Archives of Orofacial Sciences (2010), **5**(2): 36-41

ORIGINAL ARTICLE

Fracture resistance of endodontically treated teeth: an *in vitro* study

Mera Christina Michael [a], Adam Husein [a], Wan Zaripah Wan Bakar [a*], Eshamsul Sulaiman [b]

[a] School of Dental Sciences, Universiti Sains Malaysia,16150 Kubang Kerian, Kelantan. [b] Faculty of Dentistry, University of Malaya, 50603 Kuala Lumpur.

(Revised manuscript accepted 2 August 2010)

Keywords

composite resin, endodontically treated teeth, fracture resistance.

Abstract Endodontically treated teeth are generally weaker than sound teeth. The study objective was to compare the fracture resistance of endodontically treated teeth restored with different restorative techniques. Fifty extracted human maxillary central incisors of similar size were divided into five groups of 10 teeth. Group 1 was left intact as the control group. Other groups (Groups 2, 3, 4 and 5) were all endodontically treated followed by restorations using different restorative techniques; light cured composite resin (CR), CR and crown, post and CR, and post-CR core and crown respectively. The specimens were loaded in a universal testing machine with a static force at a crosshead speed of 0.5mm/min at 135° to the long axis of the root until failure. The means and the standard deviations of the maximum load at failure for groups 1, 2, 3, 4 and 5 were 1259.11N (379.12N), 578.63N (196.70N), 667.13N (298.72N), 1247.65N (294.48N) and 623.60N (193.75N) respectively. The results of one-way ANOVA showed statistically significant differences existed among the groups tested (p<0.001). Independent t-tests showed that the fracture resistance of specimens restored with either light cured composite resin or crown was statistically lower than the natural tooth (p=0.001 and p=0.003). Restoring endodontically treated with post significantly increased its fracture resistance to the level of sound tooth (p=0.002). Within the limitations of this study, endodontically treated teeth restored with post exhibited similar strength with sound natural teeth and restoration with either light cured composite resin or crown had lower fracture resistance than natural teeth.

Introduction

Endodontically treated teeth are generally weaker than sound teeth due to loss of tooth structure caused by caries and/or endodontic procedures (de V Habekost *et al.*, 2007; Hussain *et al.*, 2007). The loss of both coronal and radicular tooth structures as a result of endodontic treatment will increase the likelihood of fractures during functional loading. Endodontic procedures were responsible for 38% of reduction in flexural strength of crowns (Hussain *et al.*, 2007).

However, an endodontically treated tooth should have a good prognosis and be able to resume full function and serve satisfactorily as an abutment for a fixed or removable partial denture. Proper techniques are needed to restore such a tooth. Two factors that influence the choice of technique are the type of tooth (whether it is an incisor, canine, premolar or molar) and the amount of remaining tooth structure (Shillingburg *et al.,* 1997; Rosenstiel *et al.*, 2001). The latter is probably the most important indicator when determining the prognosis (Rosenstiel *et al.*, 2001). They also suggested that endodontically treated anterior teeth do not always need complete coverage by placing a complete crown. If the coronal structures are largely intact and loading is favorable as on anterior teeth that are farther removed from the fulcrum, a simple filling can be placed in the access cavity. Many otherwise intact teeth function satisfactorily with a composite resin restoration. Placement of a dowel in such a tooth is more likely to weaken it than to strengthen it (Shillingburg *et al.*, 1997) and tooth restored with post-and-core are

*** Corresponding author:** Dr. Wan Zaripah Wan Bakar, Fax: 09-7642026, e-mail: wzaripah@kb.usm.my

generally weaker than intact tooth (Abo El-Ela *et al.*, 2008).

However, a cast post-and-core is indicated if a substantial amount of coronal structure is missing (Rosenstiel *et al.*, 2001). In other condition, the axial reduction for a crown preparation (peripheral destruction) combined with an endodontic access preparation (central destruction) frequently leaves insufficient sound dentine to support a crown. In this case, a post and core probably is needed (Shillingburg *et al.*, 1997).

A post is a rigid structure placed in the canal of a non-vital tooth which extends coronally to hold the core material that supports the crown (Garg and Garg, 2007). Post will stabilize endodontically treated teeth (Heydecke *et al.*, 2001; 2002), but would increased the risk of fracture due to more dentine is removed (Baratieri *et al.*, 2000; Hussain *et al.*, 2007). Other studies have shown that post does not strengthen the tooth; it only serves to improve retention of core (Morgano, 1996; Heydecke *et al.*, 2001).

