0099-2399/98/2411-0768$03.00/0
JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 24, NO. 11, NOVEMBER 1998

Evaluation of Setting Properties and Retention Characteristics of Mineral Trioxide Aggregate When Used as a Furcation Perforation Repair Material

S. R. Sluyk, DDS, P. C. Moon, PhD, MS, and G. R. Hartwell, DDS, MS

Furcation perforations were created in 32 extracted maxillary and mandibular molars. The perforations were prepared in the center of the pulp chamber floor parallel to the long axis of each tooth and a saline-moistened Gelfoam matrix was placed below the perforation to simulate a clinical condition. The teeth were randomly divided into four groups, and the perforations were all repaired with mineral trioxide aggregate (MTA) and then covered with either a wet or dry cotton pellet for 24 or 72 h. Instron testing was used to measure the force required to displace the material from the perforation. The force measurements showed that MTA resisted displacement at 72 h to a significantly greater level than at 24 h ($p < 0.05$). When slight displacement occured at 24 h the material demonstrated the ability to re-establish resistance to dislodgement from the dentin wall. The presence of some moisture in the perforation during placement was advantageous in aiding adaptation of MTA to the walls of the perforation, but there was no significant difference in MTA retention when a wet or dry cotton pellet was placed in the pulp chamber during the setting time ($p > 0.05$).

Perforation of the pulpal floor in multirooted teeth results in an inflammatory reaction of the periodontium that can lead to irreversible attachment loss. If the perforation is not adequately repaired, the prognosis for these teeth is poor. Many different materials have been used to repair these defects, but none fulfill the criteria of an ideal repair material that includes sealability, biocompatibility, and the ability to induce osteogenesis and cementogenesis (1).

Mineral trioxide aggregate (MTA) has been investigated in a series of tests and has demonstrated many of the ideal properties. The sealing ability of MTA in root-end fillings was superior to that of amalgam, IRM, and Super-EBA using both dye and bacteria leakage methods and was not adversely affected by blood contamination (2). The histological response to furcation perforation repair with MTA in dogs showed cementum repair over the material and very little inflammation (3). When used as a root-end filling material in monkeys, the results showed no periradicular inflammation, new bone formation, and a complete layer of cementum had grown directly against the MTA (4).

MTA is prepared by mixing three parts powder with one part aqueous solution, by weight, to obtain a putty consistency. Because of its hydrophilic characteristic, moisture in the surrounding tissue acts as an activator of a chemical reaction in this material (5). The moisture also extends the initial setting time to a reported 2 h and 45 min, but the compressive strength has been shown to increase in the presence of moisture up to 21 days (6). To determine the proper time for placing a coronal restoration and the clinical conditions that affect the setting properties of MTA, more information is needed. The purpose of this study were to evaluate the effect of time and moisture on the setting, retention, and readaptation characteristics of MTA when used to repair furcation perforations.

MATERIALS AND METHODS

Thirty-two freshly extracted maxillary and mandibular molars were used in this study. All procedures were performed by one investigator. The teeth were stored in a formalin solution before initiation of the procedures. The crowns were removed at the level just above the floor of the pulp chamber, and the roots were removed at the level just below the furcation with a ¾-inch Damascus separating disk (GFC, Carlstadt, NJ). The remaining furcation section was mounted in an acrylic base (Triad VLC resin; Dentsply, Int., York, PA), and the thickness of the specimen was standardized at 1.6 mm by grinding from the apical side with a bonded arbor band (Healthco, Boston, MA).

A perforation was made using a #2 round bur perpendicular to each furcation section. The opening was enlarged with a #5 Gates Glidden bur (Moyco Industries/Union Broach Div., Emigsville, PA) to create a perforation 1.4 mm in diameter. Plexiglass (2.5 mm thick) was cut to fit over the mounted specimen, and a hole was drilled in the Plexiglass to correspond with the perforation (Fig. 1). This acted as a guide plate for an Instron force probe (Instron Corp., Wilmington, DE) to apply a pushout force on the MTA. Plexiglass was also used as a base below the perforation. A 2.3 mm

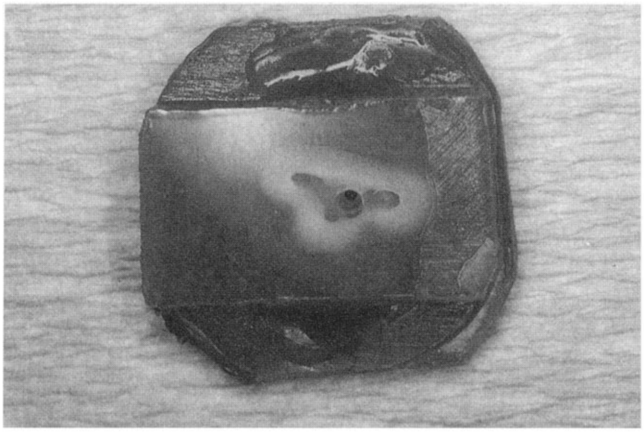

FIG 1. Furcation section mounted in acrylic base with Plexiglass guide plate over perforation.

