ENDODONTIC POST RETENTION WITH RESIN CEMENTS (ILUMI FIBER POST)

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BIOMATERIAL

ABSTRACT

Objectives: Loss of post retention is the leading cause in the cemented post. There is no good method of bonding a fiber post in a post space with resin cements because adhesive cementation into a prepared post space is difficult- due to an inability to place, dry and light cure the adhesive and the cement. A new post system (iLumi) that transmits light to the apex of the post has recently been developed. We want to know if this system will improve post retention in each section (coronal, middle and apical) of the prepared post space and if this curing improves resin penetration of the cured adhesive into the dentin tubules.

Methods: Roots of freshly extracted mandibular bicuspids without caries, cracks or defects were observed under Keyence microscope and they are selected. Radiographs were made in the B-L and M-D direction to exclude teeth with abnormal canal shapes. Only teeth with a root length greater than 11mm were included. Roots were instrumented with K-Flex hand files (# 15 to #40), irrigated with normal saline and obturated using AH26 sealer and gutta percha. A 9mm post space were prepared in each tooth by removing gutta-percha with a post space drill. Teeth were divided into 5 groups. Digital radiographs were made to confirm gutta-percha length at the apical level and to confirm post fit. Fiber posts were cemented following manufacturer's instructions under an applied constant load and stored (37°C/48 hours /distilled water). Using a low-speed diamond disc three-2 mm sections (cervical/middle/apical) were produced and stored

(normal saline /37°C/24 hours). The sectioned tooth were etched with phosphoric acid for 15 sec, rinsed with tap water and Prime and Bond Elect adhesive was applied to the post and the canal space. Calibra Ceram resin cement was placed in the canal. The Bonding agent, Post and the cement were cured at a same time with a light curing (Elispar 3M ESPE S10/1020Mw/cm²) following manufactures' instructions and stored (37°C/48 hours/distilled water). The specimen were placed in special fixture and a tensile load applied until failure Universal testing machine (INSTRON_5565O). Data were analyzed with one-way ANOVA and two post-hoc tests and Dunnett test to compare multiple groups to a single control group and Tukey HSD test to determine inter group differences (significant set at .05) by statistical analysis.

Results: The results show that without light cured on both adhesive (Prime and bond elect) and cement (Calibra Ceram) dropped the tensile strength in each section of the canal (coronal, middle, apical) of the tooth compared to light cured on both adhesive and cement. This shows that the tooth has more chances of failures and debond very easily.

Light cured only on adhesive (Prime and bond elect) and not on cement (Calibra Ceram) shows there is increase in tensile strength compared to light cured on both adhesive and cement, but no significance difference between coronal and middle section of the canal of the same group, but it shows an increase tensile strength in the apical section of the canal showing high retention. This shows that the adhesive when its light cured has a good retention and less changes of debonding.

Conclusions: The applied tensile test results obtained from all specimen groups measured post retention in three different sections of the canal. Two cements were used in this study to determine whether the post would transmit adequate light energy to the apical portion of the root to polymerize the apical section well enough to equal the bond produced with a light cured dual cure cement. The different group were used to determine whether adequate light energy would be transferred from the post to polymerize the adhesive and if enough light energy would be used to polymerize the adhesive and the resin cement (Light cured Dual cure cement are stronger= higher bond strength). If any section of the canal produces different results this will allow us to concentrate our investigation on why the values are lower in that section of the root. This study aims to enhance our understanding to see if the light energy is transmitted from the post to the coronal, middle, apical section to provide polymerization of the adhesive and the post, that is what will produce different post bond strength in different sections.

KEYWORDS: iLumi fiber post, Adhesive, Resin cements, Pull out Test, Keyence.

DEDICATION

This thesis is dedicated to my parents, my husband, my brother, and my sister for giving me immeasurable support to fulfill my dream of studying in the United States of America.

This thesis is also dedicated to my mentor, Dr. John O. Burgess, for bringing out the best in me through persistent critiques and appreciations, without which I would have never been where I am today

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LIST OF ABBREVIATIONS

C-factor- Cavity configuration factor

DC-Degree of conversion

FRPs- Fiber-reinforced posts

TIR- Total internal reflection

VLC- Visible light cure

INTRODUCTION

The clinical significance of the effectiveness of the adhesive cements in the retention of fiber posts into root canals has been emphasized by the incidents of post debonding as the most frequent failure mode of fiber post systems. The greatest failure of endodontically restored teeth is loosening of the post in the prepared post space. The bonded post is used with composite fiber posts which are adhesively bonded into the prepared post space. Effective resin infiltration of the adhesive and the adequate light curing produces effective bonding and adhesion of an endodontic post into the post space is of great interest in restorative dentistry today[1].A significant amount of literature and research has been devoted to increasing post retention by modifying the shape and post configuration (Tapered, parallel sided, threaded) to produce active, passive, or bonded post an attempt to improve post retention. The first post modification to improve post to tapered cemented posts. Active posts use threads which engage the dentin wall of the prepared post space and further increased post retention in cemented posts. The challenges to bonding to intraradicular dentin are related to the limited access, poor visibility, poor moisture control, the amount of sclerotic dentin which is atubular and difficult to bond to since its atubular dentin. Penetrations of the adhesive into the dentin tubules, the reduced number of dentinal tubules in the apical level of the root as well as the unfavorable C-factor (Cavity configuration factor) inside the root canal, the lack of effective adhesive monomers like the 10 MDP monomer or the Penta monomer another phosphate monomer which has proven to effectiveness to tooth structure[1, 2].The use of light transmitting, translucent fiber posts to transmit the light energy to polymerize the adhesive and resin cement bonds the restoration for restoring endodontically treated teeth influences the polymerization efficiency of resin cements to intraradicular dentin with an increase of the depth of resin cure[3]. By increasing the degree of conversion (DC) of the monomer present in the resin composite matrix, improvement of their mechanical properties such as the modulus of elasticity and hardness is expected.[4] When light is transmitted through the post bonded in the endodontically treated tooth through the root canal, light intensity declines by light scattering within the resin cement, shadowing by the tooth structure even in the fiber post[5]. Even with translucent fiber posts, light transmission decreased by 60% of incident light, reducing the degree of conversion (DC) of resin cement.[6]The tendency of the DC to decrease within the root canals is post-dependent which is determined by the light transmission capacity of the post.[7] Several studies have reported substantial reduction in the light intensity from cervical to middle and middle to apical region of the canal space. Perhaps the light-transmission of fiber posts which could increase the degree of conversion of resin cements was overestimated in several studies that use different polymerization criteria.[8]

Rationale of the study: Loss of post retention is the leading encountered with fiber posts. The Debonding usually occurs along the resin cement to prepared dentin post space interface producing loss of post retention in the canal space[9]. We want to know why this failure occurs because of poor curing of the adhesive or cement poor cure ort a lack of curing of the dual-cure of the cement. We want to know if the new post which transmits light to post apex will uniformly cure the resin cement to the apex of the post space and cure simultaneously the adhesive and the cement or is the dual-cure cements which has less conversion and reduce the bond of the post to dentin post space. Three sections were prepared in each tooth to record the ability of the post to transmit light and polymerize throughout the length of the post. Complications of poorly polymerized resin cement into root canals produce leachable monomers which can penetrate through the canal space to the surrounding periodontal tissue[10]. Moreover, a finite -element analysis reported that stresses concentrate in the apex in teeth restored with cemented posts especially when post insertion depth increases because the apex is thinner and has less tooth to resist stress, insufficient polymerization of the luting could affect long -term durability of the restored endodontically tooth[11]. Recently, new fiber optic posts with superior light- transmitting abilities have been introduced as means to increase light transmission to improve light curing of the resin cement[12]. According to the manufacture, these fiber optic posts increase light transmission through the post to the post apex by increasing the Total Internal Reflection (TIR) within the Acceptance Cone Angle that maximizes the light transmission delivered to the bonding agent. We want to know whether this light-transmitting fiber posts is superior to another commonly used fiber composite post in producing a more efficient polymerization of the resin cement into the root canals compared to DT post.

Purpose of endodontic post: The primary purpose of intracanal posts is to provide retention for the coronal restoration (normally crown) of endodontically treated teeth with a substantial missing tooth structure[13]**.** The restoration of endodontically treated teeth has been studied extensively. Posts are widely used for the restoration of the teeth when there is insufficient coronal tooth structure to retain a core for the definitive restoration[14]. Cast posts and cores are commonly advocated for teeth with little remaining coronal structure or for uniradicular teeth with small coronal volume.

