Biomimetic Restoration of Endodontically Treated Posterior Teeth

short thesis for the degree of doctor of philosophy (PhD)

Dr. András Forster DMD

Supervisor:
Dr. Márk Tibor Fráter DMD, PhD

University of Szeged
Doctoral School of Clinical Medicine
Szeged, 2019

Publication providing the basis of the thesis:

I. Fráter M, **Forster A**, Jantyik Á, Braunitzer G, Nagy K, Grandini S. In vitro fracture resistance of premolar teeth restored with fibre-reinforced composite posts using a single or a multi-post technique. Aust Endod J. 2017 Apr;43(1):16-22. doi: 10.1111/aej.12150. Epub 2016 May 6. PubMed PMID: 27150658. **IF: 0.838** (2017)

II. **Forster A**, Sáry T, Braunitzer G, Fráter M. In vitro fracture resistance of endodontically treated premolar teeth restored with a direct layered fiber-reinforced composite post and core. J Adhes Sci Technol. 2016 Nov: 1454-1466 doi: 10.1080/01694243.2016.1259758 Epub: 21 Nov 2016. **IF: 1.073** (2016)

III. **Forster A**, Braunitzer G, Tóth M, Szabó P. B, Fráter M. In Vitro Fracture Resistance of Adhesively Restored Molar Teeth with Different MOD Cavity Dimensions. Journal of Prosthodontics. doi**:** 10.1111/jopr.12777 Epub: 5 Mar 2018. IF: **1.452** (2018)

INTRODUCTION

It is one of the everyday challenges of restorative dentistry to restore and reinforce endodontically treated teeth (ETT). It is well known and accepted that ETT are susceptible to fracture during masticatory function. The key factor to inferior mechanical resistance of the root canal treated teeth may be found in the tissue loss related to restorative procedures (e.g.: cavity preparation, crown preparation); tooth wear and autologous causes of mechanical damage (bruxism, attrition, erosion, abfraction); and procedures priming or enabling disinfection of the root canal (access cavity preparation, coronal flaring). As a result of dental tissue loss at neuralgic points of the tooth, mechanical stability of the structure as a whole is reduced. According to the authors clinical observations and thorough review of the scientific literature it seems that there are three structural deficiencies that have to be examined, and if possible, reconstructed or compensated for in order to successfully restore the biomechanical resistance of posterior teeth and their masticatory function: 1. Condition of the *marginal ridges* 2. Condition and quality of the *pericervical dentine (PCD)* 3. Preservation of the so-called *ferrule*. The later can also be regarded as the prosthodontic entity of the PCD, also known as three dimensional ferrule.

1. In case of an interproximal laesion areas, caries undermines the marginal ridges and resulting treatment according to the classical - but still clinically applied - Black principles involves occlusal entry to the interproximal area through the marginal ridge. Loss of a single marginal ridge does introduce higher deflection of the cusps during mastication, but it seems that the remaining single marginal ridge still serves well to stabilise the cusps and prevent fracture in most situations. Loss of both marginal ridges seems to weaken the posterior teeth to a great extent. According to Black, the mesial and distal cavities serving to access and remove interproximal caries need to be connected with an occlusal box as a retentive measure for non-adhesive restorations. With adhesive restorations and slot cavity preparations connecting these two cavities needs to be prevented whenever possible (7), to ensure oral-vestibular stability of the cusps by preserving occlusal enamel+dentino-enamel junction (DEJ)+dentine truss. If not preventable either as a result of excessive preparation or occlusal caries, the tooth “suffers” a so-called MOD (mesio-occlusal-distal) cavity preparation. In these cases there are no more occlusal enamel areas connecting the oral and vestibular cusps, therefore cuspal deflection is severely higher (8) and risk of a fracture is induced. Currently there is no universally accepted measure to assess MOD cavities in terms of the cusp deflection and as a result in the therapeutic decision making process. First objective of this thesis is to understand decision making in MOD cavity situations and find a rationale for easily

indicating a restoration which is minimally invasive and maximally considers long term mechanical stability of the remaining hard tissues.

