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Evaluation of Fracture Strength of Three Post Core Systems Using Fracture Strength Test

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Abstract

The prosthetic treatment of severely damaged endodontically treated teeth often requires an endodontic post as additional retention element for core build-up prior to crown restoration. Objectives: To evaluate and compare the fracture strength of three different post and core systems - Prefabricated Glass fibre, Carbon fibre and Chair side fabricated fibre reinforced composite post in the endodontically treated mandibular premolars. Methodology: 30 Thirty mandibular premolars extracted for orthodontic reasons were selected for the fracture strength estimation. The teeth were decornoated to a level 2mm above the CEJ, treated endodotically using crown down method and obturated using single cone method. Leaving 5mm of apical gutta-percha seal intact, the 3 different post systems (two pre-fabricated and one chair-side fabricated) were cemented according to the manufacturer's instructions. The core build-up was done with custom made polyvinyl core forms. The specimens mounted in aluminium moulds were tested for fracture resistance. Results: The range of fracture strength values for glass fibre post were 726-1093N whereas Carbon fibre post ranged from 512-787N and Chair-side fabricated. Fibre reinforced composite post ranged from 425-767 N. On comparison of average peak load for fracture strength and standard deviation value of Group A, B, C; A (856+104 N) had showed significantly higher fracture strength values than the Group B (671+90 N) and group C (677+106 N) post systems. Considering the constraints of an in vitro study, Glass fibre post was expected to resist the more occlusal load to the other post systems. Conclusions: Within the limits of the present study the fracture strength test revealed that GFP showed higher fracture resistance followed by CFP and then CF-FRC. On comparison of failure modes, CFP showed two instances of unfavourable failure mode like root fracture and GFP

showed one, whereas CF-FRC (Everstick) did not show any instance of root fracture.

Keywords: Fibre reinforced composite posts, fracture strength.

Introduction

The post-endodontic restoration has become a great challenge due to increased emphasis on the maintenance and preservation of natural dentition combined with the predictability and effectiveness of the endodontic therapy. Esthetic, functional and structural rehabilitation of a severely damaged endodontically treated tooth is critically important to ensure a successful restorative outcome. Post and core restoration has been reported as the best alternative treatment option in such clinical conditions. A post provides not only intracanal retention of the core and crown restoration but also distributes loads over a larger area of the remaining root structure to achieve a biomechanically favourable stress distribution in endodontically treated teeth [1].

Since the introduction of wooden dowels by Fauchard (1700s) [2] many versions of dowels have been introduced. Generally two types of post and core systems are available; the cast post & core and prefabricated post systems. As the cast post and core restoration exhibited excellent material stability and rendered good clinical long term results, they were considered as the gold standard for the rehabilitation of endodontically treated teeth. However, it had been reported that they have inordinately high failure rate in the form of catastrophic vertical root fractures. Besides these, cast post and core has objectionable esthetics, requires removal of additional tooth structure, involves additional lab work and cost, is technique sensitive, may cause allergic hypersensitivity and is difficult to retrieve [3].

Prefabricated posts, on the other hand, gained popularity because of their easy handling, less preparatory work and low cost [4]. Prefabricated posts can be classified based on structural composition as metallic (Gold, Stainless Steel. Titanium, Brass), ceramic and fibre reinforced resin (Carbon, Graphite, Glass, Quartz) posts. Based on the design they are classified as tapered/parallel, smooth/serrated, active/passive posts [5].

Metallic (prefabricated or custom made) posts have much higher modulus of elasticity than dentin. This mismatch in the moduli could result in maximum stress concentration leading to its failure and unrestorable tooth fractures [6]. To circumvent these problems with metallic posts, a variety of prefabricated non-metallic posts / fibre reinforced composite (FRC) posts were developed. FRC posts contain a high volume percentage of continuous reinforcing fibres in epoxy polymers (with a high degree of conversion and a highly cross linked structure).

