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Mineral Trioxide Aggregate in Endodontic Treatment for Immature Teeth

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Abstract—**The aim of the present study was to test the hypothesis that the fracture strength of calcium hydroxide and mineral trioxide aggregate (MTA) filled immature teeth decrease over time.**

Immature mandibular incisors from sheep were extracted and the pulps were extirpated using an apical approach with a barbed broach, and the teeth were divided into three experimental groups. Group 1: Untreated teeth. Group 2: The root canal was filled with calcium hydroxide paste (Ultradent®-UltraCal™ XS™). Group 3: The root canal was filled with ProRoot® MTA system (Dentsply, USA). All specimens were kept in saline with 1% antibiotics at 4 °C for certain periods of time: two weeks, two months and one year. All teeth were tested for fracture strength in an Instron testing machine at the indicated observation periods. The results were subjected to statistical analysis by a one-way analysis of variance and with the t-test at a 5% level of significance. One tooth from each group was selected randomly for the histological study.

The mean fracture strengths decreased over time for all the three groups. The fracture strengths were not found significantly different from the untreated, calcium hydroxide-treated or MTA-treated teeth at two-week or two-month ($p>0.05$). However, the results for MTA-treated teeth were significantly higher than the other two groups at one year ($p=0.0137$).

The teeth with root treatment with MTA showed the highest fracture resistance at one year ($p<0.05$), since only MTA induced the expression of TIMP-2 in the dentin matrix and possibly prevents rapid destruction of collagen.

I. Introduction

ONE of the challenges in dentistry is the treatment of immature, pulpless, permanent teeth.. The introduction of apexification by the use of calcium hydroxide $Ca(OH)_2$ was pioneered by Heithersay [1] and Frank [2]. This treatment gave adequate apical healing due to its antibacterial capability caused by a high pH and the ability to induce remineralization in periapical tissues [3]-[4]. However, it was reported that the fracture strength of calcium hydroxide-filled immature teeth decreased over time because of a change in the organic matrix of dentin [5].

Mineral trioxide aggregate (MTA), a new material currently being used in pulp therapy [6], is made primarily of fine hydrophilic particles of tricalcium aluminate, tricalcium silicate, silicate oxide, and tricalcium oxide [6]-[8]. The initial pH of MTA when hydrated is 10.2 and the set pH is 12.5, which is comparable to that of calcium hydroxide. The material has been shown to have excellent biocompatibility [6], [9], antimicrobial properties [8], low cytotoxicity [7], [10], and low microleakage [11]. However, recent study also indicated that root dentin was weakened after exposure to calcium hydroxide and MTA in five weeks [12].

The mechanical properties of dentin are fundamentally determined by dentin matrix, which is mostly composed of collagen Type I [13]-[14]. There is limited information in the dental literature concerning the long term effect of either calcium hydroxide or MTA as root end-filling materials on the fracture strength of immature teeth. This study evaluated the effect of two materials mentioned above on the fracture strength of root dentin after apexification treatment for different length of time. Our hypothesis that the fracture strength of calcium hydroxide and mineral trioxide aggregate-filled immature teeth decrease over time was tested.

II. Materials and Methods

This study employed 48 mandibular incisors extracted from young slaughtered sheep, approximately 9 months of age. Care was taken not to damage the teeth during extraction, and they were stored in 1% Chloramin-T until use. The teeth were cut approximately 3 mm from the apex in order to create access to the filling materials. The pulps were extirpated using an apical approach with a barbed broach, and the teeth were divided into three experimental groups.

- Group 1. Untreated teeth.
- Group 2. The root canal was filled with calcium hydroxide paste (Ultradent®- UltraCal™ XS™) using a syringe and a Capillary™ tip
- Group 3. The root canal was filled with ProRoot® MTA system (Dentsply, USA) using a plugger and further compacted by vertical compacters of various sizes to the apex. All specimens were radiographed from lateral and facial views of the teeth before and after the root treatment (Figs. 1-2).

