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Placement of Mineral Trioxide Aggregate Using Two Different Techniques

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The purpose of this study was to determine if the adaptation of mineral trioxide aggregate (MTA) would differ when placed into simulated root canals of varying length when using two different placement and condensation methods. Hand condensation was compared to ultrasonic condensation. Eighty polyethylene tubes were divided into four groups of 20 tubes each. The tubes in the four groups were prepared to receive 3-, 5-, 7-, and 10-mm lengths of MTA respectively. Each group of 20 tubes was subdivided; 10 samples of each length had MTA placed and condensed by the hand method and the other 10 by the ultrasonic method. After condensation the samples were evaluated with a light microscope and radiographs for the degree of adaptation of the MTA to the tube walls and for the presence of voids within the MTA material itself. The results demonstrated an 80% agreement for findings between the light microscopy and radiographic evaluation. Hand condensation resulted in better adaptation to the tube walls and less voids than the ultrasonic method. There was no significant difference in the results for any of the four lengths of MTA placed by the hand method ($p > 0.9$). At this time hand condensation should be considered the preferred method for placement of MTA.

Mineral trioxide aggregate (MTA) has been shown to be very effective in sealing pathways of communication between the root-canal system and the external surface of the tooth (1). It is a powder that consists of hydrophilic particles that set in the presence of moisture (2) and has a pH of 12.5 (1). The initial setting time for the cement is 4 h (1), and the bond strength to dentin has been shown to increase significantly during the first 72 h after placement (3). The compressive strength of MTA at 21 days is ~70 MPa, which is comparable with that of Intermediate Restorative Material (IRM) and Super-EBA, but significantly less than amalgam (1).

In vitro and in vivo experiments have compared the sealing ability and biocompatibility of MTA with those of amalgam, Super-EBA, and IRM. The sealing ability of MTA has been shown in dye and bacterial-leakage studies to be superior to that of amalgam and equal to or better than Super EBA (1, 2, 4–7). The cytotoxicity of MTA has been investigated using the agar overlay and radio chromium release methods and it was found to be less toxic than IRM or Super EBA (1). When MTA was implanted in the tibia and mandibles of guinea pigs, the tissue reaction to MTA implantation was most favorable at both sites. Every MTA specimen was free of inflammation and in the tibia samples it was the material most often observed to have direct apposition to bone (4). MTA has been proven superior to amalgam as a root-end–filling material and has been shown to have an inductive effect on cementoblasts (1, 5). MTA also has been used as a capping material for mechanically exposed pulps (8, 9), for root-end induction (4, 9, 10), repair of root perforations (2, 11), and to form a root-end barrier in cases with open apical foramina (12).

MTA has been proven to be a material with several potential clinical applications because of its superior sealing property, ability to set up in the presence of blood, bactericidal effects, and biocompatibility. Some clinicians (9, 11–13) have suggested using MTA as an obturating material for the entire root-canal system. When used in this manner, it is not known how well MTA will adapt to root canal walls when placed from an orthograde approach. Will there be enough moisture available from the periodontal tissues and a moistened cotton pellet to allow the central portion of the MTA core to properly adapt and harden? At this time there are two suggested methods for placement of MTA, but to date there are no reported studies that have investigated how well MTA will adapt when placed from an orthograde approach using either of these two placement methods. The purpose of this study was to evaluate how well MTA adapts to the walls of simulated root-canal system of varying lengths using both radiographic and microscopic techniques when placed by hand and ultrasonic methods.

MATERIALS AND METHODS

In this study, 80 polypropylene tubes (Kendall Monoject, Tyco, Mansfield, MA) were used. The tubes had an inner diameter of 0.7 mm at the tip and a final diameter of 1.7 mm at an end point 10-mm from the tip. The 80 tubes were initially divided into four groups of 20 tubes each. Tubes were prepared to receive 3-mm lengths of MTA for group A, 5 mm for group B, 7 mm for group C, and 10 mm for group D. The four groups were further divided into two groups of 10 for each of the two placement techniques.

