Original Article

Effect of different dentin thicknesses between floor of pulp chamber and furcation area, alone or with addition of MTA, on fracture resistance in mandibular molars (An in-vitro study)

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Abstract

Aim: This study aimed to compare the effect of different remaining dentin thicknesses RDT (1mm, 2mm and 3mm), between floor of pulp chamber and furcation area, alone or after addition of MTA layers (1 mm and 2 mm), on fracture resistance of mandibular molars.
Subjects and methods: Access cavities were performed on fifty human extracted mandibular molars using a round diamond and tapered stone. Pulp debridement of all samples was done. Teeth were randomly assigned into 3 main groups according to dentin thickness. Group 1: remaining dentin thickness 2 mm between the floor of pulp chamber and bifurcation area (n=20). Group 2: remaining dentin thickness 1 mm between the floor of pulp chamber and bifurcation area (n=20). Group 3: average dentin thickness 3 mm between the floor of pulp chamber and bifurcation area (n=10). Group 1 and 2 were sub-divided into two equal subgroups (n=10) according to the thickness of MTA added. For group 1: Subgroup (1a): no MTA was added and subgroup (1b): 1 mm of MTA was added. For group 2: Subgroup (2a): no MTA was added and subgroup (2b): 2 mm of MTA was added. Then, a compressive force was applied toward the floor of the prepared cavity causing vertical fracture by using Instron testing machine to determine the remaining dentin thickness behaviour in all groups and their subgroups.
Results: There was no statistically significant difference between the three groups (G: 1a, 2a and 3) with p-values 0.54, 0.67 and 0.99 respectively. As well as no statistically significant difference between Group 2b and Group 1b (RDT 2 mm with 1 mm MTA) with p-value 0.12. In contrast to Group 2b and other groups (Group 3, 1a and 2a) where there were statistically significant differences with P-values= 0.05, 0.04 and 0.006, respectively.
Conclusion: Addition of a layer of 2 mm thickness of MTA to the floor of pulp chamber significantly increases the fracture resistance at bifurcation area.

Keywords: dentin thickness, MTA, Instron testing machine, endodontically treated teeth, fracture resistance

Introduction

The main objective of root canal treatment is to remove harmful pathogens from the root canal and to create an environment, in which any remaining organism cannot endure.[1]

However, endodontically treated teeth are thought to be more susceptible to fracture due to the loss of tooth vitality and structure.[2]

Apparently, the quantity of residual dental substance after endodontic access cavity preparation could influence the resistance of the tooth to fracture during function.[3]

Excessive preparation at the floor of the pulp chamber is undesirable as it may lead to more sacrifice of additional tooth structure which ultimately leads to decreased fracture resistance of tooth.[4]

It has been proposed that the most critical factor regarding fracture resistance and survival of endodontically treated molars is the amount of remaining dentin.[5]

So, our main concern that could be drawn is that preservation of tooth structure is important for maintaining resistance to fracture, especially by preserving the remaining dentin thickness (RDT) even after endodontic treatment.[6]

MTA has been used experimentally for several years and was approved for human usage by the Food and Drug Administration (FDA) in 1998.[7]

It was also shown that root canal-treated teeth obturated with MTA exhibit higher fracture resistance than untreated teeth.[8]

Thus, the purpose of this study was to compare the effect of different remaining dentin thicknesses RDT (1mm, 2mm and 3mm), between the floor of the pulp chamber and bifurcation area, alone or after the addition of MTA layers (1 mm and 2 mm), on fracture resistance of mandibular molars.

Subjects and Methods

Regarding the primary outcome (resistance to vertical fracture) it was found that 10 teeth per group will be the appropriate sample size for the study with a total sample size of 50 teeth (5 groups) the power is 80% and α error probability =0.05. Sample size was calculated using the (G power software) based on a previous study, by Silva et al, 2021.[9]

Fifty recently extracted human permanent mandibular molars were selected for the study. Pre-operative radiographs were taken from bucco-lingual and mesio-distal aspects to evaluate the internal anatomy and fulfil the eligibility criteria. All procedures were performed by the main investigator.

Inclusion Criteria:

Human mandibular double-rooted molars were collected from the department of oral and maxillofacial surgery, Faculty of Dentistry, Cairo University, having mature root apices. Teeth were intact [no cracks, fractures, decay, previous root canal treatment, restoration, calcification, or resorption], average length ranged between 18-25 mm.