2. Up until today it is the gold standard to use crown down methodology with rotary file systems when root cana treating teeth. This methodology is based on accessing the apical third of the root canal by flaring the coronal third of the root canal to an almost extensive measure. As a result of this the pericervical dentine mass of these teeth is severely reduced and biomechanical stability is likewise reduced. Substituting pericervical dentine loss was attempted with several different type of restorations from Nayyar's amalgam corem to the cast metal posts and several versions of fiber reinforced composite posts. However none of these systems is able to fully substitute the fracture strength of the teeth. Although it seems that cast metal posts hold the advantage of reinforcing endodontically treated teeth to a relatively high fracture resistance, the fracture of these teeth will most likely be catastrophic. As opposed to this fibre reinforced composite posts do not seem to strengthen endodontically treated teeth to such an extent, but fractures will most likely lead to repairable situations. As it seems that there is no optimal and accepted method of substituting the pericervical dentine, the second objective of this thesis is to find and test endo-restorative solutions which may be capable of reinforcing the PCD.

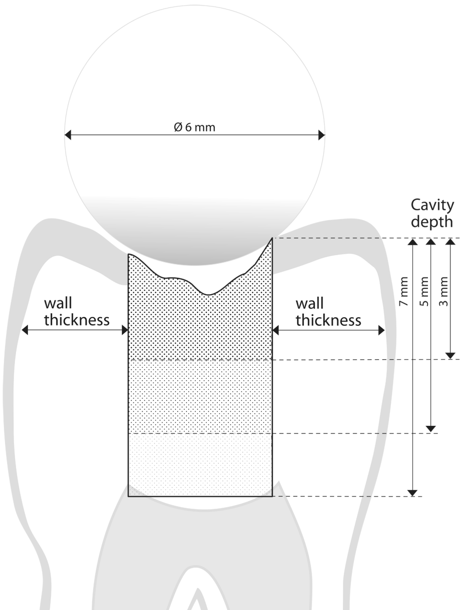
3. The prosthodontic ferrule is described as a minimum 2 mm high, minimum 1 mm thick sound dentine area coronal to the preparation margin of a full veneer crown abutment. It is clear that missing a ferrule in case of crown preparation is more likely to result in mechanical failure of the tooth as compared to a preparation with a ferrule. As the prosthodontic ferrule is anatomically described in a similar location to the PCD it can be considered as the prosthetic entity of the PCD therefore its invasion is considered to have a negative effect on the mechanical stability of the prepared teeth. In case of severely compromises teeth preparing a ferrule is only possible by invading the biologic width. An act that is generally not supported. As an alternative, these teeth can be restored without a ferrule, which seems to be one of the biggest challanges of restorative dentistry. Previously proposed and tested methods in such situations are: the endocrown, cast metal posts, adhesive restorations, and fibre reinforced composite posts applied in several ways. However until today there is no universally accepted solution to restoring non-ferrule teeth.

The third objective of this thesis is to find and test endo-restorative solutions that are capable of reinforcing teeth without a prosthodontic ferrule.

METHODS

1. Mechanical changes resulting from different size MOD cavity preparations:

   120 mandibular 3rd molars extracted for periodontal or orthodontic reasons were selected for this investigation. MOD cavities with different wall thicknesses and with different depths were prepared by the same trained operator in 9 of the groups. With wall thickness of 3,5 mm 2,5 mm or 1,5 mm, and a depth of 3 mm, 5 mm és 7 mm resulting in 9 experimental groups and a control group. In the samples in which the depth was meant to be 7 mm an endodontic access was prepared and endodontic treatment was carried out. After finishing cavity preparation the enamel was acid-etched selectively with 37% phosphoric acid for 15 seconds, rinsed with water and air-dried. The cavity was adhesive-treated with G-aenial Bond (GC Europe, Leuven, Belgium). G-aenial Flo A2 (GC Europe, Leuven) and Gradia Direct Anterior A2 was applied with and oblique layering technique, to reconstruct the anatomic shape of the teeth. The specimens were embedded, and load to fracture test was performed. A force vs. extension curve was dynamically plotted for each tooth.