The tubes were then obturated with MTA using either an ultrasonic or conventional (hand) placement method. The ultrasonic-placement method consisted of selecting a Spartan MTS, CPR 1 tip (Tulsa Dentsply, Tulsa, OK), which would fit freely into the tubes. The ultrasonic tip was used to pick up and initially place the MTA material into the selected tube. The MTA was then packed into the apical portion of the tube by activating the ultrasonic Spartan tip and slowly moving the MTA material apically using a 1- to 2-mm vertical packing motion. The packing procedure was accomplished in 30 s for each tube in the ultrasonic groups (A-1, B-1, C-1, and D-1). In the conventional (hand)-placement method, a small amount of MTA was picked up with a number 5/7 endodontic plugger (Thompson Dental, Missoula, MT) and placed into the selected tube. The 5/7 plugger was then used to pack the MTA to the appropriate length. The conventional-placement (hand) subgroups were designated as groups A-2, B-2, C-2, and D-2.

All tube-wall surfaces had to be covered with MTA to be an acceptable completed sample. After each tube was obturated to the appropriate length, a cotton pellet moistened with 1 ml of saline was placed coronally and the remaining unfilled coronal length of the tube was temporized with Cavit (ESPE America, Norristown, PA). The 3- to 4-mm length of unfilled coronal space for the cotton pellet and Cavit was the same for all the tubes.

The tubes were placed into a moistened "oasis," using a modified procedure by Lee et al. (2), for 1 week. At the end of 1 week, each length of MTA sample was examined for voids using radiographs and a light microscope (10×) at 1-mm intervals starting at the apical end. Radiographs were taken before the tubes were removed. To properly view the specimens with the light microscopic, it was necessary to eliminate the plastic tube. As a result of a pilot study, it was concluded that placing the plastic tubes and MTA in the oven at 400 to 450°F for 30 min would evaporate the plastic tubes without affecting the MTA sample. This pilot study demonstrated that there was no change in the density of the MTA before and after heating to this high temperature, so the material remained chemically stable. The MTA also was examined before and after heating with the microscope and radiographs in the pilot study and no changes were observed in the physical appearance of the material.

All samples were radiographed before tube removal, and each radiograph was viewed using a standard view box (Henry Schein, Melville, NY). The radiographs were inspected for voids at 1-mm intervals on each 3-, 5-, 7-, and 10-mm–length specimen. After tube removal, microscopic evaluation was made at 10× magnification using a light microscope (Bausch and Lomb, Rochester, NY). Voids were noted at the same 1-mm intervals as with the radiographs. Each specimen was evaluated using a scoring system of 1, 2, or 3. The scoring was based on the following criteria (Fig. 1).

1 = no voids present
2 = if the void(s) extended less than halfway through the diameter of the area of the specimen being examined
3 = if the void(s) extended to a depth greater than half the diameter of area of the specimen being examined

Because there were multiple measurements of samples for each length and placement condition, a repeated-measures analysis method was necessary. A mixed-model, repeated-measurement analysis was performed separately for each assessment method, including length, placement, and interaction.