Endodontically treated anterior teeth have traditionally been restored with cast metal post and cores. These metal posts have a higher modulus of elasticity (are stiffer than) than the supporting dentin; this mismatch in modulus could lead to stress concentration and leads to failure. This has led to search for a radiopaque resin post with reinforcing fibers with a modulus closer that of dentin. Tooth-color posts have increased in popularity since they were introduced in 1997.Prefabricated post systems have become popular because they can provide satisfactory results while saving chair time and reducing costs. Tooth-color fiber reinforced posts have esthetic advantages, including increased transmission of light throughout the root and the overlying gingival tissues. Moreover, fiber-reinforced posts[15]eliminate the problems produced by corrosive reactions that can occur with metal alloy prefabricated posts. Fiber-reinforced posts also have the advantage of easy removal if endodontic retreatment is required. An important characteristic of fiber-reinforced posts is their elastic modulus, which is like that of dentin, resin cements, and resin core materials. According to Peroz et al.,[16] endodontic posts should be placed in endodontically treated teeth when only one or none cavity wall is remaining to retain the core material, provided that adequate ferrule height 1.5-2mm of vertical tooth structure exists. Posts may not be required to restore endodontically treated teeth if treated molars with large remaining pulp chambers have adequate retention to retain a core restoration or with anterior teeth with minimal tooth structure loss, placement of endodontic posts is not considered necessary[17]. When multiple canals exist in one tooth that required post and core, should be placed in the largest and straightest canal to provide the most appropriate post space preparation without the risk of weakening or perforation of the root. A good rule is do not place a post larger than the endo file used in the canal. If it is then use a post with higher modulus metal for example. For the restoration of endodontically treated tooth, numerous techniques and materials have been suggested and evolved through the years with marked improvements in both biomechanical and aesthetic properties.

History of endodontic posts: The first historical attempt related to the placement of posts in the roots is attributed to Pierre Fauchard in 1747-commonly referred to as the Father of Modern Dental Prosthesis- where he used the "tenons" or otherwise metal dowels or pivots screwed into the roots to retain fixed dental prostheses. In the early 1800s, Dubois de Clemand described the porcelain pivot crown as a crown-post combination used to retain artificial porcelain crown into a root canal. It worth mentioning that early pivot crowns in the United states used wooden (white hickory) pivots. Within the moist environment, the wood expanded the pivot was retained in place; however vertical root fracture occurred consequently[18]. Gradually, metal pivots replaced wooden pivots and more retentive features of thread pins, surface roughening and split designs were incorporated to increase mechanical spring retention of the posts. Regarding the choice of the metal, Harris in 1839 proposed the use of gold and platinum posts. In 1869, G.V. Black described the porcelain -faced crown with a screw inserted into canal filled with gold foil. The "Richmond crown", a screw-retained crown on a threaded tube in the canal was introduced in 1878 but found to be impractical early after its use. Cast post and core were developed during the 1930s marking the replacement of the one-piece post crowns[18]. With casting at laboratory stage, a tapered post that conforms to the original taper of the root canal preparation could be produced following impression making procedures with wax or auto polymerizing acrylic resin[19]. Until the mid-1980s, the cast post was considered the safest method for the restoration of endodontically treated teeth; where after decades of use, this type of treatment was scientifically rendered a predisposing factor for root fractures[20]. The clinical use of prefabricated post combined with composite resin-based cores was initiated in 1966[21]. During the last decades, prefabricated metal posts in a variety of structural designs have been used widely with different combinations of core materials following direct chairside techniques which eliminated the extra appointment need with indirect casting procedures saving an appointment and reducing the cost for the procedure. Among the different types of prefabricated metallic posts, parallel-sided, threaded posts provided the highest tensile resistance to dislodgement from the root compared to cemented, tapered ones[22]. However, both cast and prefabricated metallic posts share the disadvantages of loss of retention, increased incidents of root fractures, root fracture with active and passive post placement is about 3.7%, risk of corrosion, and intracanal stress concentration as well as the least conservative management of the tooth structure upon their placement[23, 24]. As an alternative to conventional cast and prefabricated metallic posts, Duret et al[25]. introduced the carbon fiber post- and -core system named Composipost in 1990. The Composipost dowel was made of equally stretched and aligned carbon/graphite fibers, embedded in an epoxy resinmatrix[23]. This post was black and radiolucent. The clinical performance of Composipost system has been evaluated in several retrospective and prospective studies in comparison with other types of posts and manifested satisfactory success rates within the follow-up periods[15, 26, 27]. The clinical use of carbon fiber posts revealed the main disadvantages of the lack of radiopacity and ability to conceal under all-ceramic or composite restorations. As a result, quartz and glass fiber posts were introduced to address esthetic requirements for tooth restorations as well as more radiopaque posts[28]. These fiber post systems are based on glass, polyethylene, and quartz fibers and several marketed examples such as Aesthetic Plus posts, DT Light posts, FRC Postec posts, FiberKor posts, DentinPost, have been evaluated in various studies[23]. Current clinical and laboratory evidence validates the use of these fiber post systems in preference to metallic and zirconia posts for the restoration of endodontically treated teeth[29]. With the advancements in dental ceramics, Meyenberg et al. (1995) introduced zirconia posts for the nonvital teeth[30].Despite the advantages of high flexural strength and fracture toughness of zirconia, major clinical limitations of its use as a post material arise primarily due to the increased risk for root fractures and the inability to bond the resin media. Large clinical study demonstrate success- can press lithium disilicate to the zirconia post and have a great system. If we could not bond to zirconia we could not zirconia crowns to teeth[29]. In addition, zirconia posts present many difficulties upon removal but not much different that flexipost- theared split shank post from the intracanal area and it is in fact practically impossible to grind off a luted zirconia post[31]. Ultrasonic help but very tough.

Classifications of posts: According to Caputo and Standlee classification of post design[13], three main combinations are distinguished as: 1) Tapered, serrated or smooth sided, cemented into a post space prepared with a matched-size post drill; 2) Parallel-sided, serrated, or smooth-sided, cemented into matched cylindrical channels prepared by a post drill; 3) Parallel-sided, threaded and inserted into pre-tapped channels cemented into a slightly small post space compared to the post.

According to Robbins[13], posts are classified as metallic or non-metallic posts; metallic posts consists of custom-cast posts, and prefabricated posts and non-metallic posts consists of carbon fiber posts, tooth colored posts.

According to material composition three posts grouping can be formed: A) Metal posts-which consists of stainless steel, titanium and titanium alloys and gold plated brass also base metal alloy, B) Ceramic and zirconium posts, and C) Fiber posts which consists of carbon fiber posts, Quartz fiber, Glass fiber, and silicon fiber posts.

Rosensteil classification prefabricated posts into- 1) Tapered, smooth- sided posts, 2) Tapered, serrated posts, 3) Tapered, threaded posts, 4) Parallel, smooth-sided posts, 5) Parallel, serrated posts.

Regarding surface characteristics, posts are divided into- A) Active-if they mechanically engage the dentinal walls with threads and B) Passive-if their retention is relied on the cement. Regarding surface characteristics, posts are active- if they are mechanically engage the dentinal walls with threads or passive- if their retention is relied on the cement. Despite their superior retention, active posts exert greater stress into the root than passive posts do. Linde et al study active post (Dentatus) tapered threaded post most stressful same as Parapost about 3% for both. So even though people say active post are stressful they produced no more long-term root fracture than passive posts.

Fiber-reinforced Posts (FRPs)

Composition: FRC posts are made of carbon, quartz or glass fibers, embedded in a matrix of epoxy or methacrylate resin. Fibers, 6 and 15μm are oriented parallel to the post long axis of the post[32]. Fiber density, i.e. the number of fibers per mm^2 of post cross-sectional surface, varies between 25 and 35% mm depending on the post type. Therefore, in a transverse section of the post 30-50% of the area is occupied by fibers. The adhesion between quartz or glass fibers and resin matrix is enhanced by silane application of the fibers prior to embedding. A strong interfacial bond increases load transfer from the resin to the matrix of the fibers and is essential for an effective reinforcement of the post[33].

FRC post shape: FRC posts are available in different shapes: cylindrical, cylindroconical, conical, double-tapered, and the oval shape[29]. The post literature clearly demonstrate that parallel-sided posts are more retentive than tapered posts[13]. Dual-tapered posts more closely adapt to the shape of the endodontically treated canal, and provide a better adaption to the post and canal space without using excess preparation which weakens the tooth. Some commercial posts have retention built into the occlusal portion of the post with a coronal head or serrations to increase core retention form[34]. Oval-shaped glass fiber posts were recently introduced for better adaptation into ovoid-shaped canals to improve post canal space adaption. For ovoid-shaped canals, the use of an ultrasonic oval-shaped tip has been suggested for a more conservative post space preparation[35].

