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Influence of glass fibre post cementation depth on dental root fracture

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SUMMARY

Introduction. Glass fibre posts that are newer and have better properties are gaining more popularity than metal posts. However, there is no consensus about the optimal cementation depth of glass fibre posts. In our study, we have attempted to assess fracture resistance of roots restored with glass fibre posts cemented at different root depths.

Materials and methods. Specimens were formed with peeso reamers and a special reamer adapted for the cementation of glass fiber posts at different depths. Glass fibre posts were cemented using self-etching cement: in group 1 – at the depth of 2/3 of the working length of the root canal (11 mm), in group 2 – at the depth of 1/2 of the working length of the root canal (7.5 mm) and in group 3 – at the depth of 1/3 of the working length of the root canal (5 mm). Dental roots were standardized by preparing their walls to equal measurements with a mill. Specimens were embedded on a metal plate at a 45° angle and were vertically pressed with a hydraulic press in buccolingual direction. Fracture force was recorded in Newton (N) to the breaking point.

Results. After data analyses with ANOVA and T-test software, the null hypothesis was confirmed: there was no statistically significant difference among the results of all 3 groups (P >0.05).

Conclusion. The cementation depth of the glass fibre posts that we studied has no influence on root fracture resistance.

Key words: post, depth, fracture resistance, root, core.

INTRODUCTION

The main function of a post and core is to provide stability to a restored tooth and to protect a tooth by evenly dispersing and distributing masticatory forces along the tooth. Up until 1980, cast metal posts and cores were used for the restoration of endodontically treated teeth. Demand for more aesthetics and better physical properties lead to the popularity of glass or carbon fibre reinforced zirconia and composite posts that are more and more often given preference to the metal ones in modern odontology (1).

The main factors that influence tooth strength are the interface between the post and the tooth and the post's stiffness and rigidity. If a too rigid metal post (harder than dentine) is used, tooth fracture risk increases (2).

Meanwhile, nowadays ceramic and glass fiber posts are preferred for their aestethic qualities, biocompatibility, good physical qualities and quality adhesive bonding with dental tissues (3). A glass fibre post is made of silanizated glass or quartz fibres bound by methacrylate- or epoxy-polymer matrix. The fibers guarantee strength, while the function of the methacrylate- or epoxy polymer matrix is to transfer load to the fibres and also to protect them from the moisture of the oral cavity (3). According to some authors, BisGMA and epoxy resin cements are most often used for the cementation of glass fibre posts as these resin-based materials create a strong bonding system and chemical and micromechanical bond with tooth tissue. Due to the fact that their modulus of elasticity is similar to that of dentine (18-42 GPa) and that they have a strong bonding system, glass fiber posts together with resin cement evenly distribute the forces affecting the tooth, stress forces are transmitted vertically along the root (4) and, thus, fracture resistance of a restored tooth increases (3).

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Glass fiber post system characteristically forms strong adhesive bonding between core buildup and tooth tissue: a gap-free single unit, a post-cement monoblock is created in which the loading forces are evenly distributed to all the components of the monoblock (3). This monoblock is a complex system composed of several parts inside of which operate multi-axial, unevenly-distributed stress fracture forces that depend on the external load and its direction (5). When a tooth is exposed to stress, glass fibres stretch evenly and uniformly to their breaking point. On removal of this stress, the fibres return to their original length (3).

With metal posts, the „gold standard" is their cementation at the depth of 2/3 of the working length of the root canal (6). However, the properties of glass fibre posts are different to those of metal posts, so cementation depth of glass fiber posts is open to discussion (7-9). According to some authors, when a post is cemented deeply (2/3 of the working length of the root canal**),** more hard tissues are removed while widening the root canal. As a result, root strength is compromised. The longer the glass fiber post, the more dentine is lost and the weaker the root becomes. Also, the deeper the post is cemented, the more difficult it is to achieve quality adhesive bonding between the post and tooth tissues along the whole length of the cementation. On the other hand, some authors assert that reduced fibre glass post length compromises its retention and increases stress force on the dentine (9).

Thus, although a post cemented at greater depth guarantees proper stability, biomechanical tooth resistance that directly relates to the amount of remaining tooth tissues should not be ignored. Therefore, in glass fibre post system the „gold standard" should be root canal preparation that is both sufficient to withstand pressure during mastication and as minimal as possible to minimize root weakening. This is particularly important in clinical situations with short roots and low clinical dental crowns. Besides, some authors suggest that with a glass fibre post properly set in the canal, its retention is already sufficient and great depth is unnecessary (10). Different sources most often recommend minimum 1-1.75 mm root dentine thickness around the post. Studies have also proved that smaller amount of root dentine (0.5 mm) around the post reduces root fracture resistance (7).