Although there were suggestions that endodontically treated anterior teeth have favourable prognosis with just composite resin restoration, it is of concern if those teeth will still remain as strong as sound teeth. The aim of this study was to evaluate the fracture resistance of endodontically treated anterior teeth following different restorative treatment as compared with sound teeth.

Materials and methods

The Universiti Sains Malaysia's Human Research Ethics Committee had approved this study. Fifty intact recently extracted human maxillary central incisors of 23mm ± 1mm in length from mixed population were collected and stored in 0.1% thymol solution. Ultrasonic scalers (Dentsply, Germany; Piezon Systems, EMS, Switzerland) were used to remove soft tissues, calculus and debris from the teeth before examination under light microscope (Leica, Germany) for detection of any cracks or fractures. The teeth were randomly divided into five groups of 10 teeth each by using manual block randomization protocol (www.randomization.com).

Endodontic treatment

Group 1 (G1) was left intact as control. Endodontic treatment was done for the other forty teeth. A standardized triangular shape template size 3mm x 3mm x 3mm made of clear plastic was used to outline the access cavity on the palatal surface of each tooth before prepared with endodontic access bur (Dentsply Maillefer, Switzerland). Remnants of pulpal tissue were extirpated using barbed broach (Dentsply Maillefer, Switzerland) and working length was standardized at 22mm (1mm short of the tooth length). Canals were instrumented manually by using conventional step back technique with K-file size 40 (Denstply Maillefer, Switzerland) as master apical file following the International Standardization Organization (ISO) protocol and accomplished by increasing 3 files. Throughout the procedures, canals were irrigated with 2.5% sodium hypochlorite and dried with paper points size 40 (Meta Biomed, Korea). Obturation was accomplished using cold lateral condensation technique with master gutta percha size 40, accessory gutta percha cones (Denstply Maillefer, China) and AH 26 silver-free sealer (Denstply De Trey Gmbh, Germany). Intra-oral periapical radiograph was taken to confirm enough condensation and length of the root canal filling. Excess gutta percha was cut at the CEJ level before temporarily restored with Caviton (3M ESPE). All the specimens were stored in individual screw-capped glass contained water which was then placed in an incubator (Sanyo, Japan) at 37^0C for 14 hours to ensure complete setting of the sealers.

Restorations

Samples in Group 2 to 5 were restored using different restorative techniques. Group 2 (G2) were restored with light cured composite resin (CR); Group 3 (G3) with CR and temporary crown; Group 4 (G4) were placed with metal posts and CR whereas Group 5 (G5) with combination of metal post, CR and temporary crown. The composite resin used was microhybrid Filtek Z100 (3M ESPE) of shade A3 and the temporary crowns were constructed from Protemp 4 (3M ESPE) following manufacturer's instructions. For post space preparation, Gates Glidden drills (Dentsply Maillefer, Switzerland) size 3 and ParaPost drills (Coltene Whaledent, USA) up to the size of red (1.5mm) were used, leaving 5mm gutta percha from the apex. Posts were cemented with Ketac Cem Easymix (3M ESPE) before restored with CR. Crown preparation following reduction for all ceramic crowns (Shillingburg *et al.,* 1997; Rosenstiel *et al.*, 2001) using alginate templates held in stock tray and cemented with Ketac Cem Easymix (3M ESPE). Throughout the experiment, samples were stored in distilled water all the time after each procedure to prevent dehydration.

Fracture testing

The roots of all samples were coated with a thin layer of a rubberized self curing silicon film (Dent-e-con, Germany) to simulate the periodontal membrane (Heydecke *et al.*, 2001) prior to mounting. Each tooth was then mounted 2mm below cemento enamel junction in an auto-polymerized acrylic resin (Simplex Rapid, UK). The resultant acrylic blocks were of 25mm x 25mm x 20mm in dimension. A protractor was used during the mounting procedure to ensure that the long axis of the teeth was vertically aligned (Ahmad, 2009).

Universal Testing Machine (Shimadzu, Japan) with Trapeziumx operating software was used for the load testing. The load was applied at 135° angle along the long axis of the tooth in frame cell to simulate Class I occlusal relationship between maxillary and mandibular incisors (Heydecke *et al.*, 2001; Akkayan and Gülmez, 2002; Heydecke *et al.*, 2002; de Melo *et al.*, 2005). The active tip of the machine (made up from stainless steel, round in shape with a diameter of 2mm) was positioned at 3mm below the incisal edge on the palatal surface of the teeth. Compressive load under a constant speed of 0.5mm/min was applied (Heydecke *et al.*, 2001; Heydecke *et al.*, 2002) and maximum fracture loads were recorded for analysis. Fracture pattern for each sample was examined under light microscope (Leica, Germany).

