Fracture Resistance and Failure Patterns of Endodontically Treated Mandibular Molars Restored Using Resin Composite With or Without Translucent Glass Fiber Posts

Ziad Salameh,† Roberto Sorrentino,‡† Federica Papacchini,† Hani F. Ounsi,§ Esam Tashkandi,* Cecilia Goracci,† and Marco Ferrari†*

Abstract

The elastic modulus of the restorative material is important in restoring endodontically treated teeth. This study aimed to compare the fracture resistance and failure patterns of 90 mandibular molars restored using resin composites with or without fiber posts, with respect to the number of residual cavity walls. Five restoration types were performed corresponding to different wall defects (groups 1-5). Groups were divided in two subgroups corresponding to the use or absence of fiber posts. Teeth were loaded and resistance of specimens was measured as the axial compressive load to cause fracture and macroscopic fracture patterns were observed. One way ANOVA revealed a significant difference in fracture resistance ($p < 0.001$). Tukey post hoc test also revealed significant differences between groups as samples restored with fiber posts exhibited mostly restorable fractures. It was concluded that the resistance of endodontically treated mandibular molars restored with composite resins is mainly affected by the number of residual walls. Using fiber-reinforced posts optimized fracture patterns. *(J Endod 2006;32: 752–755)*

Key Words

Bonding, fiber post, fracture pattern, mandibular molars, nonmetallic restorations

From the *Department of Prosthetic Dental Sciences, King Saud University, Riyadh, Saudi Arabia; †Department of Dental Materials, School of Dental Medicine, University of Siena, Italy; ‡Department of Fixed Prosthodontics, University of Naples "Federico II", Italy; §Department of Endodontics, School of Dental Medicine, Saint-Joseph University, Beirut, Lebanon.

Address requests for reprints to Prof. Marco Ferrari, Dipartimento di Scienze Odontostomatologiche, Università degli Studi di Siena, Policlinico Le Scotte, Viale Bracci—53100 Siena, Italy. E-mail address: ferrarimar@unisi.it.

0099-2399/$0 - see front matter

doi:10.1016/j.joen.2006.02.002

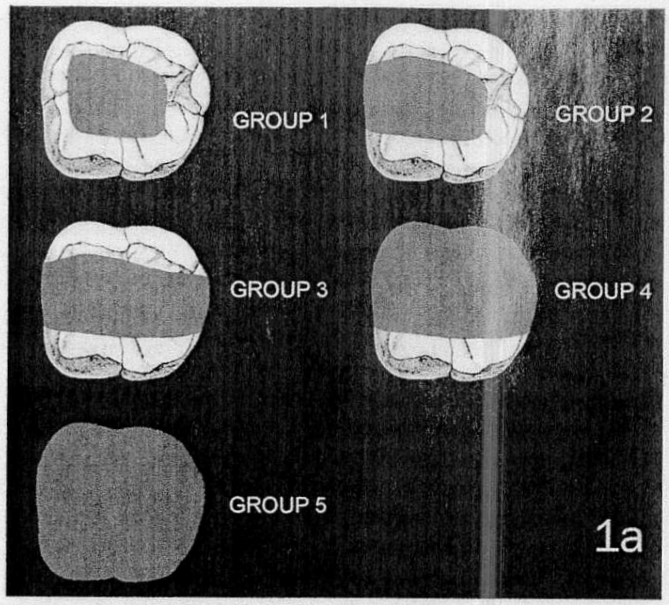
Endodontically treated teeth (ETT) are considered to have a higher risk of fracture because of their inherently poor structural integrity as a result of pre-existing caries and/or tooth preparation (1, 2). Loss of the roof of the pulp chamber and/or the marginal ridges is further factors that are likely to influence the fracture resistance of such teeth (3). The fracture potential of ETT have been studied, yet to date, no definite causal relationship between fracture and the type of restoration has been established, and controversies remain regarding which material or technique would be ideal for their rehabilitation.