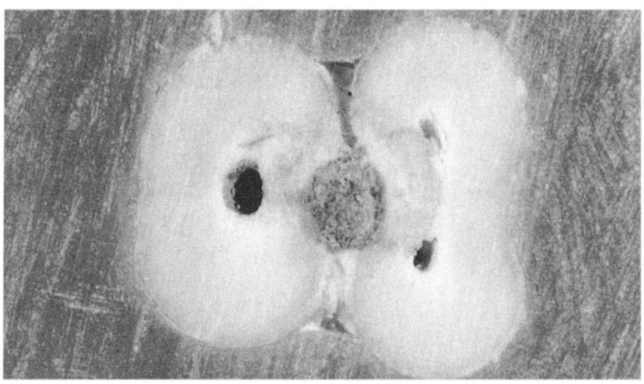

FIG 2. Well-adapted MTA repair when a moistened perforation and matrix were used.

diameter space was created below the perforation to accomodate placement of the matrix material. Gelfoam (Upjohn Co., Kalamazoo, MI) was used as the matrix material and was moistened with saline from the coronal side to simulate a clinical condition. Preliminary observations with a light microscope at ×40 magnification revealed that placement of MTA into the perforation without a moist matrix resulted in poor adaptation to the perforation walls. Large gaps were present between the material and perforation walls in underfilled and overfilled specimens (Figs. 2 to 4).

The 32 teeth were randomly divided into four equal groups. MTA powder (three parts by weight) was mixed on a glass slab with a cement spatula with one part anesthetic (2% xylocaine with 1:100,000 epinephrine; Astra, Westborough, MA), as recommended by the developer of the material (Torabinejad, personal communication, 1995). When the mixture exhibited a putty consistency, after 30 s of mixing, it was immediately placed into the perforation with a MRFL plastic instrument (Hu-Friedy, Chicago, IL). A MCBRL plugger (Hu-Friedy), followed by a wet cotton pellet, was used to condense the material gently into the perforation site.

Setting characteristics were varied by placing a wet or dry cotton pellet in contact with the MTA for 24 or 72 h. In group 1, a wet cotton pellet (wet) was placed over the MTA for the 24-h setting time. In group 2, a wet cotton pellet was placed over the MTA for the 72-h setting time. Group 3 was the same as group 1, except that a dry cotton pellet (dry) was used, and group 4 received a dry cotton pellet for 72 h. After each sample was prepared, it was

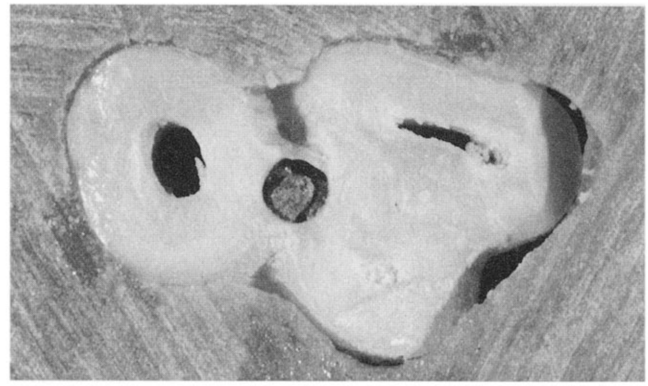

FIG 3. Underfilled and poorly adapted MTA repair when a dry perforation and no matrix were used. Note voids as *dark circumferential areas* between the MTA and perforation wall.

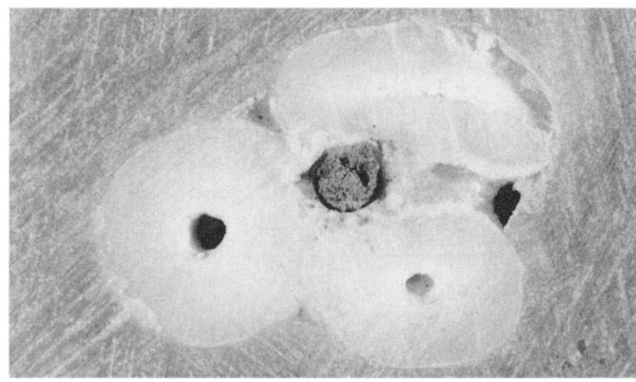

FIG 4. Overfilled and poorly adapted MTA repair when a dry perforation and no matrix were used. Note voids between the MTA and perforation wall.

