THE FRACTURE CHARACTERISTICS OF GLASS FIBER POST AND CORE ON USING DIFFERENT TYPES OF CORE RESIN MATERIALS

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Statement of problem. Glass fiber post is one of recent developments to accommodate esthetic restoration for endodontically treated teeth. This has many advantages over conventional post system in physical properties, esthetic factor, risk of root and restoration fracture, adhesion to core, radiopacity, removal and retrievabilty, biocompatibility and chemical stability.
Purpose. This in vitro study was to evaluate the most suitable type of resin core for the glass fiber post through surveying the fracture modes and the maximum load that fractures the tooth.
Material and methods. 50 sound maxillary premolars restored with glass fiber posts(ParaPost® Fiber White) and different types of resin cores(ParaCore, Z100™, Rebilda® and Admira®) were prepared and loaded to faiure in a universal test machine.
The maximum fracture load and fracture mode were investigated in the specimens that were restored with resin and those of metal cast and core. With the data, Wilcoxon rank sum test was used to validate the significance between the test groups, and Tukey' s studentized range test was used to check if there is any significant statistical difference between each test group. Every analysis was approved with 95% reliance.
Results. On measuring the maximum fracture load of teeth specimens, there was a significant difference between the maximum fracture loads of the tooth specimens. ParaCore showed the highest mean maximum fracture load followed by Z100™. And, the distribution of fracture mode of tooth specimens showed generally Type D, the three parted fracture of the core around the post was mostly seen(62.5%), and specifically, ParaCore showed 90% and Z100™ showed 100% Type D fracture.
Conclusion. Referring to the values of maximum fracture load and mean compressive fracture load, ParaCore and Z100™ had high values and are recommended as tooth colored resin core material for glass fiber post.
CLINICAL IMPLICATIONS. This study was carried out intending to be of aid in selecting the appropriate resin core for the glass fiber post. The dual cure type composite resin ParaCore and light cure type composite resin Z100™ have good properties and are recommended as tooth colored resin core material for glass fiber post.

Key Words
Glass fiber post, Fracture, Core resin

Over the past 20 years, there has been a rapid progress in developing dental materials for restorations. And because of increased demands for natural and esthetic dental treatment, there are many efforts in improving the physical and mechanical properties of dental material used in esthetic dentistry.

Teeth, which are extensively damaged through dental caries or trauma, generally require endodontic treatment followed by post and cores, to preserve the remaining root and to restore the lost tooth structure, before restoring the tooth with a crown.

After the development of the first post made of wood by Fauchard in the 18th century, many posts of various forms and materials were made. The early posts were made of wire, which were the improved through the development of casting techniques. In the 1970s, ready-made posts made of gold alloys, stainless steal etc. were developed. In the 1980s, carbon fiber posts were made in regards to prevent root fracture. And in the 1990s, zirconium posts were made to improve esthetics.[1-6] Although cast posts, ready-made posts, carbon fiber posts and zirconium posts are generally used under all ceramic crowns, they still have the problems of falling out, causing root fractures and unsatisfying esthetics. Cast metal posts and ready made posts have good strength, but the shade, translucency, and root fracture caused by discrepancy of physical properties with the tooth structure is still a problem.[1-6] Zirconium posts and quartz fiber posts have the shade similar to teeth. Zirconium posts have great shade and translucency, but still has a potential to cause root fracture due to the difference of physical properties between the post and the tooth, and the adhesive strength to the resin core is lower than that of other posts. Quartz fiber posts have the advantage of having the appropriate elasticity, reducing the possibility of root fracture, but because of the carbon particles, it cannot provide us with the satisfactory shade and translucency. Quartz fiber posts are also very radiolucent.[2-4]

The most resent post, the glass fiber post, is a post with biocompatible glass fiber and fillers mixed into the resin matrix. It is reported to have the advantage over the existing post in physical properties, esthetics, potential of root and restoration fracture, adhesive strength with the core, radiopacity, biocompatibility, chemical stability and in many other aspects, and it can be easily removed and retreated when needed. Especially the physical properties such as the modulus of elasticity, yield strength, flexural strength are similar to the dentin, which reduces the possibility of root fracture.[2-6]

For the core, which is placed on the post to replace the lost tooth structure, amalgam, glass ionomer cement reinforced with silver, hybrid glass ionomer, compomer and composite resin etc. are the materials of choice. Amalgam has good physical properties and is economical, but has the problems of slow setting time, low adhesive ability to the tooth structure, discoloration of adjacent tissue due to corrosion. Glass ionomer cement reinforced with silver, hybrid glass ionomer and compomer have advantages in setting time, adhesive ability to the tooth structure, resistance to decay(from fluoride), but has lower physical properties compared to amalgam and composite resin. Therefore composite resin is the most recommended material to use beneath all ceramic restorations because of its relatively superior physical properties, shade, adhesive ability to the tooth structure, convenience, and setting time.[2,7-12]

There are many factors that influence the prognosis of a tooth restored with post and core, the most consequential factor is the remaining coronal tooth structure. In the early days, posts and cores were used to strengthen the endodontically treated tooth. But actually the post and core itself does not influence the strength of the tooth. It relates only to the resistance and retention of the coronal restoration. Teeth restored with post and cores can occasionally fail, which leads to post, core or root fracture.[13-18]

There are many studies reported about carbon fiber posts, but still there are insufficient amount of studies about using the recently developed glass fiber posts, and further more there are no lab studies using natural teeth restored with glass fiber posts. In this study, natural teeth restored with glass fiber posts, which is the most suitable post to use beneath all ceramic crowns for esthetics, and different types of resin cores were prepared and intraoral load was represented with the universal test machine. The fracture modes and the maximum load that fractures the tooth, according to the type of the resin core, were surveyed. The data was then used to figure out the most suitable type of resin core for the glass fiber post. This study was carried out intending to be of aid in selecting the appropriate resin core for the glass fiber post.

