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Original Article

Evaluation of the Effect of Furcation Perforation on the Fracture Resistance of Endodontically Treated Mandibular Molars

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ABSTRACT

Background: Root perforations are among the most common procedural complications during root canal treatment; these complications have a poor prognosis. This study aimed to evaluate the effect of furcation perforation on the fracture resistance of endodontically treated mandibular molars.

Method: Sixty intact extracted mandibular molars were divided into two groups; with a marginal ridge (access only) and without a marginal ridge (MOD and access cavity preparation). The two groups underwent endodontic treatment and were divided into three subdivisions: the first group was prepared without any furcal perforation, the second group had a 1-mm perforation in the furcation area, and the third group was prepared with a 3-mm perforation in the furcation area. The furcation perforation site was filled with calcium hydroxide powder and covered with glass-ionomer (GI). The teeth were restored with posterior composite resin. The teeth were then mounted in acrylic blocks and tested with a Testometric machine under compressive strengths. The fracture resistance diagram of each tooth was drawn. The data were analyzed with two-way ANOVA. The fracture patterns were evaluated after separating the teeth from acrylic blocks.

Results: Loss of marginal ridge had no significant effect on fracture resistance measurements (P=0.312), but the furcal perforation variable resulted in significant differences in fracture resistance measurements (P=0.004). Teeth without furcal perforation differed significantly from the teeth with a 3-mm furcal perforation in fracture resistance (P=0.009). The 1-mm furcal perforation group differed significantly from the 3-mm furcal perforation group in fracture resistance (P=0.011).

Conclusion: The teeth with a 3-mm furcal perforation exhibited lower fracture resistance than the two other groups.

Keywords: Fracture resistance, Marginal ridge, Perforation

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Introduction

Although tooth perforation is not the primary cause of treatment failure in endodontics, it is one of the destructive conditions that often leads to tooth extraction (1). Teeth with endodontic treatment usually lose a large volume of their structure due to caries, previous restorative procedures, root canal treatment, and access cavity preparation (2). Decreased dental structure and loss of healthy dentine, due to tooth preparation, make teeth more prone to fracture (3). Preparing larger cavities can lead to the removal of a large amount of tooth structure, and the more the dentine is removed, the lower the fracture resistance (FR) will be. The remaining tooth structure is crucial (4).

Furcation perforation creates a communication between the root canal system and the supporting periodontal tissue in the furcation area, resulting from resorption, caries, or iatrogenic errors by dentists (5). The latter occurs during access cavity preparation due to incorrect orientation of the bur or upon searching for calcified root canals and during post space preparation. It has been reported that 47% of perforations occurred during endodontic treatments and 53% were due to prosthodontic procedures. In a previous study, the prevalence of perforations in maxillary teeth (74.5%) was higher than that in mandibular teeth (25.5%) (6). Furcal perforation leads to adverse clinical consequences and should be treated as soon as possible (7). Trauma from furcal perforation and subsequent inflammation might rapidly establish a communication between the pulp and gingival sulcus, eventually leading to irreversible periodontal lesions (8). The tooth support is provided by the combined action of the periodontal ligament (PDL) and alveolar bone. When the PDL is intact, occlusal loads are transmitted to the surrounding bone structure (9). A study found that furcal perforations caused by extensive internal resorption can alter the prognosis of the tooth due to the loss of significant tooth structure (10). A study reported that 40.3% and 4.2% of endodontically treated teeth were extracted due to periodontal disease and iatrogenic perforations or stripping, respectively (1). There is a gap in the knowledge about the effect of furcal perforation with or without marginal ridge on fracture resistance. This study evaluated the effect of furcation perforation on the fracture resistance of endodontically treated mandibular molars.

Materials and Methods

The Ethics Committee reference number was IR.KMU.REC.1388.84.

