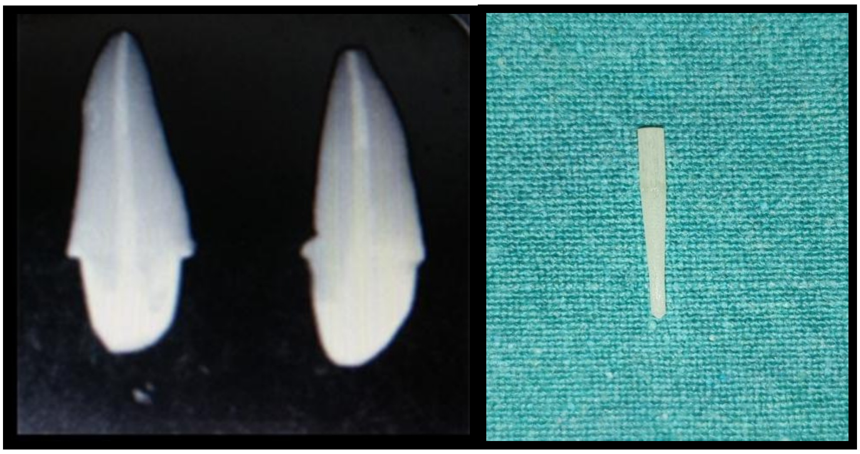

Fig.1 Radiograph of D.T Light treated samples and D.T Light post.

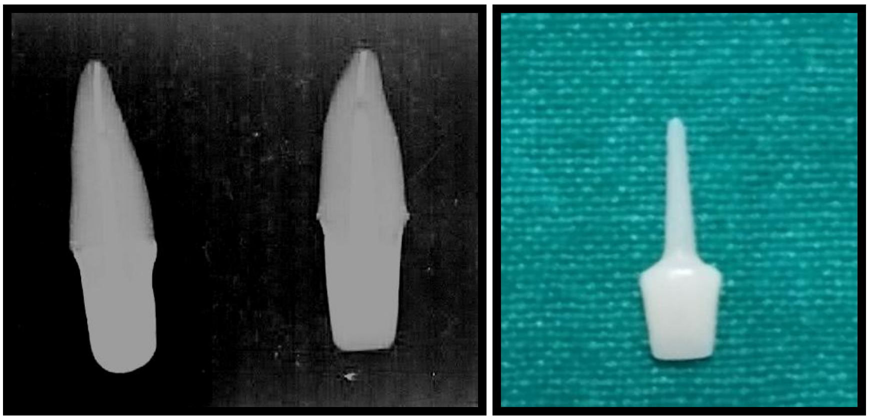

Fig.2: Radiograph of Edelweiss treated samples and Edelweiss post.

Periodontal ligament simulation

All the roots were wrapped with tin foil to a depth of 2 mm apical to the cementoenamel junction (CEJ). Specimen were mounted in self-cure acrylic resin blocks of 3cms in height and 2cms in diameter to a level 1mm apical to CEJ. Each tooth was removed from the resin block when primary signs of polymerization were noticed. The tin foil was then replaced by light body polyvinylsiloxane impression material (Aquasil ultra LV; Dentsply, Germany) that was injected into acrylic resin. The tooth was then reinserted into the resin blocks and excess impression material was removed using a surgical blade.

Thermocycling process

All the samples were thermocycled for 500 cycles from 5 to 55 ^{0}c ± 5^{0}c with a dwelling time of 30 seconds in each bath and a transfer time of five seconds.

Testing of Samples for Fracture Resistance

All the samples were subjected to Universal testing machine (Instron testing machine 8801, U.K.) at a speed of 1mm per minute by placing the acrylic blocks into a prefabricated jig which allows the plunger of universal testing machine to apply the load at an angulation of 45° to the long axis of the tooth on the palatal surface. The first deflection on the "stress-strain chart" records was considered as the fracture value for each sample. The value was noted at which the tooth fractures in Newton.