MATERIAL AND METHODS

Red color coded ParaPost® Fiber White(Coltene Whaledent® Inc., Mahwah, U.S.A.) with a diameter of 1.25mm was used for the glass fiber post. ParaCore(Coltene Whaledent® Inc., Mahwah, U.S.A.), Z100™(3M Dental Products, St.Paul, U.S.A.), Rebilda®(VOCO, Cuxhaben, Germany) and Admira®(VOCO, Cuxhaben, Germany) were used for the core resin(Table I). The tooth surface, which will face the core was treated with the manufacturers recommended adhesive system (Table II).

First, we cleaned the post with alcohol and then washed it with air water syringe. The surface was sandblasted and etched for increased adhesive strength with the tooth structure.[19] We sandblasted the surface with Minilbaster™(Miniblaster, Israel), which is used attached to the unit, in 4 directions for 2 seconds each from a distance of 3cm using 50㎛ aluminum oxide. Then it was etched

Table I. The resin cores used in this study

Name	Polymerization mode	Main compositions	Manufacturer
ParaCore	Dual cure	Bis-GMA, EGDMA, TMPTMA Dibenzoyl peroxide	Coltene Whaledent® Inc. (Mahwah, U.S.A.)
Z100™	Light cure	Bis-GMA, TEGDMA	3M Dental Products (St.Paul, U.S.A.)
Rebilda®	Self cure	Bis-GMA, UDMA Dibenzoyl peroxide	VOCO (Cuxhaben, Germany)
Admira®	Light cure	Ormocers®, Bis-GMA, HEMA	VOCO (Cuxhaben, Germany)

* Bis-GMA : Bisphenol A diglycidyl methacrylate
EGDMA : Ethylenglycol dimethacrylate
TMPTMA : 1,1,1 Trimethylolpropan trimethacrylate
TEGDMA : Triethylenglycol dimethacrylate
UDMA : Diurethane dimethacrylate
Ormocers® : 3-dimensionally curing anorganic-organic co-polymers

Table II. The bonding systems used in this study

Name	Bonding system	Compositions
ParaCore	ParaCore system	Etching gel (ETCHANT 15) ParaPost® Adhesive Conditioner A ParaPost® Adhesive Conditioner B
Z100™	Scotchbond™	Etchant Primer / Adhesive Activator / Catalyst Ceramic primer
Rebilda®	Solobond Plus	Etching gel (Vococid) Primer / Adhesive
Admira®	Admira® Bond	Etching gel (Vococid) Total etching bonding agent

Fig. 1. Schematic drawing of test specimen showing dimensions in mm.
a. Bucco-lingual view of the tooth specimen
b. Occlusal view of the tooth specimen

with 37% phosphoric acid and washed using air water syringe for 1 minute.

50 sound maxillary premolars were selected and rinsed in sodium hypochlorite and reserved in saline. First of all, all the coronal portions of the teeth were prepared under water spray with a diamond disc. The canals were shaped to the file #45. The teeth were positioned on the sample holder and buried in acrylic resin(ORTHO-JET, Lang Dental Mfg. Co. Inc., Wheeling, U.S.A.). Then the surfaces were smoothened perpendicular to the longitudinal axis of the tooth with 500-grit SiC paper. The canals were prepared 7mm deep with a 1.25mm diameter red color coded Para Post® standard drill, rinsed with 2.25% sodium hypochlorite and saline and were not filled.

And for standardization of the canal preparation, a metal template with a cylindroid of 1.5mm minor axis, 2.5mm major axis and 2.5mm height was made and located exactly in the pulp chamber. Sections of the teeth were made with a diamond disc under water spray.

The length of the processed glass fiber post, having a 1.25mm diameter, were adjusted to 11mm with a coronal length of 4mm. The canals were dried with air and paper points, treated with self etching ED primer(Kuraray Co. Ltd., Osaka, Japan) for 60 seconds and dried again. Resin cement(Panavia F®, Kuraray Co. Ltd., Osaka, Japan) was applied on a lentulo spiral to spread the cement on the walls of the canal, and on the post surface for adhesion. The post was placed into the canal and pressed with finger pressure. The surplus cement was removed with a brush and the remaining cement was cured with light(XL3000, 3M Dental Products, St. Paul, U.S.A.) from 4 directions for 40 seconds, and neatly removed.

In order to form casts of the same size, a cylindroid of 3.5mm minor axis, 5.5mm major axis and 4.5mm height was cast, then finished with the milling machine. Then Pattern resin(GC Corp., Tokyo, Japan) was coated on the cast core surface, removed after setting time, then cast to make a standard metal template (Fig. 1).

Using the standard metal template, the resin cores with the shape of a cylindroid of 3.5mm minor axis, 5.5mm major axis and 4.5mm height were made by curing 2mm after 2mm. The light curing time or setting time, depending of the polymerization method, was abided by the manufacturers instructions.

The post and core for the control were built with Spee-Dee Plastic pin(Pulpdent Corp. of America) and Pattern resin(GC Corp., Tokyo, Japan) using the direct method, then cast with Type Ⅳ gold alloy. The coronal core was made with the same standard metal template to standardize the size.

The cast metal post and core went through sandblasting procedure and adhesed with Resin cement(Panavia F®, Kuraray Co. Ltd., Osaka, Japan) like the glass fiber post.

40 resin cylinders(10 of every type) of 3mm diameter and 10mm height were made to test the compressive fracture load of the resin cores.

Thermal cycling using the Thermocycling tester(Tokyo TL., Tokyo, Japan) was carried out to reproduce the same thermal change as the oral cavity.[7,20] The temperatures for the two water tanks were set to 5℃ and 55℃. The thermal cycling for the samples were wet to 1500 cycles. And the dwell time of the water tanks and the transfer time between the water tanks were set to 15 seconds.