The present study was performed on 60 extracted mandibular molar teeth [without caries, previous restorations, cracks, and fractures as observed under a stereomicroscope (Eurotek International Ltd., Warsaw, Poland) at ×25 magnification]. The teeth had separate mesial and distal roots. Samples that were much larger or smaller than a normal tooth (according to an endodontist's opinion with more than 10 years' experience) by measuring the buccolingual and mesiodistal dimensions of the teeth were excluded (11).

The teeth were immersed in 2.6% sodium hypochlorite solution for 30 minutes, followed by storage in saline solution at room temperature until the study was instituted.

Standard access cavities were prepared in all the teeth to achieve access cavities with similar dimensions (12). A high-speed handpiece with water and air spray and #8 long diamond fissure burs (MANI, Tochigi, Japan) were used for access cavity preparation. After 10 preparation procedures, the burs were replaced by new ones. Then mesiolingual, mesiobuccal and distal root canals were negotiated by a #10 K-file, and the working length (WL) was determined after visualization of the file beyond the apex at 1 mm shorter than this length (if the canals were calcified, they were excluded). Apical preparation was carried out until #20 K-file could reach the WL. Rotary Hero 642 (Micro-Mega, Besancon, France) files were used with RC Prep (Well-Prep, Vericom Co, Anyang, Korea) as lubricant according to the manufacturer's instructions for cleaning and shaping the root canals with any curvature. Coronal pre-flaring was carried out with GG #2 and #3 (MANI, Tochigi, Japan). Preparation continued until file #40 with 4% taper reached the WL. Irrigation with 0.9% saline solution and 5.25% NaOCl was carried out between files.

The root canals were dried with paper points (Dentsply/Tulsa Dental. Tulsa. OK, US), followed by obturation with lateral condensation technique with AH26 sealer (Dentsply/Tulsa Dental. Tulsa. OK, US). The teeth were randomly divided into six groups:

1. MR-0P (With marginal ridge, 0mm perforation)
2. MR-1P (With marginal ridge, 1mm perforation)

3. MR-3P (With marginal ridge, 3mm perforation)
4. MRL-0P (Marginal ridge loss, 0mm perforation)
5. MRL-1P (Marginal ridge loss, 1mm perforation)
6. MRL-3P (Marginal ridge loss, 3mm perforation)

In the late three groups (4,5,6) mesio-occluso-distal (MOD) cavity was added to the prepared access cavity, using a diamond bur under air and water spray. The MOD cavity was prepared with a buccolingual dimension equal to half of the distance between the buccal and lingual cusps, and the proximal box was prepared with a buccolingual dimension equal to half of the distance between the buccal and lingual cusps (1.5 mm axial depth and 1 mm above the CEJ). The buccolingual width was measured by a Vernier, and an attempt was made to make the cavity dimensions as similar as possible (13).

One-millimeter furcal perforation was first created at the middle of the pulp chamber floor using a long-neck round handpiece bur #1014 (MANI, Tochigi, Japan) (1 mm in diameter). Three-millimeter furcal perforation was created using a round #031 handpiece bur (Meisinger, Neuss, Germany) under water and air spray at the center of the pulp chamber floor. The furcal perforations were filled with calcium hydroxide powder (Golchai, Karaj, Iran). Although MTA is a material of choice but in this *in-Vitro* study we used calcium hydroxide to fill the furcal perforation because it does not have any effect on fracture resistance and does not bond to the tooth structure.

The powder was coated with GI (GC Corporation, Tokyo, Japan) to prevent calcium hydroxide from being washed away during the etch-and-bonding steps.

All teeth were restored with posterior composite resins as follows: First, the tooth surface was etched with 37% phosphoric acid for 15 seconds and then rinsed and dried. Single Bond (3M ESPE) bonding agent was applied in two layers on the tooth surface and was polymerized for 10 seconds using a light-curing device (Coltolux, Germany) according to the manufacturer’s instructions. The head of the device was placed in close contact with the specimens as much as possible; then, the composite resin was placed incrementally in 2-mm layers and polymerized with a light-curing device for 20 seconds. After completing the restorative procedure, excess material was removed with a composite resin polishing bur (MANI, Tochigi, Japan). The samples were then incubated for seven days at 37°C.

