Effect of bonding and post length to the dislodgement characteristics of fiber reinforced composite root canal post

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Abstract

Purpose: The aim of this in vitro study was to investigate the forces needed to dislodge bonded and mechanically attached individually formed fiber-reinforced composite (FRC) posts from a simulated root canal.

Materials and Methods: Two different groups of FRC posts were made. The first group simulated bonded individually formed FRC posts and the second group simulated mechanically attached individually formed FRC posts to a root canal. The fiber post material in both groups (everStick Post, GC Corporation) consisted of unidirectional E-glass fiber reinforcement in a semi-interpenetrating polymer network (IPN) polymer matrix. The fiber material was formed into posts (diameter of 1.5-1.6 mm) by rolling it between two microscope glasses and light-polymerizing it. Different post lengths were made. Artificial root canals were made by drilling holes in polymethylmethacrylate (PMMA) blocks. The final post lengths inside the blocks in both groups were: 2, 3, 4 and 6 mm (n= 6/length). FRC posts in the blocks were tested with a 2-point bending test where the load was applied 0.5 mm from the end of the post.

Results: Both length and bonding had a significant effect on the dislodgement force ($p < 0.001$). The shortest posts differed statistically significantly from the other post lengths ($p< 0.05$). Greater force was needed to dislodge bonded FRC posts compared to not bonded FRC posts in every tested post length. The minimum post length inside the artificial root canal to achieve adequate mechanical retention, i.e. without bonding to simulated root was 3 mm.

Conclusion: This study highlighted the importance of good bonding of FRC posts to root canal.

Key words: Root canal post, Fiber-reinforced composite post, individually formed FRC post, attachment, dislodgement, depth, bonding

Introduction

Fiber-reinforced composite (FRC) posts are used when reconstructing endodontically treated teeth with severe loss of coronal tooth structure. Preservation of dental tissue, the use of posts with isoelastic properties matching to that of dentin and stable bonding of post to root canal are the most critical factors for a successful restoration of an endodontically treated tooth [1, 2]. When minimal tooth structure remains, the retention for the restoration is decreased and the risk of root fractures increases. A post should be considered only in cases of reduced remaining tooth structure and when core retention from the root canal is necessary [3].

Most studies in the literature agree that FRC posts have lower and less severe failure modes than metal posts [4]. With stiff metal posts, failures relate mainly to higher stress concentrations in the root canal dentine. Root fractures caused by stiff metal posts are more likely to be more severe than fractures with FRC posts [5, 6]. FRC posts have more dentine like properties, thus spreading the chewing forces evenly along the root during function [7].
The prefabricated FRC posts are made of reinforcing fibers (carbon/graphite, glass, quartz) and finally polymerized resin matrix of epoxy polymers or dimethacrylates between the fibers, which form a solid post of a predetermined diameter. In order to optimize the strength and the stiffness of FRC posts, continuous unidirectional fibers are used and orientated along the long axis of tooth [8]. Although prefabricated FRC posts are widely used and accepted in the restoration of root canal treated teeth they have shortcomings that should be taken into consideration [9]. One of the most important disadvantages of prefabricated FRC posts is the poor bonding which occurs as post decementation, loosening and detachment of the post from the root canal and in the end often leads to secondary caries [2]. The finally polymerized resin matrix in these posts is cross-linked and do not allow good bonding to resin cements and core composites [9, 10]. Also, with prefabricated FRC posts (especially the thin size) the fiber volume

is too low in the coronal or cervical parts leading to inadequate stiffness and marginal breakdown [9, 11].

Individually formed FRC posts are made of non-polymerized fiber-resin prepregs, consisting of E-glass fibers and a light-curing resin matrix which forms a semi-IPN matrix after curing. Due to the semi-IPN matrix it is possible to achieve better bonding with these posts to resin luting cements and core composites. The idea of the individually formed FRC post is to fill the entire space of the root canal and coronal parts with fiber reinforcement thus increasing the load-bearing capacity of the system [9, 12]. In the literature there are reports of higher load-bearing capacity with thick and short FRC posts compared to thin and long ones [13]. Also improved bonding between post and resin luting cement has been stated with individually formed FRC posts with a semi-IPN polymer matrix compared to prefabricated FRC posts with a cross-linked polymer matrix [14-16]. How much the bonding and the length of the FRC post affects the dislodging force and attachment of post to root canal is not clearly demonstrated by in vitro studies.