However, some authors believe that the stress experienced by glass fibre post system does not correlate with post's depth (8, 9). This conclusion was reached applying finite element method after restoring maxillary incisors model and assessing the transmission of stress forces in teeth with different depth glass fibre posts. „Finite element method (FEM) also referred to as finite element analysis (FEA) involves a series of complex calculations undertaken to predict specific results for a complex and specific geometric assembly by integrating outcomes obtained in smaller elements defined by a specific mesh. This analysis is particularly helpful for indicating the mechanical aspects of biomaterials and human tissue that can be difficult to measure *in vivo*" (11). This method allows to calculate tension in various biological structures. It has been concluded that the deeper a post is cemented, the better its stability is. However, this study does not reflect a real clinical situation as it is based only on mathematical computations. Not only the depth of glass fibre post cementation is clinically very important; other important factors include post adaptation in the canal, total working lenght of the root canal, the distance between the tip of the post and the apex that should not be less than 3mm in order to ensure proper sealing (9).

The presence of a ferrule strongly influnces the strength of the tooth restored with a post. It is thought that while preparing a tooth for coronal restoration when that tooth has lost a lot of tissue, giving a full 360° circumferential ferrule considerably increases tooth fracture resistance (4, 7, 12). Besides, it is argued that the ferrule plays an important role in the distribution of the post and core stress forces to the whole tooth-post complex and significantly reduces stress forces that accummulate in the cervical area (5). Authors define the "ferrule effect" is a longstanding restoration principle applied to treat teeth that have suffered substantial structure loss. A shoulder is formed around the tooth widening the crown in the direction of the root apex. This preparation technique reduces stress forces on the tooth, thus protecting the tooth from fracture. It is believed that the ferrule effect strengthens teeth against functional, lateral and wedging forces and reduces the accumulation of stress forces in dental tissues (4) (Figures 1, 2). Studies have proved that even a 2mm ferrule preparation increases root fracture resistance (4, 8, 13).

In view of the most recent studies, the tendency to cement posts deeper in order to improve their stability is feasible when the ferrule is not prepared. For this method, tapered posts should be given preference because with deeper cylindrical post cementation its diameter will be wider at the breaking point. In general, in clinical practice cylindric posts are more and more often substituted with tapered ones: cylindric post use is linked both with removal of more dental tissue and the destruction of the natural canal shape at preparation, and this compromises the strength of a restored tooth (8) .

Many different factors influence the strength and fracture resistane of an endodontically treated tooth restored with glass fibre post, post cementation depth being one of them. However, in literature there is no

Fig. 1. No ferrule effect

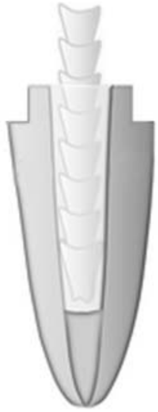

Fig. 2. Ferrule effect

uniform opinion about optimal glass fibre post length. Different authors have different recommendations. The length recommended in various resources is equal to or greater than the hight of the crown, or it is recommended to calculate it according to the canal lenght: half, two thirds or three fourths of the root lenght (14).

This study sought to evaluate fracture resistance of dental roots with glass fibre posts cemented at different depths.