The data was analyzed using Statistical Package of the Social Sciences (SPSS) version 12.0 (SPSS Inc., Chicago IL). One-way analysis of variance (ANOVA) and Independent *t*-test were employed to compare the mean fracture loads of the groups.

Results

The mean and standard deviation of the maximum load till fracture (in Newton) for each group is presented in Figure 1. One way ANOVA test indicated that there was a statistically significant difference of maximum load till fracture among all the tested groups ($p<0.05$) (Table 1). Independent *t*-test was carried out to compare the means of different groups (Table 2). The results indicate that the means maximum load till fracture for all groups except group 4 were statistically lower than the control intact teeth (GI). Mean of group 4 (samples restored with metal post and CR) was significantly higher than all other tested groups (2, 3 and 5) and not statistically significant when compared to the control group ($p=0.95$). In term of fracture pattern, majority of the samples were fractured near the cemento-enamel junction in the oblique direction (Table 3).

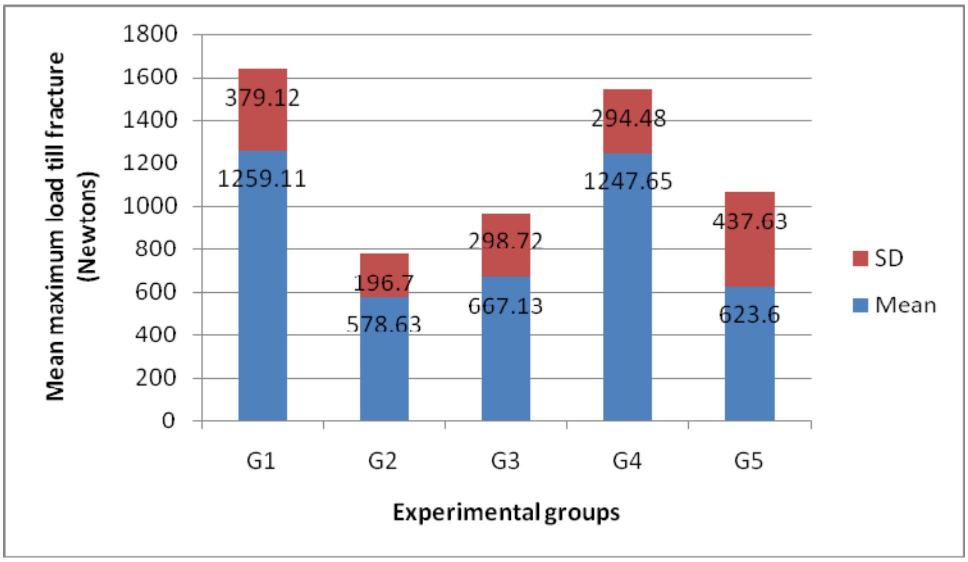


Figure 1 Mean maximum load till fracture (Newton)

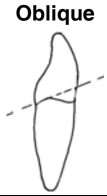
Table 1 The results of one way ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4806561.690	4	1201640.422	15.175	.000
Within Groups	3563265.414	45	79183.676		
Total	8369827.104	49			

Table 2 Comparison between groups using Independent *t* test

Group (J vs. K)	Mean Differenc (J-K)	95% Confidence Interval		*p* value
		Lower Bound (K)	Upper Bound (J)	
G1 vs. G2	680.47730	322.8976	1038.0570	0.000869
G1 vs. G3	591.97950	234.3998	949.5592	0.002731
G1 vs. G4	11.45740	-346.1223	369.0371	0.953055
G1 vs. G5	635.51140	277.9317	993.0911	0.002278
G2 vs. G3	-88.49780	-446.0775	269.0819	0.389117
G2 vs. G4	-669.01990	-1026.5996	-311.440	0.000419
G2 vs. G5	-44.96590	-402.5456	312.6138	0.551384
G3 vs. G4	-580.52210	-938.1018	-222.942	0.002244
G3 vs. G5	43.53190	-314.0478	401.1116	0.720055
G4 vs. G5	624.05400	266.4743	981.6337	0.000169

Table 3 Fracture patterns of the samples

Type of Fracture / Group	Horizontal	Vertical	Oblique 	Oblique 
G1	40% (at CEJ)		60%	
G2		20% (until CEJ)	80%	
G3			100%	
G4	20% (2mm below CEJ)			80%
G5			50% (temporary crown fracture)	50% (temporary crown fracture)