After evaluation of fracture resistance, fractured samples were evaluated for mode of failure under stereomicroscopic analysis (x20). Data was collected and the results were tabulated for statistical analysis. Fractures were classified as favourable if it was located in the incisal third of the root and catastrophic if located apical to that point including multiple fractures.

Statistical analysis

Statistical analysis was performed using the statistical package for the social sciences (SPSS), version 20.0. After obtaining each sample's values, verified the distribution of data with the Shapiro-wilk test. As the data was following the normal distribution, an independent t-test was performed for the statistical analysis. When the 'p' value was less than 0.05, the statistical test was considered significant.

RESULTS

Upon intergroup comparison using an independent t-test, there was a statistically significant difference between the two groups. The mean fracture resistance value of Group - I that is D.T. Light posts Group (420N), is significantly higher than Group-II that is Edelweiss posts Group (289N) with (p-value =.00) which is less than 0.05 at a 95% confidence interval.(Table 1). Mean fracture resistance values were plotted in chart diagram (Fig. 3).

Table 1: Intergroup Comparison of Fracture Resistance.

GROUPS	Mean(N)	Standard deviation	Standard Error	F value	P value
Group I (n=22)	420.54	116.10	24.75	3.71	.00
Group II (n=22)	289.17	69.08	14.72		

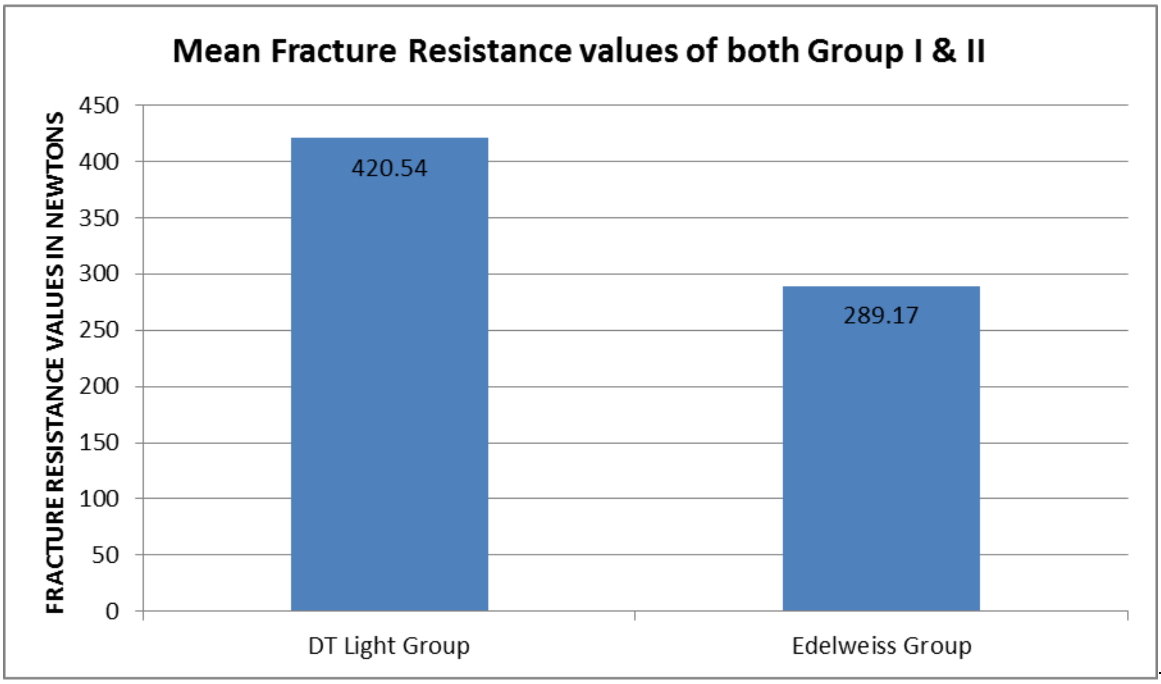

Figure 3: Chart Diagram representing Mean fracture resistance values.