MATERIALS AND METHODS

This study used 18 recently extracted, caries- and crack-free, endodontically untreated filling-free mandibular central incisors that before the study (not longer than 3 months) were stored in physiologic sodium chloride solution at room temperature. Exterior teeth root surfaces were sandblasted; the roots of all teeth were standardized to 15 mm. All teeth were treated endodontically: pulp chambers were opened, the canal locations were found, canals were widened with „K3 Files" („Kerr") machine instruments, irrigated with 2% sodium hypochlorite solution "Chloraxid" („Cerkamed"). Canals were dried and obturated with single cone „K3" gutta-percha points using „Pulp fill" („Biodinamica") sealer. 24 hours later specimens were randomly divided into 3 groups, 6 teeth per group, and their canals were widened at different depths by size 1, 2, 3, 4 peeso („FKG swiss endo") reamers (0.70 mm, 0.90 mm, 1.10 mm, 1.30 mm in diameter) and by a special tapered „FibreKleer 4X" („Pentron") reamer (violet colour, 1.375 mm in diameter) that is tailored for glass fibre post cementation: in group 1 – at 11 mm depth (2/3 of the working lenght of the root canal); in group 2 – at 7.5 mm depth (1/2 of the working lenght of the canal); in group 3 – at 5 mm depth (1/3 of the working lenght of the canal) (Table). In each group of the specimens tapered, silanized „FibreKleer 4X" glass fibre posts („Pentron"), first disinfected with alcohol, were cemented at respective depths, with 5 mm of the posts protruding in the coronal parts of the teeth. Self-adhesive dual-cure resin cement „Breeze" („Pentron") was used; the ferrule effect was not created. In order to standardize the specimens, root walls were prepared using a mill measuring root diameter at three points in mesiodistal and buccolingual directions: 5 mm from the apex, 10 mm from the apex and 15 mm from the apex. Root diameter after abrasion with the mill in buccolingual direction: 5 mm from the apex – diameter 4.5 mm, 10 mm from the apex – diameter 5 mm, 15 mm from the apex (at the coronal part of the root) – 5 mm. Root diameter after abrasion with the mill in mesiodistal direction: 5 mm from the apex – diameter 2 mm, 10 mm from the apex-diameter 3 mm, 15 from the apex (at the coronal part of the root) – diameter 3 mm (Figures 3, 4). Specimens were embedded on a metal plate at a 45° angle and were vertically pressed with a hydraulic press „Toni Technik 2020" (maximum compressive load of this compressive strength testing machine – 600 KN) in buccolingual direction at the Building Materials Research Center of the Department of Building Materials of Kaunas University of Technology with the assistance of senior lab technician Mantas Lazauskas. Fracture force was recorded in Newton (N) to the breaking point of a specimen using „testXpert V7.11" software. „Microsoft Excel", ANOVA (Analysis of variance) and T-test softwares were used for data analyses.

RESULTS

The means of study results were different in each group. In group one (specimens with glass fiber posts cemented at the depth of 2/3 of the working length of the root canal), the compressive load necessary for tooth fracture was the smallest in comparison with that in other groups and was insignificantly different from the results of group 2 (specimens with glass fiber posts cemented at the depth of 1/2 of the working length of the root canal). A bigger difference of results was observed between group 2 and group 3 (specimens with glass fiber posts cemented at the depth

Table. Groups of specimens with respect to glass fibre post cementation depth

Group	Number of specimens	Canal working lenght	Post cementation depth	Post prodruding from the root in the dental crown
1	6	15 mm	11 mm (2/3)	5 mm
2	6	15 mm	7.5 mm (1/2)	5 mm
3	6	15 mm	5 mm (1/3)	5 mm

of 1/3 of the working lenght of the root canal): the biggest compressive load was necessary to break group 3 specimens. After data analyses with ANOVA and T-test software, the null hypothesis was confirmed: there was no statistically significant difference among the results of all 3 groups (P>0.05).

DISCUSSION

Our *in vitro* study has shown the depth of the cementation of our tested posts does not significantly influence tooth fracture resistance. Considering our results, it should be kept in mind, however, that *in vitro* studies do not reflect real clinical situation in the oral cavity. In our study, tooth was impacted with a load diagonally (at 45° degrees) to its vertical axis while in the oral cavity, a tooth is affected not only by diagonal, but also lateral and vertical forces (1).

Many factors can influence reduced fracture resistance of the tooth, for instance, remaining amount of tooth tissue, bacterial interaction in the dentine, loss of moisture in dentine tubules (15). A tooth is always moist in the oral cavity, while upon extraction it quickly dries out. In the course of this study extracted teeth were stored in physiological saline solution.

In addition to this, prosthodontic treatment is recommended after endodontic treatment of a tooth with a glass fibre post. It is therefore recommended to restore the crown to imitate the conditions closer to the clinical ones. In our study no crown restoration was done.

In the course of this study, roots were exposed to even, single-application maximum load while in clinical situations the natural forces of mastication are recurrent and weaker (1). However, some authors think that restored tooth fracture resistance decreases even more after recurrent loading. An endodontically treated tooth is more sensitive to constant deformations that occur because of tissue loss and possible errors and cracks that form at the time of tooth preparation. Reduction of tooth fracture resistance can also be related to the weakening of fibres and the methacrylate- or epoxy-polymer matrix of the glass fibre post and the extension of the crack that is present in the complex. This causes restored tooth fracture after recurrent load (16). Besides, with *in vitro* studies, microcracks can form at the time of tooth extraction. Therefore roots should be evaluated under a microscope prior to the study.