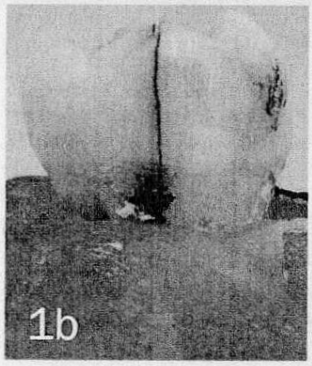
Although posts are necessary to retain coronal build-up materials, they do not reinforce roots and may even weaken them through loss of radicular dentin necessitated by post-space preparation (4). Furthermore, and particularly regarding prefabricated posts, the interfaces between materials of different moduli of elasticity represent areas of weakness as local discrepancies influence stress-strain distribution (4). In this respect, posts with similar biomechanical properties to dentin, viz. carbon fiber-reinforced posts, were developed (5–7). These were followed by translucent glass or quartz fiber-reinforced posts with better esthetic properties. A major advantage of such posts is the possibility of using composite restorative materials to rebuild missing coronal structure, which offers better interfacial integrity through the use of materials of similar elastic moduli (8, 9). Furthermore, since chemical bonding is not possible with the matrices used in post fabrication, chemical bonding can be achieved between post fibers and core material by applying a silane agent (10). Etching of the post surface is also possible using 10% hydrogen peroxide, thus increasing the surface area and improving the micromechanical retention at the post-core interface (11).

The aim of the present study was to compare the fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composites with or without translucent glass fiber posts, and with respect to the number of residual cavity walls. The null hypothesis tested was that there is no association between the fracture resistance (and patterns) of endodontically treated mandibular molars restored by means of resin composite with or without glass fiber-reinforced posts, and the number of residual cavity walls remaining coronally.

Materials and Methods

Ninety human mandibular first and second molars, extracted for periodontal reasons, were selected. Teeth with caries and/or previous restorations were excluded. Dental plaque, calculus and periodontal tissues were removed. The teeth were stored in 0.9% saline solution at 37°C. Canal morphology was verified from standardized apical radiographs (70 kV and 0.08 s) both in the mesio-distal and bucco-lingual directions. The pulp chamber of each tooth was opened and working length was determined visually by placing a size #10 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) at the apical foramen. Root canals were instrumented using stainless steel K-files #10, 15, 20 (Dentsply-Maillefer) followed by rotary Ni-Ti instruments (ProTaper, Dentsply-Maillefer) according to the manufacturer's instructions. All canals were prepared to the F2 size and instruments discarded after use in four root canals or if instrument deformation was visible. Root canals were irrigated between instrumentation with 2 ml 5.25% sodium hypochlorite. All teeth were obturated using the warm vertical condensation





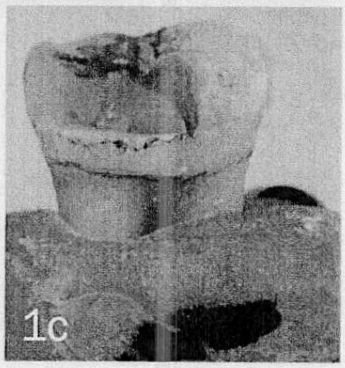


Figure 1. (*a*) Schematic drawing representing the loss of dentinal walls in each group. (*b*) Sample from group 3a exhibiting a nonrestorable vertical fracture extending in the mesial root. (*c*) Sample from group 5b exhibiting a restorable fracture. The acrylic resin was removed with a carbide bur to show that radicular fracture did not occur. It appears clearly that the failure occurred rather in the restorative material before root fracturing stress levels could be obtained.

technique, using calibrated gutta-percha points (F2, Dentsply-Maillefer) and an endodontic sealer (AH26, Dentsply-Maillefer).

To account for the influence of root canal morphological variations on the results, teeth were classified according to their mesio-distal and bucco-lingual dimensions and proportionately distributed among the experimental groups so as to have similar representation of morphologies within them. Experimental group 1 comprised 10 teeth (control group) while groups 2 to 5 comprised 20 teeth each. The specimens were prepared as follows (Fig. 1*a*):

Group 1 (control group): the pulp chamber was filled with a flowable resin composite material (X-Flow, Dentsply-Caulk, York, PA) and a micromatrix resin composite material (Ceram X, Dentsply-Caulk); all coronal walls were left intact;

Group 2: the distal wall of each tooth was removed, using the limits of the marginal crest as an anatomic reference. The cavity was extended towards the access preparation to create a divergent disto-occlusal standardized adhesive preparation. The cervical margin was placed 1 mm apical to the CEJ;

Group 3: both the distal and mesial walls of each tooth were removed to create a mesio-occluso-distal (MOD) cavity; the same preparation criteria used in group 2 was adopted;

Group 4: the distal, mesial and buccal walls of each tooth were removed; the same preparation criteria used in previous groups were adopted;

Group 5: the whole crown of each tooth was removed 1 mm coronally to the most occlusal point of the CEJ.

