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Effect of root resection on the apical sealing ability of mineral trioxide aggregate

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Objective. The purpose of this in vitro study was to determine the minimum depth of mineral trioxide aggregate (MTA; ProRoot; DENTSPLY/Tulsa Dental, Tulsa, Okla) required to maintain an apical seal following root resection.
Study design. In 10 instrumented teeth, MTA was used to obturate the apical 6 mm of the root canal and was allowed to set for 48 hours. Leakage was determined by means of a fluid filtration method at a pressure of 20 cm H_2O. Leakage was measured before root resection, and after 3, 4, 5, and 6 mm apical resections. Data were analyzed by means of a Kruskal-Wallis one-way analysis of variance with $P < .05$.
Results. Fluid leakage was shown to increase after each resection, but did not reach statistical significance ($P < .05$) until 4 mm of the apex had been removed.
Conclusion. The results indicate that root resection did not significantly affect the sealing ability of MTA when at least 3 mm of the MTA remained. Although there was a statistically significant difference in leakage following the 4 mm resection, it is unknown what the biological difference would be between the 3 mm and 4 mm resections.
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Leakage into and out of the canal space following endodontic therapy may be one of the major causes of endodontic failure. Various materials have been used in an attempt to seal the root canal and prevent leakage: silver points, gutta-percha, zinc oxide-eugenol, calcium hydroxide, composite resins, and glass ionomer cements. An ideal obturation material should adapt well to the walls of the preparation and the root canal system. It should also be nontoxic, well tolerated by the periapical tissues, noncorrosive, dimensionally stable, radiopaque, and nonabsorbable. Finally, it should promote healing and not be affected by the presence of moisture.[1] Unfortunately, none of the previously mentioned obturation materials can claim to possess all of these qualities.

In 1993, mineral trioxide aggregate (MTA; ProRoot; DENTSPLY/Tulsa Dental, Tulsa, Okla) was introduced as a root-end filling material.[2] MTA appears to possess the biologic and physical properties of an ideal filling material. MTA has been shown to have superior sealing ability when compared with amalgam or Super-EBA in dye and bacterial leakage studies.[2-5] The cytotoxicity of MTA was shown to be less than that of amalgam, intermediate restorative material, or Super-EBA (Harry J. Bosworth Co, Skokie, Ill) when the radiochromium release method was used.[6] The biocompatibility of MTA has been established in animal studies.[7,8] MTA has been evaluated for use in apexification,[9] perforation repair,[10-12] and repair of root resorption[13] and as a root-end filling material.[14-17] The purpose of this study was to evaluate by means of a fluid filtration method the ability of MTA to provide an

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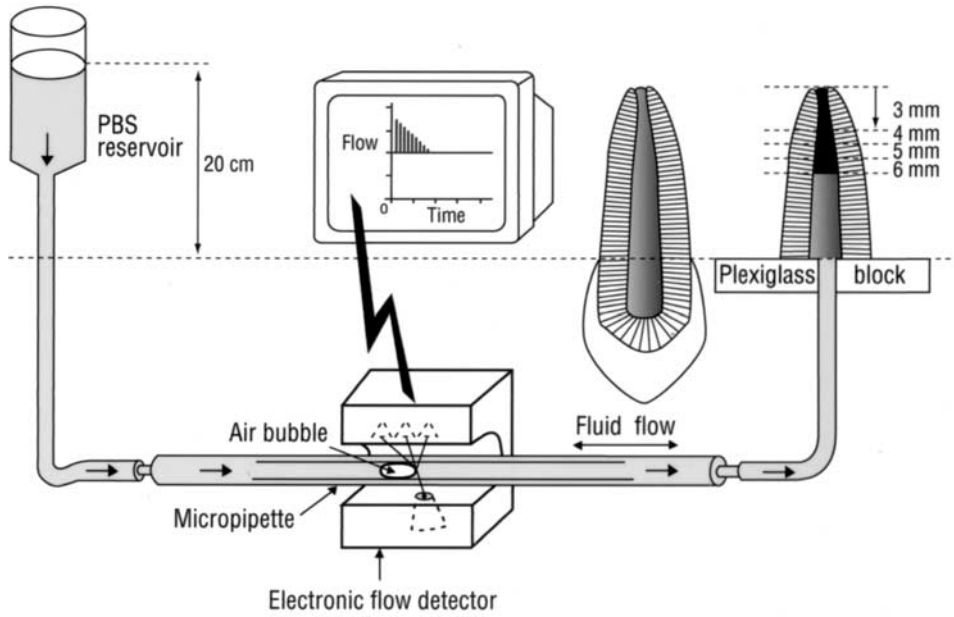

Figure. Schematic showing a specimen connected to the fluid filtration device that was used to measure fluid flow, under a pressure of 20 cm H_2O, before and after various levels of resection.

apical seal, and to determine the minimum depth of MTA required to maintain an apical seal following root resection.