FRC posts have many advantages of being highly esthetic, less incidence of post or root fractures and better retention as these are actually bonded to the tooth structure rather than cemented. In addition, these posts are biocompatible, ready to use, easy to place and retrieve (when endodontic retreatment is required) and saves the productive chair side time [3]. Multitudinous biomechanical advantages such as good fatigue strength, potential to reinforce a compromised root, modulus of elasticity closer to dentin leading to uniform stress distribution, property to yield prior to root fracture [7], resistance to corrosion [8] and reduced incidence of non-retrievable root fractures made these posts a material of choice [9].

Durett et al (1988) first developed Composipost™ [10] made of carbon/graphite fibres embedded in epoxy resin. However, they are black in colour and lack cosmetic qualities. In 1992, esthetic (white or translucent) fibre posts (glass or quartz) were introduced without compromising the modulus of elasticity and biocompatibility. Glass fibre posts can be made of electrical (E-glass), S-glass (high strength glass) and quartz fibres (pure silica) [10]. Everstick, a new post system containing unidirectional silanized E-glass fibres (60Vol %) in light polymerizable dimethacrylate - polymethylmethacrylate (PMMA) matrix has been developed. PMMA chains plasticize the cross linked BISGMA matrix of the everStick ™ FRC and reduces stress formation in the fibre matrix interface during deflection which was assumed to contribute to the higher flexural strength. “Pliability” is the prime beneficial property which enables easy adaptability in eccentricities of the canal morphology [11].

Clinical longevity of the post and core restoration can be considered as a cumulative function of the thickness of the remaining dentin, the magnitude and direction of the load; the design and fit of the post and the quality of the cement layer [12]. It has been reported that the fracture resistance of the tooth is directly related to the amount of the remaining coronal tooth structure [13]. An ideal post system should exhibit fracture resistance higher than the average masticatory forces [9].

The present study was undertaken to evaluate and compare fracture resistance among the three fibre reinforced composite posts Viz. Prefabricated Carbon (Fibreopost ™), Glass (Relyx ™) fibre posts and Chair side fabricated Glass fibre (Everstick ™) posts.

Materials and Methods

The purpose of this study was to evaluate the fracture strength of prefabricated glass fibre, prefabricated carbon fibre and chair side fabricated Fibre reinforced composites post systems. (Photograph 1, 2, 3).

Human mandibular premolars extracted for orthodontic reasons were collected and stored in normal saline until the commencement of the specimen preparation. Thirty human mandibular premolars extracted for orthodontic reasons were selected which had single straight canal, no detectable caries, no signs of fracture or craze lines, a root length of atleast 14 ± 0.5 mm and [14] almost similar bucco-lingual dimensions. Teeth with more than one or curved or bifurcated canals, immature root apices, fracture or craze lines, thin curved roots and anomalies and hypoplastic defects were excluded.

The specimens selected were decoronated (Photographs 4,5). The teeth were root canal treated and post space was created. The prepared teeth were categorized into 3 groups randomly - Group A: Relyx-Unicore™ (Prefabricated Glass fibre post, 3MEPE), Group B: Refropost™ (Prefabricated Carbon fibre post, Angelus) and Group C: Everstick™ (Chair side fabricated Fibre reinforced composite post). Each EverStick post was pre-cut to the desired length, trial fitted into the root canal, shaped and initially light cured for 20 seconds. The posts were then removed from their respective canals with tweezers and again thoroughly light cured on all sides for 40 seconds. The posts were coated with a layer of dual cure resin cement which was light cured immediately before cementation for 10 seconds. The prepared post space was etched with 37% phosphoric acid. The dual cure resin cement was mixed on a mixing pad after dispensing equal amounts of Calibra light shade base and regular viscosity catalyst paste for 20-30 seconds. This mix was spread on the post surface and introduced into the canal space with a lentulo spiral. The post was seated immediately and pre-cured for 10 seconds which led to gelling of excess cement at the margin facilitating easy clean up. The inserted post was stabilized throughout the self- cure set time of 6 minutes by applying moderate and consistent pressure on the post (Photographs 14A, 14B, 14C, 14D and 15). The core was build upto 5 mm using polyvinyl sheets 0.5mm using thermoforming machine (EASY-VAC, 3A Medes). A thin layer of composite was applied to the exposed post and decornated flat surface and light cured for 40 seconds. Onto this, the clear custom made core forms (Photograph 6) loaded with composite were seated and light cured for 40 seconds. Later the polyvinyl core forms were cut and ripped off [15]. The specimens were then mounted in an aluminum mold filled with acrylic resin.