Groups 2 through 5 were divided into two subgroups, designated a and b ($n = 10$ each). Subgroups 2a through 5a were restored with an approximately 2 mm thick layer of flowable resin composite material (X-Flow, Dentsply-Caulk), followed by several layers of micromatrix resin composite material (Ceram X, Dentsply-Caulk). In subgroups 2b through 5b, the coronal build-up was preceded by placement of a translucent glass fiber post (DT Light Post, RTD, St. Egreve, France). Each post was tried into the root canal and cut to adequate length with a diamond bur so as to cover its occlusal end with at least 2 mm of composite resin. The post surface was silanized with Calibra Silane (Dentsply-Caulk) for 60 s. The canal walls were etched with 36% phosphoric acid for 15 s, and then rinsed and dried with paper points. Prime & Bond NT Dual-Cure (Dentsply-Caulk) was used as an adhesive and light-cured for 20 s using a halogen light-curing unit (Astralis 10, Ivoclar-Vivadent, Schaan, Liechtenstein) at 750 mW/cm^2, before luting the posts with a dual-cure resin cement (Calibra, Dentsply-Caulk), according to the manufacturer's instructions. Light curing was performed through the post for 40 s.

Using transparent matrices (Hawe Striproll, Kerr-Hawe, Bioggio, Switzerland), a standardized incremental composite build-up technique was used, consisting of light-curing for 40 seconds of each 2 mm of resin composite increment. A simplified anatomic build-up technique was used to restore the occlusal surface of the crowns.

Each tooth was embedded in a block of self-curing acrylic resin (Orthoresin, Lang Dental MFG., Co., Wheeling, IL) using a silicone mold, leaving 2 to 3 mm of the root exposed so as to morphologically evaluate the eventual root fractures. A 0.5-mm layer of polyvinylsiloxane impression material (Flexitime, Heraeus Kulzer, Hanau, Germany) was applied in the root region to simulate the periodontal ligament before embedding the tooth. Specimens were stored for less than 1 week in distilled water at room temperature before testing. A universal loading machine (Triaxal Tester T400 Digital, Controls srl, Cernusco s/N., Italy) was used for evaluating static fracture resistance. Each specimen was inserted vertically into the holding device and a stainless steel rod having a 3 mm tip diameter was used to apply the controlled load in a direction parallel to the longitudinal axis of the tooth. The point of load application was 2 mm from the tip of the buccal cusp towards the central fossa, to simulate occlusal load. Crosshead speed was 1 mm/minute, and all samples were loaded until fracture while maximum breaking loads were recorded in Newtons (N) by a computer (Digimax Plus, Controls srl) connected to the loading machine. Fracture resistance of the test specimens was specifically measured as the axial compressive load to cause fracture and determined by noting an evident load drop with the mechanical testing machine. Macroscopic fracture patterns were observed after ink perfusion to highlight fracture lines, photographs were taken using a digital camera, and the mode of failure was classified as restorable or unrestorable (fractures were classified as unrestorable if root fractures occurred). Data were statistically analyzed with SPSS 12.0 (SPSS, Inc., Chicago, IL). The Kolmogorov-Smirnov test was used to verify the normality of the data distribution. The one-way ANOVA was then used, followed by Tukey post hoc test for multiple comparisons; p was set to 0.05 for all statistical tests.

Results

According to the Kolmogorov-Smirnov test, the data had a normal distribution that allowed for further statistical analyses. One way ANOVA

TABLE 1. Means and Standard Deviations of Fracture Resistance (in Newtons)

WALLS left (group)	No post (subgroups a)		Post (subgroups b)	
	Mean	SD	Mean	SD
0 walls (5)	833.4^{c}	179.7	677.2^{c}	21.3
1 wall (4)	653.1^{c}	36.5	706.8^{c}	130.8
2 walls (3)	1195.2^{a}	332.9	878.2^{ac}	135.6
3 walls (2)	1606.8^{b}	410.5	1512.2^{ab}	267.0
4 walls (1)	1197.9^{a}	363.5	—	—

Different letters indicate statistically significant differences. For the number of residual walls, the Tukey post hoc test showed that between groups 4a, 4b, 5a, and 5b, differences in the fracture resistance of the teeth were not statistically significant ($p > 0.001$), but the differences were statistically significant with group 1, 2a, 2b, 3a, with group 3a significantly different from group 2a, 2b, and group 1 significantly different from 2a.

revealed that the difference in fracture resistance of the specimens was statistically significant ($p < 0.001$). Mean fracture resistances, standard deviations, and Tukey post-hoc test results are given in Table 1. Results of modes of failure (restorable, Fig. 1*b*; unrestorable, Fig. 1*c*) are given in Table 2.