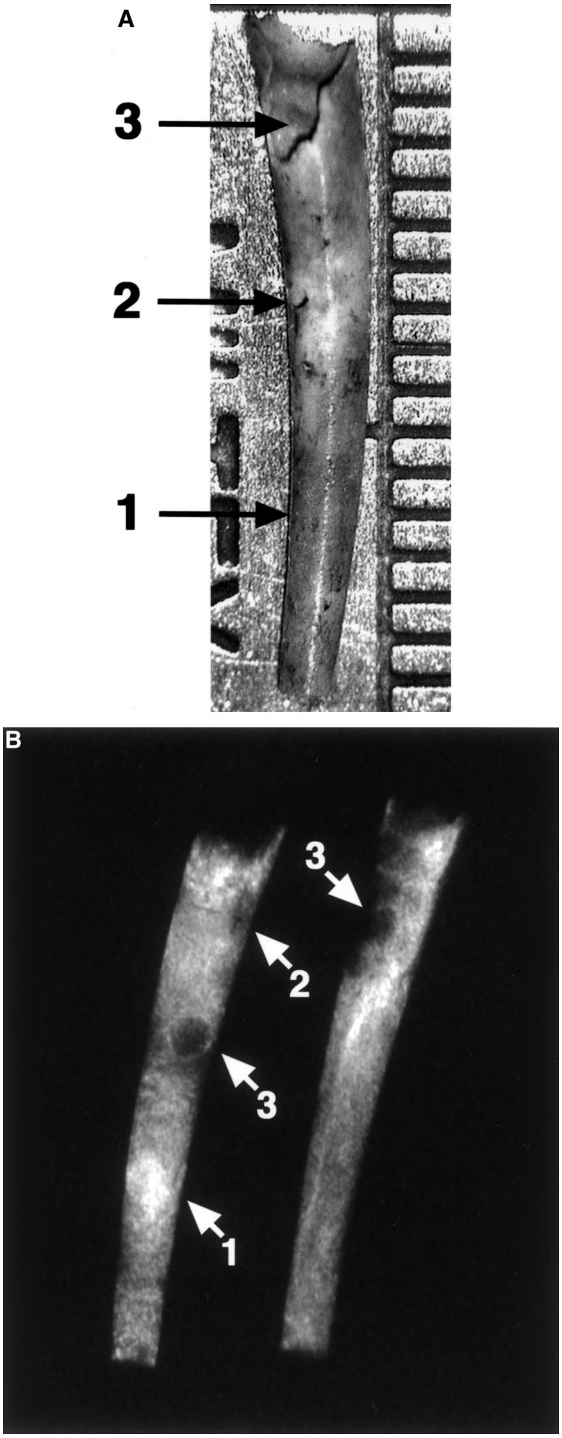

FIG 1. Grading for microscopic technique (*A*) and for radiographic technique (*B*).

RESULTS

Across all of the assessments, the agreement between the two methods (radiograph and microscope) was good, with over 80% of the assessments in complete agreement. The largest disagreement occurred where no voids were evident as determined with the microscope but more than half of the area of the same sample had observable voids when examined radiographically (n = 54 cases). There also were 18 cases where the radiograph indicted no voids

TABLE 1. Results of the number of graded voids for each specimen length and placement method

Length (mm)	Placement	*n*	Grade				SD
			1	2	3	Mean	
Microscope							
3	Hand	30	30	0	0	1.000	0.000
3	US	30	22	1	7	1.500	0.861
5	Hand	50	47	3	0	1.060	0.240
5	US	50	8	8	34	2.520	0.762
7	Hand	70	68	2	0	1.029	0.168
7	US	70	34	2	34	2.000	0.993
10	Hand	100	97	1	2	1.050	0.297
10	US	100	78	5	17	1.390	0.764
Radiograph							
3	Hand	30	28	2	0	1.067	0.254
3	US	30	17	2	11	1.800	0.961
5	Hand	50	47	3	0	1.060	0.240
5	US	50	8	2	40	2.640	0.749
7	Hand	70	67	3	0	1.043	0.204
7	US	70	36	5	29	1.900	0.965
10	Hand	100	92	5	3	1.110	0.399
10	US	100	62	17	21	1.590	0.818

US = ultrasonic.

TABLE 2. Mean and 95% confidence intervals of ultrasonic and hand placement

Method	Length (mm)	LS Mean	SE	95% CI		Adjusted p Value
Microscope						
Hand	3	1.00	0.143	0.72	1.28	0.0619
US	3	1.50	0.143	1.22	1.78	
Hand	5	1.06	0.128	0.80	1.32	<0.0001
US	5	2.52	0.128	2.26	2.78	
Hand	7	1.03	0.122	0.79	1.27	<0.0001
US	7	2.00	0.122	1.76	2.24	
Hand	10	1.05	0.117	0.82	1.28	0.1713
US	10	1.39	0.117	1.16	1.62	
Radiograph						
Hand	3	1.07	0.153	0.76	1.37	0.0046
US	3	1.80	0.153	1.49	2.11	
Hand	5	1.06	0.139	0.78	1.34	<0.0001
US	5	2.64	0.139	2.36	2.92	
Hand	7	1.04	0.133	0.78	1.31	0.0001
US	7	1.90	0.133	1.64	2.16	
Hand	10	1.11	0.127	0.86	1.36	0.0381
US	10	1.59	0.127	1.34	1.84	

CI = confidence interval; LS = least square; SE = standard error.

but the microscopic exam indicated voids covering more than half of the individual specimen.