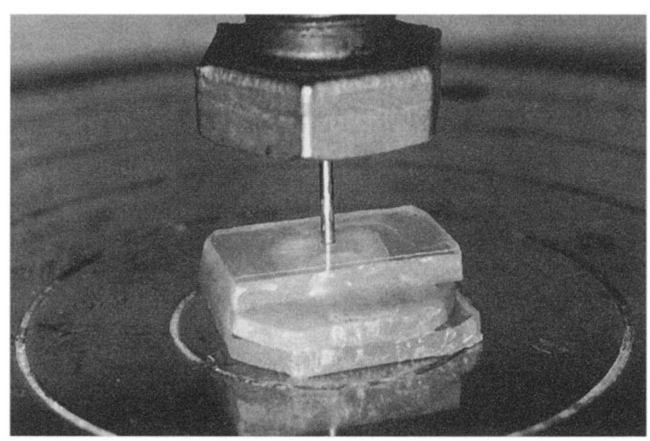

FIG 5. Instron testing of MTA furcation perforation repair material.

sealed in plastic wrap (Palmero Dental MFG/Sales Co., Statford, CT) to prevent drying of the specimens during the setting period.

The hole in the guide plate was aligned over the perforation and secured with sticky wax. The Instron force probe was then inserted through the guide plate (Fig. 5) to apply a vertical force to the MTA using an Instron machine (Instron Corp.). The maximum force applied to the MTA before displacement occurred was recorded in pounds of force. The test was stopped after 0.2 mm displacement of the MTA, and specimens were sealed in 100% humidity for an additional 14 days. The pushout test was then

TABLE 1. Results: pounds of force required to displace MTA after initial test of 24 or 72 h

Group	n	Minimum Force	Maximum Force	Mean	SD
1) 24-h wet	8	1.3	2.9	2.2	0.6
2) 24-h dry	8	1.7	3.2	2.6	0.7
3) 72-h wet	8	3.3	8.6	6.3	2.2
4) 72-h dry	8	2.7	14.5	9.7	4.1

No significant differences between groups 1 and 2 and between groups 3 and 4. Significant differences existed between groups 1 and 3 and between groups 2 and 4 ($p < 0.05$).

TABLE 2. Results: pounds of force required to displace MTA at the 14-day retest

Group	n	Minimum Force	Maximum Force	Mean	SD
5) 24-h wet	8	1.7	7.0	3.7	1.9
6) 24-h dry	8	3.5	12.0	6.7	3.0
7) 72-h wet	8	0.9	8.8	4.3	2.6
8) 72-h dry	8	2.4	12.1	6.5	3.3

Significantly more force was required to displace groups 5 and 6, and significantly less force was required to displace groups 7 and 8 when compared with initial tests in Table 1 ($p < 0.05$).

repeated for all four groups to determine if readhesion had occurred between the MTA and the dentinal wall.

The mean dislodgement force and standard errors were calculated for the eight groups and then compared using paired *t* tests.

RESULTS

The 24-h wet group had a mean retention value of 2.2 lb and the 72-h wet group had a mean retention value of 6.3 lb. There was a significant difference between these groups ($p < 0.05$). The 24-h dry group had a mean value of 2.6 lb and the 72-h dry group had a mean value of 9.7 lb. There was also a significant difference between these groups ($p < 0.05$). The resistance to dislodgement of the MTA was significantly greater at 72 h under both wet and dry conditions. The dislodgement force in pounds for each group is reported in Table 1.

There was a difference between the 24-h wet and 24-h dry, but the difference was not significant ($p > 0.05$). There was also a difference between the 72-h wet and 72-h dry, and again the difference was not significant ($p > 0.05$).

The resistance to displacement for the 24-h wet group increased from 2.2 to 3.7 lb when retested at 2 wk after its initial dislodgement. This difference was significant ($p < 0.05$). The resistance of the 24-h dry group after initial dislodgement increased from 2.6 to 6.7 lb at 2 wk. This change was also statistically significant ($p < 0.05$). These findings demonstrated that MTA has the ability to re-establish resistance to dislodgement from the dentinal walls under the conditions of this study when the initial displacement occurred 24 h after placement of the MTA.

In the 72-h wet group, the retention decreased from 6.3 lb to 4.3 lb, and in the 72-h dry group retention decreased from 9.7 lb to 6.5 lb when retested at 2 wk. Both of these findings were statistically significant ($p < 0.05$). Therefore, in these cases where the initial displacement occurred 72 h after MTA placement, the retention strength significantly decreased, but the results were still greater than the initial 24-h measured values for wet or dry cotton pellets. The mean ±SEs for each group after 14 days of storage are reported in Table 2.