Depth/Wall thickness	3.5 mm	2.5 mm	1.5 mm
3 mm	A	B	C
5 mm	D	E	F
7 mm (Endo)	G	H	I

2. Restoration of endodontically treated premolar teeth with occlusal cavity preparation:

   Seventy-two upper premolar teeth, extracted for periodontal or orthodontic reasons were selected for this investigation. Occlusal access cavity was prepared and the teeth were root canal treated. After root canal treatment the guttapercha was cut back according to minimally invasive principles as designed for each of the groups: group 1,2. had the guttapercha cut back 8 mm’s apical to the cemento-enamel junction (CEJ). group 3,4,5. had the guttapercha cut back 2 mm’s apical to the CEJ. Every group recieved the same adhesive treatment and was restored according to the technique designated for the group:

group 1: The teeth received a prefabricated, conventional FRC post (0,8 GC Fiber post, GC Europe, Leuven, Belgium). Luting of the posts and the core build-up was performed with a dual-cure resin composite core material (Gradia Core, GC Europe, Leuven, Belgium). The outlines of the restoration were finished with dental composite (G-aenial Posterior P-JE, GC Europe, Leuven, Belgium).

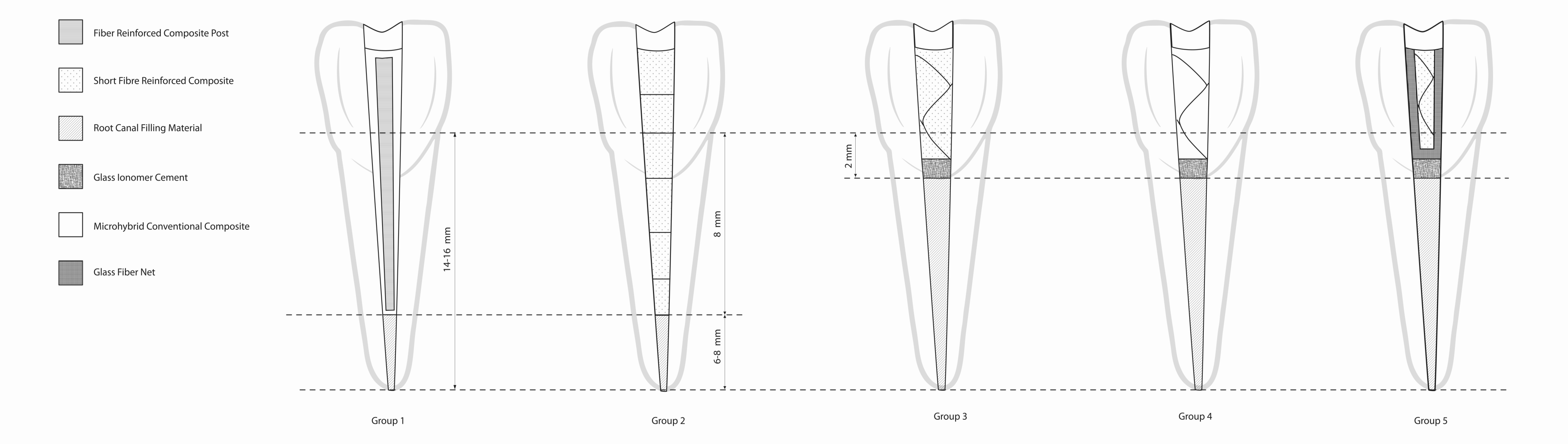
group 2: The teeth were reconstructed with a novel method of building a direct layered fiber-reinforced composite post and core (DLFRC post and core) from SFRC (EverX Posterior, GC Europe, Leuven, Belgium). The DLFRC post and core was horizontally layered in 1-2 mm segments. Light curing of the layers was carried out through a light transmitting post (GC Fiber Post,GC Europe Leuven) for 80 seconds per layer. The outlines of the restoration were finished with dental composite (G-aenial Posterior P-JE, GC Europe, Leuven, Belgium).