Biomechanical properties: One of the most important requirement of intracanal materials for successful restoration of endodontically treated teeth- aside from their biocompatibility and bonding abilities to tooth structure – is to have physical and mechanical properties similar to that of dentin[36]. Several studies have concluded that fiber reinforced composite posts exhibit similar biomechanical properties such as modulus of elasticity with the dentin[37]. Post flexural strength and modulus of rupture determines fracture resistance of the post. Results of a three-point bending test found the flexural strength of fiber and metal posts to be respectively four and seven times higher than that of the root dentin[38]. Properties of glass fiber-reinforced posts are related to amount of fiber, resin content, increased fiber diameter and porosity[39]. The clinical significance of the fiber post systems, in addition to being more biologically compatible with the tooth structure is the reduction of the risk for root fractures. What has been rendered the weakest point is the bond of the post to dentin[39]. Several studies reported oblique or horizontal fractures in the middle third of the root or vertical root fractures to occur in the use of intracanal cast posts[40]. Likewise, in vitro testing, higher potential risk for root fractures occurred with zirconium posts where compared with fiber posts when tested under intermittent loading in a wet environment[41]. This occurs in vitro only not in clinical studies. On the other hand, fiber posts with a modulus of elasticity similar to dentin exhibited a more favorable failure mode as fractures occurred at the cervical third of the roots or the cores[42]. These types of fractures (core/ post fractures) would allow retreatment without jeopardizing the overall integrity of the tooth. A recent invitro study by Franco et al. concluded that post length is not as important to the mechanical behavior of glass fiber posts as it appears for the metal posts after the observation that different tested post lengths failed at similar fatigue loads[43]. On the contrary, shorter post lengths found to transfer more forces to the less rigid dentin in the cervical area increasing the risk for cervical fractures[44]. Studying the effect of post dimension on fracture resistance of post-restored teeth, Li et al. concluded that fracture resistance decreases with the increasing ferrule height, which potentially can prevent the ultimate failure.

Radiopacity: Fiber post composition determines its radiopacity. Glass fiber posts exhibit lower radiodensity than quartz fiber posts which in turn are more radiolucent than carbon fiber posts. The more radiopaque the fiber the more radiopaque the post are. However, all fiber posts are less opaque than metal or zirconia dowels. Low radiodensity of polyethylene fibers may be a limitation of these reinforcing materials.

Adhesive mechanism: The long-term prognosis of endodontically treated teeth with intracanal posts depends, in large part, on post retention[45]. Adequate post retention can be achieved with the use of parallel, active posts, increased post length, as well as more retentive luting agents to enhance post retention[13]. While several types of luting agents have been used for the post cementation such as zinc phosphate, resin, glass ionomer, and resin modified glass-ionomer cements, resin cements are currently the most reliable option to provide effective long term retention since they can bond to tooth and the post with less leakage[46]. Different techniques and materials have been tested to provide an effective bond between the fiber post and the resin cement. Several studies[47-52]evaluated the effectiveness of pretreatment techniques either on post surface or dentin substrate as well as tested different types of luting cements. Post surface can be treated chemically with salinization and etching with hydrofluoric or phosphoric acid[48, 53]. It has been suggested that a combination of chemical and micromechanical post surface conditioning can result in more predictable adhesion mechanism[54]. The clinical significance of the effectiveness of the adhesive cements in the retention of fiber posts into root canals has been emphasized by the incidents of post debonding as the most frequent failure mode of fiber post systems[9]. Moreover, the weakest link of bonded endodontic restorations has found to be between the dentin and the adhesive layer[55]. The challenges in bonding to intraradicular dentin are related to the limited access, visibility and moisture control, the deposition of cementum and secondary dentin, the reduced number of dentinal tubules in the apical level of the root as well as the unfavorable C-factor (cavity configuration factor) inside the root canal[1]. Interestingly, it was reported that the superficial interaction of acidic resin monomers of the oxygen inhibition layer of some adhesives with the resin cement initiators could decrease the cement polymerization[7]. To measure the post retention in different intracanal levels, micro tensile tests and “thin-slice” push out test have been proposed[54]. The latter has found to be the most accurate technique to evaluate the bond strength between fiber posts and intracanal dentin[56]. According to an in vitro study[51], the bond strength between the FRPs and the resin cement is dependent on the type of the post, surface treatment and resin cement. Likewise, it has been demonstrated that the type of fibers and the polymerization mode can influence the bonding between the fiber posts and the luting agent[57]. A study by Kremeier et al.[58] concluded that the selection of the fiber post is more critical than the luting cement to achieve excellent post retention. In regards to the bond strength between FRPs and root dentin, post retention varied with the activation mode- light or auto-polymerization – of post adhesive cementation and post/ root regions[59]. Furthermore, it has been reported that the thickness of the cement layer did not influence the bond strength at significance levels[60]. Fiber - reinforced posts can be luted to dentin layer with chemical, light, or dual-polymerizing agents. Aside for the polymerization mode of the resin cements, various cementation procedures for the bonding of endodontic posts have been recommended as follows: self-adhesive resin cement, phosphoric acid with self-adhesive resin cement, three-step etch - and -rinse adhesive system or two-step adhesive system with conventional resin cement[61]. Currently, dual-cure resin cement in combination with “etch-and-rinse” adhesives can obtain the most reliable result in fiber post cementation[9], as opposed to the combination with self-etching adhesives. On the other hand, the self-adhesive cementation approach was found to be a good alternative for luting fiber posts because of the high bond strengths and the lower polymerization stress values. Similarly, it was reported that bond strength of self-adhesive and glass ionomer cements produced greater post retention compared with dual-cured resin cements. In addition to that and despite the fact that the use of either dual-cure or self-curing composites for the luting of fiber posts are recommended due to the decreased light transmittance at the deeper intracanal levels. There is also an incompatibility between dual cure and chemical cured resin cements and a light cured bonding agent- for this manufacturer recommend mixing an dual cure additive to the bonding agent to improve the bond between the adhesive ad the resin cement. Studies have shown no difference in the bonding effectiveness between translucent posts and light- curing or dual- cured composite resins. Considering the various and conflicting results among the studies for the bonded endodontic restorations, a universal protocol for the cementation procedure of fiber posts is not yet established. Nonetheless, several combinations of post and dentin surface pre-treatment, adhesive agents, resin cements and fiber posts have yielded higher bond strength values than other while tested, and recommendations are provided for a predictable application at clinical level.

Light transmitting ability: When light is transmitting through the root canal, a significant reduction of light intensity occurs in the event of light scattering within the resin cement and shadowing caused by the tooth structure and the post[7, 12, 62]. To enhance the polymerization of resin cement at increased depths, the use of translucent light-transmitting posts was suggested[63]. Even with the use of translucent fiber posts, light transmission can be limited to values lower than 40% of incident light, thus affecting the degree of polymerization of resin cement[6]. Goracci et al., in their spectrophotometric analysis found significant variability on the light transmittance among ten different fiber posts that can be related to the decreased curing efficacy of resin composites at the further root canal depths[63]. The differences found in the light transmission values of many tested fiber posts are likely to be related to variations in their chemical and structural composition. In addition, it has been stated that the ability of light-transmitting posts to increase the depth of cure of resin cements might be overestimated in several studies that implemented different polymerization criteria[8]. The depth of cure (DOC) is defined as the thickness of resin-based composite that is “adequately” cured and it can be described as the gradation of cure with the depths of resin material due to light attenuation at increased depths[8, 64]. Generally, composite-related factors (shade, translucency, resin filler particle size, load and distribution, photo initiator type and concentration) and light-related factors (light intensity, spectral distribution, irradiation source and irradiation duration) can affect the depth of the cure of resin materials. For the fiber post luted systems, the absorption, reflection, and transmission of the light seems to be dependent both on the resin matrix in regards to the size and concentration of the filler and pigment color and on the fiber post composition[65]. A significance parameter for the evaluation of the photo-activation of composite resins is the degree of conversion (DC) which represents the proportion of the remaining concentration of the aliphatic C=C double bonds in a cured sample relative to the total number of C=C bonds in the uncured material and can be measured basically with Fourier Transform Infra-red Spectroscopy (FT-IR)[66]. It has been reported that the tendency of the degree of conversion of the monomer to decrease within the root canals seemed to be post-dependent and associated with the light transmission capacity of the post[7]. It is also inversely dependent on the distance from the light-tip surface as a result of radiant energy attenuation while it passes through the composite material. Furthermore, a recent study of Zobra et al.,[67] showed that the use of different light sources such as quartz-tungsten-halogen (QTH), light-emitting diode (LED), and plasma arc (PAC) did not affect the DC of light-transmitting plastic posts. In the meantime, several studies[7, 12, 68] have demonstrated substantial reduction in the light intensity from cervical region to middle and then apical region of the root canal. It can be concluded that light intensity at the deepest intracanal levels may be insufficient to induce adequate clinical luminous activation of cements[69] and consequently a reliable bond strength between the fiber posts and the apical dentin. Although, dual-cure resin cements have been the cement of preference for the luting of FRPs, inadequate polymerization of resin media can still occur as some are relying mainly on light activation for curing[70]. In addition to that and according to Pfeifer et al., incompatibility between simplified adhesives and dual-cured resin cements can be the result of non-photoactivated resin-based luting cements[71].