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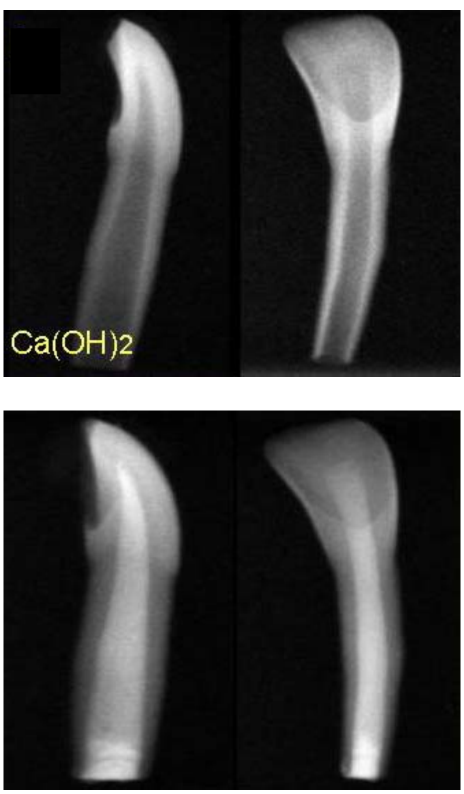
(a)

(b)

Fig. 1. Lateral and facial views of the mandibular incisors (a) before and (b) after root filling with Mineral trioxide aggregate (MTA).



(a)

(b)

Fig. 2. Lateral and facial views of the mandibular incisors (a) before and (b) after root filling with calcium hydroxide.

All teeth were kept in saline with 1% antibiotics at 4 °C for certain periods of time: two weeks, two months and one year [15]. The saline was exchanged once a month.

One tooth from each group was selected randomly for histological study, and the rest of the samples were embedded in a block of orthodontic resin (Dentsply, USA), 23 mm × 20 mm × 15 mm, in such a way that the long axis of the tooth was aligned with the central axis of the resin block, and the incisal edge of the tooth was positioned 4 mm away from the surface of the resin. The resin was left one hour for complete setting. The specimens were mounted in an Instron universal testing machine (Instron, model 1125, Canton, Massachusetts). A spade was placed on the facial surface of the specimen parallel with the incisal edge and close to the block of the resin, 3 mm from the incisal edge. A force was applied with the spade at a speed of 1 mm/min until fracture. Surfaces were further studied under a light microscope with their images digitally captured. Finally, the fracture strength (force/area) was calculated in MPa.

The results were subjected to statistical analysis by a one-way analysis of variance and with the *t*-test at a 5% level of significance.

III. Results

Table 1 and Figures 3 and 4 summarize the results of the fracture strength testing. The mean fracture strengths decreased over time for all three groups (Figure 3). Although the untreated teeth showed the highest value (45 MPa) at two-weeks, the fracture strengths decreased (25 MPa) significantly after two months ($p=0.0003$); on the other hand, the teeth treated with calcium hydroxide or MTA, decreased, but not significantly over time ($p>0.05$, Figure 3).

For the MTA treated teeth, the fracture strengths were not found significantly different from the untreated or calcium hydroxide-treated teeth at two-weeks or two-months ($p>0.05$). However, the results were significantly higher than the other two groups at one year ($p=0.0137$, Figure 4). An unexpected finding revealed that fracture resistance of MTA treated teeth was increased from 29 MPa to 35 MPa (20%) between two months and one year.

The histological analysis showed presence of tissue inhibitor metalloproteinase (TIMP)) only in the teeth treated with MTA.

TABLE I.
MEAN FRACTURE STRENGTH OVER TIME OF IMMATURE TEETH WITH ROOT CANAL UNTREATED, OR AFTER THERAPY WITH EITHER CALCIUM HYDROXIDE OR MTA

Mean Fracture Strength (Mpa)		**Grouped by Time**		
		Two-week	Two-month	One-year
Grouped by Materials	None	45.00 a	27.00 b	25.00 e
	Calcium hydroxide	36.00 a,c	33.00 b,c	27.00 c
	MTA	37.00 a,d	29.00 b,d	35.00 d

Groups identified by different letters are significantly different ($p<0.05$).Groups with the same letters are not significantly different ($p>0.05$).