The aim of this in vitro study was to get more knowledge of bonding and post length effect on FRC post dislodgement from and attachment to simulated root canal. The first hypothesis of this study was that bonded individually formed FRC posts require more force to dislodge from the root canal than just mechanically attached FRC posts. The second hypothesis was that the force needed to dislodge the FRC post increases linearly as post length increases in the mechanically attached post group.

Materials and methods

Two different groups of individually formed FRC posts (everStick Post, GC Corporation, Tokyo, Japan) were made. The post material in both groups consisted of unidirectional E-glass fiber composite (diameter of 1.5-1.6 mm, ~ 4000 glass fibers per bundle) (Table 1).

Table 1. *The tested FRC post.*

Material	Type of FRC post	Polymer matrix	Composition	Preparation	Post diameter (mm)	Lot No
everStick POST (GC Corporation)	individually formed	semi-IPN	E-glass (electric glass, silanated), bis-GMA, PMMA	GC composite primer	1.5-1.6	1707261 1503181

The FRC post material was rolled into the form of posts with a diameter of 1.5-1.6 mm by hand between two microscope glasses. Each post was simultaneously light-polymerized (Elipar S10, 3M ESPE, Maplewood, USA) through microscope glasses for 40 seconds (Figure 1) during rolling. After initial light-curing the everStick Posts were light-polymerized completely using a light curing oven (Ivoclar Targis Power in program P1) for 25 minutes.

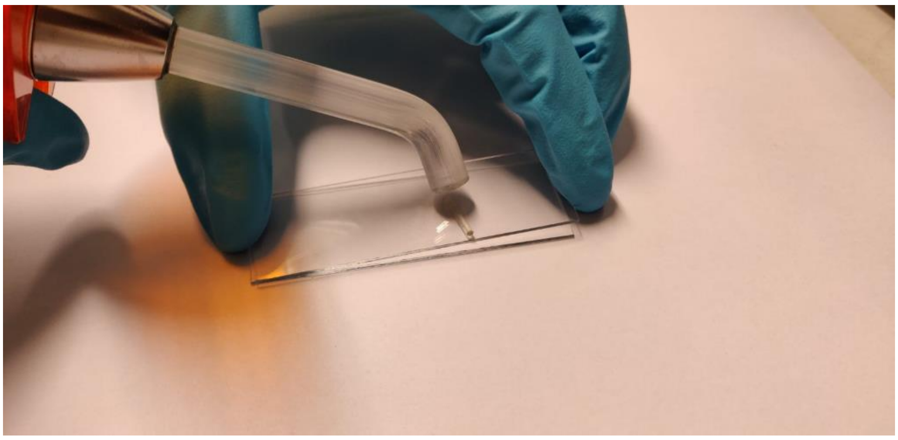

Figure 1. *Light-curing the FRC post.*

FRC posts were first trimmed with scissors and then wet-ground smooth to exact length with Struers LaboPol-21 (silicon carbide abrasive paper P1200, Federation of European Producers of Abrasives) (Figure 2). The final post lengths were: 6, 7, 8 and 10 mm (n=6/ group).

A pipe of Polyvinyl chloride (PVC) was cut (Fox band saw) in the predetermined post lengths. The other end of the pipes was sealed with tape. Polymethylmethacrylate (PMMA) blocks were made by mixing (PMMA)-powder and MMA-liquid (1.7g:1ml) that was casted into the sealed PVC-pipes and heat-cured in a Heat- and pressure chamber (IVOMAT for 15 minutes, 400 kPa, 60 °C) (Figure 3). After heat-curing, both ends of the PMMA blocks were wet-ground smooth with Struers LaboPol-21-grinding machine (silicon carbide abrasive paper P1200, Federation of European Producers of Abrasives) (Figure 2).