To measure fracture resistance using a surveyor (Saeshin Precision Ltd., Daegu, South Korea), the prepared teeth were mounted in self-cured acrylic resin blocks with the long axis of all the specimens perpendicular to the horizon.

The teeth were mounted in blocks 1 mm apical to the CEJ (8). Each sample was then placed in the Testometric device (Testometric Micro 500; Testometric Company, Ltd., Lancashire, UK) to perform the compressive strength test (Figure1).

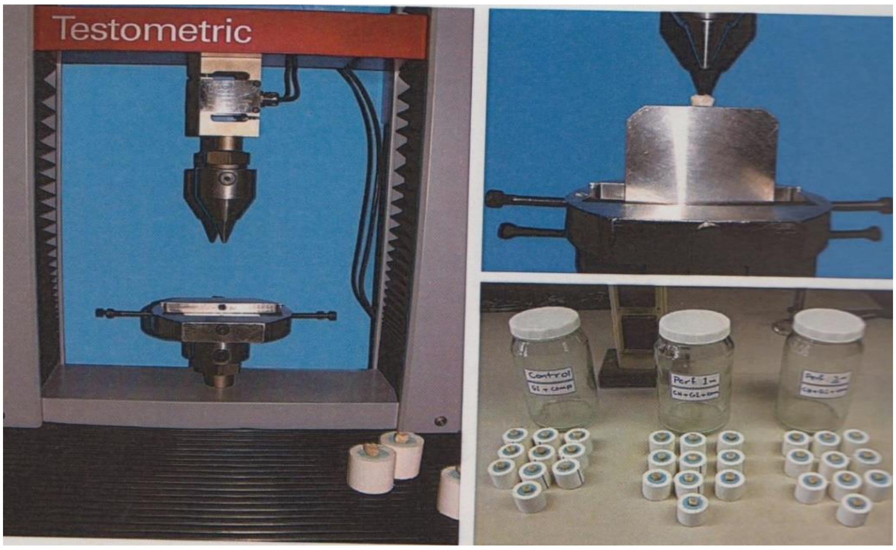

Figure 1. Testometric Machine

The force was applied by a metal cylinder with a round end, measuring 6 mm in diameter (similar to the upper palatal molar cusps). The force was applied to the middle of the occlusal surface to contact the working and non-working cusps (11).

The device's crosshead speed was 0.5 mm/min, and the force was applied until the sample fractured (Figure 2).

The downward motion was observed in the diagram drawn by the device software (Figure 3).