MATERIAL AND METHODS

Twelve freshly extracted human maxillary and mandibular canines were used in this in vitro study. Following extraction, the teeth were stored until use at 4°C in saline containing 0.2% sodium azide. All procedures were performed by 1 investigator (E.L.L.). The crowns of the teeth were removed with an Isomet saw (Buehler Ltd, Lake Bluff, Ill), leaving a root 12-14 mm in length. Pulpal tissue was removed by means of Flexofiles (DENTSPLY/Maillefer, Tulsa, Okla) and 5.25% NaOCl (Clorox; Clorox Co, Oakland, Calif). The canals were instrumented to an ISO size 70 file at the apical foramen and flared by using a 1-mm step-back technique to an ISO size 90 file. One mL of 5.25% NaOCl was used as an irrigant after each file. A final flush was made with 5 mL of 5.25% NaOCl, and the canals were dried with paper points.

In 10 teeth, the apical 6 mm of the roots were obturated with MTA in the following manner: the MTA was mixed according to the manufacturer's instructions and placed into the canal with an Endogun (Medidenta Int Inc, Woodside, NY). The material was compacted with paper points and Schilder pluggers (DENTSPLY/Caulk, Milford, Del). During obturation, the apical portion of the root was placed on a moistened cotton pellet to provide an apical stop for the obturation material. Following obturation, a cotton pellet moistened with saline was placed into the canal space and in contact with the MTA. A radiograph was taken to verify the density of the apical fill. The coronal access was sealed with Cavit (ESPE America, Inc, Norristown, Pa), and the teeth were stored in a humidor at 37°C and 100% humidity for 48 hours. Two unfilled teeth served as positive controls. Each filled tooth served as its own negative control.

After 48 hours, the teeth were removed from the humidor and prepared for evaluation of leakage by means of a fluid filtration method.[18] Eighteen-gauge stainless steel tubing was placed through the center of $2 \times 2 \times 0.7$-cm plexiglass squares, flush with the lower surface. The junction of the tubing to the plexiglass was sealed with C&B Metabond (Parkell, Farmingdale, NY). The distance from the apex to the bottom of the plexiglass was measured with a digital micrometer (Mitutoyo, Tokyo, Japan) to the nearest 0.1 mm. After obtaining control measurements on the MTA-filled canals, a mark was made with a scalpel blade on the external root surface 3.0 ± 0.1 mm from the original apex to permit consistent resection of the apical 3 mm. This was repeated at 1.0 ± 0.1 mm increments after obtaining repeated fluid conductance measurements until 6 mm had been resected. The Cavit and cotton pellets were removed from the tooth roots, and the flattened occlusal surface of the tooth root was sealed to the lower surface of the plexiglass over the stainless steel tubing with C&B Metabond, forming a direct

Table. Microleakage of MTA–filled roots (n = 9)

	Fluid leakage ($\mu L\ min^{-1}\ cm\ H_2O^{-1}$)	
Thickness of MTA	*Mean ± SD*	*% of control*
6	0.001 ± 0.002[a]	2.8
3	0.004 ± 0.005[a]	11.1
2	0.014 ± 0.001[b]	38.9
1	0.020 ± 0.011[b]	55.6
0	0.029 ± 0.002[c]	80.6

Positive control microleakage = 0.036 ± 0.001 ($\mu L\ min^{-1}\ cm\ H_2O^{-1}$). Groups identified by the same superscript letters are not significantly different ($P > .05$). Different letters identify significantly different groups ($P < .05$).

communication with the root canal (Figure). The root canals were filled with water through the 18-gauge tubing with a 27-gauge needle, with careful attention paid to removal of any air bubbles. The tubing was then connected to a micropipette/microsyringe system connected to a Flodec device (DeMarco Engineering, Geneva, Switzerland). The specimens then underwent fluid filtration as described by Derkson et al[18] to test for microleakage. Microleakage tests were conducted for three 2-minute periods with a pressure of 20 cm H_2O, and the results were averaged. Fluid conductance, in microliters per minute ($\mu l\ min^{-1}\ cm\ H_2O^{-1}$), was calculated for each tooth. During the course of the study, 1 tooth was lost as a result of a blockage in the stainless steel tube portion of the plexiglass block.