Figure 2. *FRC posts and PMMA blocks were ground with Struers LaboPol-21.*

Figure 3. *Heat- and pressure chamber.*

Simulated root canals were made into the PMMA blocks by drilling holes (diameter of 1.8 mm) that were 1 mm longer than the posts, leaving space for the resin cement at the bottom of the post space. The first group of FRC posts was bonded with resin (44.3 % BIS-Gma, 44.3% TEGDMA, 0.7 % CQ, 0.7 % DMAEMA) to the simulated root canals; first the resin was pipetted in the hole and then the post was submerged inside it. The second group of FRC posts simulated mechanically attached posts and they were covered with wax to prevent attachment to simulated root canal walls. Wax was applied by dipping the tip of the posts to a wax hexan (composite n-hexane) mix, evaporated and thereafter the posts were submerged in the holes. After placing the FRC posts in the simulated root canals the posts in both groups were light-cured (Elipar S10, 3M ESPE, Maplewood, USA) from the tip of the posts for 40 seconds (Figure 4).

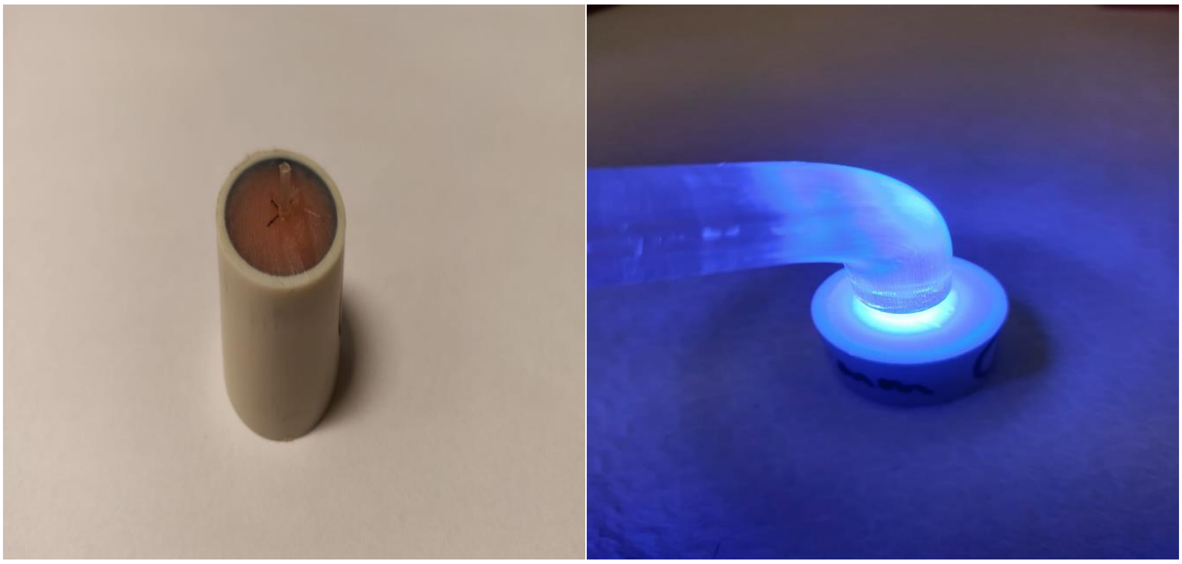

Figure 4. *Attaching and light-curing the post to the simulated root canal in the PMMA block.*

The length of the FRC post protruding from the PMMA block, to which the bending force was applied, was 4 mm long (Figure 5). Thus the total post lengths in both groups were 6, 7, 8 and 10 mm and the final post lengths inside the simulated root canals in both groups were: 2, 3, 4 and 6 mm.