Mode of failure

Investigator evaluated the mode of failures of both post and core systems under Stereomicroscope at 20x. In Group I, 77% of the fractures were favourable fractures, of which 54% were core fractures, and 23% were post fractures. In Group II, 95% of the fractures were favourable fractures, and 05% were catastrophic fractures. (Table 2)

Table 2: Mode of failure.

Type of fracture	D.T. Light group		Edelweiss group	
Favourable fractures	77%	54% core fracture	95%	All are fractured at the level of post
		23% Post fracture		
Catastrophic fractures	23%		05%	

DISCUSSION

In the present study, 44 maxillary human central incisors were taken. Due to their vulnerable position in the dental arch, the maxillary central incisors are the most sensitive teeth to trauma and fractures.[11] Use of extracted teeth as specimen reproduces conditions close to the clinical situation.[8] The samples were stored moist in distilled water throughout the study. It is the preferred method of storage[12] with the least negative influence on the measured bond strength of resin composite to dentin, as suggested by Titley KC et al.[13]

For all the samples in this study, the length of the post maintained in the root canal was 10mm as it has been suggested that one of the criteria for selecting the length of the post would be 2/3rd length of root for optimal retention.[14] The length of the post influences stress distribution in the root and thereby affects its resistance to fracture.

All posts in the study were cemented with dual-cure resin cement. Dual-cure resin cements are expected to have the favourable properties of both photocuring (sufficient time and control for proper seating of the post into the canal) and auto curing (polymerization without the influence of post space depth) systems.[15] Core build-up for all the samples in Group I was done using a nanohybrid composite resin material. Group II's core build-up is not required as post and core is a single unit material that produces a true monoblock effect. Monoblock components behave as one unit under functional forces, with better distribution of stress and enhanced fracture resistance.[16]

All the samples in this study were thermocycled for 500 cycles from 5 to 55^{0} c with a dwelling time of 30 seconds in each bath and a transfer time of five seconds. The ISO TR 11450 standard (1994) reports that 500 thermocycles in water (5°C and 55°C) are an appropriate method to test the thermal stability of dental material.[17]

In the present study, the fracture resistance was tested using the universal testing machine. It is considered the most commonly used laboratory testing to evaluate several characteristics of dental restorative materials such as compressive, flexure, tensile, and shear strength under static loading.[18,19] Various studies have also mentioned the point of applying load as one of the major factors to achieve dependable lab results. In this study, the loading force was applied palatally at an angle of 45° to the tooth's long axis to mimic the clinical class I occlusion in the anterior region.[20]

In a study, the mean maximum anterior tooth occlusal force was 200 to 228N.[21] Another study reported a mean maximum incisor occlusal force of 93 to 150N.[22] Based on these findings, 180 to 200N of fracture resistance can be considered a safe evaluation threshold.

D.T. group showed a mean fracture resistance value of 420 N in this study. D.T. light posts are constructed from unidirectional, pretensed, quartz fibers (60%) bound in an epoxy resin matrix. D.T. light posts contain crystalline quartz fibers, which are more rigid and a greater volume of fibers in its composition.[21] D.T. light posts are presilanated[22] and if the fibres are presilanated a good interfacial bonding formed between fibres, and resin matrix can ensure load transfer, which helps in reinforcement.[23] During the manufacturing process the fibres are pre- stressed in tension ,soaked in resin and polymerized. When the resin is finally cured the tension in the fibres will be released and, the resultant resin surface will be under compression. The SEM images of posts demonstrated no voids on external surface as well as in cross & longitudinal sections. Hence the tensile stresses can be easily absorbed.[24] D.T. light posts are light-transmitting posts in which light could participate in resin cement polymerization in the apical third like the coronal third. This may be explained by the unidirectional longitudinal orientation of the reinforcing quartz fibers that could facilitate the transmission of light up to the tip of the post.[25]

Akkayan et al. evaluated fracture resistance of endodontically treated teeth restored with four different prefabricated post systems (titanium, quartz fiber, glass fiber, and zirconia), with composite core and metal crown. D.T. Light posts were less prone to fracture than teeth restored with any other three post systems.[1]

In this study, the Edelweiss group showed a mean fracture resistance value of 289N. It is an unique, single-piece, high-strength customizable composite POST & CORE system. The Edelweiss POST & CORE composition is barium glass, strontium, and zinc oxide (antibacterial) embedded in resin. The crystals are sintered to a monoblock which leads to perfect mechanics within the material.