To place the load 45° to the longitudinal axis of the tooth evenly, a special transparent zig was made with acrylic resin(ORTHO-JET, Lang Dental Mfg. Co. Inc., Wheeling, U.S.A.) to place the tooth stably. And a core covering zig which covers 2mm of the coronal core was made (Fig. 1) to prevent the load from local conventration and to define the angle of the load.[21-23]

The tooth block was placed on the universal test machine(Instron 6022, Instron Ltd, U.K.), load was given with the cross head speed set to 1mm/min untill the tooth fractured, to measure the maximum fracture load of the post and core. The compression fracture load of the resin samples were also measured.

After the fracture load test, the fracture lines were observed and classified into type A to E (Fig. 2). The most typical tooth of each type was selected, cut bucco-lingually through the middle of the post and core with a Low speed saw(ISOMET, BUEHLER, Lake Bluff, U.S.A.) under water spray. And the fracture surface was observed under SEM(S-2700, HITACHI, Ltd., Japan), amplified to ×200.

With the data of the maximum fracture load of each tooth and compressive fracture load of the resin samples, Wilcoxon rank sum test was used to validate the significance between the test groups, and Tukey' s studentized range test was used to check if there is any significant statistical difference between each test group. Every analysis was approved with 95% reliance.

RESULTS

Measurement of the maximum fracture load of the tooth

Maximum fracture load of the tooth specimens according to the Wilcoxon rank sum test, there was a significant difference between the maximum fracture loads of the tooth specimens. Among ParaCore, Z100™, Rebilda® and Admira®, ParaCore showed the highest mean maximum fracture Load followed by Z100™. Both the cast metal post and core specimen did not fracture till the load of 1000N. According to the Turkey test, there was significant difference between ParaCore and

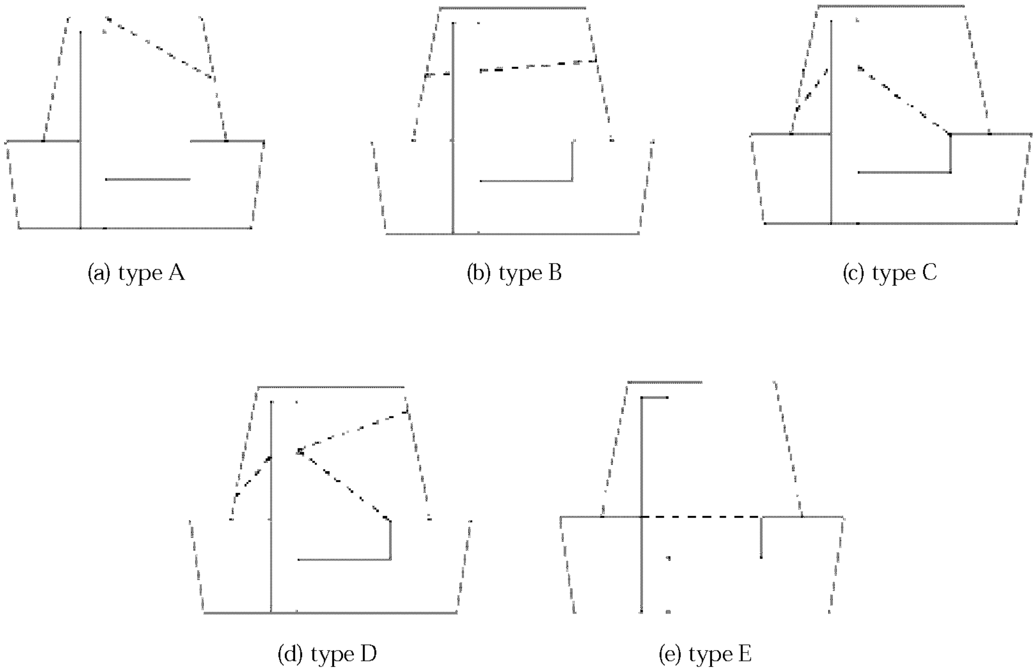

Fig. 2. Schematic representation of main fracture lines in catastrophic failure.
(a) type A : The fracture of the core unrelated to the post.
(b) type B : The fracture of the core without the fracture of the post, the fracture line is parallel to the tooth cutting surface.
(c) type C : The two parted fracture of the core around the post.
(d) type D : The three parted fracture of the core around the post.
(e) type E : The fracture of the post and core.

Rebilda®, ParaCore and Admira®, Z100™ and Rebilda®, and Z100™ and Admira®, but no significant difference between ParaCore and Z100™ and Rebilda® and Admira®.(Fig. 3, Table III)

Measurement of the compressive fracture load of the resin samples

According to the Wilcoxon rank and sum test, there was significant difference among compressive fracture load of the resin specimens. Among ParaCore, Z100™, Rebilda® and Admira®, Z100TM showed the highest mean value followed by ParaCore. According to Turkey test, There was significant difference between ParaCore and Admira®, Z100™ and Rebilda®, Z100™ and Admira®, but there was no significant difference between ParaCore and Rebilda®, ParaCore and Z100™, and Rebilda® and Admira®.(Fig. 4, Table IV)

Fracture patterns

The distribution of fracture mode of tooth specimens is as shown in Table Ⅴ, generally Type D, the three parted fracture of the core around the post was mostly seen(62.5%), and specifically, ParaCore showed 90% and Z100™ showed 100% Type D

Table III. The means of maximum fracture load of teeth specimens(N)

	n	Means ± SD (N)	Tukey gruop
ParaCore	10	697.6 ± 87.7	A
Z100™	10	586.7 ± 97.4	A
Rebilda®	10	365.5 ± 69.9	B
Admira®	10	354.4 ± 78.0	B
Cast post	10	1000≤	