DISCUSSION

Guidelines for the clinical use of MTA as an intracoronal perforation repair material are needed due to the newness of the material. Arens et al. (7), in a case report of repair of furcation perforations, recommended covering the MTA with a wet cotton pellet and a layer of IRM for 1 to 3 days to encourage setting. They also stated that the entire access cavity could be filled with MTA, but because of the material's slow set, the patient should avoid eating for 4 h postoperatively. Lee et al. (5) condensed the material into lateral root perforations and filled the entire access cavities with the same paste in an in vitro model. Pitt Ford et al. (3) filled furcation perforations and the entire access cavities with MTA in dogs and stated that the final restoration may then be placed 1 to 7 days after the repair procedure.

The results of this study support the recommendations of placing a cotton pellet and temporary restoration over the MTA for 72 h to encourage setting. At 72 h, the MTA resisted displacement significantly more than at 24 h. The primary advantage of using a temporary restoration, rather than filling the entire access with the MTA, is protection of the perforation repair site with a faster setting material.

When the MTA was slightly displaced (0.2 mm) at 24 h, the retention increased above the 24-h value when the material was retested 14 days later. This indicates that the chemical reaction continued beyond the initial 24-h setting period and that improved resistance to displacement from the dentinal wall had occurred. When the MTA was slightly displaced at 72 h, the retention decreased below the 72-h value when retested 14 days later. This indicates that the complete resistance level was not re-established. Although resistance seems to be re-established if MTA is slightly displaced at 24 h, it did not reach as high a level of retention as the undisturbed 72-h groups. The MTA was completely displaced from the perforation at the 14-day retest. Observation with a light microscope (×40) confirmed that the entire repair material was displaced from the dentin surface rather than the material separating from itself.

The saline-moistened Gelfoam provided a barrier in this model so that underfilling or overfilling of the MTA was not observed. It also simulated the moist clinical environment present in the periodontal and bone tissues adjacent to the perforation site. The moisture present in these tissues would provide the wet environment needed by the MTA for adaptation to occur. The working time was limited to <4 min in this study, because the material began to dehydrate on the mixing slab if left for a longer period of time. When placed into the perforation, the MTA material absorbed moisture from the wet matrix and maintained its putty consistency. This improved the flow and wetting characteristics of the material, thus allowing for better adaptation to the dentin walls.

When comparing the use of a wet or dry cotton pellet in the pulp chamber, the results did not show a significant difference. A possible explanation is that the amount of moisture in the matrix is adequate to keep the hydrophilic powder moist, and the condition of the pellet in the pulp chamber makes little difference.

Based on the results of this study, it is recommended that a matrix be used and that the matrix material be moistened with anesthetic solution before placement of the MTA into the perforation defect. A wet or dry cotton pellet should be placed in contact with the MTA and covered with a temporary restoration for 72 h before placement of the permanent restoration.

The authors thank Dr. Mahmoud Torabinejad for supplying the MTA needed to conduct this study. The experimental design was solely that of the authors.

Dr. Sluyk was formerly an advanced education student in endodontics at Virginia Commonwealth University School of Dentistry, Richmond, VA. He is currently practicing in Scottsdale, AZ. Dr. Moon is director of Dental Materials Science, Department of General Practice; and Dr. Hartwell is chairman, Department of Endodontics, Virginia Commonwealth University School of Dentistry, Richmond, VA. Address requests for reprints to Dr. G. R. Hartwell, Department of Endodontics, Medical College of Virginia/Virginia Commonwealth University School of Dentistry, Box 980566, Richmond, VA 23298-0566.

References

1. Hartwell GR, England MC. Healing of furcation perforations in primate teeth after repair with decalcified freeze-dried bone: a longitudinal study. J Endodon 1993;19:357–61.
2. Torabinejad M, Pitt Ford TR. Root end filling material: a review. Endod Dent Traumatol 1996;12:161–78.
3. Pitt Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol 1995;79:756–62.
4. Torabinejad M, Pitt Ford T, McKendry D, Abedi H, Miller D, Kariyawasam. Histological assessment of mineral trioxide aggregate as a root-end filling in monkeys. J Endodon 1997;23:225–8.
5. Lee SJ, Monsef M, Torabinejad M. Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. J Endodon 1993;19:541–4.
6. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endodon 1995;21:349–53.
7. Arens DE, Torabinejad M. Repair of furcal perforations with mineral trioxide aggregate. Oral Surg Oral Med Oral Pathol 1996;82:84–8.

A Word for the Wise

You've probably heard these basic tenets of scientific experimentation, but if not, they're worth committing to memory: "If reproducibility may be a problem, conduct the experiment only once." "If a straight line relationship is required, obtain only two data points." And of course, the most pithy of all: "Variables don't; constants aren't."

R. Bacon