Discussion

Endodontic procedure will remove sound tooth structure starting with those involved in the preparation of access cavity which may severely affect the strength and integrity of a tooth. In addition, intra canal preparation with instruments such as gates glidden burs and various files will further remove tooth structure. Physical maneuvering during endodontic procedures in the form of access cavity and canal preparations and obturation may also introduce micro-cracks and fatigue that could further weaken the tooth. All those possibilities together with well established fact of reduced moisture content will make intact endodontically treated teeth generally weaker or more brittle than their vital counterparts (Rosenstiel *et al.*, 2001). Therefore, restoring such teeth may require different procedures in order to maintain function and serviceability. A common issue with endodontically treated teeth is fracture resistance.

In this study, comparison had been made in term of fracture resistance of intact endodontically treated anterior teeth restored with various restorative techniques against similar sound teeth. The results of this study indicate that the mean maximum load to fracture of intact endodontically treated anterior teeth restored with composite resin or composite resin and temporary crown without post were significantly lower than natural teeth. The ability of those teeth restored with the two restorative techniques (without the use of post) to withstand occlusal load was about half of sound natural teeth. However, comparing to human biting force which was estimated to be ranging from 500 to 600 N (Rosentritt *et al.*, 2000), the results of this study showed that the strength of intact endodontically treated anterior teeth restored with composite resin or composite resin and temporary crown without post is within the range of maximum human biting force. Thus the techniques could be applicable clinically in patients with normal biting force and with no parafunctional activities such as clenching and bruxism.

The results also showed that there were no statistically significant differences of maximum load to fracture between the groups restored with composite resin alone and composite resin plus temporary crown. Therefore, it may be adequate clinically to restore intact endodontically treated anterior teeth with just composite resin in patients with normal biting force. Full coverage restoration is not always necessary to restore those teeth. This finding echoes other similar views (Shillingburg *et al.*, 1997; Rosenstiel *et al.*, 2001). Restoration with full coverage restoration will add other disadvantages such extra clinical procedures and time, unnecessary removal of tooth structure and extra cost. The restoration will not add extra strength to those teeth.

Other findings of this study indicated that intact endodontically treated anterior teeth restored with prefabricated titanium post and composite resin was able to withstand mean maximum load to fracture to the level of intact sound tooth. Statistical analysis showed that there were no significant differences of mean maximum load to fracture of intact endodontically treated anterior teeth restored with prefabricated titanium post and composite resin with sound teeth. Within the limitation of this study, it is proved that intact endodontically treated anterior teeth restored with metal post and composite resin was as strong as sound teeth. Although this is encouraging, it is important to note that placing a post into a canal is a risky procedure. And it is an accepted concept that posts do not strengthen endodontically teeth, in fact they may further weaken those teeth. The main function of a post is to retain the core. However, in cases of severe loss of tooth structure, posts should have the ability to prevent root fracture by allowing the transfer and distribution of force and stress. This is due to the high flexural strength and high modulus of elasticity of posts which allows them to withstand large amount of stress before bending and transmitting the load to the root (Al-Wahadni *et al.*, 2008). Post also may be indicated in patients with some parafuntional habits such as clenching and bruxism as increased biting force may require stronger restorations. In normal patients, other technique as discussed previously should be adequate.

The mean maximum load to fracture for the control group and the group of teeth restored with post and composite resin were almost similar with another study (Heydecke *et al.*, 2002). The similarity may indicate this study was properly conducted as per standard protocol.

However, the results for group 5 were questionable. In this group, teeth were restored with titanium post, composite core and temporary crown. During the testing procedure, the temporary crowns were fractured first thus rendered the maximum loads to fracture of the teeth inaccurate. It was evident from the low value of maximum load to fracture when compared with other groups especially group 4 which also being restored with metal post. The material used for the construction of temporary crown was not strong enough to withstand loading forces. Before the experiment, samples in group 5 were expected to perform better than or as well as samples in group 4 which produced similar results to sound teeth. Future studies should consider stronger materials for the crowns so that premature fracture of the crowns could be avoided.

Regarding the fracture pattern, oblique fracture was the most common followed by horizontal fracture and then vertical fracture. These results showed that the vulnerable area for fracture of intact endodontically treated central incisors is around cemento-enamel junction (CEJ). Although vertical fracture was less common, it should be noted that the use of acrylic resin for mounting might have influenced the outcome. Acrylic resin is not comparable to the alveolar bone. The nature of load application is also different in clinical environment as compared with the static universal testing machine, which may significantly affect the fracture pattern (de Melo *et al.*, 2005). Future studies may use cyclic loading for better simulation of clinical scenario.