Figure 2. Teeth after perforation

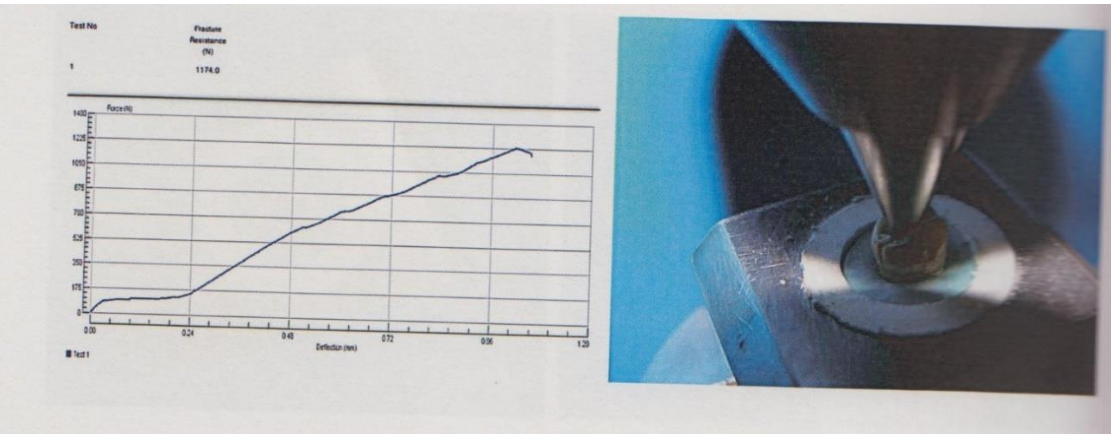

Figure 3. Diagram drawn by Testometric machine for each tooth

Resistance to fracture was recorded in Newton (14). In the next step, the teeth were retrieved from the acrylic blocks, and their fracture pattern was determined based on the following criteria:

1) Fracture limited to the restoration, 2) fracture only in the tooth structure, 3) fracture in the tooth structure and restoration, 4) fracture in the tooth, restoration, and furcation, 5) unclear fracture pattern.

Statistical Analysis

The data were analyzed through SPSS version 18 (SPSS Inc, Chicago) and using two-way ANOVA and post hoc Tukey tests to show the impact of marginal ridge and the size of furcation perforation as independent variables on fracture resistance as a dependent variable. The level of significance was set at P=0.05.

Results

Table 1 presents the means and standard deviations of fracture resistance in the six study groups.

Table 1. Means and standard deviations of fracture resistance in six study groups

Fracture resistance Groups	Mean	SD
Control with marginal ridge	1473.300	190.012
Perforation 1 mm with marginal ridge	1515.250	552.669
Perforation 3 mm with marginal ridge	832.790	429.235
Control without marginal ridge	1639.410	919.725
Perforation 1 mm without marginal ridge	1562.080	721.838
Perforation 3 mm without marginal ridge	1098.120	549.770
Total with marginal ridge	1273.780	513.876
Total without marginal ridge	1433.203	759.692

Loss of marginal ridge did not result in a significant difference in the fracture resistance (P=0.312), but the furcal perforation size gave rise to a significant difference in the fracture resistance (P=0.004).

The two independent variables (loss of marginal ridge and furcal perforation) effects did not interfere with each other (P=0.85).

The diameters of furcal perforations, which resulted in a significant difference in fracture resistance in the groups, are shown in Table 2.

Table 2. Determining the effect of furcal perforations on fracture resistance in the samples

Comparison (perforation size)	Mean Difference	S.E	P-Value
0-1	17.6900	191.26706	0.995
0-3	590.9000	191.26706	0.009
1-3	573.2100	191.26706	0.011

Teeth without furcal perforation differed significantly in fracture resistance from the teeth with 3-mm furcal perforations (P=0.009). Also, the 1-mm furcal perforation group differed significantly from the 3-mm group in fracture resistance (P=0.011). However, the non-perforation group did not differ significantly from the 1-mm furcal perforation group in fracture resistance (P=0.995).

Concerning tooth fracture patterns, no sample was found with a fracture pattern limited to the restoration. Also, 26.7% of fracture patterns were limited to the tooth structure. In 55% of cases, fractures were observed both in the tooth and restoration. In 8.45% of cases, the fracture was observed in the tooth, restoration, and furcal perforation simultaneously. In 10% of cases, the pattern of failure was unclear (Table 3).

Table 3. fracture patterns in the study groups

Fracture patterns Groups	Fracture in restoration	Fracture in tooth	Fracture in tooth and restoration	Fracture in tooth and restoration and furcation	crack	total
Control with marginal ridge	0	3	6	0	1	10
1mm perforation with marginal ridge	0	3	4	0	3	10
3 mm perforation with marginal ridge	0	5	1	3	1	10
Control without marginal ridge	0	2	7	0	1	10
1mm perforation without marginal ridge	0	3	7	0	0	10
3 mm perforation without marginal ridge	0	0	8	2	0	10
percentage	0%	26.7%	55%	8.4%	10%	100%

Discussion

According to this study, Loss of marginal ridge had no significant effect on fracture resistance, but the furcal perforation variable resulted in significant differences in fracture resistance. Teeth without furcal perforation and with a 1-mm furcal perforation differed significantly from the teeth with a 3-mm furcal perforation in fracture resistance but, 1-mm furcal perforation did not differ from non-perforated teeth in fracture resistance.