Fracture tests were conducted using Zwick universal loading machine (Photograph 7). Each specimen was inserted into the holding device and a controlled load was applied using stainless steel tip with a tip-diameter of 2mm, in a direction parallel to the long axis of the tooth at a cross head speed of 1mm/min (Photograph 8). Load was applied on the buccal surface as to simulate an occlusal load [16]. All specimens were loaded until fracture and maximum fracture loads were recorded in Newtons. The failure threshold was defined as the maximum load a sample could withstand.

Failure loads, modes of failure (Photograph 9) were recorded and were statistically analyzed. Individual groups were compared using unpaired t-test. The significance of the difference between all the three groups was analyzed using One Way ANOVA, Post-Hoc and Un-paired t-test.

Results

In this study, prefabricated glass fibre, carbon fibre, and chair side fabricated fibre reinforced composite posts (Group A, Group B, Group C) were selected to evaluate the Fracture strength and Intracanal stress distribution using Universal testing machine. Thirty endodontically treated teeth were prepared with similar dimensions and tested for fracture strength on universal testing machine at cross head speed of 1mm/min. The recorded data was tabulated and statistically analyzed using one way ANOVA test, post hoc test and un-paired t-test.

The failure loads recorded in Group A (GFP), Group B (CFP) and Group C (FRC) were shown in Tables 4, 5, 6, Graphs 1, 2, 3 respectively. Failure loads of Group A (Glass fibre) post ranged from 1093N- 726N, Group B (Carbon fibre) ranged from 787N-512N and Group C (Fibre reinforced composite post) ranged from 767 N–425N.

The mean failure loads and SD for the three groups were as follows: Group A - 856±104 N, Group B- 671±90 N and C - 677±106 N (Table 1).

The mean difference of failure loads between the three groups was compared using One-way ANOVA Post-Hoc and Unpaired t-test. According to Post-Hoc test, the mean difference between Group A and B, and Group A and C was found to be statistically significant ($p < 0.05$). No statistical significant difference was found between Group B and C ($P > .05$). (Table 2)

Similarly, Un-paired t-test also showed statistically significant difference between Group A & B ($t=4.49$) and Group A & C ($t=3.91$) ($p<0.05$), but no significant difference was found between Group B and C ($t=0.14$, $p>.05$) (Table3).

The failure modes, favorable (core fracture, post fracture, post displacement) and unfavorable (any root fracture) of the three groups were shown in Table 7. In the present study, the highest incidence of favorable failure modes (90%) was observed in all the three groups, the majority being core fractures, 9 in Group C, 8 each in Groups A & B. Post displacement was observed in 2 samples each in Groups A & C. None of the groups experienced post fracture. Unfavorable failure mode, root fracture (10%) was observed in 1 sample in Group A and 2 in Group B.

Discussion

The dental literature is replete with the techniques for restorations in endodontically treated teeth. Generally, an endodontically treated tooth undergoes coronal and radicular loss due to prior pathology, chemo mechanical preparation and restorative procedures, attracts special attention in aesthetic and functional rehabilitation [17]. The increased fracture susceptibility of endodontically treated teeth had attributed to the increased brittleness of dentin due to loss of moisture [18]. The severe loss of crown structure is a key reason for the increase in fracture predilection of endodontically treated teeth, due to the maximum concentration of stresses at the cervical region of the tooth and a special emphasis was laid on the importance of conserving the bulk of dentin to maintain the structural integrity of endodontically treated teeth.

Restoring these mutilated with the "post systems" strengthens and reinforces the damaged tooth, reduces stresses in the cervical area, and facilitates the distribution of stresses over a wide area and on to the radicular dentin. Multifarious post systems exist for the restoration of endodontically treated teeth that have inadequate tooth structure to support the final restoration. The classification of posts mentioned in the literature are metallic and non-metallic, prefabricated and custom made, tapered and parallel, treaded and non-threaded, active and passive etc [5].