Exclusion Criteria:

Teeth with extensive caries, Internal or external resorption, Calcifications and pulp stones and Complex root and root canal anatomy.

Classification and Preparation of Samples:

The external root surfaces of the teeth were thoroughly washed under running water and cleaned from any hard deposits by an ultrasonic scaler. Teeth were then immersed in 5.25% sodium hypochlorite (NaOCl) solution for half an hour to disinfect the teeth and remove any soft tissue debris that remained on the root surfaces. The prepared teeth were finally stored in a sterile saline solution until use to preserve natural teeth hydration. Conventional coronal access cavities were prepared in all the teeth followed by pulp debridement using manual K-Files # 10 and 15 for all canals.

Then samples were randomly divided into three main groups according to dentin thickness. Group 1: remaining dentin thickness 2 mm between floor of pulp chamber and furcation area (n=20). Group 2: remaining dentin thickness 1 mm between floor of pulp chamber and furcation area (n=20). Group 3: average dentin thickness 3 mm between floor of pulp chamber and furcation area (n=10) (Figure 1). Only for group 1 and 2, depth marker burs (size 1&2) were used respectively for making holes in the floor of pulp chamber till reaching the required depth (Figure 2). Those holes were connected using Endo-z bur mounted on a high-speed handpiece under sufficient coolant. Groups 1 and 2 were sub-divided into two equal subgroups (n=10) according to the thickness of MTA added. For group 1: subgroup (1a): no MTA was added, and subgroup (1b): 1 mm of MTA was added (Figure 3). For group 2: subgroup (2a): no MTA was added, and subgroup (2b): 2 mm of MTA was added (Figure 4). Pre- and postoperative radiographs were taken to determine the remaining dentin thickness before and after adding different thicknesses of MTA.

Figure 1: Periapical radiograph of the sample in group 3 with dentin thickness 3 mm between floor of the cavity and bifurcation area

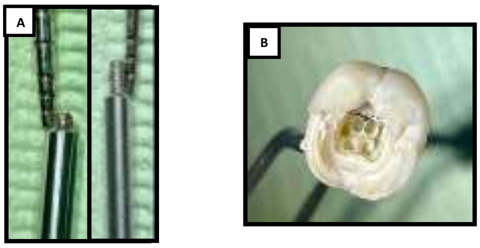

Figure 2: (A) Depth marker bur size 1 and 2. (B) Clinical photograph of the sample showing the holes in the floor of pulp chamber

Figure 3: Group (1b): (A) Preoperative periapical radiograph of the sample. (B) Postoperative periapical radiograph of the sample after reaching a distance of 2 mm between floor of the cavity and bifurcation area. (C) Postoperative periapical radiograph of the sample after adding 1 mm MTA

Figure 4: Group (2b): (A) Preoperative periapical radiograph of the sample. (B) Postoperative periapical radiograph of the sample after reaching a distance of 1 mm between floor of the cavity and furcation area. (C) Postoperative periapical radiograph of the sample after adding 2 mm MTA

Assessment of fracture resistance:

Samples were individually mounted vertically in polymethyl methacrylate (PMMA) resin blocks to a depth of 1 mm apical to the cement-enamel junction (CEJ). The blocks with the vertically aligned roots were mounted on the universal testing machine (Figure 5). A cylindrical hardened steel rod (3 mm diameter) was used to apply the force toward the floor of the prepared cavity causing vertical fracture. The load of fracture in Newtons was converted to Mega-pascals (MPa) by using the following formula:

$$MPa = \frac{Maximum\ load\ in\ Newtons\ (N)}{\pi/4\ \times\ (Area\ of\ Cross{-}section\ of\ plunger\ of\ contact)^2}$$

π =3.14 (constant value)

Area of cross section of plunger = 3 mm (uniform for all specimens)

Figure 5: Sample mounted on the universal testing machine for fracture resistance test

Statistical Analysis:

Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data for the fracture resistance test showed a parametric distribution (normal). The mean and standard deviation values were calculated in each group. One Way Anova followed by Post hoc test was used to compare between more than two groups for fracture resistance test. The level of significance was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 22 for Windows.