However, many studies have evaluated the effect of various factors on perforation prognosis, such as size, time, position, and type of restorative material used for sealing the area and its effect on tooth survival (8). This study evaluated the effect of furcation perforation on fracture resistance in mandibular molar teeth.

Jamshidy *et al*. showed no difference in fracture resistance in teeth with 1- and 2-mm furcal perforations compared to non-perforated teeth (15), consistent with our results, but the effect of the loss of marginal ridge was not considered. Askerbeyli Ors *et al*. showed that furcal perforation size has a negative effect on fracture resistance (16).

This study aimed to stimulate occlusal forces on the teeth, as closely as possible, with the occlusal forces applied by the opposite jaw. Therefore, the palatal cusp dimensions of the maxillary molar teeth were measured from many gypsum casts, and their average was estimated at 6 mm.

The metal cylinder was initially made with an approximate length of 5 cm. The pilot study showed that with this length, the cylinder bent due to the application of force. Finally, the metal cylinder was used for applying force with a cone-shaped round-end beak, 6 mm in diameter, and with a short length.

Endodontically treated teeth often lose their structure due to extended caries, previous restorations, or endodontic treatment, and this reduction in tooth structure and dentine loss weakens the tooth (2). Gokturk *et a.l* showed that intact teeth have higher fracture resistance than teeth with MOD cavity preparation with direct composite restoration (17). The same result was reported by Reeh *et al*. (18).

According to the results, the teeth with marginal ridges were less resistant to fracture than the teeth without marginal ridges, which can be explained by two points. First, dentine bonding is likely to create a strong bond between tooth structure and posterior composite restorations (19). The composite resin used to repair MOD and access cavities was Filtek P60, a packable, nanofilled, and high-filler composite resin.

Abe *et al*. investigated differences in the packable composite resins' behaviors and showed that the Filtek P60 composite resin has a modulus of elasticity equal to or higher than dentine (20). Papadogiannis *et al*. reported similar results in 2007 by examining the fatigue characteristics of four posterior composite resins (21). They showed that Filtek P60 composite resin exhibited the best behavior against fatigue, and according to this study, it is a suitable posterior composite resin to bear occlusal forces.

Recent studies have shown that teeth restored with resin-bonded porcelain inlays had the same cusp hardness as unrestored teeth, and teeth restored with conservative restorations exhibited greater strength because a bond is formed between the tooth structure and the ceramic material. These teeth exhibited less cuspal flexibility, more resistance to fracture, and less microleakage (22).

Therefore, the present study results showed that Filtek P60 composite resin's fracture resistance is higher than dentine, and tooth restoration with posterior composite resin can play the role of a marginal ridge.

Secondly, the study was performed under static conditions, in which heat and pressure cycles were not applied to the teeth; it is likely that if they were placed under thermal cycles or in artificial oral conditions, the results could have been different. Eakle *et al*. investigated the effect of thermal cycles on fracture resistance and microleakage in composite resin-restored teeth, reporting that the tooth strength decreased over time due to the thermocycling process (23).

Since 3-mm furcal perforation significantly decreased fracture resistance, it is recommended that the effect of different materials in repairing 3-mm furcal perforations be evaluated in future studies. It should also be noted that in clinical situations, the residual structure of endodontically treated teeth is less than the standard MOD cavity (prepared in this study); therefore, further studies are recommended.

Conclusion

Under the condition of this in-vitro study, Loss of marginal ridge does not affect fracture resistance measurements, but the furcal perforation variable results in different fracture resistance measurements. Teeth without furcal perforation differ from the teeth with a 3-mm furcal perforation in fracture resistance. The 1-mm furcal perforation differs from the 3-mm furcal perforation in fracture resistance.

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