The Edelweiss post & core system is a laser sintered monoblock designed to avoid the wedging effect. The posts have a conical shape for perfect post space adaptation. The post's translucency allows uninterrupted light transmission for complete polymerization, even at the most apical portion of the post.

Maryam Rezaei et al. evaluated fracture resistance of upper central incisors restored with cast posts, fiber-reinforced composite post with composite core, and composite post and core. Fiber-reinforced posts proved to be the most clinically suitable restoration concerning esthetic and restorable fracture patterns. Composite posts exhibited the lowest fracture resistance for the reconstruction of upper central incisors with extensive structure loss.[1] As the Edelweiss post and core are made of composite resin, the result of lower fracture resistance may be in accordance with this study.

The D.T. Light posts with fibres have the flexural strength of 655-838 Mpa whereas Edelweiss posts without fibres has flexural strength of 200 Mpa according to the manufacture's information. This might be attributed to the lower results with Edelweiss posts.

The bite force results from the action of jaw elevator/masticatory muscles modified by the craniomandibular biomechanics. Invivo bite force is recorded by one or two transducers placed in occlusion during clenching. The use of pressure-sensitive sheets, strain gauges, thin force, and sensing resistors has been reported in the literature to measure bite force. The maximum bite force is in the molar region, which varies between 300-600N in healthy adults in natural dentition. In the anterior region, the measured force is 120-240N.[26]

In the present study, the average fracture resistance of both groups are above 120-240N values. In most of the static loading studies, evaluation was a load to fracture. When load values exceed the maximum biting force observed clinically, it may be misleading when the material with the highest load to fracture is judged best. So the translation of the results of invitro tests to the clinical performance should be done with caution. Hence the relevance of the invitro tests to predict the clinical performance can be validated by prospective control clinical trials.

Mode of failure is important from the clinical point of view as it determines whether the tooth can be re-restored and continue function. In the present study, the failed samples were analyzed using a Stereomicroscope at 20X magnification. On comparing modes of fractures, 95% of Edelweiss group samples showed favourable fractures, and 5% showed catastrophic fractures. In the D.T. Light group, 77% of the samples showed favourable fractures, and 23% showed catastrophic fractures. These failures were probably due to the dichotomous structure of prefabricated post restorations. The concentrated stress at the interface between post and core can lead to such failures.[3]

A fascinating finding was seen upon evaluation of fractures. Though, the fracture resistance of the D.T. Light post was significantly higher, most catastrophic fractures (23%) were observed in this Group (Fig. 4). (77%) showed favourable fractures, out of which 54% demonstrated core fractures and 23% presented post and core fractures. Failure mode revealed lower fracture resistance of the core, and remaining fractures were visible at the interface between post and core.