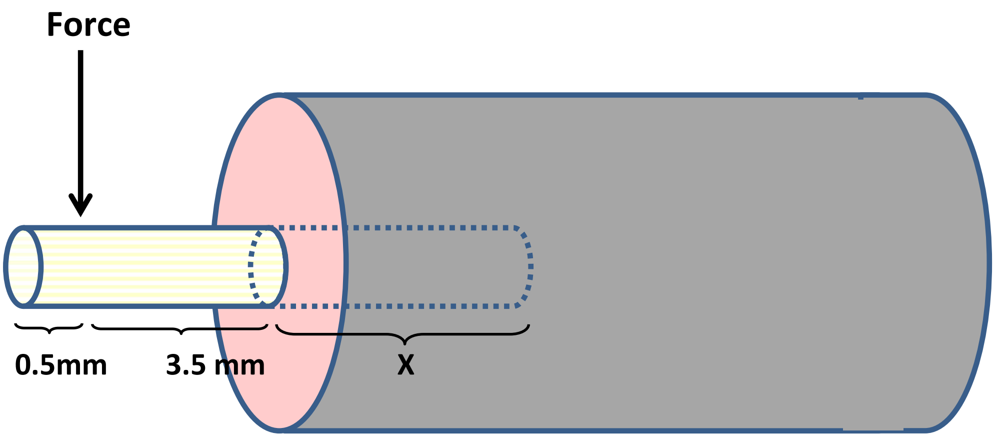

Figure 5. *Schematic drawing of the test set-up. The final post length inside the simulated root canal is marked as X.*

The FRC posts were tested with a 2-point bending test (Lloyd-Ametek LR30K Plus) (Figure 6). The mechanism of post dislodgement was bending of the post at first stage and after that post dislodgement from the cement at a certain point. The data from the bending dislodgement forces was gathered to a computer program (NEXYGEN Plus) and the data was further analyzed.

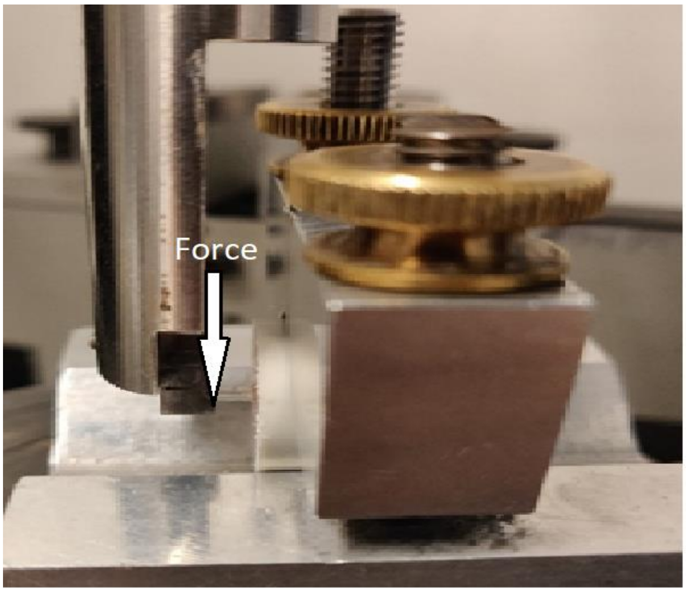

Figure 6. *The 2-point bending test of the posts.*

Statistical Analysis

The data was analyzed using two-way ANOVA using independent factor of fiber length and adhesion (IBM SPSS Statistics version 23 for Windows) followed by Tukey post Hoc tests. The level of statistical significance was considered to be 0.05.

Results

A summary of the results is shown in Figure 7 and Table 2. Two-way ANOVA revealed that both length and adhesion had a significant effect on the dislodgement force ($p < 0.001$). Post length of 2 mm differed statistically significantly from other post lengths (3, 4 and 6 mm) (Tukey, $p < 0.05$). The posts of 6 mm length had no statistically significant difference between bonded and not bonded groups. On the load-deflection curve the fracture behavior during loading can be followed (Figure 8a-b).