Polyethylene fibers: Ultra-high molecular weight polyethylene fibers coated with a dentin bonding agent are used to build-up endodontic post and cores. As the fibers adapt to the root canal, canal enlargement is not required according to the manufacturer. The woven fibers have a modulus of elasticity similar to that of dentin and are claimed to create a dentine-post-core mono-block allowing for a more favorable stress distribution along the root. Only two clinical studies of polyethylene fiber posts are available. In the clinical trial by Turker et al., 1 out of 42 dowels debonded over a three-year follow-up period. During the same observation period, 1 out of 87 posts loosened in the prospective study by Ayna et al. It should, however, be considered that in the latter investigation only anterior teeth in patients aged between 8 and 12 were considered.

HYPOTHESIS AND AIMS

1. To measure and compare the ILUMI post retention in sections (coronal, middle, apical) with and without an adhesive and with and without light curing.
2. To measure and compare the tensile load required to remove the bonded iLumi post into three tooth sections (coronal, middle, apical) of the 5 groups.
3. To measure and compare the sectioned tooth (coronal, middle, apical) and post under Keyence to see the mode of failure in each section of the tooth (coronal, middle, apical).

NULL HYPOTHESIS

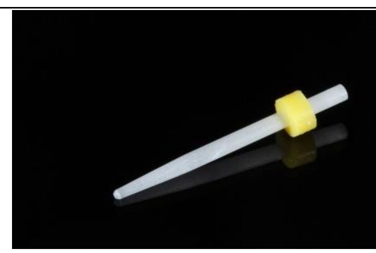
There will be no difference in post retention and when an adhesive or light cure is applied during post cementation.

MATERIALS

The materials used in the present study are summarized in Table 1.

Table 1: Trade names and pictorial representation of restorative materials used in the study.

Material	Manufacturer	Lot No	Image
Calibra Ceram (Dual cure)	Dentsply	160131	
Prime and Bond elect	Dentsply	160331	

Adhese Universal	Ivoclar	W41908	
Variolink Esthetic LC	Ivoclar	X14915	
Phosphoric acid	3M		
ILUMI Post	iLumiSciences Inc.,	UR-8001	

BioRoot RCS	Septodont	B13415	
K-Files	Kerr Dental	031156 445	
Post space	iLumi sciences Inc.,	-	

Table 2: Composition and classification of materials used in this study.

Material	**Classification**	**Composition**	**Curing Time**
Calibra Ceram (Dual cure)	Resin cement	Urethane di methacrylate, Di-Tri-methacrylate resins, Phosphoric acid modified acrylate resin,	20s

		Barium boron fluoroaluminosilicate glass, Organic peroxide initiator, Camphorquinone, Accelerators, Hydrophobic amorphous silicon dioxide, UV stabilizers, Titanium dioxide, Butylated hydroxy toluene.	
Prime and Bond Elect	Bonding agent	Mono-di-trimethacrylate resins, PENTA (dipentaerythritol Penta acrylate monophosphate), Acetone, water, Diketone, organic phosphate oxide, Stabilizers, cetylamine hydro fluoride.	20s
Adhese Universal	Bonding agent	Methacrylates, ethanol, water, highly dispersed silicon dioxide, initiators, stabilizers.	10s
Variolink esthetic LC	Resin cement	Urethane dimethacrylate, and further methacrylate monomers. Inorganic fillers-ytterbium trifluoride and spheroid mixed oxide.	20s

		Initiators, stabilizers, and pigments are additional ingredients.	
Phosphoric acid	Etchant	32% phosphoric acid	15s
iLumi Post	Post system	Glass optical fibers Epoxy resin.	20s
BioRoot RCS	Sealer	Powder/liquid ratio. Tri-calcium silicate and is monomer-free.	-

Table 3: Characteristics of the fiber posts and Post space investigated.

Material	**Shape**	**Post size and diameters**	**Composition**
iLumi Fiber optic post	Tapered	Size #1 D1:0.8mm D2:1.35mm	Glass optical fibers (70% weight) Matrix: epoxy resin (30% weight)
Post canal space	Tapered	Size #1 D1: 0.8mm D2: 1.35mm	

METHODS

Specimen preparation: 50 extracted caries-free human mandibular bicuspids were selected for this study and the specimens were sectioned into 3 regions (coronal, middle, apical) using a low speed diamond saw machine as shown in figure 1. 150 extracted sectioned specimens with 150 fiber optic ILUMI post were used in this study. Radiographs were made in the B-L and M-D direction to exclude teeth with abnormal canal shapes as shown in figure 1. Only teeth with a root length greater than 11mm were included. The crown were removed by cutting it at the CEJ with a low speed diamond saw (Isomet 1000, Buhler, Lake Bluff, NY, USA). First, the root canals were mechanically enlarged with K- flex hand files (#15 to # 40), and syringe irrigation with 2.5% Sodium hypochlorite (NaOCL). The definitive preparations had a 6 -degree taper (as a result of the instrument shape) and a diameter of 0.3 mm at the apex. The canals were rinsed with water, dried with paper points (Kerr, Romulus) and obturated gutta percha using a master cone and lateral condensation with root canal sealer (Bio-root SC). The canal space of each specimen were enlarged with low-speed drills provided with the post system: creating a 9mm post space. Secondly, specimens were sectioned producing one 3mm sections per region (cervical/middle/apical) using low-speed diamond saw (Buehler/ Illinois) and the specimens were randomly divided into 5 groups of 10 specimens each. In this study, the bonding of specimens is different. The tooth is sectioned into 3 different regions (coronal, middle, apical) and each section the post is cemented to see the retention in each section of the canal as shown in figure 3.

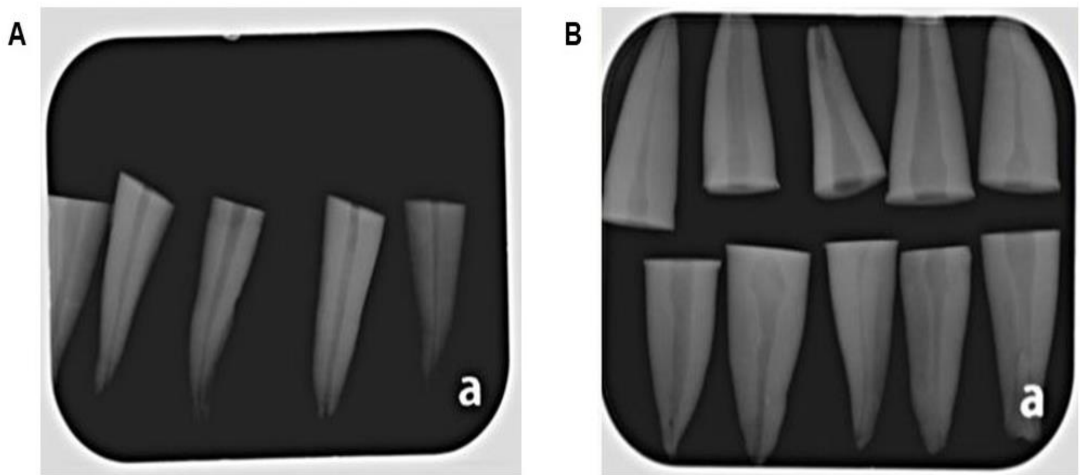


Figure 1: Radiographs of human mandibular bicuspids, Radiograph (A) shows the B-L view, (B) shows the M-L view.