* n : number of specimen SD : standard deviation
A, B : statistical grouping for load value of materials (Kruskal-Wallis test & Tukey grouping) significantly different between groups($p<0.05$)

Table IV. The means of compressive fracture load of resin specimens(N)

	n	Means ± SD (N)	Tukey gruop	
ParaCore	10	1121.1 ± 167.9	A	B
Z100™	10	1330.4 ± 172.7	A	
Rebilda®	10	989.5 ± 152.5	C	B
Admira®	10	864.5 ± 173.4	C	

* n : number of specimen SD : standard deviation
A, B, C : statistical grouping for load value of materials (Kruskal-Wallis test & Tukey grouping) significantly different between groups($p<0.05$)

Table V. The distribution of fracture mode of teeth specimens

	type A	type B	type C	type D	type E
ParaCore		1		9	
Z100™				10	
Rebilda®		4	2	3	1
Admira®	2	4	1	3	

fracture. By Rebilda® and Admira®, Type B the fracture parallel to the tooth cutting edge limited to the core was seen mostly(40%).

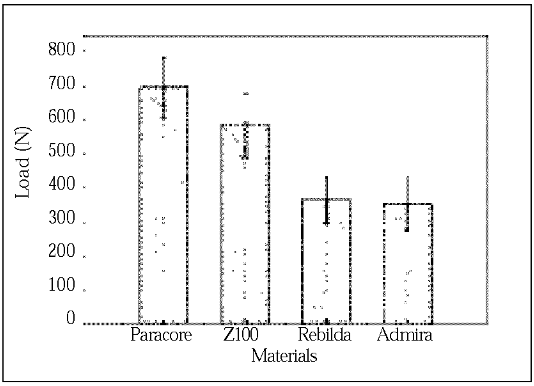

Fig. 3. The means and standard deviations of maximum fracture load in the tooth specimens.

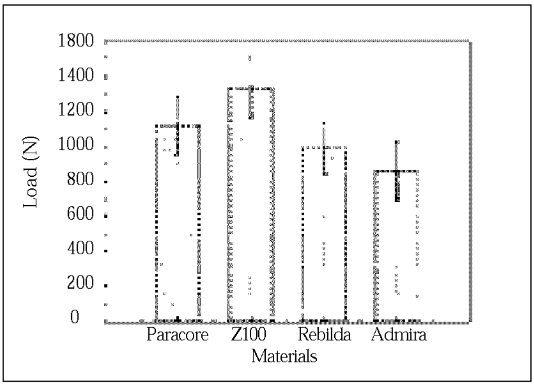

Fig. 4. The means and standard deviations of compressive fracture load in the resin specimens.

Scanning Electron Microscope (SEM) view of the fracture region

According to the SEM view of type A(Fig. 5), which the fracture of the core is not related the post the fracture sites of the teeth, and type C, which shows a two parted fracture of the core around the post(Fig. 9), we can see that the bond between the glass fiber post and resin core is firm. And in type B(the fracture is restricted to the core, unrelated with the post and the fracture line is parallel to the incisal edge), the resin core and dentin was separated, but the bond between the glass fiber post and resin core was firm(Fig. 6). And it can be seen

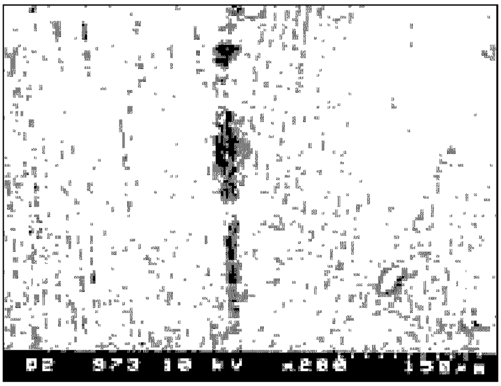

Fig. 5. The interface of glass fiber post and resin core in type A fracture(×200)
(F : Glass fiber post, R : Resin core)

Fig. 6. The interface of glass fiber post, resin core and dentin in type B fracture(×200)
(F : Glass fiber post, R : Resin core, D : Dentin)

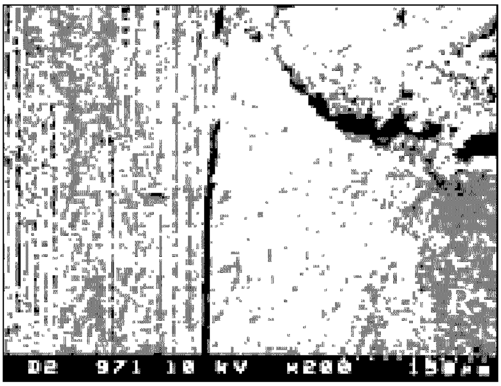

Fig. 7. The interface of glass fiber post and resin core in type B fracture(×200)
(F : Glass fiber post, R : Resin core)

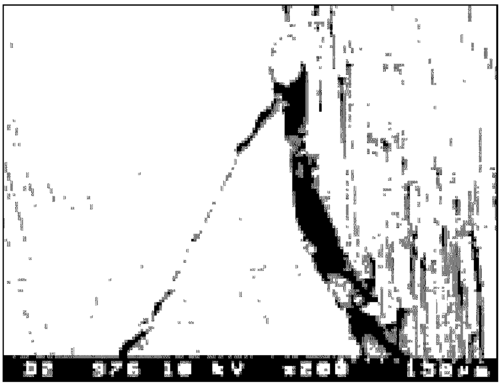

Fig. 8. The interface of glass fiber post and resin core in type D fracture(×200)
(F : Glass fiber post, R : Resin core)