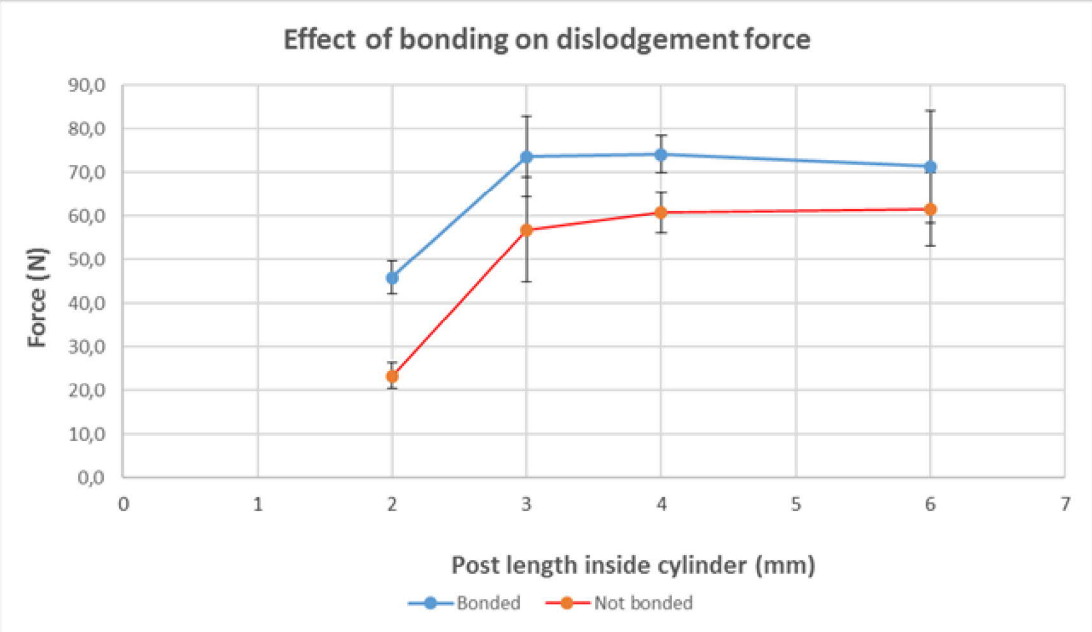

Figure 7. *The effect of bonding on the dislodgement force (N) in different post lengths (mm). Vertical lines represent standard deviations (SD).*

Table 2. *Dislodgement force and standard deviations in parenthesis in Newton (N) of the tested FRC posts.*

Length	**Bonded**	**Not bonded**
2	45.9 (3.8)^{aA}	23.3 (3.0)^{aB}
3	73.7 (9.3)^{bA}	56.9 (12.1)^{bB}
4	74.2 (4.2)^{bA}	60.7 (4.6)^{bB}
6	71.4 (12.9)^{bA}	61.6 (8.3)^{bA}

Small Superscript letters within columns indicate statistical difference ($p<0.05$, Tukey).
Big superscript letters within rows indicate statistical difference ($p<0.05$, Tukey).