Figure 2: Extracted human mandibular bicuspids

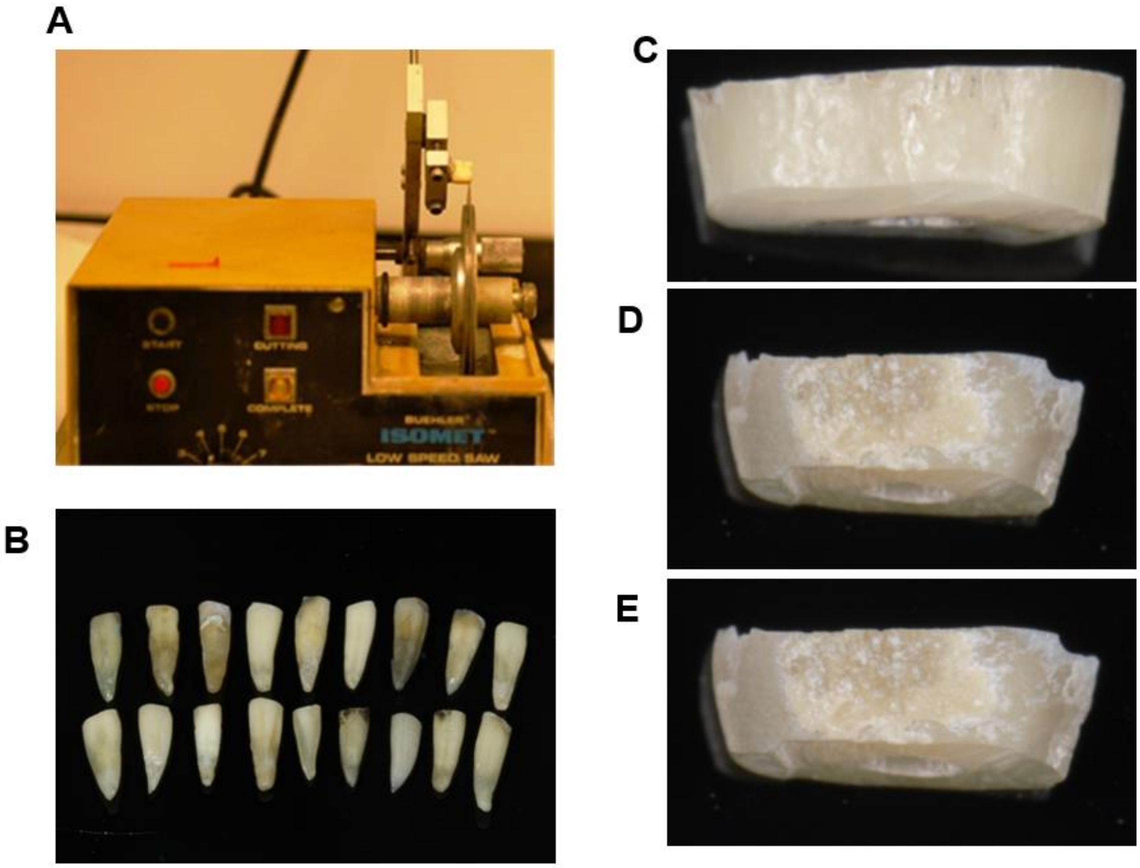


Figure 3: Preparation of the tooth specimens A) Buehler diamond saw machine for making tooth into sections, B) Tooth are sectioned up to CEJ, C) Coronal section of the prepared canal, D) Middle section of the prepared canal, E) Apical section of the prepared canal.

Group 1: Ten specimens were treated with Calibra Ceram, and adhesive (Prime and Bond Elect). In this group both the adhesive and cement were light cured. The sectioned root canal (coronal, middle, apical) were first etched with 37% phosphoric acid for 10s, rinsed using a water syringe and then gently dried with paper points. The adhesive (Prime and Bond Elect) was applied in the walls of the prepared canal for each section and to the post with 5s agitation, Excess adhesive was removed with a micro brush, air dried for 5s, and light cured for 20s in the sectioned specimens not on the post. The cement (Calibra Ceram) were placed in the canal injected and both the adhesive and cement along with the iLumi fiber post and was light cured for 20s.The specimens were stored in normal saline at 37°C for 24 hours prior to testing. A tensile load was applied at cross head speed of 1mm/min until the post was removed. Peak failure load was recorded. The overall steps in the preparation are shown in the figure 4. In this study the spacing between the top of the post and the section tooth was controlled. The space from the coronal section to the top of the post was 11mm and for the middle section the distance between the top of the section and the top of the post was 14 mm, and in the apical section the distance between the top of the post and the top of the section was 17 mm as shown in the figure 5.

Group 2: Ten specimens were treated with Calibra Ceram and Adhesive (Prime and Bond Elect). In this group both the adhesive and cement was not light cured. The sectioned root canal (coronal, middle, apical) were first etched with 32% phosphoric acid for 10s, rinsed with water and then air dried with paper points. Then the adhesive (Prime and Bond Elect) was applied, agitated for 5 seconds, the excess removed with micro brush, air dried for 5s, and not light cured. The cement (Calibra Ceram) were placed in the canal and both the cement and adhesive along with the post was not light cured. The specimens were stored in normal saline at 37°C for 24 hours prior to testing. The spacing between the top of the post and the section tooth was maintained as in group 1. A tensile load was applied at cross head speed of 1mm/min until the post debonded. Peak failure load was recorded. The space from each section was maintained as described in group 1.

Group 3: Ten specimens were treated with both adhesive and cement following the manufacturer's directions. In this group only adhesive in the sectioned canals was light cured not the cement. The sectioned root canal (coronal, middle, apical) were first etched with 37% phosphoric acid (total etch, Caulk) for 10s, rinsed using a water syringe and then gently dried with paper points (Kerr). The adhesive (Prime and Bond Elect) is applied into the sectioned canals and to the post after agitation for 5s, the excess adhesive was removed by means of micro brush, air dried for 5s, and light cure for 20s in the canal not on the post. The cement (Calibra Ceram) were placed in the canal injecting it but the cement along with the post is not light cured only adhesive in the sectioned canals were light cured. The specimens were stored in normal saline at 37°C for 24 hours prior to testing. The spacing between the top of the post and the section was maintained as in Group 1. A tensile load was applied at cross head speed of 1mm/min until the post is removed. Peak failure load was recorded. The space from each section was maintained as described in group 1.

Group 4: Ten specimens were treated with both adhesive and cement following the manufacturer's directions. In this group only, cement with the post in the sectioned canals was light cured not the Adhesive. The sectioned root canal (coronal, middle, apical) were first etched with 37% phosphoric acid (total etch, Caulk) for 10s, rinsed using a water syringe and then gently dried with paper points (Kerr). The adhesive (Prime and Bond Elect) was applied into the sectioned canals and to the post, after 5s agitation, the excess adhesive removed with a micro brush, air dried for 5s, but not light cured. The cement (Calibra Ceram) was injected into the canal it, and the cement along with the post was light cured for 20s. The specimens were stored in normal saline at 37°C for 24 hours prior to testing. The spacing between the top of the post and the section was maintained as in group 1. A tensile load was applied at cross head speed of 1mm/min until the post was removed. Peak failure load was recorded. The space from each section was maintained as described in group 1.

Group 5: Ten specimens were treated with Adhese universal and Variolink esthetic LC following the manufacturer's instructions. In this group only, the cement along with the post was light cured not the adhesive. The sectioned root canal (coronal, middle, apical) were etched with 37% phosphoric acid (Total etch, CAULK/ DENTSPLY) for 10s, rinsed using a water syringe and then gently dried with paper points (Kerr). The adhesive (Adhese Universal) was applied into the sectioned canals by means of a micro brush and even to the post. After agitating for 5s, excessive adhesive was removed with a paper point and gently air dried for 5s, but not light cured. The cement was applied onto the sectioned canal along with the post and light cured for 20s. The specimens were stored in normal saline at 37°C for 24 hours prior to testing. The spacing between the top of the post and the section was maintained as in Group 1. A tensile load was applied at cross head speed of 1mm/min until the post was removed. Peak failure load was recorded. The space from each section was maintained as described in group 1.