The cast metallic posts have been reported as successful in reinforcing the remaining tooth structure albeit, its disparity in the biomechanical properties with the root dentin (had to transfer excessive stresses) resulting catastrophic root fractures. Motivated by the disadvantages of the metal post systems, Duret et al (1988) [10] introduced carbon fibre reinforced composite posts and emphasized the necessity of the posts having biomechanical properties similar to that of dentin [6].

Few alluring advantages with the use of prefabricated posts include reduced chair side time, relatively simple procedure, ease in placement and retrieval (when endodontic retreatment is required) etc [3, 7-9]. The prefabricated tapered post has an edge over the other designs in that they follow outline of the prepared canal and conserve the tooth structure [3]. In the present study, Relyx 3M ESPE (prefabricated tapered Glass fibre reinforced post), Refropost Angulus (prefabricated tapered Carbon fibre reinforced post) and Everstick™ (Chair side fabricated fibre reinforced composite post) were considered.

The present in-vitro study was planned to be done on human extracted premolars because they are subjected to more lateral forces during mastication when compared to incisors and molars [19].

Though the clinical longevity is dependent on a multitude of factors, the material properties of the post which influences the success of the restoration are fracture strength, modulus of elasticity and mode of transfer of occlusal stresses (stress distribution) onto the supporting structures. Fracture strength is the stress at the beginning of fracture and the original cross section area of the specimen. As the cross section of the specimen is standardized, the load at the beginning of the fracture directly correlates the fracture strength of the material [3].

The specimen preparation for the fracture strength test involved decoronation of the selected premolars at 2mm above the CEJ to mimic the clinical situation of severe tooth structure loss. As the fracture strength is dependent on the post and core dimensions, teeth of uniform length of 14±0.5mm were selected [14]. Ni-Ti rotary instruments were used for biomechanical preparation in a crown down technique as it allows uniformity in cleaning & shaping the canals, conservation of tooth structure provides three dimensional obturation of the root canals (without the use of accessory cones)[57,58]. Single cone obturation method was adopted as it provides better apical seal when compared to laterally compacted technique. AH plus root canal sealer, an epoxy bis-phenol resin based (sealer) was chosen, keeping the advantages into consideration like long term dimensional stability, less micro leakage in addition to its radio opacity, anti-bacterial property and biocompatibility [20].

The effects on the post length & diameter on the final performance have been studied in numerous works [21-29]. Post length has significant effect on retention [30] and stress distribution [31, 32]. Short wide posts lead to elevated stress concentration in the cervical regions. Post placement beyond 2/3rd root length does not decrease cervical stress but increases stress in apical region [33]. According to Leary [34] the posts with a length of atleast 3 quarters of the root length, offered the greatest rigidity & least root deflection. Short posts are especially dangerous & have a much higher failure rate [4, 35, 36]. As greater post diameter entails eliminating a greater amount of dentin [37-39], many works recommend limits for the diameter [37, 40, 41]. Goodacre [40] suggested that post diameter should not exceed 1/3rd of the root diameter at any location. A standardized post length of 13mm with a diameter of 1.5 mm was selected in order to eliminate the subjective errors in the assessment of fracture strength.

During post space preparation, various methods have been advocated for the removal of gutta percha [42]. In the present study, rotary method of gutta percha removal was done using a commercially available post drill, as this method is faster and facilitates uniform standardized post space preparation for all the specimens.

A minimum of 5mm of gutta percha was left intact for the apical seal at the end of post space preparation. Investigators have demonstrated that maximum retention of post and clinical success is achieved when the post is as long as possible while still retaining a positive apical seal of 5mm of gutta-percha. [43-47]

In this study, Calibra dual cure resin cement (Calibra-Dentsply) was used for cementation for the post because of limited light penetration into the root even in case of translucent post, better handling properties, low film thickness, fluoride release and high strength. The applicator bristle brushes supplied by the respective manufacturers for adhesive application were used; thus limiting solvent volatilization as this could interfere with the polymerization process [33]. According to Leary, it is important to avoid adhesive accumulation in the apical third of the root canal because the restricted access to this area can create additional difficulty for the light activation process; thus making this region predisposed to post displacement prior to complete cement setting [33].