Discussion

This study was designed to assess the fracture resistance and pattern of failure of mandibular molars restored using microhybrid resin composite with or without translucent fiber-reinforced posts. The study also attempted to take into consideration the degree of destruction of the crown before restoration. Given the finding that the number of residual cavity walls and the resistance to fracture was related, as was the fracture pattern and the presence or absence of fiber-reinforced posts, the null hypothesis was rejected.

The use of resin-based cement in this experimental design was intended to circumvent the potentially detrimental influence that eugenol-containing root canal sealers have on the adhesion between root dentin, luting agents and fiber posts. However, the potential negative influence of sodium hypochlorite on bond strength was not taken into account. It has elsewhere been shown that the presence of a periodontal analogue is of importance in fracture testing, resulting in significant modifications in modes of fracture (10). The present study took this into consideration by adding a layer of silicone simulating the periodontium.

The choice of load direction (parallel to the long axis of the tooth) was also designed to simulate physiological function and to obtain a degree of nonaxial loading through existing occlusal contact variations. For this reason, it was not deemed necessary to have the loading tip contact simultaneously the two inner cuspal sides as this would have generated a wedge effect that might have skewed the results (11). The forces placed on the dentition during normal masticatory function are generally small compared to the maximal biting force. Anderson (12, 13) was the first to measure loads on mandibular molars using strain gauges and found that the maximum whole tooth load varied between 7.2 and 14.9 kg (70.6 and 146 N) when eating meat, biscuit or carrots. De Boever et al. (14) reported forces of between 2.4 and 7.2 kg (23.5 and 70.6 N) using transmitters in removable pontics, and concluded that functional chewing forces are variable from session to session and change with the consistency and viscosity of the food. More recently, maximum biting force on the first molar was reported as approximately 859 N (15), and elsewhere as (878 N) (16). The mean fracture load recorded in this study for the control group was 1198 N that is higher than both the maximum chewing and biting loads reported. Groups 2 and 3 also displayed fracture resistances that were greater than the maximum loads. Groups 4 and 5, however, showed fracture resistance values in the range of maximal biting loads but greater than physiological masticatory forces. Thus, it may be suggested from these data that crown coverage is not necessary in molars restored with composite resins. However, this study did not take into account the effect of aging of dental bonds (17), long-term behavior of such restorations (18), or the influence of parafunctional habits (19).

No significant differences between sub-groups, representing the influence of a post for a given coronal restoration, were noted. Significant differences did emerge, however, among the groups, whereby the more the residual walls, the higher the resistance, with the exception of group 1 that exhibited a significantly lower fracture resistance than group 2a. Data regarding compressive and flexural properties of the posts and core materials used were not available, and thus the observed behaviors of specimens under loading conditions could not be interpreted with regard to the relative differences in mechanical properties of post material, composite resins and tooth structure (20). However, it could be suggested that the influence of cavity design, as reflected by the behavior of multi-walled restorations (groups 1 and 2) is important. However, corroborating evidence for this is needed through further investigations.

The ink perfusion produced an interesting finding. Contrary to the findings with metallic posts, it would appear that the use of fiber-reinforced posts has a positive effect on the fracture pattern, resulting in most fractures being restorable. Recently, it has been found that post geometry can significantly affect post retention (21, 22), and there is every reason to suppose that a variation of the geometry of posts used in this study could have produced a different outcome.