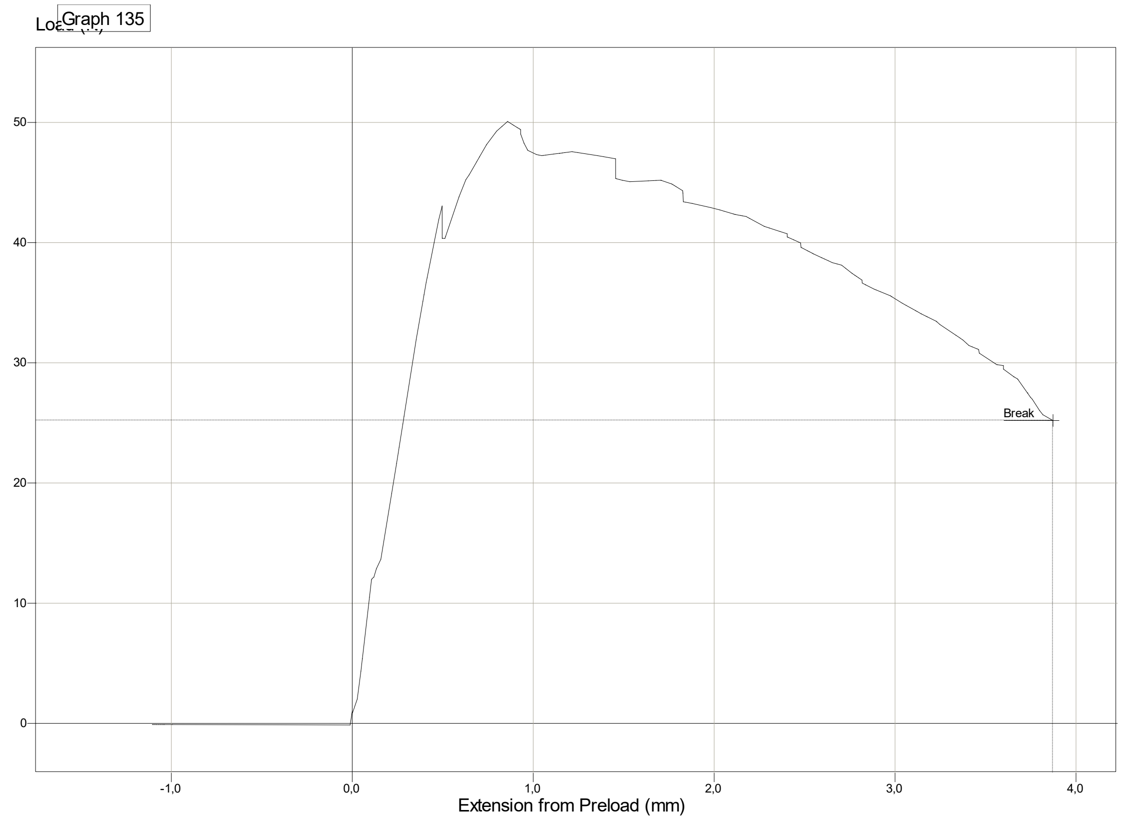

Figure 8 a. *The load-deflection behavior in the 2mm bonded group under loading.*