Results

The highest mean value was recorded for Group 2b [G2b: remaining dentin thicknesses RDT 1mm with 2 mm MTA] (1758.78 N± 403.55), followed by Group 1b [G1b: RDT 2 mm with 1 MTA] (1234.09± 399.27), then Group 3 [G3: RDT 3 mm] and Group 2a [G2a: RDT 1 mm without MTA] (1153.92± 301.88 and 956.84± 301.88 respectively). While the least mean value was recorded for group 1a [G1a: RDT 2 mm} (909.06±265.82) as shown in table 1.

There was a statistically significant difference between group 2b and all other groups except for group 1b (Table 1, figure 6). As for the correlation between G 3 (RDT 3mm) and the other groups (Group 1a,1b and 2a) where there was no statistically significant difference recorded between them with the P-values were 0.768, 0.995 and 0.878, respectively Table (1).

Table (1): The mean, standard deviation (SD), maximum (Max) and minimum (Min) values of fracture resistance (N) in different groups.

Groups	Fracture resistance (N)		
	Mean± SD	Max	Min
G1a: RDT 2 mm	909.06± 265.82^{b}	646.42	1206.27
G1b: RDT 2mm + 1mm MTA	1234.09± 399.27^{ab}	646.04	1689.89
G2a: RDT 1mm	956.84± 301.88^{b}	576.49	1352.06
G2b: RDT 1mm + 2 mm MTA	1758.78± 403.55^{a}	1034.50	2052.02
G3: RDT 3mm	1153.92± 416.52^{b}	466.17	1632.30
P-value	0.003*		

Superscripts with different small letters indicate statistically significant difference within the same column. *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

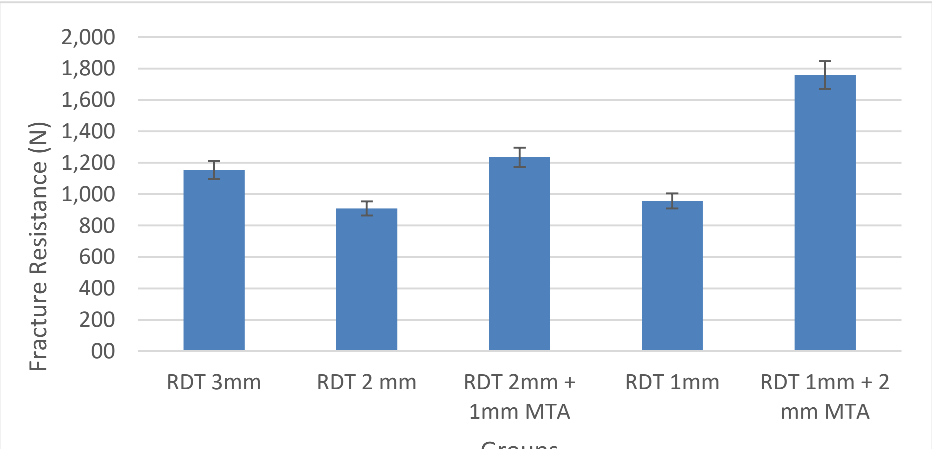

Figure 6: Bar chart for fracture resistance test (N) in different groups

Results concerning the types of fracture that occurred in the samples of different groups are shown in (Figure 7).

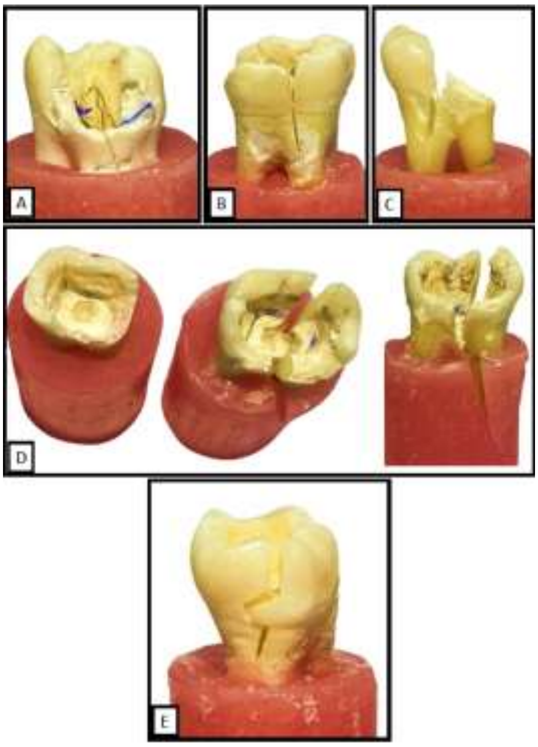

Figure 7: Representing types of fracture in each group: (A) Group 1a: RDT 2 mm. (B) Group 1b: RDT 2 mm with 1 mm MTA. (C) Group 2a: RDT 1 mm. (D) Group 2b: RDT 1mm with 2 mm MTA. (E) Group 3: RDT 3 mm

Different types of fracture were recorded which included vertical and oblique (chisel) pattern of fracture (Figure 8).