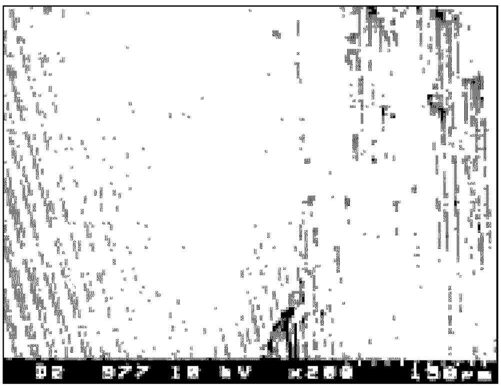

Fig. 9. The interface of glass fiber post and resin core in type C fracture(×200)
(F : Glass fiber post, R : Resin core)

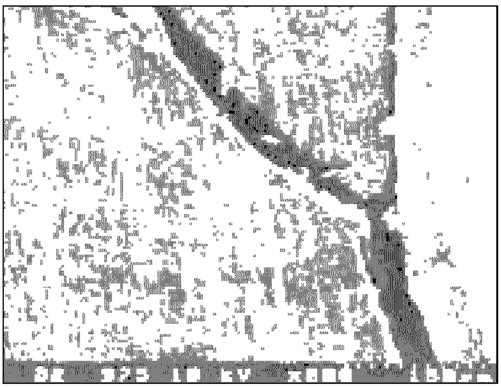

Fig. 10. The fractural interface of metal cast post and dentin (×200)
(D : Dentin, C : Cast post)

that the bond between the glass fiber post and resin core at the site of fracture(Fig. 7, 8). And the broken bond between glass fiber post and resin core is to be seen at the region containing fracture lines. And although the tooth that was restored by metal cast post and core did not fracture under high load, there was a root fracture in the cross section of the samples(Fig. 10).

DISCUSSION

Glass fiber post is a recently developed material, which is used under all ceramic restorations for a more natural and esthetical appearance. Its physical properties, esthetics, risk of root fracture and restoration fracture, adhesive properties to the core above, radiopacity, and possibility of removal and retreatment are considerably superior compared to the existing post system. And it is also biocompatible and chemically stable.[2-6] But glass fiber post is not a panacea. It tends to bend when in contact with intraoral saliva and there is risk of secondary dental caries and dislocation of the post, which is the result of its sensibility to humidity.[24] Therefore careful treatment is required at practice.

The practitioner has to consider many factors when choosing a post system. Resistance of root fracture and the fracture of the post itself, retention, stress breaking ability, esthetics, like shade and translucency, coherence with other core materials and function of the post-core as one unit through cohesion etc. are those factors.[5,6]

There are to major patterns of post and core failure. One of them is caused from retention loss as the dislocation of the crown and post. The other is caused from the fracture of the root, post and core.[15,16] Hatzikyriakos et. al. has reported failure patterns 3 years after endodontic treatment and restoration. Root fracture occupied 2.6%, complex influence from root caries and destruction of the post and core took up to 1.9% and loss of cement between the crown and post-core occupied 3.2%.[15] Torbjorner et. al. reported, based on 4-5 years of postoperative clinical assesment, that retention loss is the major of post failure, and that maxillary teeth show more failure than those of the mandible, especially the maxillary incisors.[16]

The water content of the dentin-root complex is related to the endodontic state of the tooth. And age is in invertial proportion to the water content, due to the accumulation of the dentin around the tubules. And the coronal dentin contains double the amount of dentinal tublues than that of the root. Furthermore there is a risk of overloading when to much tooth structure is removed from caries removal, accessing the cavity or shaping the canal. And decrease of tactile sensation due to deterioration in the function of the periodontal ligament also involves risk of overload.[25-28] Therefore the fracture resistance of the nonvital tooth depends mostly on the residual tooth structure.[17,27-30] According to Tjan and Whang et. al., 2-3mm of residual tooth structure after the post gives significant resistance to fracture.[29] And Sorensen and Engleman et. al. reported that it is important to maintain more than 1mm of coronal tooth structure above the metal collar ferrule.[30] Milot and Stein et. al. reported that when most of the tooth stucture remains, the post has almost nothing to do with resistance of root fracture.[17] And after there was a suggestion that the ferrule effect has little to do with wedging effect or resisting the root fracture, cast metal post and cores are almost not indicated.[30-32]

Maintaining the residual tooth structure is one of the purposes of restoring the endodontically treated tooth.[33] Therefore the fracture restricted to the core, which leaves chance in restoring the tooth, is a much more favorable fracture compared to the fracture of the root, which almost always leads to extraction.[34] Cast metal post and cores do bear a considerably heavy load,[35] but although glass fiber post and resin core bears less, it can maintain the tooth structure through the fracture of the core. In other words, the fracture of the core prevents the fracture of the root.[34]

Much the same in this study, the tooth restored with cast metal post and core beared a relatively heavy load, but according to the SEM view, it can be seen that there are indications of root fracture (Fig. 10). Therefore this study is in accord with the other study results in the fact that the composite resin gave way at a lower load than the root.[34-36] However, it is not easy to retreat the tooth with a fractured post that does not involve any sound tooth structure. But the glass fiber post can be a solution to this problem.[35]

The materials used to substitute the lost coronal portion are amalgam, glass ionomer cement reinforced with silver, hybird glass ionomer, compomer and composite resin. But the most appropriate material to use under the all ceramic crown is the composite resin, which has the proper shade, relatively better physical properties, adhesability to the tooth structure and convenience.[2,7-12] But composite resin might deform permanently through mechanical stimulation and heat. It also has poor volume stability that can lead to dislocation of the core and failure of the restoration.[2,12,23,37,38] Dislocation of the core can bring about recurrent dental caries and failure of the endodontic treatment. And therefore titanium and lanthanide particles are added to reinforce the mechanical properties. However it must not be overlooked that the residual tooth structure plays a important roll in the prognosis.