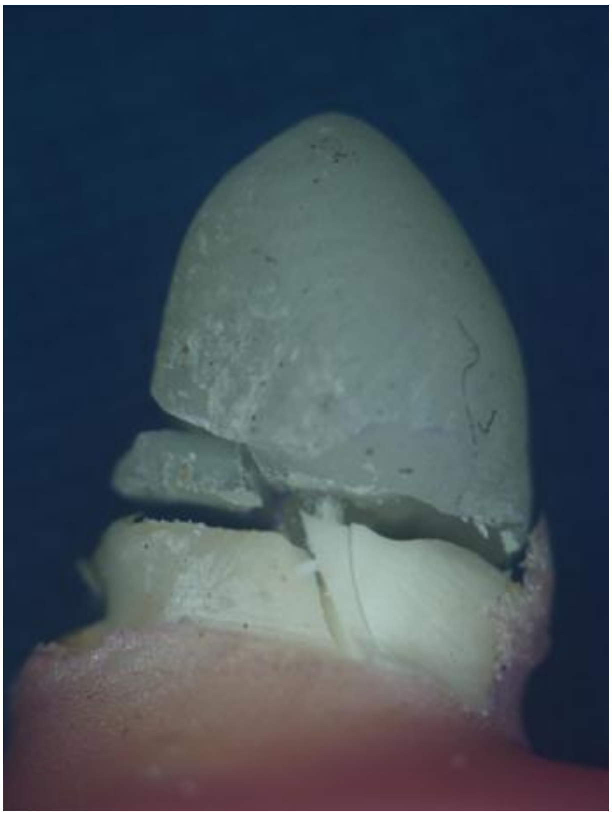

Figure 4: Catastrophic fracture of Double unit post and core sample.

This factor leads to the opinion that though the post is strong, the failure occurred because of the core's inferior properties. This observation is as per studies that reported the discrepancies between mechanical properties of the post and core materials are the reason for failure.[5]

The catastrophic failures involved multiple fractures making them unfavourable to re-restore.

A systematic review on clinical performance and failure modes of pulpless teeth restored with posts has reported a study with similar results. Upon 84 months of follow-up, survival rate for the glass fibre posts was 90.2%. Various fracture modes were observed. A cervical root fracture on a premolar, a catastrophic fracture involving middle root fracture on an incisor, as well as one canine with increased mobility and one core fracture on a premolar.[27]

Whereas in the Edelweiss post and core group, 95% of fractures were favourable (Fig. 5), and all were at the post level. Only 5% were unfavourable fractures. The fractured specimens revealed clean and apparent post fracture with a single fracture plane like chisel fracture, and all are re-restorable. However, the point to be noted, that fractures in both groups happened above the normal masticatory force.

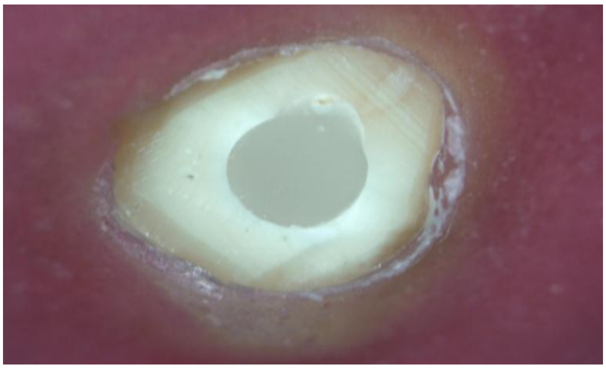

Figure 5: Favourable fracture of Single unit post and core sample.

The null hypothesis was rejected as there are differences in the fracture strength and failure pattern of teeth restored with prefabricated single unit post and core system and prefabricated double unit post and core system.

Some of the limitations observed in this study are the load applied is static type of loading and unidirectional, unlike the natural forces acting on the teeth, which are dynamic. The amount of force and direction of force also changes in centric and non-centric positions. Oral dynamics can be included for future research. In order to acknowledge the results obtained with the present study, this should be followed by long term clinical studies to assure the performance of the material under normal clinical conditions.

The concept of single unit post & core is appreciable. There is a scope for improvement of mechanical properties of the system.

CONCLUSION

Within the limitations of the present study it was concluded that fracture resistance of D.T. Light group that is double unit post and the core system is higher than that of Edelweiss group that is single unit post and core system. The single unit post and core system showed more favourable fractures when compared to the double unit post and core system. Fracture resistance values of both the groups are more significant than that of average maximum biting force in the Incisor region.

Clinical significance: Optimum fracture resistance with more than the clinical loading force with favourable fracture is desirable in clinical situation. Use of Edelweiss post and core in clinical scenarios will reduce clinicians' chair-side time as there is no need for core build-up with composite resin.

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