In this study, specimens were not exposed to thermocycles and mastication was not imitated. In other *in vitro* studies, special pieces of equipment were used to simulate the conditions in the oral cavity: antagonistic teeth were imitated, mastication cycles were simulated (vertical movement downwards that simulates the bite of incisors; lateral movements; vertical movements upwards that imitate opening of the mouth), 50N force was used and 300,000 such cycles were performed, which simulates mastication function of one year (17).

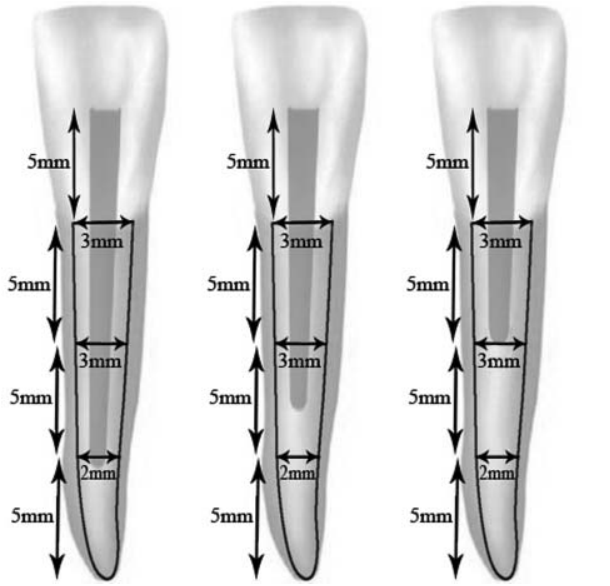

Fig. 3. Shematic view of the specimens after root walls abrasion in mesiodistal direction and post cementation at different depths

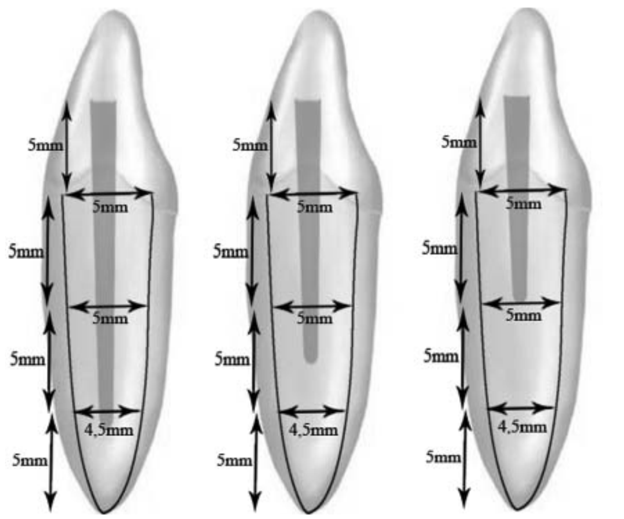

Fig. 4. Shematic view of the specimens after root walls abrasion in buccolingual direction and post cementation at different depths

Evaluating our study results, it is also necessary to take into account that physiologically tooth root is surrounded by periodontium that not only anchors the tooth in the bone, but also absorbs mastication forces that affect the tooth (18). Periodontium and alveolar bone were not imitated for the specimens of our study. The strength of restored teeth also depends on aging processes, oral temperature changes, dental wear, moisture and antagonists (1).

Tooth strength can also depend on the irrigation fluids used for endodontic treatment, such as sodium hypochlorite solution or **e***thylendiamintetraacid* (19).

The most common concentration of sodium hypochlorite solution used for endodontic treatment is 0.5% – 5.25%. In order to save time and ensure proper root canal disinfection, some specialists use larger amounts of bigger concentration and bigger flow rate sodium hypochlorite solution. Such use can cause adverse effect of sodium hypochlorite solution on root canal dentine: it can affect physical-mechanical properties, such as resistance to bending, the modulus of elasticity, stiffness, and, by doing this, increase the possibility of failure. *Ethylendiamintetraacid (EDTA) is used to remove smear layer from dentine walls before obturation. According to some resources, this material can also affect dentine, that is reduce its strength. It is thought that concurrent use of* sodium hypochlorite solution and e*thylendiamintetraacid* affects dentine surface by weakening its mechanical properties (19).