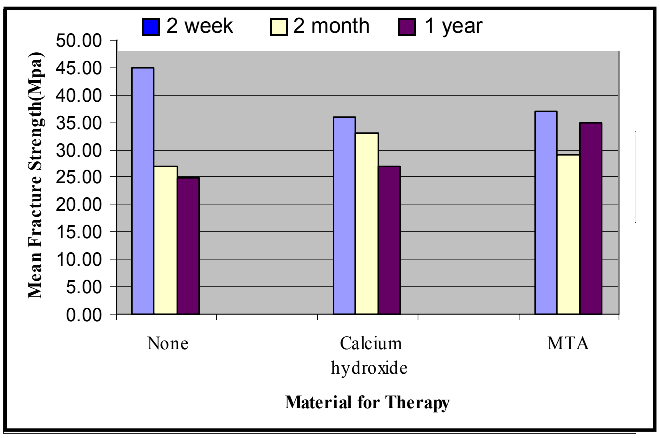


Fig. 3. Mean fracture strength of immature teeth with root canal untreated, or after therapy with either calcium hydroxide or MTA: Mean fracture strengths vs. materials for root treatment.

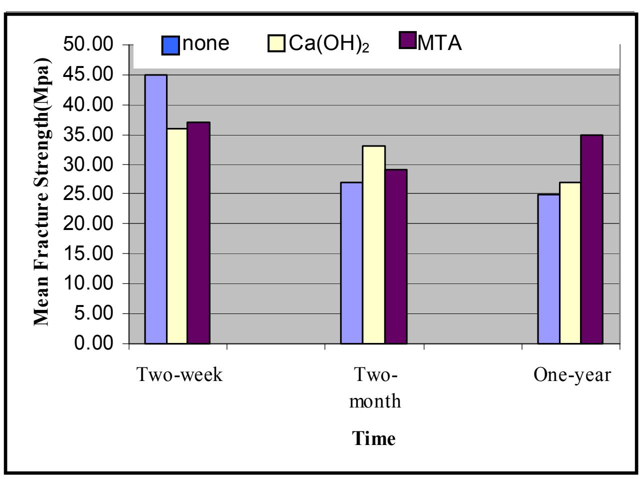


Fig.4. Mean fracture strength of immature teeth with root canal untreated, or after therapy with either calcium hydroxide or MTA: Mean fracture strengths vs. time.

IV. DISCUSSION

The mechanical properties of dentin are fundamentally determined by dentin matrix, which is largely Type I collagen [13], [14]. The present study showed that the fracture strengths with roots filled with calcium hydroxide decreased, but not significantly over time ($p=0.185$, Figure 3). The strength measured was 36 MPa at two-weeks, then decreased by approximately 8.3% at two-months, and further by approximately 26% at one year.

Our finding that calcium hydroxide had a negative effect on the strength of the dentin is in agreement with [16], [12].

On the other hand, for the MTA treated teeth, the fracture strengths dropped to 35 MPa from 37 MPa, a decrease of only 5.4% after one year. The value was significantly higher than the calcium hydroxide treated and untreated groups ($p=0.0137$, Figure 4). MTA is a new material currently being used in pulp therapy [6]. Previous studies have revealed that it has actually induced cementogenesis [17], and bone deposition with minimal or absent inflammatory response [18]. Recent studies also show that MTA stimulated the release of production of interleukin and cytokines [19]-[21], which could induce TIMP expression and suppress degeneration of collagen [22]. Since the MTA treated teeth was the only group that exhibited the expression of TIMP-2 among the three groups, using MTA as a root filling material might prevent the teeth from becoming brittle over time. We are in the process of obtaining more histological results which would shed some light for clinic practitioners in this area.

In this study, the highest fracture strength (45 MPa) was obtained with untreated teeth at two-weeks; however, the fracture strengths decreased significantly ($p=0.0003$) after two months and one year and dropped 44%.

V. CONCLUSION

The present study appears to support the hypothesis that the fracture strength of calcium hydroxide and mineral trioxide aggregate-filled immature teeth decreased over time. However, the teeth with root treatment with MTA showed the highest fracture resistance at one year ($p<0.05$).

The new finding of this study is that MTA treated teeth after initial decrease, reverse the process and fracture resistance increases between 2 months and one year. It can be explain by the fact that MTA induces the expression of TIMPA-2 in dentin matrix and suppresses degeneration of collagen.

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