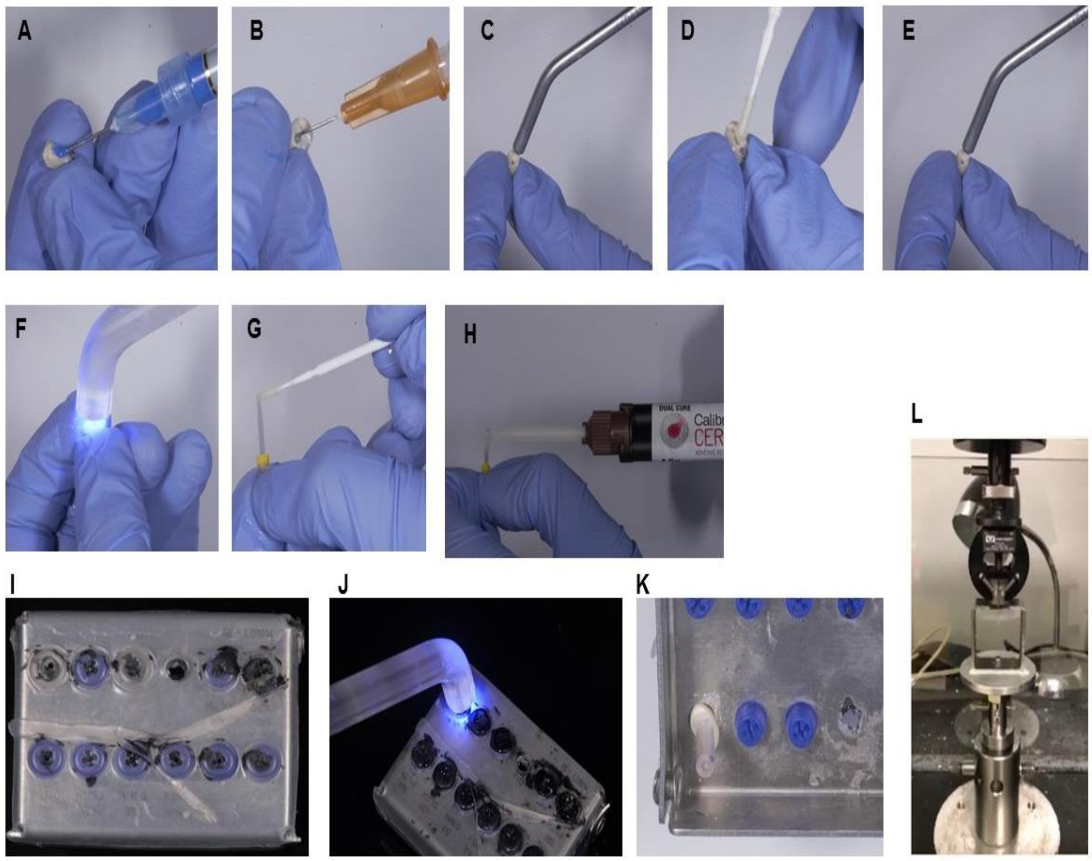


Figure 4: Step by step preparation method. A) Etchant application, B) Etchant rinsed with water, C) Etchant air dried, D) Adhesive applied on the sectioned canal, E) Adhesive air dried, F) Adhesive light cured, G) Adhesive applied to the Post, H) cement applied in post, I) Matrix fabrication, J) Light curing the post and the cement in the sectioned canals, K) Inside the matrix, L) Pull out fixture.

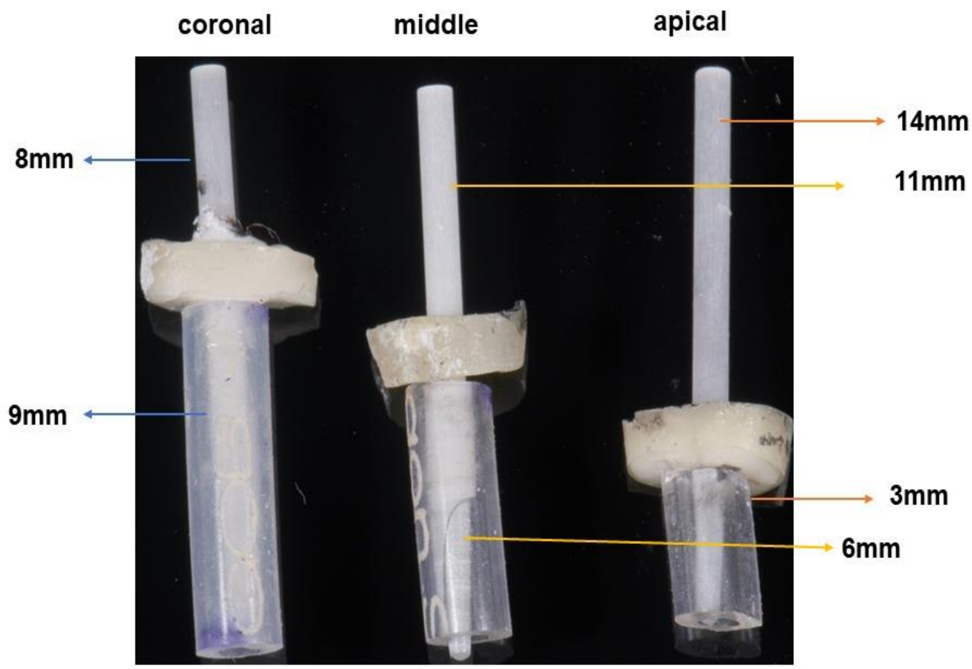


Figure 5: Final specimens showing the remaining length of post inside the canal.

RESULTS

In this study, two types of results are conducted to determine the average, standard deviation of each section of all the groups and also to see the intergroup differences between each groups. The ANOVA showed that the intergroup differences were present between the groups. To compare multiple groups to a single control group, a post-hoc test (Dunnett T) test was used. Dunnett T test comparing the control group (Group 1 vs group 2, group 3, group 4 and group 5). A second post-hoc test was used to determine differences between all group (Tukey HSD test). This study determined the post retention in three areas of the tooth: coronal, middle, and apical section to determine the adhesion and post retention influenced by the light transmission through the post.

For the coronal section: Using Dunnett T test using group 1 as the control shows that Group 1 is statistically greater than group 2 (p=0.005). Group 1 is statistically less than group 5 (p=0.003). Nothing else is significantly different from group 1(p>.05). Using the Tukey HSD post-hoc test three statistically different groups as shown in table 4. Coronal sections group 2 vs coronal section group 3 (p=0.046). Coronal sections group 1 vs group 3 vs group 4 (p=0.98). Coronal sections group1 vs coronal section group 5 (p=0.055).

Groups	N	Subset 1	Subset 2	Subset 3
Group 1	9		79.8112	79.8112
Group 2	9		72.9184	
Group 3	9	72.9184	76.4394	
Group 4	9			
Group 5	8			114.5113
Significance		.050	.980	.055

Table 4: Tukey HSD test showing the comparison of the coronal section of all five groups.

For the middle section: Using Dunnett T test group 2 was significantly less retentive than group 1. Middle sections were different in all comparisons with the control (group 1) were statistically the same ($p>0.05$). Using Tukey HSD Test-Group 2 was significantly lower than all other groups. Groups1, group3, group4, group5 are statistically the same ($p=0.614$) as shown in table 5.

Groups	N	Subset 1	Subset 2
Group 1	9		91.0856
Group 2	9	46.9500	
Group 3	9		89.9277
Group 4	9		110.2622
Group 5	8		110.7888
Significance		1.000	.614

Table 5: Tukey HSD test showing the comparison of middle section in all the five groups.

For the apical section: Using the Dunnett T test-

Group 1 and group 2 were significantly different from each other (p=0.49).

Group 1 is significantly less than group 3.

Group 2 is significantly less than group 5.

Using the Tukey HSD test the apical sections in group 1, group 2 and group 4 were not statistically different (p=0.075). Group 3 and group 5 were not statistically different from each other (p=0.912).

The two groups were significantly different but group 3 and group 5 were significantly greater than group 1, group 2 and group 4 as shown in table 6.

Groups	**N**	**Subset 1**	**Subset 2**
Group 1	9	17.88889	
Group 2	9	8.11111	
Group 3	9		30.75000
Group 4	9	18.75000	
Group 5	8		34.12500
Significance		.75	.912

Table 6: Tukey HSD test showing the comparison of apical section of all the five groups.

Furthermore, below figure 6, figure 7 and figure 8 explains average and standard deviation (tensile strength MPa) of the coronal section, middle section and apical section of the tooth. The graphs explain the comparison between group 1 light cured adhesive and cement using dual cure cement (Calibra Ceram) vs group 2 non-light cured adhesive and cement using dual cure cement (Calibra Ceram) vs group 3 light cured adhesive and non-cured cement using dual cure cement (Calibra Ceram) vs group 4 light cured cement and non-cured cement using dual cure cement (Calibra Ceram) vs group 5 light cured cement and non-cured adhesive using light cure cement (Variolink Esthetic).

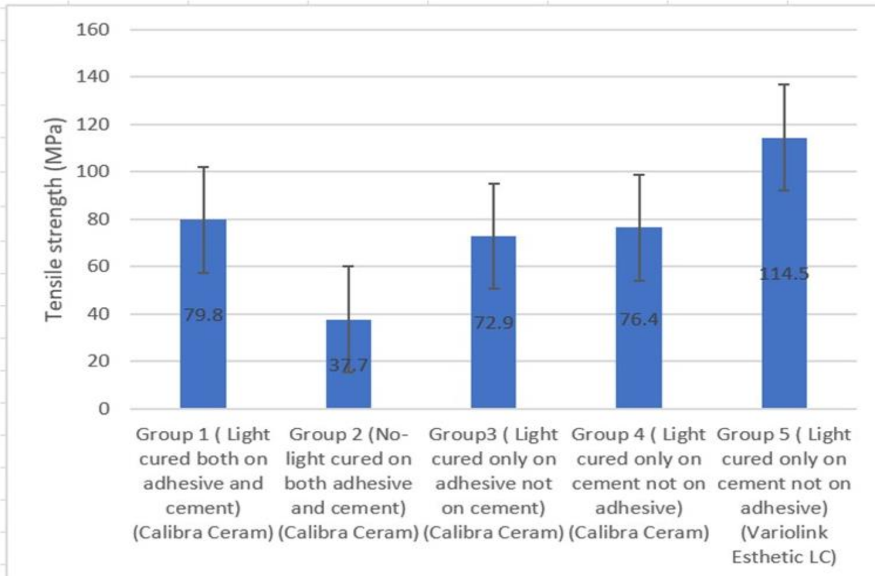


Figure 6: Tensile strength of the coronal section of all the five groups.