In the present study, the core build up was done using CERAM X-Duo, a nano-ceramic composite restorative material, which has the advantages like high fracture toughness, excellent handling properties and better surface finish. Core build-up materials are used to reconstruct endodontically treated or fractured teeth and these materials must show sufficient strength to resist stresses that may be generated during function including those resulting from stress concentrating elements in prefabricated dowels. Composite resin has a long history of use as a core material due to its ease of manipulation. It is available in light-cured, auto-polymerized, and dual-cured formulations, and it comes in tooth colors and contrast colors for posterior use. A major advantage of composite is its ability to be bonded to tooth structure and then to serve as a substrate to which a ceramic crown can be bonded. Laboratory studies have confirmed adequate fracture toughness and compressive strength in a static load test. Fracture strength values depend on the core material used [48].

In the present study, custom made clear core forms were prepared as a template for core build up which were prepared taking into consideration the determined core dimensions. The layering technique of core restoration was undertaken so as to improve fracture resistance by approximately 30% over the bulk technique. This decreased fracture rate may be a result of improved condensation of the individual layers or a better adaptation of the core material on dentin & post[82]. After the completion of the core build-up, all the specimens were mounted in aluminium moulds using self-curing acrylic to a level 2mm below the CEJ to mimic the natural relation between the bone level and CEJ. Marcelo JRR (2009) [39] used "Build-up caps" for premolars in order to standardize core dimensions. The embedded teeth were subjected to compressive fracture tests using Zwick universal testing machine.

Several in vitro studies have determined the resistance to fracture of post-core restored teeth under static loads and have found lower [49, 50], the same [51, 52], or higher [53] strength for teeth restored with fibre posts compared with teeth restored with metal posts. The present in vitro study made an attempt to compare the fracture strength and mode of failure in single rooted endodontically treated mandibular premolar teeth restored with three posts- prefabricated glass fibre, carbon fibre and chair-side fabricated fibre reinforced post.

The fracture strength of teeth restored with Relyx Unicore™ (glass fibre) post was higher than Refropost™ (CFP) and everStick ™ (CF-FRC). Similarly higher fracture loads were measured experimentally for teeth restored using glass fibre posts, as observed in previous works [54, 55]. EverStick posts recorded the second best fracture resistance values (677.1 ± 100.8 N), which is less than the glass fibre posts tested. This could be attributed to the IPN structure of the post that results in an inter diffusion bonding phenomenon, enabling the stick resin to penetrate the post, as well as establish a strong bond to the dentin via the resin cement [56].Whereas, Carbon fibre posts recorded the lowest mean fracture resistance value (671.2 ± 85.2 N), but still within the range recorded by other glass fibre posts [57]. The high cross-link density of the matrix in a prefabricated FRC post makes it difficult to bond the post to composite resin luting cements [58].

Loading was applied directly on to the core, as no crown was used in accordance with previous studies, for simplification purposes and to exaggerate the load effect on the tooth. However, this might have affected the stress distribution within the tooth and the magnitude of fracture and fracture modes of the specimens [59]. In the present study, 90% of the sample had favorable (core fractures, post displacement) and 10% had unfavorable (root fractures) modes. However, it is not clear whether fibre reinforced posts can actually provide adequate support for a core. Flexure of a fibre reinforced posts may result in greater stress on the composite resin core, causing premature failure of the core restoration [12, 60-63]. In the present study, 10% of the samples showed post displacement failure mode, this could be due to the interfacial bond strength between the post, cement and dentin which were in accordance with the results given by Fernanda and co-workers [30]. None of the samples in group C (CF-FRC) showed post fractures, post displacement & root fractures. Even though the fracture resistance of CF-FRC posts was inferior to GFP, they performed superiorly when fracture mode was taken as a parameter.

Conclusion

Within the limits of the present study the fracture strength test revealed that GFP showed higher fracture resistance followed by CFP and then CF-FRC. On comparison of failure modes, CFP showed two instances of unfavorable failure mode like root fracture and GFP showed one, whereas CF-FRC (Everstick) did not show any instance of root fracture.