The strength of an endodontically treated tooth also depends on the amount of remaining coronal dentine and on its quality. Some authors believe that fracture resistance increases significanly when there is more coronal dentine. Unaffected coronal dentine should be preserved so that it would be possible to form a coronal shoulder below the restored core buildup and remaining dental tissue junction. This will increase retention and core resistance due to the ferrule effect, and this will increase mechanical tooth fracture resistance (20). With a ferrule in place, tooth dentine is exposed to different stress: stress forces in the cervical area of the tooth decrease and the elasticity of this area increases (15). In addition to this, remaining coronal dentine forms a more stable post space for the post and core, which increases rotation resistance (13).

Root dentine wall thickness is also a very important factor when assessing fracture resistance of the tooth. Irrespective of the size of the post, it is very important to retain as much of root canal tissue as possible while preparing the post space. Besides, it is important to bear in mind that root diameter buccolingually is different from the diameter mesiodistally. Therefore it is necessary to assess root morphology, taper, curving and crown/root angulation when preparing the canal for a post . After performing root canal treatment, an endodontologist should prepare the post space as he/she already knows the structure of root canal system. It is also believed that post diameter (and diameter of the canal already prepared for the post) should not exceed 1/3 of the root diameter at its narrowest point (18). Dentine wall thickness of the specimens used in our study (0.8 mediodistally and 1.8 bucollingually) did not fully meet the recommendations of optimal thickness by some authors (1 mm – 1.75 mm), but was bigger than critical wall thickness (0.5mm) at which fracture is much more likely to occur (7). Some authors believe in correlation between fracture resistance and the diameter of the post used for restoration - the larger the post, the bigger fracture resistance (17). However, this assumption is questionable because the use of a large diameter post substabtially weakens root dentine walls, which, in turn, decreases tooth fracture resistance.

An ideal glass fibre post system should withstand a force bigger than the mean force of mastication (15). The glass fibre post system used in our study is of adequate quality and strength for practical use: root fracture means (429.4 N; 436 N; 541,7 N) were significantly bigger than average masticatory force of a man (285.01 N) and a woman (253.99 N) (21).

Results similar to the results of our study were received in the study performed by C. Şahin and co-authors (18). These authors studied glass fibre and metal posts cemented at 6mm and 8mm depth, also assessing fracture in relation with the hight of alveolar bone. Their study results indicated that there was no correlation between root fracture and depth of the post or the hight of the alveolar bone. It was concluded that due to quality bonding system even a post cemented at 6mm depth had the same fracture resistance as a post cemented at 8mm depth. Other authors (8, 13, 14, 22) also did not report statistically significant difference of fracture resistance in relation to post cementation depth. However, some other sources mention that, differently from metal posts, glass fibre posts, most probably due to their mechanical properties being close to those of dentine, do not influence the mechanical qualities of a restored tooth. The retention of such a post is increased with a bonding system with resin cement which enables odontologists to remain more conservative in their choice of a post depth. In addition to this, reduced post cementation depth allows better polymerization of light-curing cement: with a smaller depth of fibre glass post, light source reaches the innermost areas easier (14). It should also be kept in mind that post cementation at smaller depth allows to use more canal obturation material to isolate the root apex prior to post cementation. This aspect is important because root apex is a system of canals made up of many lateral accessory canals (13).

Since it is assumed that a post cemented at greater depth is linked with better retention, when assessing optimal post depth, tooth fracture resistance rather than post retention in the canal should be taken into consideration: decementation can be treated by restoring the core and applying more cement. In case of root fracture, however, the tooth is most often extracted (15).

Glass fibre posts are recommended for clinical practice for their quality bonding system with dental tissues and good physical properties, such as the elastic modulus that is similar to that of the dentine. However, in order to better evaluate optimal glass fibre post cementation depth more studies with larger sample size and longer *in vivo* trials are necessary.

CONCLUSIONS

Fracture resistance of teeth with tapered, silanized „FibreKleer 4X“ glass fibre posts („Pentron“) cemented at the depth of 1/2 of the working length of the root canal was bigger than that of the teeth with glass fiber posts cemented at the depth of 2/3 of the working length of the root canal, but smaller than that of the teeth with glass fiber posts cemented at the depth of 1/3 of the working length of the root canal.

There is no statistically significant difference among the results of all 3 groups. The cementation depth of the „FibreKleer 4X“ glass fibre posts („Pentron“) that we studied has no influence on tooth fracture resistance.

CONFLICT OF INTEREST

The authors state none financial conflict relationships with manufacturers of any materials or devices described in the manuscript of interest.

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