group 3: The cavities were restored with SFRC material applied in an oblique incremental technique. The material was placed in consecutive 2 mm thick increments. The outlines of the restoration were finished with dental composite (G-aenial Posterior P-JE, GC Europe, Leuven, Belgium).

group 4: The cavities were restored with micro hybrid composite restorative material (G-aenial Posterior PJ-E, GC Europe, Leuven, Belgium) applied with an oblique incremental technique.

group 5: The cavity walls were coated with flowable composite (G-aenial Flo, GC Europe, Leuven, Belgium)and before curing, a piece of pre-impregnated glass fiber net (Everstick net, GC Europe, Leuven, Belgium) (10 mm long, 3 mm width) was cut and embedded inside the flowable composite first in buccal to lingual, then a mesial to distal direction. After curing for 40s, another glass fiber band was adapted to the walls circumferentially, forming the FRC “box”. The remaining central part of the cavity was restored with SFRC and a final layer of composite

The prepared specimens were embedded and load to fracture test was applied with 45° load angle. The maximum failure load was recorded in Newton’s (N). After mechanical testing, the specimens were examined for fracture patterns.


Fiber Reinforced Composite Post
Short Fibre Reinforced Composite
Root Canal Filling Material
Glass Ionomer Cement
Microhybrid Conventional Composite
Glass Fiber Net
14-16 mm
8 mm
6-8 mm
2 mm
Group 1
Group 2
Group 3
Group 4
Group 5

3. Restoration of endodontically treated premolar teeth without ferrule effect:

   Fifty upper premolar teeth extracted for periodontal or orthodontic reasons were selected for this study. Before root canal treatment, all crowns were sectioned at the level of the CEJ perpendicular to the longitudinal axis. After root canal treatment, post space was prepared in the root portions of the teeth with a depth of 10 mm, as measured from the CEJ. Regardless of the exact type, the main posts were placed in a way that 5.0 mm was left above the level of decoronation, and 10.0 mm was inserted into the root canal. This way, a uniform 15.0 mm fiber length was achieved. The same adhesive protocol was used for all of the groups. For the restorations, two different types of FRC posts were used: a prefabricated, "rigid" conventional FRC post (0,8 GC Fiber Post, GC Europe, Leuven, Belgium) and an elastic FRC post (0,9 EverStick POST, GC Europe, Leuven, Belgium). For bonding, a dual-cure one-step self-etch adhesive system (Gradia Core Self-Etching Bond, GC Europe, Leuven, Belgium) was used, according to the manufacturer's instructions. Luting of the posts and the core build-up was performed with a dual-cure resin composite core material (Gradia Core, GC Europe, Leuven, Belgium).

   group 1: one single conventional FRC post

   group 2: ne main conventional FRC post and one collateral post using a "multi-post technique"