The self cure system and dual cure system are recommended for the composite resin. Resin using the light cure system has the risk of incomplete polymerization due to failure of intensity of the light source, insufficient exposure to the light and excessive thickness. In contrast, autopolymerized resin is more convenient as the paste type, and because of its favorable flow, it is much easier to shape and inject into the void in the tooth structure.[8,39]

When choosing the core material, the amount and mode of stress must be considered because it effects the stress transmission of the post. As the firmness increases, the stress goes more directly to the root and less to the post.[23] Metal cores are known to cause great stress in the coronal part and to send the stress directly to the root.[11,40] It is also important to choose a core which has similar physical properties with the post, because of the favorable strong interface and lower risk of microleakage and failure.[11] Because glass fiber post consists of 42% glass fiber, 29% filer and 29% of resin in weight percentage,[2] chemical adhesion with the composite resin can also be expected. Trope et. al. reported that shaping the canal weakens the tooth, and that although the post cannot strengthen the tooth, the strength can be improved by filling the post cavity and access cavity with composite resin.[28]

Most of the microleakage between the tooth and composite resin occurs because of the shrinkage of the resin, which can be reduced by using the dentin bonding system.,[40] Microleakage causes fluid contamination and dissolution of the material,[42] and decrease of the adhesive strength of the core which results in the increase of the risk of core fracture.[21] Therefore the failure rate of the post and core can be improved by using additional adhesion between the resin core, adhesive system and dentin.[43] External circumstances, like the cleanliness of the tooth surface, also play a role in adhesion of the resin and the tooth. For example, residual temporary cement is thought to be a primary factor that causes decrease of adhesion strength between the resin and dentin. Especially temporary cements containing euginol softens the resin core, therefore may not be used.[44-47]

According to type A, the fracture of the core unrelated with the post, and type C, which shows a two parted fracture of the core around the post through the SEM view of the fracture sites of the teeth, we can see that the bond between the glass fiber post and resin core is firm. In type B(the fracture line is parallel to the incisal edge without any fraction of the post), the resin core and dentin was separated, but the bond between the glass fiber post and resin core was firm(Fig. 5). Considering the separation of the bond between the glass fiber post and resin core at the site of fracture, we can estimate that the bond between the core and dentin breaks first, then the adhesive strength between the glass fiber post and resin core weakens, and the core breaks last. This estimation corresponds to the previously mentioned reports.[13,21,41,43]

Compressive strength and tensile strength are important factors of core material. Generally the core replaces a great part of the tooth structure. Therefore it must be able to bear functional and nonfunctional stress coming from many directions.[8] Toughness of a material is defined as the amount of energy needed to cause the fracture, which indicates the resistance of a material to fracture. But cracks of brittle materials tend to progress to fracture. This property has not much to do with the resistance to the crack at the start, but more to do with the resistance to the progression of the already existing crack or flaw.[48] Through studies and experiments, it is known that toughness of composite resin can be deteriorated due to moisture or contamination by saliva.[49-51] And thermocycling is related to microleakage, microcraking and surface dissolution of composite resin, but is not directly to deterioration of the toughness of the material.[20]

Cho et. al. have reported that light curing composite resin has more favorable compressive strength and tensile strength than that of autopolymerizing composite resin.[8] This corresponds to the result of this study, which shows that the light curing composite reisn Z100™ has sufficiently higher compressive strength than the autopolymerizing composite resin Rebilda®. The low filler content, in other words higher flowability, of the paste type Rebilda® compared to Z100™ might be the reason of this result. And Combe et. al. reported that ceramic filled composite falls behind hybrid resin composite in every aspect of physical properties, especially the compression strength related to the masticatory load.[9] In this study, the ceramic filled composite Admira®[52-54] showed the lowest value in the maximum fracture load and compressive fracture load tests, which corresponds to the other reports. Generally fillers improve the fracture toughness,[49,50,55] but when hard, irregular particles mix with comparatively soft resin matrix, the fracture toughness might decrease instead. It is presumed that this phenomenon is caused by overlapping of the particle modified energy field.[56]

That is, when Rebilda® and Admira® was used for core resins, because of the poor fracture strength due to their relatively low compressive strength and toughness, fracture type A and type B were the most frequent fracture patterns(Table Ⅴ). Here, type A is not related to the fracture of the core and type B is the fracture of the core itself, unrelated with the post and the fracture line is parallel to the incisal edge. And the maximum fracture load was also small and tooth specimens made by Z100™ and ParaCore which have relatively high compressive strength, also showed high fracture load (Table Ⅳ).

During this study, there were limitations in reproducing the fracture modes naturally, because the root was buried in acrylic resin block.[32,34] But the reason why we did not reproduce the periodontal ligament was, if the ligaments were to be reproduced by coating soft elastic rubber impression material on the root, not only that accurate angle of the load to the longitudinal axis of the tooth cannot be given, but the rubber material has its limitations in representing the function, alignment and viscoelasticity of the periodontal ligament.[21] And the canals were not filled, according to the results of many studies which point out that filling the canal does not influence the strength of the root.[57-59]

In this study, we investigated the failure patterns not through periodic, long-term load, but static, short-term load was applied to the tooth. Therefore additional study concerning about fatigue load,[21-23] insufficient adhesive strength between the resin cement and the crown, the effect of deformation of the resin core due to masticatory or shearing force on failure of glass fiber post, and whether the improvement of adhesive strength of the glass fiber post and resin core can lower the failure rate or not, is needed.

CONCLUSIONS

Glass fiber post is a recent development to accommodate esthetic restoration for endodontically treated teeth. Tooth specimens were made using glass fiber post(ParaPost® Fiber White) and different types of core resin materials(ParaCore, Z100™, Rebilda® and Admira®) and were loaded to faiure in a universal test machine. The maximum fracture load and fracture mode were investigated in the specimens that were restored with resin and those of metal cast and core. The results are as follows.