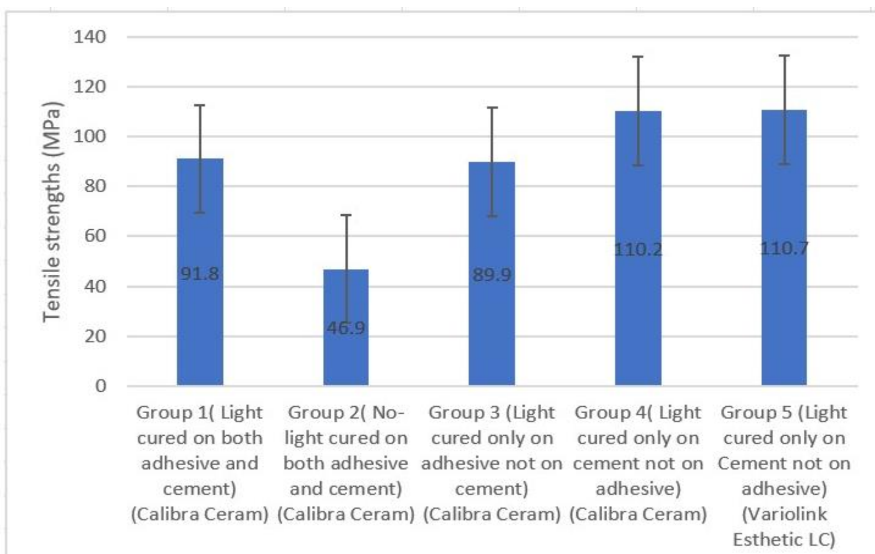


Figure 7: Tensile strength of the middle section of all five groups.

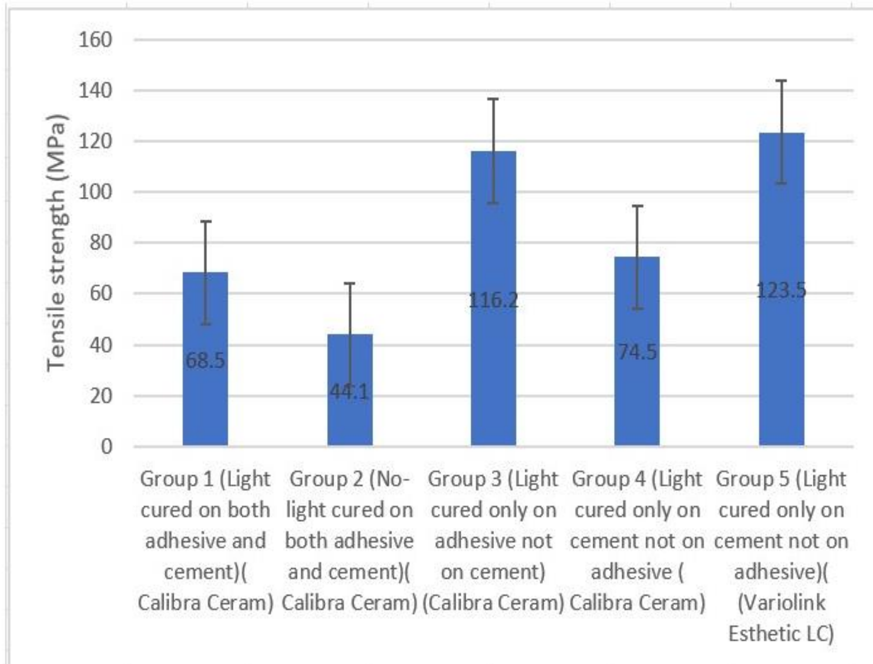


Figure 8: Tensile strength of apical section of all the five groups.

Failures: In order to study the mode of failure (Cohesive, adhesive, or mixed) in this study due to two different cements used (light cure and dual cure), we selected random sections in each of the 5 groups after tensile testing and was observed under Keyence microscope at 40X magnification to classify failure.

Comparing group 1 and group 2 the mode of failure in each section is different as shown in figure 9. In group 1 of the coronal section and the apical section, the mode of failure is approximately 80% cohesive failure, and in the middle section it is 90% mixed failure approximately. In group 2, the mode of failure for coronal section and apical section is 90% cohesive failure approximately and for the middle section it is 90% adhesive failure approximately.

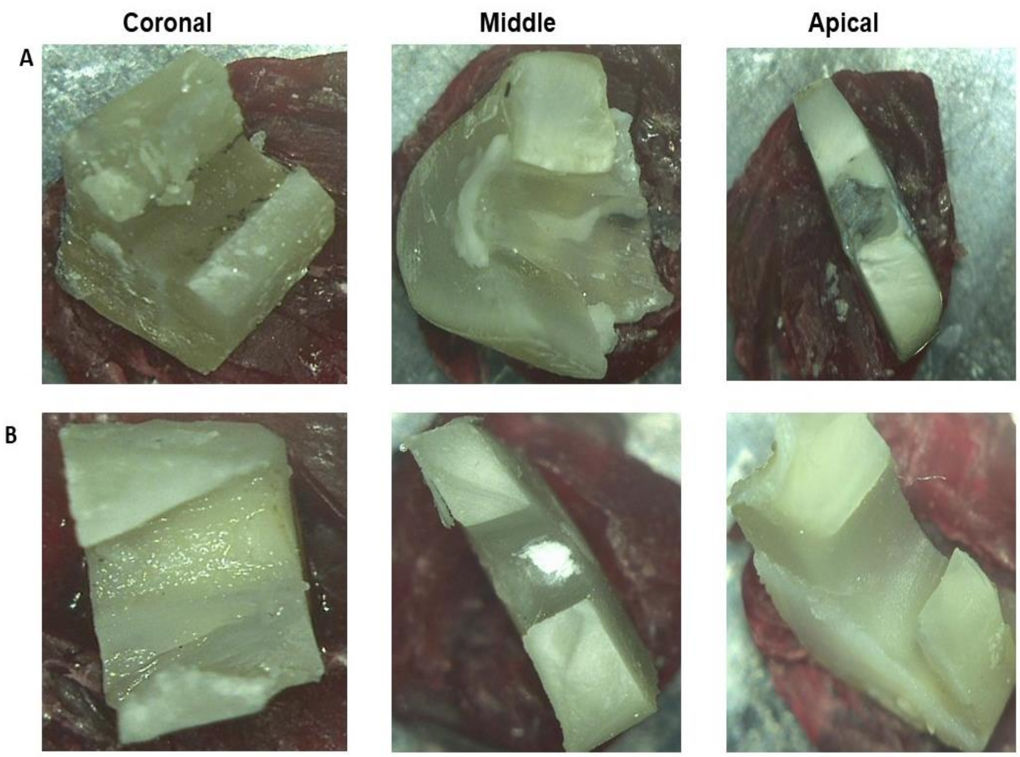


Figure 9: Mode of failure in each section of the two groups, A is group1, B is group 2.

The mode of failure for group 3 and group 4 for each section is shown in the figure10. Group 3, the coronal section and middle section mode of failure is 100% approximately adhesive failure and for the apical section it is 80% mixed failure approximately. For the group 4, the coronal section, middle and apical section has 90% adhesive and 10 cohesive failure approximately.