   group 3: one single elastic FRC post

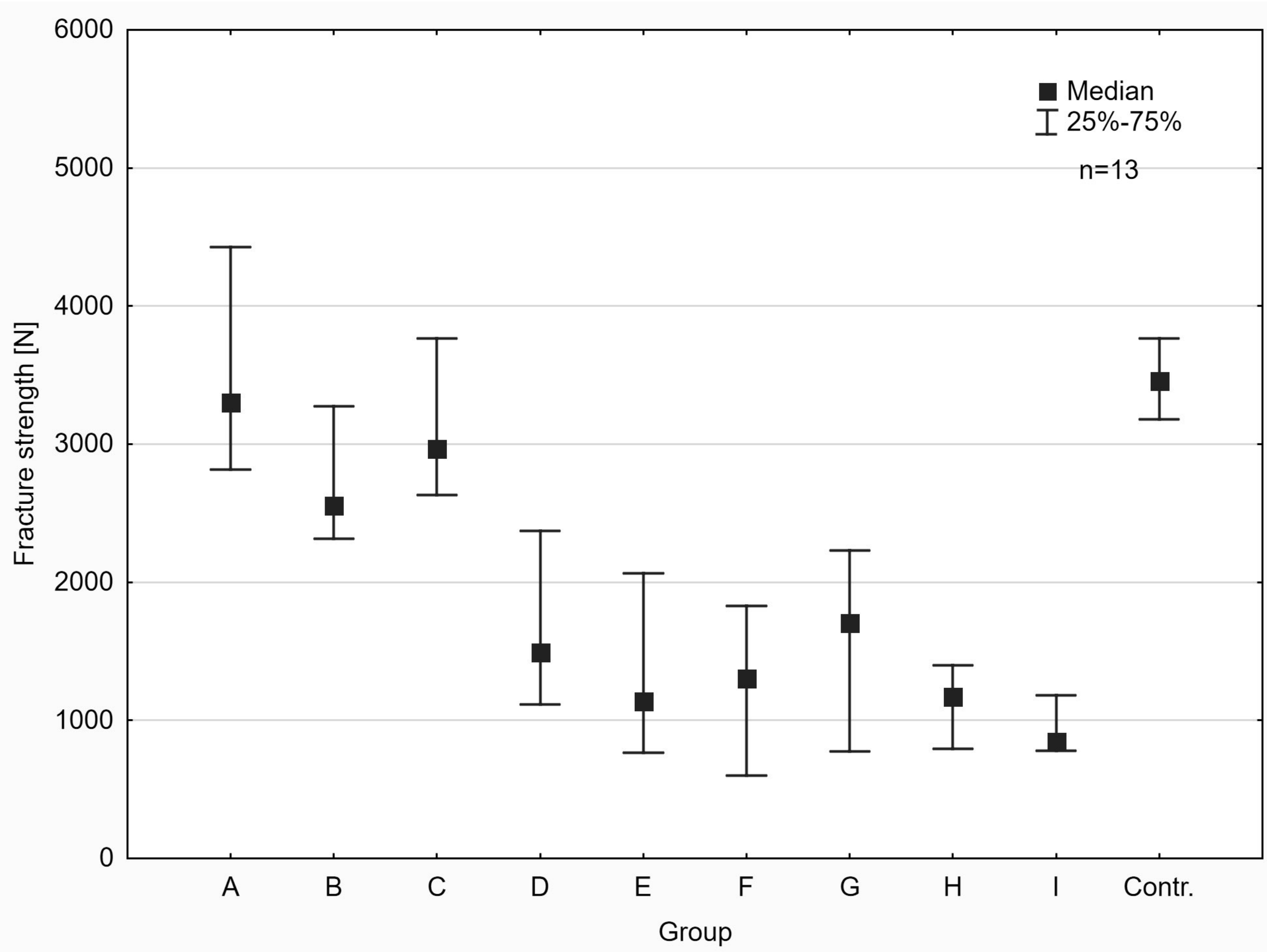
   group 4: one main elastic FRC post and one elastic collateral post a "multi-post technique"

   group 5: as many elastic FRC posts (0.9 mm) as possible bundled according to the thickness of the root canal using the lateral condensation method described by Hatta and co-workers

   In order to ensure the uniformity of the specimens, the composite resin core build-ups were standardised using cellulite core-forming matrices of the same size. The prepared specimens were embedded and load to fracture test was applied with 45° load angle. The maximum failure load was recorded in Newton's (N). After mechanical testing, the specimens were examined for fracture patterns.

RESULTS

1. Mechanical changes resulting from different size MOD cavity preparations:



As the Kruskal-Wallis ANOVA indicated significant variance, post-hoc pairwise tests were performed. The pairwise tests indicated significant difference between the control group and all 5 and 7 mm groups (D,E,F,G,H,I). 3 mm groups (A,B,C) did not show significant difference as compared to the control. Significant difference was found between group A and all 5 and 7 mm groups (D,E,F,G,H,I). No significant differences were found between 3mm cavity depth groups (A,B,C). Comparing the 5 and 7 mm cavity depth groups, there was no statistical difference between any of them.