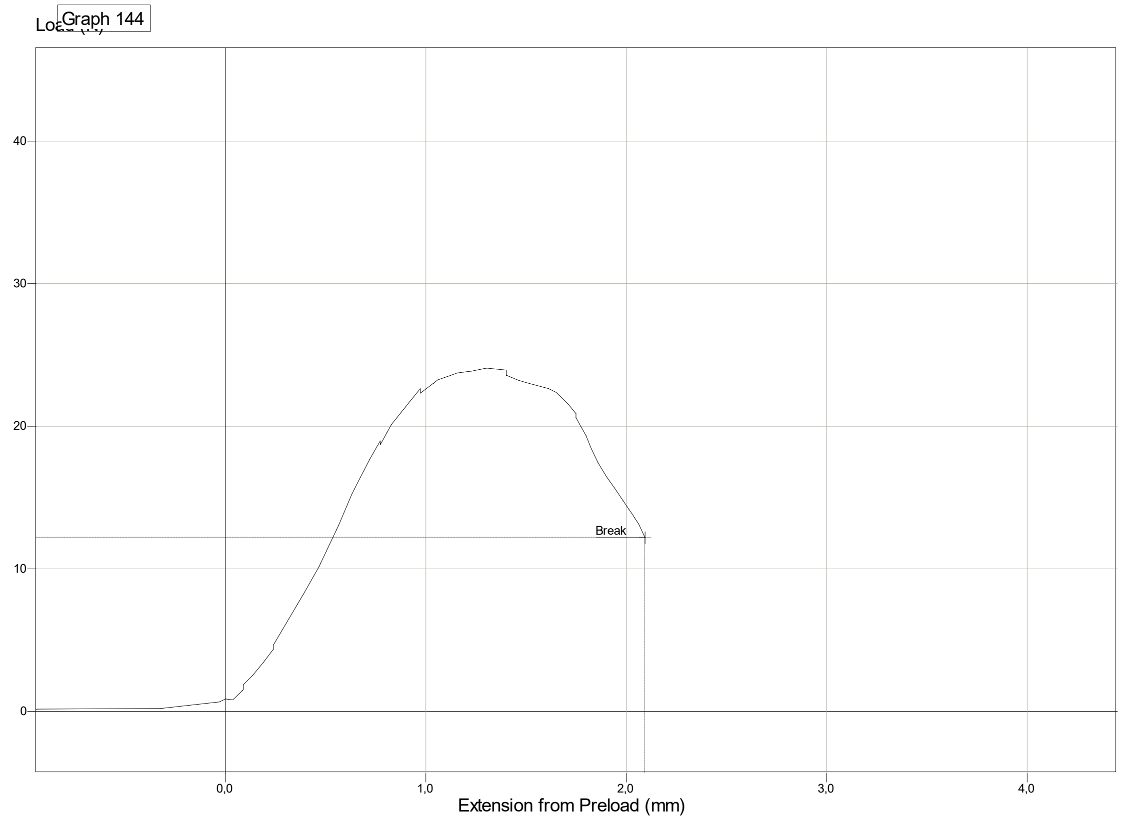

Figure 8 b. *The load-deflection behavior in the 2mm non-bonded group under loading.*

Discussion

In this in vitro study the dislodging forces needed to dislodge bonded and not-bonded individually formed fiber-reinforced composite (FRC) posts from simulated root canal were studied with a simplified in vitro model. The study was made to get an insight to the failure mechanism of post system in cylindrical root canal by varying the post length and adhesion of the post to the walls of the cylinder. The model simulated the clinical condition, where the post length may not have reached the conventionally agreed level and the bonding could have deteriorated initially or could have weakened by time [17]. Although the model was simple, it was the first experimental approach to evaluate the effects of post length and adhesion (bonding) of the post to root canal on the load-bearing force by quasi-static loading test. The results can be considered as an indicator of the worst-case scenario when short FRC posts are used in a root canal with parallel walls.

The results showed that greater force was needed to dislodge bonded FRC posts compared to not bonded FRC posts in all post groups except for the longest 6 mm post group and thus the first hypothesis was partly accepted. The second hypothesis that the needed dislodgement force increases linearly as post length increases in the mechanically attached post group was rejected. The results show that bonding is needed in order to achieve adequate retention of FRC post to the root canal. During the loading event, the post is bended and shear stress is applied to the interface of the post and simulated root canal. In the group with bonding, the shear stress, i.e. dislodgement causing stress is resisted by the interfacial adhesion of resin to simulated root canal and post itself. Obviously by lengthening the post, the increased bonding area and mechanical support are compensating the adhesion. Interestingly, in both categories (bonded and non-bonded groups), the threshold length of post where the mechanical retention begun to influence was 3.0 mm. The dislodgement force was considerably higher for the bonded posts. In overall, the load values were relatively low which highlights the known fact that FRC posts with the diameters of 1.5 mm do not necessarily provide enough support to the core and crown if the system is lacking the supporting ferrule. In fact, the limitation of adequate support by the regularly used FRC posts, regardless of prefabricated or individually formed in type, with diameter of ca 1.5 mm has been the rationale to start using individually formed posts with considerably larger post diameters.

According to the results in this laboratory study minimum post length needed to achieve adequate retention to root canal was found out to be 3 mm (Figure 7). The reduced result of the shortest posts (2 mm) is probably due to the fact that the post easily slips out of the canal in the bending test since there is poor support from the sides of the test block to the sides of the post. Clinically, post submerges under 3 mm are not advised to use due to poor dentin support and easy dislodgement from canal. The recommendation in the literature for flexible prefabricated FRC posts is a preparation length of approximately half the root length or a post length equal to the length of the clinical crown, leaving at least 4-5 mm of root canal filling material apically to maintain a good apical seal [18, 19]. With individually formed FRC posts with effective bonding mechanism of IPN polymer matrix it may be retentive enough with shorter post lengths. Our results support this idea which has also been reported in an earlier study [13].

In this study the biggest and smallest numbers in each group were left out of statistical analysis.

Potential sources of error in this in vitro study could have been the exact point of applied force on the post end which may have varied in two point bending test. The wax layer of non-bonded posts may have been broken at some point and bonding may have happened which might have given unwanted resistance for the post. The precise post space depths and post lengths may have had minor variance. During light-curing of the resin the angle of light-curing device could have caused minor error and uneven curing of resin. This can cause variation in resin-polymerization. These potential errors of hand manufacturing process could have been affecting the end results. Another limitation of the study design was the quasi-static loading conditions. Clinically, the post-core-crown system is affected by dynamic loading conditions and therefore more emphasis is needed to study the post systems with fatigue loading tests in the future.