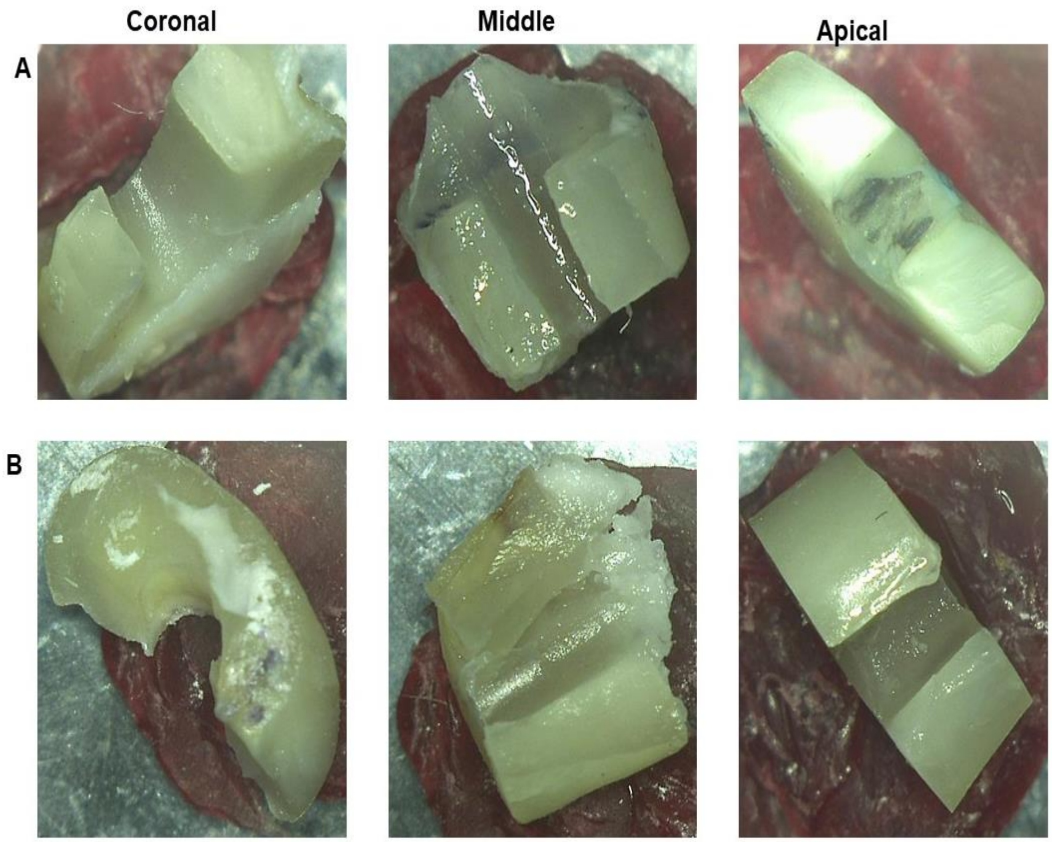


Figure 10: Mode of failure in each section of the two groups, A is group 3, B is group 4.

The mode of failure for group 5 for each section is shown in the figure 11. In group 5 the mode of failure for coronal section is 100% cohesive failure and for middle section it is 100% adhesive failure and for the apical section it is 80% adhesive and 20% cohesive failure approximately.

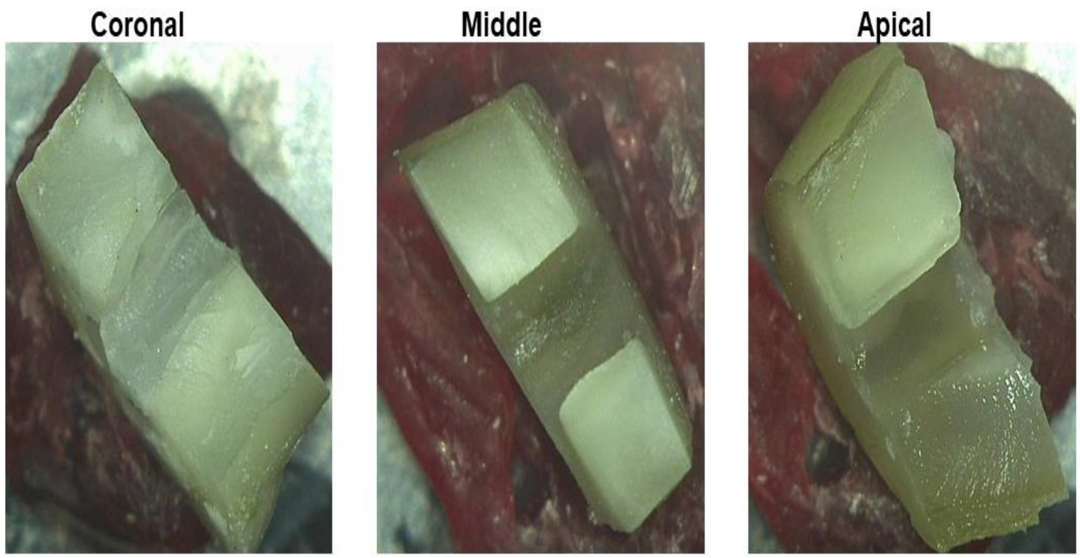


Figure 11: Mode of failure in each section of Group 5.

- Most of these failure are mixed failures (adhesive and cement).
- Adhesive failures were present when the adhesive was not light cured, the control and the group 5 were 90% cohesive failure.

DISCUSSION

The null hypothesis was rejected as there is a difference in post retention when an adhesive or light cure is applied during post cementation.

When we don't light cure the adhesive and cement the tensile strength drops compare to the group that is light cured both the adhesive and the cement. The use of translucent light-transmitting posts has been recommended to enhance the polymerization of resin cement at increased depths[63]. Several studies[7, 12, 68] have reported a substantial reduction in the light intensity from coronal to apical area of the root canal even when translucent fiber posts were used. However, the ability of light-transmitting posts to increase the depth of cure of resin cements might be overestimated in several studies that implemented different polymerization criteria[8]. Aside from that, no study that we can find in the literature has demonstrated the ability of a fiber post to transmit enough light to increase the resin cement resin polymerization in the entire length of the canal space which is critical in increasing post retention. The limited depth of cure (DOC) is the result of the potential gradation of cure within the depths of the material due to light attenuation. The light transmission in the post deceases some along the length of the post- in the post light transmission it decreases toward the apical part of the post. In order to determine the depths of cure, several methods have been described in the literature[72]. In this study, the light-transmitting capabilities of new fiber post systems was examined with the use of endodontically treated, extracted premolar teeth. Posts were cemented into these sections representing the coronal, middle and apical sections of the root. Light applied to the post had to travel through the length of the post to the apex and also provide enough light energy to polymerize the resin cement and the adhesive. The resin cement cured with and without light curing through the occlusal of the post to measure the ability of light transmittance of the at its maximum level possible and thus cure each level of the resin cement. For this same reason, both light -cure resin cement and dual-cure resin cement was used to determine the auto-polymerization effect. In this study the light cure cement has good retention in all sections compared to dual cure cement used in four groups, and therefore when we light cure only the cement and not the adhesive as in group 5(light cure cement) and group 4 (dual cure cement), the retention in the middle section is same but the coronal and apical section for the group 5 are higher than group 4. For the fiber post the absorption, reflection, and transmission of the light seems to adequate to polymerize the light cured resin cement as well as light cured adhesive at all three levels. Likewise, the differences found in the light transmission values of many tested fiber posts may be related to composition[73]. In a previous study completed at UAB[74], the difference in the weight of the cured resin in simulated root canals revealed a clear correlation between the light transmittance and the type of post in regard to different fiber composition, fiber density and structural characteristics. The light transmission by this post is better than what has been previously reported by other authors and adequate to cure a light cure resin cement and the adhesive. The critical angle can be determined by the difference in refraction indices between the core and the cladding materials and represents the angle of incidence above which the total internal reflection occurs. If the light rays cross the boundary at angles lower than the critical angle, then they are refracted from the core into the cladding, preventing light transmission along the fiber. The differences in light transmission among various posts can be attributed to differences found in the fiber diameter, fiber orientation pattern and matrix[63]. The experimental post used in this study (iLumi fiber optic post) is composed of fibers that each one (core) is coated with high “Numerical Aperture” (NA) cladding that is responsible for forcing all light rays in the acceptance angle to be totally internally reflected and transmitted to the end. As D.T. light post fibers are not bounded from the same cladding as the iLumi post, the significant difference in the weight and length of cured cement between the two posts used in the previous UAB thesis, could verify the superior light- transmitting ability of the latter. In this study the results shows that this iLumi fiber post can adequately cure a light cure resin cement and adhesive in all the sections of the canal.

LIMITATIONS

Based on results and Discussions we have deduced that the results and conclusion of this study are based on an in-vitro evaluation where oral and clinical conditions are not fully replicated and there is a need to test more post strengths to determine the potential durability of the post especially in fatigue testing. The above results in this study concluded that light cured cement has good tensile strength in all the three sections-coronal section, middle section, apical section of the tooth compared to dual cure cement and therefore concluded that if the post has low strength this has to be improved to increase the strength and prevent possible clinical post fractures.

CONCLUSIONS

Within the limitations of the present study, the iLumi post can transmit light and polymerize a light cured resin cement retained post as measured by the post retention in the coronal, middle and apical section of extracted teeth. With the above results in this study I concluded that the retention of post cemented no light curing produced the lowest post retention of all groups.

FUTURE RESEARCH

Previous and current studies are based on invitro, which did not have proper set of protocol, So the future research should focused on a protocol for predictable chairside use and exploitation of the advantages of this new iLumi fiber post system at its maximum. Also the future research has to be focused on varying the light curing time to obtain the optimal bond of the post in the canal has to be conducted. There is no study conducted on different curing units, this invitro future research has to be conducted to see an effect on retention of the post. There is no previous studies that show different adhesive cure better in low light ones with camphor quinone photoinitator in it, this future research on the iLumi fiber posts has to be conducted. Also, to determine the bond of iLumi fiber posts with resin modified glass ionomer cements to see the bond strength of the iLumi fiber post would be the future research of the study.

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