2. Restoration of endodontically treated premolar teeth with occlusal cavity preparation:

The control group exhibited the highest fracture resistance. The application of the DLFRC post and core technique yielded the highest fracture resistance among the restored groups. The fracture resistance of Group 2 (DLFRC post and core group) did not differ significantly from the intact teeth (control group). The rest of the groups proved to be significantly different from the control group in terms of fracture resistance. There was no statistically significant difference

Group	Sig. compared to Control (p, post-hoc)	N	Minimum (Newtons)	Maximum (Newtons)	Mean (Newtons)	Std. Deviation
Control	-	12	605.85	1205.83	922.34	189.21
Group 1	.005	12	208.28	802.61	501.30	186.65
Group 2	1.000	12	352.85	1171.19	727.98	287.37
Group 3	.009	12	123.59	865.93	511.61	225.20
Group 4	.005	12	216.67	748.44	456.24	189.75
Group 5	.023	12	303.64	682.83	536.35	126.41

when comparing the restored groups regarding their fracture resistance. In terms of fracture patterns, the tested groups 2,3,4,5 were identical (Table 4.). Only the control group and the FRC post showed dominantly repairable fractures.

3.

4. Restoration of endodontically treated premolar teeth without ferrule effect:

Csoport	N	Medián	Minimum	Maximum	SD
Több elasztikus csap	10	240.64	146.88	330.12	63.85
Több konvencionális üvegszálas csap	10	237.99	165.93	361.63	55.26
Egy elasztikus csap	10	215.98	57.22	312.04	66.33
Egy konvencionális üvegszálas csap	10	154.50	65.99	271.22	56.63
Laterálkondenzáció elasztikus csapokkal	10	227.30	142.82	367.88	72.20

group 4 (containing one main and one elastic FRC post) showed the highest average fracture resistance, however, this difference was only significant compared to group 1 (containing a single conventional FRC post). Group 2 (containing one main and one collateral conventional FRC post) showed significantly higher fracture resistance compared to group 1. However, neither of the multi-post techniques yielded significantly better results than the single elastic post technique. In terms of fracture patterns, the tested groups were almost perfectly identical. The application of more elastic posts would not result in more favourable fracture patterns

DISCUSSION

In the investigations of this thesis the two methods where utilised to examine the mechanical properties of the specimens. Static load to fracture is considered to be one of the effective means to study the mechanical properties of posterior teeth. racture patterns where examined and categorised and restorability was assessed according to Scotti et al (46). Examinations were done under an optical microscope with a two-examiner agreement. A restorable fracture is above the CEJ, clinically meaning that the tooth can be restored, while a non-restorable fracture extends below the CEJ clinically resulting in extraction of the tooth unless surgical or orthodontic procedures are applied.

Marginal ridges: If an MOD cavity is prepared in a molar tooth, both marginal ridges are lost and the fracture resistance of the tooth is significantly reduced. It is widely accepted and published that the defining measure of assessing the stability of the cusps in such cases is the thickness of the cavity walls. According to several authors if the cavity wall is thicker than 2-2.5 mm the cusps are considered stabile and if thinner than this measure they are considered to be fragile. The results of this thesis suggest that cavity wall thickness is not a major influencing factor of cusp stability. Comparing 3.5mm, 2.5mm and 1.5 mm cavity wall thickness in case of the 3, 5 or the 7 mm cavity depth groups, mechanically similar behaviour was measured after being restored with a conventional dental composite. In this thesis reducing only the wall thickness, without changing the depth of the cavity, did not cause a significant reduction in fracture strength. 3 mm can be considered a safe cavity depth for adhesive direct restorations. These results rather suggest that a cavity of 5mm depth is already in the "danger zone" when talking about direct composite restorations without cusp coverage. From the results it seems that cavity wall thickness is only secondary to cavity depth in molar MOD cavities in terms of fracture strength, as the change in cavity wall thickness did not lead to a significant difference neither between the groups in the “safety zone” nor between the “danger zone” groups. There is no statistical difference between the 5 and 7 mm results so endodontically treated molars with an MOD cavity are not significantly weaker mechanically as compared to molars with a vital pulp and intact pulp space with a 5 mm deep MOD cavity. Therefore root canal treated molars are not weaker or more fragile by nature. They are weaker as a result of tissue loss in the biomechanically sensitive anatomic locations such as the marginal ridges.