1. On measuring the maximum fracture load of teeth specimens, the order of maximum value was ParaCore, Z100™, Rebilda®, Admira®. ParaCore and Z100™ showed a significant higher value than Rebilda® and Admira®($p<0.05$).
2. The means compressive fracture load of resin specimens, the order was Z100™, ParaCore, Rebilda®, Admira®, and there were significant differences® between Z100™ and Rebilda®, Z100™ and Admira®, and ParaCore and Admira® ($p<0.05$).
3. The fracture mode of tooth specimens showed the type D fracture, the three parted fracture of the core around the post was most common type of the fracture mode(62.5%). The type D fracture appeared at 100% of ParaCore and 90% of Z100™. The type B fracture, the fracture of the core without the fracture of the post, the fracture line is parallel to the tooth cutting surface was most common at Rebilda® and Admira®(40%).
4. The teeth restored with metal cast post and core didn`t showed the fracture of post and core, in spite of high loads. However root fractures at the sectional view of specimens could be found.

In conclusion, referring to the values of maximum fracture load and mean compressive fracture load, ParaCore and Z100™ had high values and are recommended as tooth colored resin core material for glass fiber post. Further researchs using glass fiber post and composite resin for core material will be needed.

REFERENCES

1. Desort K.D. The prostodontic use of endodontically treated teeth : Theory and biomechanics of post preparation. J Prosthet Dent 49 : 203-6, 1983 .
2. Quintas A.F., Dinato J.C., Bottino M.A. Aesthetic posts and cores for metal free restoration of endodontically treated teeth. Pract Periodont Aesthet Dent 12 : 875-84, 2000.
3. Roberto Martelli. Fourth-generation intraradicular posts for the aesthetic restoration of anterior teeth. Pract Periodont Aesthet Dent 12 : 579-84, 2000 .
4. Freedman G.A. Esthetic post-and-core treatment. Dental Clinics of North America. 45(1) : 103-16, 2001.
5. Assif D., Bitenski A., Pilo R., Oren E. Effect of post design on resistance to fracture of endodontically treated teeth with complete crowns. J Prosthet Dent 69 : 36-40, 1993.
6. Assif D., Oren E., Marshak B.L., Aviv I. Photoelastic analysis of stress transfer by endodontically treated teeth to supporting structure using different restorative techniques. J Prosthet Dent 61 : 535-43, 1989.
7. Tirado J.I.M., Nagy W.W., Dhuru V.B., Ziebert A.J. The effect of thermocycling on the fracture toughness and hardness of core buildup materials. J Prosthet Dent 86 : 474-80, 2001.
8. Cho G.C., Kaneko L.M., Donovan T.E., White S.N. Diametral and compressive strength of dental core materials. J Prosthet Dent 82 : 272-6, 1999.
9. Combe E.C., Shaglouf A.M.S., Watts D.C., Wilson

N.H.F. Mechanical properties of direct resin core buildup materials. Dent Mater 15 : 158-65, 1999.
10. Levartovsky S., Goldstein G.R., Georgescu M. Shear bond strength of several new core materials. J Prosthet Dent 75 : 154-8, 1996.
11. Yaman P., Thorsteinsson T.S. Effect of core materials on stress distribution of posts. J Prosthet Dent 68 : 416-20, 1992.
12. Oliva R.A., Lowe J.A. Dimensional stability of composite used as a core material. J Prosthet Dent 56 : 554-61, 1986.
13. Mannocci, F., Ferrari, M., Watson, T.F. Microleakage of endodontically treated teeth restored with fiber posts and composite cores after cycling loading : A confocal microscopic study. J Prosthet Dent 85 : 284-91, 2001.
14. Margano S.M. Restoration of pulpless teeth : Application of traditional principles in present and future contexts. J Prosthet Dent 75 : 375-80, 1996.
15. Hatzikyriakos A.H., Reisis G.I., Tsingos N. A 3-year postoperative clinical evaluation of posts and beneath existing crowns. J Prosthet Dent 67 : 454- 81, 1992.
16. Torbjorner A., Karlsson S., Odman P.A. Survival rate and failure characteristics for two post designs. J Prosthet Dent 73 : 439-44, 1995.
17. Milot P., Stein S. Root fracture in endodontically treated teeth related to post selection and crown design. J Prosthet Dent 68 : 428-35, 1992.
18. Sorensen J.A., Martinoff J.T. Intracoronal reinforcement and coronal coverage : A study of endodontically treated teeth. J Prosthet Dent 51 : 780-4, 1984.
19. Tae-Hyung Kim, June-Sung Shim, Keun-Woo Lee. The study of shear bond strength using glass fiber post and composite resin core. J School of Dent. Yonsei univ. : in press.
20. Gale M.S., Darvell B.W. Thermal cycling procedures for laboratory testing of dental restorations. J Dent 27 : 89-99, 1999.
21. Huymans M.C., Peters M.C., Van der Varst P.G., Plasschaert A.J. Failure characteristics of endodontically treated premolars restored with a post and direct restorative materials. Int J Endodont 25 : 121-129, 1992.
22. Huymans M.C., Peters M.C., Van der Varst P.G., Plasschaert A.J. Failure behavior of direct post and core restored premolars. J Dent Res 71(5) : 1145-50, 1992.
23. Huymans M.C., Peters M.C., Van der Varst P.G., Plasschaert A.J. Failure behavior of fatigue-tested post and core. Int J Endodont 26 : 294-300, 1993.
24. Vallitu P.K., Ruyter I.E., Ekstrand K. Effect of water storage on the flexural properties of E-glass and silica fiber acrylic resin composite. Int J Prosthodont 11 : 340-50, 1998.
25. Gutmann J.L. The dentin-root complex : Anatomic and biologic considerations in restoring endodontically treated teeth. J Prosthet Dent 67 : 458-67, 1992
26. Helfer A.R., Melnick S., Schilder H. Determination of the moisture content of vital and pulpless teeth. Oral Surgery 34 : 62-5, 1972.
27. Assif D., Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. J Prosthet Dent 71 : 565-7, 1994.
28. Trope M., Maltz D.O., Tronstad L. Resistance to fracture of restored endodontically treated teeth. Endodontics Dental Traumatology 1 : 108-11, 1985.
29. Tjan A.H.L., Whang S.B. Resistance to root fracture of dowel channels with various thickness of buccal dentin walls. J Prosthet Dent 53 : 496-500, 1985.
30. Sorensen J.A., Martinoff J.T. Clinically significant factors in dowel design. J Prosthet Dent 52 : 28-35, 1984.
31. Loney R.W., Kotowicz W.E., McDowell G.C. Three-dimensional photoelastic stress analysis of the ferrule effect in cast post and cores. J Prosthet Dent 63 : 506-512, 1996.
32. Sirimai S., Aiis D.N., Morgano S.M. An in vivo study of the fracture resistance and incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent 81 : 262-9, 1999.
33. Sorensen J.A., Engelman M.J. Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent 63 : 529-36, 1990.
34. Fraga R.C., Chaves B.T., Mello G.S.B., Siqueira J.F. Jr. Fracture resistance of endodontically treated roots after restorations. J Oral Rehab 25 : 809-813, 1998.
35. Sorensen J.A., Engelman M.J. Effect of post adaptation on fracture resistance of endodontically treated teeth. J Prosthet Dent 64 : 419-24, 1990.
36. Bex R.T., Parker M.W., Judkins J.T., Pelleu G.B. Effect of dentinal bonded resin post-core preparations on resistance to vertical root fracture. J Prosthet Dent 64 : 412-5, 1990.
37. Kovarik R.E., Breeding L.C., Caughman W.F. Fatigue life of three core materials under simulated chewing conditions. J Prosthet Dent 68 : 584-90, 1992
38. Hirasawa T. et al. Initial dimension change of composite in dry and wet conditions. J Dent Res 62 : 28-31, 1983.
39. Plasmans P.J., Welle P.R., Vrijhoef M.M. In vitro resistance of composite resin dowel and cores. J Endodont 14 : 300-4, 1988.
40. Ko C.C., Chu C.S., Chung K.H., Lee M.C. Effects of posts on dentin stress distribution in pulpless teeth. J Prosthet Dent 68 : 421-7, 1992.
41. Tjan A.H.L., Grant B.E., Dunn J.R. Microleakage of composite resin cores treated with various dentin bonding systems. J Prosthet Dent 66 : 24-9, 1991.
42. Freemann M.A., Nicholls J.I., Kydd W.L., Harrington G.W. Leakage associted with load fatigue-induced preliminary failure of full crowns placed over three different post and core systems. J Endodont 24 : 26-32, 1998.
43. Rosentritt M. et al. Comparison of in vitro fracture