During the experiment, precautions were taken to minimize the variabilities. Standardized endodontic access cavities were outlined and prepared on each tooth to reduce the potential effect of different amount of tooth structure loss on the strength of those teeth. Natural human teeth were used in this study to simulate clinical conditions. The teeth were embedded in acrylic resin 2mm below the cemento enamel junction to mimic the position of the root in the bone and rubberized self curing silicon was used to simulate periodontal ligament and to provide cushioning effect as in clinical scenarios (Heydecke *et al.*, 2001; 2002).

Conclusion

Within its limitations, the results of this study showed that intact endodontically treated maxillary central incisors were generally weaker than their intact sound counterparts. However, the strength of those teeth was almost similar to their intact sound counterparts when posts were used for restoring them. Posts may be indicated to restore intact endodontically treated maxillary central incisors in selected cases only as other restorative techniques did produce mean maximum load to fracture comparable with already established maximum human biting force. As this study is experimental, proper clinical studies are needed before recommendation can be made.

Acknowledgments

The authors would like to thank staffs of Polyclinic and Craniofacial Laboratory, School of Dental Sciences, Universiti Sains Malaysia; Biomaterial Laboratory, Faculty of Dentistry, University of Malaya and Faculty of Dentistry, Universiti Teknologi Mara for their contributions throughout this study. This study was supported by a Universiti Sains Malaysia's short term grant (304/PPSG/6131540).

References

Abo El-Ela OA, Atta OA and El-Mowafy O (2008). Fracture resistance of anterior teeth restored with a novel nonmetallic post. *J Can Dent Assoc*, **74**(5): 441.

Ahmad MA (2009). Fracture resistance of weakened root structure reinforced by twotypes of composite resin and endodontic sealer. *Universiti Sains Malaysia*, 2009. Master of Science dissertation.

Akkayan B and Gülmez T (2002). Resistance to fracture of endodontically treated teeth restored with different post systems. *J Prosthet Dent*, **87**(4)**:** 431-437.

Al-Wahadni AM, Hamdan S, Al-Omiri M, Hammad MM and Hatamleh MM (2008). Fracture resistance of teeth restored with different post systems: in vitro study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, **106**(2)**:** e77- e83.

Baratieri LN, De Andrada MA, Arcari GM and Ritter AV (2000). Influence of post placement in the fracture resistance of endodontically treated incisors veneered with direct composite. *J Prosthet Dent*, **84**(2): 180-184.

de Melo MP, do Valle AL, Pereira JR, Bonachela WC, Pegoraro LF and Bonfante G (2005). Evaluation of fracture resistance of endodontically treated teeth restored with prefabricated posts and composites with varying quantities of remaining coronal tooth structure. *J Appl Oral Sci*, **13**(2): 141-146.

de V Habekost L, Camacho GB, Azevedo EC and Demarco FF (2007). Fracture resistance of thermal cycled and endodontically treated premolars with adhesive restorations. *J Prosthet Dent*, **98**(3): 186-192.

Garg N and Garg A (2007). *Textbook of Endodontics*, 1st edn. New Delhi: Jaypee Brothers Medical Publishers.

Heydecke G, Butz F, Hussein A and Strub JR (2002). Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. *J Prosthet Dent*, **87**(4): 438-445.

Heydecke G, Butz F and Strub JR (2001). Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in vitro study. *J Dent*, **29**(6): 427-433.

Hussain SK, McDonald A and Moles DR (2007). *In vitro* study investigating the mass of tooth structure removed following endodontic and restorative procedures. *J Prosthet Dent*, **98**(4): 260-269.

Morgano SM (1996). Restoration of pulpless teeth: application of traditional principles in present and future contexts. *J Prosthet Dent*, **75**(4): 375-380.

Rosenstiel SF, Land MF and Fujimoto J (2001). *Contemporary Fixed Prosthodontics*, 3rd edn. St. Louis, Missouri: Mosby Inc.

Rosentritt M, Fürer C, Behr M, Lang R and Handel G (2000). Comparison of in vitro fracture strength of metallic and tooth-coloured posts and cores. *J Oral Rehabil*, **27**(7): 595-601.

Shillingburg HT, Hobo S, Whitsett LD, Jacobi R and Brackett SE (1997). *Fundamental of Fixed Prosthodontics*, 3rd edn. Chicago, Illinois: Quintessence Publishing Co. Inc.