Pericervical Dentine Reinforcement: In this thesis, endodontically treated premolars restored with an oblique layered occlusal composite restoration (Group 4) showed the lowest fracture resistance among all groups. However these restorations where not statistically significantly weaker than the other types of tested restorations. Although not proven by statistical significance it seems evident that in the current investigation the fracture resistance of restorations shows a tendency to get higher as the number of glass fibers is increased. The DLFRC post and core technique (Group 2) produced the highest fracture resistance values among the restored groups in the present study. There was no statistically significant difference between the group 2 and the intact teeth. The DLFRC post and core concept theoretically could present a possibility to compensate for most of the known weaknesses of the presently accepted endo-restorative options with a not complicated, clinically feasible and reproducible methodology. The DLFRC post and core technique according to the findings of this investigation might hold the potential of reinforcing the root and particularly the pericervical area, which is highly beneficial when shear forces are also present (f.e.: 45 degree loading). . It has to be noted that the reported advantages come at the price of increased application time and technically more demanding clinical procedure as compared to Group 1. Development of materials, instruments and light curing equipment specifically for such purposes could be promising and could resolve the main shortcomings of the DLFRC post and core method as described in this investigation.

Substituting the Prosthodontic Ferrule: The results of this study appear to favour the use of multiple posts in the same root canal. Restorative options with a single elastic post also seem to yield good results probably as a result of the palsticity of the post making it capable to fill the assymetric root canal space obtained as a result of minimally invasive post space preparation. Both multi-post techniques (rigid FRC (group 2.) and elastic FRC (group 4)) yielded significantly higher fracture resistance than the single post conventional FRC restoration (group 1) It is interesting to note that neither of the two multi-post techniques yielded significantly different fracture resistance from the single elastic post technique. In the present study the individual posts described by Hatta et al. (group 5) yielded better results than restoration with a single FRC post (groups 1 and 3). However, the difference did not reach the level of statistical significance.

CONCLUSION

The investigations described in the thesis attempt to find a biomimetic rationale of restoring posterior teeth by the means of applying novel diagnostic measures and utilising new endo restorative techniques. Within the limitations of this thesis the following conclusions can be drawn:

Marginal ridges of molar teeth and PCD of premolar teeth are some of the key anatomic features to be preserved in order to maintain the biomechanical integrity of the posterior root canal treated teeth.

Molar teeth with a 3 mm or shallower MOD cavity are considered to be safely restorable with conventional adhesive restorations. Molar teeth with MOD cavities of 5 mm or deeper - including endodontically treated molar teeth - are considered to be in the “danger zone” if placing adhesive composite restorations. In these situations cusp coverage should be considered. It is also understood that cavity wall thickness does not significantly influence fracture resistance in the described circumstances.

Natural premolar teeth exhibit higher fracture resistance then the ones that are endodontically treated through an occlusal access and restored except for the DLFRC post and core restored group. DLFRC post and core behaves mechanically similarly in the described conditions as the natural control tooth therefore it can be considered a biomimetic endo-restorative solution. In terms of fracture patterns conventional FRC posts exhibited more favourable fracture patterns then the other restored groups. The direct layered short fibre-reinforced post and core is a promising alternative to the currently accepted restorations of ETT, and as such should be further investigated.

Single rooted premolars restored in absence of a ferrule show significantly higher fracture resistance, when a multi post technique or a single elastic post is applied as compared to a conventional rigid single FRC post. Once utilizing a multipost technique the elasticity of the post did not yield any significant difference in the described circumstances. Single canal teeth restored with multiple posts achieved superior fracture resistance to teeth restored with single, conventional FRC posts.