Within the limitations of this study, it can be concluded that the resistance to fracture of endodontically treated mandibular molars restored with composite resins is mainly affected by the number of residual coronal walls. More walls are clearly beneficial, although it also seems that one wall could be sacrificed to compensate for the C-factor. Fracture resistance is not affected by the presence or absence of fiber-reinforced posts. While coronal coverage may remain the recognized standard of care for posterior ETT that are also subjected to parafunctional forces, the findings suggest that many such teeth that are not subjected to heavy occlusal forces, may be adequately restored with

TABLE 2. Modes of failures

WALLS left (group)	No post (subgroups a)		Post (subgroups b)	
	Unrestorable	Restorable	Unrestorable	Restorable
0 walls (5)	40%	60%	0%	100%
1 wall (4)	40%	60%	0%	100%
2 walls (3)	60%	40%	30%	70%
3 walls (2)	70%	30%	50%	50%
4 walls (1)	60%	40%	—	—

Samples restored with fiber posts mostly exhibited restorable fractures while teeth restored without fiber posts mostly exhibited unrestorable fractures (Fig. 1*b*). This was particularly true for groups with one or no walls left (groups 4 and 5) were subgroups b showed 100% restorable fractures (Fig. 1*c*).

bonded resin composites. In such cases, the use of posts seems to optimize fracture patterns and so facilitate re-treatment. Further research is still necessary to investigate the longevity of such restorations especially in clinical conditions, and the possible influence of parafunction.

Acknowledgment

This research was supported by College of Dentistry Research Center, King Saud University, Riyadh, KSA, Grant no. F1110.

References

1. Tidmarsh BG. Restoration of endodontically treated posterior teeth. J Endod 1976;2:374–5.
2. Eakle WS, Maxwell EH, Braly BV. Fracture of posterior teeth in adults. J Am Dent Assoc 1986;112:215–8.
3. Reeh ES, Douglas WH, Messer HH. Stiffness of endodontically treated teeth related to restoration technique. J Dent Res 1989;68:1540–4.
4. Assif D, Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. J Prosthet Dent 1994;71:565–7.
5. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000;13:9B–13B.
6. Fredriksson A, Astback J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber reinforced epoxy resin posts. J Prosthet Dent 1998;80:151-15.
7. Sidoli GE, King PA, Setchell DJ. An in vitro evaluation of carbon fiber based post and core system. J Prosthet Dent 1997;78:5–9.
8. Trope M, Langer I, Maltz D, Tornstad L. Resistance to fracture of endodontically treated premolars. Endo Dent Traumatol 1986;2:35–8.
9. Steele A, Johnson BR. In vitro fracture strength of endodontically treated premolars. J Endod 1999;25:6–8.
10. Soares CJ, Pizi ECG, Fonseca RB, Martins LRM. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. Braz Oral Res 2005;19:11–6.
11. Korioth TWP, Versluis A. Modeling the mechanical behavior of the jaws and their related structures by finite element analysis. Crit Rev Oral Biol Med 1997;8:90–104.
12. Anderson DJ. Measurements of stress in mastication 1. J Dent Res 1956;135:664–70.
13. Anderson DJ. Measurements of stress in mastication 2. J Dent Res 1956;135:671–3.
14. De Boever JA, McCall WD, Holden S, Ash MM. Functional occlusal forces: an investigation by telemetry. J Prosthet Dent 1978;40:326–33.
15. Cosme DC, Baldisserotto SM, Canabarro Sde A, Shinkai RS. Bruxism and voluntary maximal bite force in young dentate adults. Int J Prosthodont 2005;18:328–32.
16. Ahlberg JP, Kovero OA, Hurmerinta KA, Zepa I, Nissinen MJ, Kononen MH. Maximal bite force and its association with signs and symptoms of TMD, occlusion, and body mass index in a cohort of young adults. Cranio 2003;21:248–52.
17. Ferrari M, Mason PN, Goracci C, Pashley DH, Tay FR. Collagen degradation in endodontically treated teeth after clinical function. J Dent Res 2004;83:414–9.
18. Armstrong SR, Vargas MA, Chung I, et al. Resin-dentin interfacial ultrastructure and microtensile dentin bond strength after five-year water storage. Oper Dent 2004;9:705–12.
19. Fernandes AS, Dessai GS. Factors affecting the fracture resistance of post-core reconstructed teeth: a review. Int J Prosthodont 2001;14:355–63.
20. Galhano GA, Valandro LF, de Melo RM, Scotti R, Bottino MA. Evaluation of the flexural strength of carbon fiber-, quartz fiber-, and glass fiber-based posts. J Endod 2005;31:209–11.
21. Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M. The contribution of friction to the dislocation resistance of bonded fiber posts. J Endod 2005;31:608–12.
22. Pirani C, Chersoni S, Foschi F, et al. Does hybridization of intraradicular dentin really improve fiber post retention in endodontically treated teeth? J Endod 2005;31:891–4.