FRC post problems mainly occur as decementation which leads to marginal caries and post loosening and detachment [2, 20]. Therefore it is necessary for clinicians to understand how to create reliable and enduring cemented root canal post restorations. This study emphasized the importance of good bonding from a biomechanical point of view. Also, this study showed the benefits of using fiber material with good bonding ability.

References:

1. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J 2011; 56: 77-83.

2. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). Quintessence Int 2008; 39: 117-129.

3. Dangra Z, Gandhewar M. All about Dowels - A Review Part I. Considerations before Cementation. J Clin Diagn Res 2017; 11(8): 06-11.

4. Schwartz R, Robbins J. Post Placement and Restoration of Endodontically Treated Teeth: A Literature Review. J Endod 2004; 30: 289-301.

5. Schmitter M et.al. Influence of clinical baseline findings on the survival of 2 post systems: a randomized clinical trial. Int J Prosthodont 2007 Mar-Apr; 20(2): 173-8.

6. Sari T, Ozyesil AG. The fracture resistance of teeth restored with different adhesive dowels. Acta Odontol Scand 2013; 71(5): 1232-7.

7. Bru E, Forner L, Llena C, Almenar A. Fibre post behaviour prediction factors. A review of the literature. J Clin Exp Dent 2013; 5(3): e150-3.

8. Vallittu PK. High-aspect ratio fillers: fiber-reinforced composites and their anisotropic properties. Dent Mater 2015; 31: 1-7.

9. Pekka K. Vallittu (2018). An overview of development and status of fiber reinforced composites as dental and medical biomaterials, Acta Biomaterialia Odontologica Scandinavica 2018; 4(1): 44-55.

10. Rasimick B, Wan J, Musikant B, Deutsch A. A review of failure modes in teeth restored with adhesively luted endodontic dowels. J Prosthodont 2010; 19: 639-646.

11. Tanner J, Le Bell-Rönnlöf A-M, Vallittu P, 2017. Root canal anchoring systems. In: Vallittu P and Özcan M (Eds), Clinical Guide to Principles of Fiber-Reinforced Composites in Dentistry. Woodhead Publishing, Elsevier, Duxford, UK, pp. 97-109.

12. Le Bell-Rönnlöf A-M, Lassila LVJ, Kangasniemi I, Vallittu PK. Load-bearing capacity of human incisor restored with various fiber-reinforced composite posts. Dent Mater 2011; 27: e107-e115.

13. Hatta M, Shinya A, Vallittu PK, Shinya A, Lassila LVJ. High volume individual fiber post versus low volume fiber post. The fracture load of the restored tooth. J Dent 2011; 39: 65-71.

14. Mannocci F, Sheriff M, Watson TF, Vallittu PK. Penetration of bonding resins into fibre-reinforced composite posts: a confocal microscopic study. Int Endod J 2005; 38: 46-51.

15. Le Bell A-M, Tanner J, Lassila LVJ, Kangasniemi I, Vallittu PK. Bonding of composite resin luting cement to fiber-reinforced composite root canal posts. J Adhes Dent 2004; 6: 319-325.

16. Le Bell A-M, Lassila LV, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. J Dent 2005; 33: 533-539.

17. Cardoso MV, de Almeida Neves A, Mine A, Coutinho E, Van Landuyt K, De Munck J, Van Meerbeck B. Current aspects on bonding effectiveness and stability in adhesive dentistry. Aust Dent J 2011; 56(1 Suppl): 31-44.

18. Cecchin D, Farina A.-P., Guerreiro C.-A.-M. and Carlini-Júnior B. Fracture resistance of roots prosthetically restored with intra-radicular posts of different lengths. J Oral Rehab 2010; 37: 116-122.

19. Adanir N, Belli S. Evaluation of Different Post Lengths' Effect on Fracture Resistance of a Glass Fiber Post System. Eur J Dent 2008; 2: 23-28.

20. Schmitter M, Hamadi K, Rammelsberg P. Survival of two post systems – Five-year results of a randomized clinical trial. Quintessence Int 2011; 42: 843-850.