Immediately following the initial measurements of fluid leakage, the teeth and plexiglass squares were disconnected from the Flodec and the apical 3 mm of the roots of the experimental teeth were resected with a high-speed handpiece with a diamond bur and water coolant to simulate apical surgery. Following resection of the roots, the specimens were immediately reconnected to the Flodec, and 3 microleakage tests were again conducted and averaged as previously described. Three additional resections of 1 mm each were performed, and microleakage was tested after each resection. The data were gathered and analyzed by means of a Kruskal-Wallis one-way analysis of variance on ranks, followed by Student-Newman-Keuls multiple comparison tests at a significance level of $P \leq .05$.

RESULTS

Fluid conductance in the untreated positive controls was measured at 0.036 ± 0.001 $\mu L\ min^{-1}\ cm\ H_2O^{-1}$. In the roots filled with 6 mm of MTA, fluid conductance was only 0.001 ± 0.002 $\mu L\ min^{-1}\ cm\ H_2O^{-1}$. This represents a reduction of microleakage of 97.2%.

Fluid leakage was shown to increase after each resection, but did not reach statistical significance ($P < .05$) until 4 mm of the apex had been removed (2 mm of MTA remaining, Table). The final resection removed all MTA, leaving an unfilled canal space that had a hydraulic conductance of 0.029 ± 0.002 $\mu L\ min^{-1}\ cm\ H_2O^{-1}$, a value that is not statistically different from the positive controls ($P = .49$). The results indicate that a 3-mm apical resection did not statistically decrease the sealing ability of MTA when at least 6 mm of the material was originally used to obturate the apical portion of the instrumented canal.

DISCUSSION

This in vitro study attempted to simulate in vivo conditions by subjecting the filled canals to 20 cm of water pressure, in an orthograde direction for convenience. In vivo root fillings are subjected to a similar retrograde pressure from periapical bone. This pressure is within the range of marrow space pressure reported by Held and Thron.[20] The fluid filtration technique was chosen for leakage assessment because this method provides a quantitative measurement of microleakage over a longitudinal period of time without destruction of the experimental specimens.

When the apical 6 mm of the prepared root canals received an orthograde filling with MTA, the fluid conductance fell from 0.036 $\mu L\ min^{-1}\ cm\ H_2O^{-1}$ to 0.001 $\mu L\ min^{-1}\ cm\ H_2O^{-1}$, a reduction of 97.2% compared with the fluid conductance of the canals before treatment. The residual or posttreatment leakage was measured 48 hours after placement of 6 mm of MTA. This posttreatment fluid leakage is similar to that reported by Johnson et al[19] for other root-end filling materials. When the apical 3 mm of the root was removed, there was a 4-fold increase in fluid conductance. However, because of increased variance, this value was not statistically significant, although it may be biologically significant. After removing another 1 mm of the root, the fluid conductance increased 14-fold, a difference that was statistically significant. It would seem prudent to produce MTA fills that are greater than 6 mm to permit 3-mm apical resections that leave more than 3 mm of residual MTA.

The biocompatibility of MTA has been established by previous studies.[7,8] When placed as a root-end filling following root resection, MTA has been shown to be equal or superior to amalgam, composite resins, glass ionomer cements, and Super-EBA in its ability to create and maintain an adequate apical seal over time.[14-17] Although MTA has been used as an apical plug,[9] the authors are unaware of any previous studies using MTA in an orthograde fashion prior to root resection.

There are many clinical situations that may require root resection, including zip perforations in the apical third of the root canal, ledged or blocked canals which prevent adequate cleansing and debridement of the

apical portion of the canal, and anatomical variations in the apical third that may give rise to the need for resection of the apical portion of the root. In roots with single canals where preparation of an isthmus is not required and root resection is anticipated, it may be possible to obturate the apical 7 to 10 mm of the canal with MTA, allow adequate time for the material to set, then resect the apical 3 mm of the root without the need for a root-end preparation and root-end filling. This speculation needs to be confirmed by future in vitro studies before it can be recommended for clinical use.

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