strength of metallic and tooth-coloured posts and cores. J Oral Rehab 27 : 595-601, 2000.
44. Watanabe E.K. et al. Temporary cements remnants as an adhesion inhibiting factor in the interface between resin cements and bovine dentin. Int J Prosthodont 10 : 440-52, 1997.
45. Xie J., Powers J.M., McGuckin R.S. In vitro bond strength of two adhesives to enamel and dentin under normal and contaminated conditions. Dent Mater 9 : 295-9, 1993.
46. Woody T.L., Davis R.D. The effect of eugenol-containing and eugenol-free temporary cements on microleakage in resin bonded restorations. Oper Dent 17 : 175-80, 1992.
47. DeWald J.P., Moody C.R., Ferracane J.L. Softening of composite resin by moisture and cements. Quintessence Int 19 : 619-21, 1988.
48. Lloyd C.H. The fracture toughness of dental composites. II. The environment and tenperature dependence of the stress intensification factor (KIC). J Oral Rehab 11 : 257-72, 1984.
49. Ferracane J.L., Antonio R.C., Matsumoto H. Variables affecting the fracture toughness of dental composites. J Dent Res 66 : 1140-5, 1987.
50. Lloyd C.H., Lannetta R.V. The fracture toughness of dental composites. I. The development of strength and fracture toughness. J Oral Rehab 9 : 55-66, 1982.
51. Lloyd C.H. The fracture toughness of dental composites. III. The effect of environment upon the stress intensification factor (KIC) after extended storage. J Oral Rehab 11 : 3 93-8, 1984.
52. Manhart J., Kunzelmann K.H., Chen H.Y., Hickel R. Polymerization contraction stress in light-cured packable composite resins. Dent Mater 17: 253-59, 2001.
53. Manhart J., Kunzelmann K.H., Chen H.Y., Hickel R. Mechanical properties and wear behavior of light-cured packable composite resins. Dent Mater 16 : 33-40, 2000.
54. Manhart J., Kunzelmann K.H., Chen H.Y., Hickel R. Mechanical properties of new composite restorative materials. Int J Biomed Mater Res 53 : 353-61, 2000.
55. Pillar R.M., Vowles R., Williams D.F. The effect of enviormental aging on the fracture toughness of dental composites. J Dent Res 66 : 722-6, 1987.
56. Goldman M. Fracture properties of composite and glass ionomer dental restorative materials. J Biomed Mater Res 19 : 771-83, 1985.
57. Leary J.M., Aquilino S.A., Svare C.W. An evaluation of post length within the elastic limits of dentin. J Prosthet Dent 57 : 277-81, 1987.
58. Trabert K.C., Caputo A.A., Abou-Rass M. Tooth fracture - A comparison of endodontic and restorative treatment. J Endodont 4 : 341-5, 1978.
59. Weine F.S. Endodontic therapy. CV Mosby p144 : 1976.
60. Young-Soo Lee, Ik-Je Kang. Mechanical properties of quartz fiber post. J Korea Academy of Prosthodontics. 40(1) : 68-78, 2002.

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