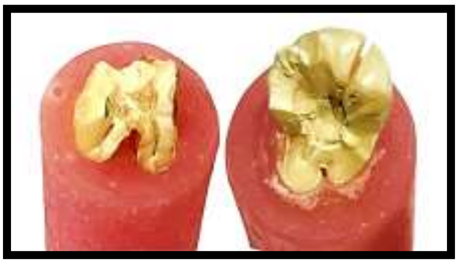

Figure 8: Teeth showing a chisel type of fracture

Discussion

Access cavity preparation may lead to scarification of additional tooth structure which ultimately might lead to decrease fracture resistance of tooth. Thus, minimally invasive cavities were suggested in an attempt to maintain the fracture resistance of teeth by partially preserving dentin thickness in the teeth.[10] The concept behind a positive association between the amount of dental structure preserved during access cavity preparation and fracture resistance seems to be logical.[11] So, this study aimed to compare the effect of different remaining dentin thicknesses RDT (1mm, 2mm and 3mm), between floor of pulp chamber and furcation area, alone or after addition of MTA layers (1 mm and 2 mm), on the fracture resistance at the bifurcation area of mandibular molars in a laboratory setting as it offers many advantages. The laboratory part of the study may help in the prediction of clinical outcomes and behaviour of the tooth under compressive force.[12]

Mandibular molars are subject to an excessive loss of dentin resulted from the access cavity preparation.[13,14] In 2006, Lobbezoo et al.[15] demonstrated that the action of jaw muscles can generate interocclusal forces responsible for elastic flexure of the mandible and significant clinical modification of posterior sections of the lower arch during stomatognathic functioning. Mechanical preparation was not performed in order to preserve more root dentin and maintain better fracture resistance of the whole tooth, just a pulp debridement for all samples was done as the mechanical preparation adversely affects the fracture resistance of roots which increased the possibility of teeth fracture.[16,17]

Depth marker burs were used to establish holes in the floor of pulp chamber in a depth of 1 mm and 2 mm layers rather than the conventional inverted cone bur, in order not to rely on manual abilities and personal experience.[18] A proper and standardized results can then be obtained.

Instron testing machine proved to be the simplest to perform and provides a fully standardized test.[19] There was no statistically significant difference between the three groups (1a, 2a and 3) coinciding with the previous studies[20-23] which demonstrated that there was no correlation between the percentage of dentin removed by access cavities and the fracture resistance of teeth. Recently, Silva et al., (2021)[12] reported that, it is logical to conclude that for every unit loss in hard tissue volume, a correlative drop in the ability to resist compression forces would result. Teeth being different in terms of hard tissue volume, it is better to determine the percentage reduction in relation to the original tooth volume and correlate it to the fracture strength.

A statistically significant difference recorded between Group 2b and other groups. That means 2mm of MTA can enhance fracture resistance of the specimens as MTA has reasonable compressive strength and hardness which are sufficient to withstand occlusal loads or the placement forces of restorative materials.[24] In the same line Hatibović-Kofman et al., (2008)[25] concluded the MTA-treated teeth showed the highest fracture resistance at 1 year (P<0.05). This may be explained by the fact that MTA induced the expression of the tissue inhibitors of metalloproteinases (TIMP-2) in the dentin matrix and thereby possibly prevented destruction of the collagen matrix.

The findings of the present study showed that the addition of a layer of 2 mm thickness of MTA to the floor of pulp chamber significantly increased the fracture resistance at the bifurcation area of all cases of remaining dentin thickness.

Conclusion:

The addition of a layer of 2 mm thickness of MTA to the floor of pulp chamber significantly increase the fracture resistance at the bifurcation area of all cases of remaining dentin thickness.

Conflict of Interest:

The authors declare no conflict of interest.

Funding:

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Ethics:

This study protocol was approved by the ethical committee of the faculty of dentistry-Cairo university on: 29/6/2021, approval number 7621

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