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Legends Figure and Tables

Table 1: Comparison of mean fracture resistance value and range of standard deviation in Group A (Glass fiber), Group B (Carbon fiber) and Group C (FRC Post).

Group	Min value	Max value	Average	Std.	Var.
Group A	726.9	1093.6	856.5	98.7	11.52
Group B	512.5	787.6	671.2	85.2	12.69
Group C	425.3	767.0	677.1	100.8	14.89

Table 2: Comparison of fracture resistance value between three post materials by one way ANOVA test.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	221267.731	2	110633.865	10.981	.000
Within Groups	272029.488	27	10075.166		
Total	493297.219	29			

Table 3: Peak load of fracture in Chair side fabricated Fiber reinforced composite post system (Group C)

Specimens	Area Direct Sq.mm	Peak load Newton
C1	8mm	767.0
C2	8mm	705.6
C3	8mm	570.1
C4	8mm	760.2
C5	8mm	727.1
C6	8mm	711.4
C7	8mm	657.5
C8	8mm	686.9
C9	8mm	760.2
C10	8mm	425.3

Figure 1: Rely X Glass Fiber reinforced Post (GFP)

Figure 2: Reforpost Carbon Fiber reinforced Post (CFP)

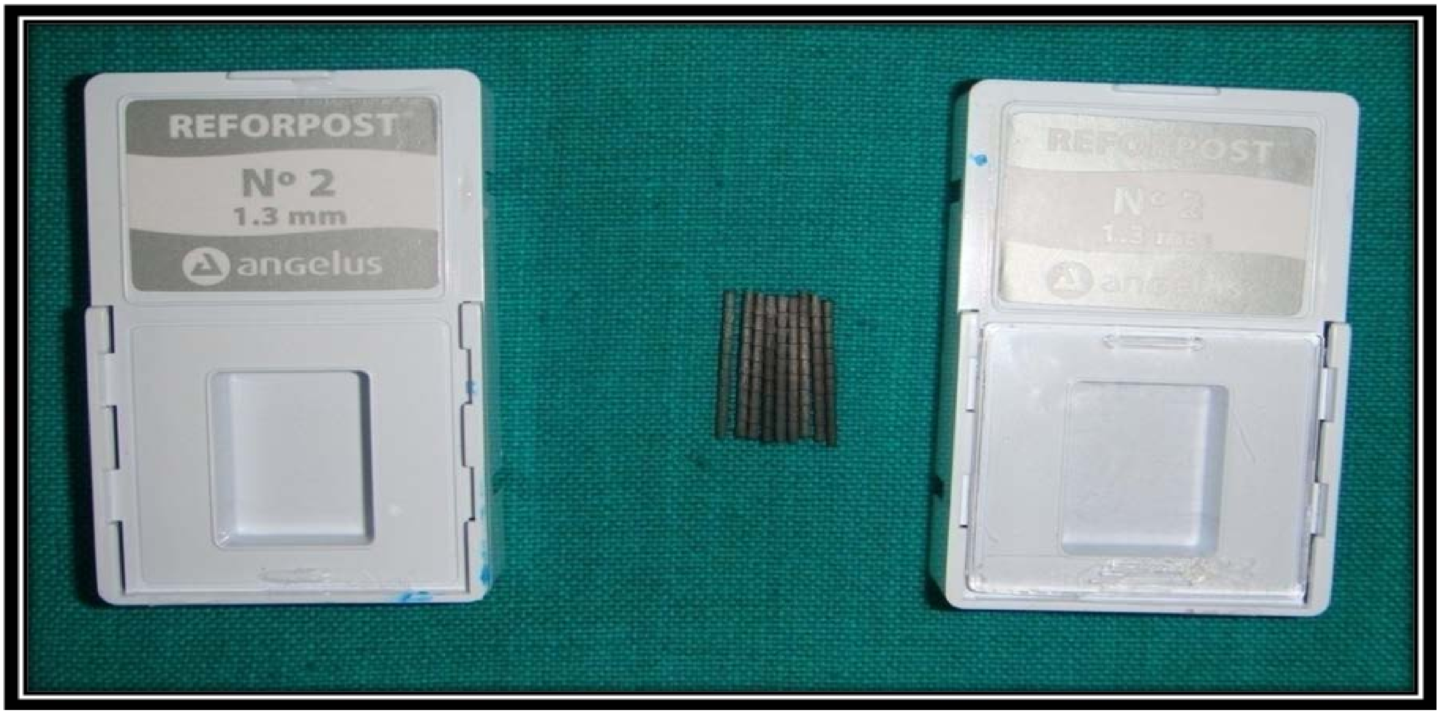


Figure 3: Everstick Chairside Composite Fibre Reinforced Post (CF-FRP)

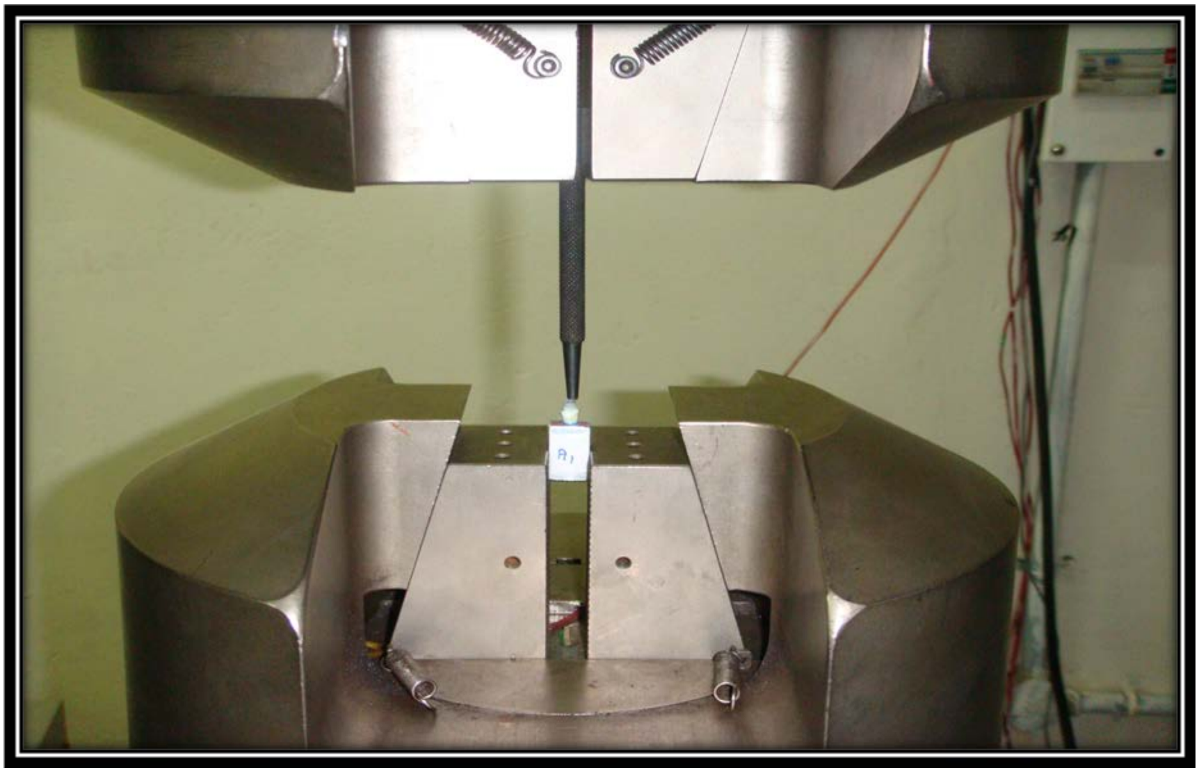
Figure 4: Decoronation Procedure

Figure 5: Tooth Decoronatedat 2mm below CEJ

Figure 6: Custom made Core forms for Core Buildup

Figure 7: Zwick Universal Testing Machine

Figure 8: Fracture Strength testing on a mounted specimen



PHOTOGRAPH 9: Fractured Specimens after Fracture Strength Test


A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10