The number of graded voids for each specimen length and placement method is shown in Table 1 along with the number of samples with grades 1, 2, or 3. The means for all of the observations under each experimental condition also are noted in Table 1. The worst result (grade 3) occurred rarely with the hand-packing method but often in samples that were placed with the ultrasonic methods.

A mixed-model, repeated-measurement analysis was performed separately for each assessment method, including length, placement, and interaction, and the results are given in Table 2. Sample length and placement method had a significant effect on the mean grades for both the microscopic and radiographic analyses. The microscopic analysis of the hand- and ultrasonic-placement methods were significantly different for the 5-mm and 7-mm sample lengths but not for the 3-mm and 10-mm lengths (Table 2). The radiographic analysis showed that the hand- and ultrasonic-placement methods were significantly different for all sample lengths but the magnitude of the difference varied, depending on length. The means and 95% confidence intervals also are demonstrated in Fig. 2. The hand-placement method was uniformly good (low values) and the results for the four lengths were not significantly different for this method ($p > 0.9$).

DISCUSSION

The results of this study demonstrated that there were significantly less voids at all lengths when the hand-placement method was used. The ultrasonic method in this study resulted in poorer adaptation to the tube walls and more surface voids in the set

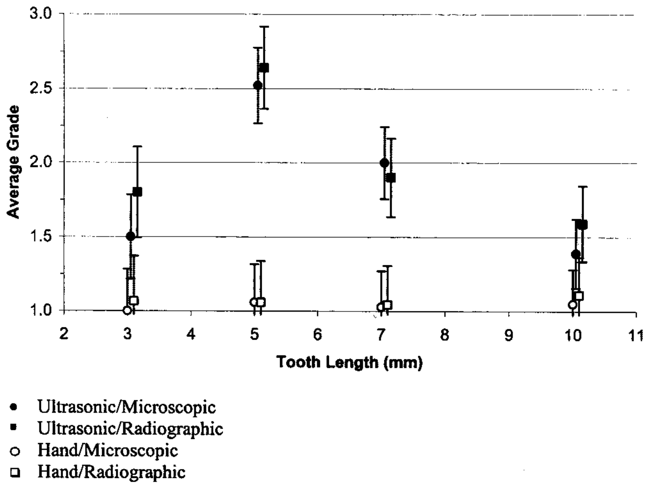

FIG 2. Means and 95% confidence intervals.

material. The radiographic and microscopic evaluations were in agreement more than 80% of the time. The largest disagreement occurred when no voids were evident with the microscopic evaluation but the specimen had a void that was demonstrated by the radiographic method. This phenomenon occurred more frequently in the ultrasonic placement groups than in those groups packed with the hand instrument. The reason for this difference is conjecture at this time but may have been the result of the ultrasonic tip pushing the MTA material against the wall of the plastic tubes and leaving voids in the body of the material as the tip was removed from the specimen.

After the obturation procedure, the tube-wall surfaces were visually inspected to ensure that the walls were covered with MTA, to be considered an acceptable sample. This initial visual observation would have benefited from a radiographic evaluation, which could have detected many of the internal voids and allowed corrections to be made at that time. As a result, although the tube-wall surfaces appeared visually covered with MTA, the core of the MTA specimens had voids that created radiolucent areas, which could be seen radiographically. The results of this study suggest that whether analyzing the specimens microscopically or radiographically, the method of placement and the length of the MTA sample had an effect on the outcome.

One weakness of the evaluation method was that the measurements were arbitrary and, at best, ordinal in nature. However, there is currently no consensus for standardization of evaluating adaptation and condensation of MTA.

The plastic tube used in this experiment is only one of the many models that could have been used for testing the placement of the MTA material. It was selected for this initial study because the shape and diameter could be better controlled than would be the case with human teeth (14). Future studies with natural teeth could be attempted if the shape and size of the prepared canal can be standardized. More importantly methods can be developed whereby the tooth structure can be removed so that the MTA sample is not damaged. This is key if an accurate microscopic evaluation is to be performed. The natural tooth model would certainly better simulate the actual clinical situation.

In a similar study using calcium hydroxide, Metzger and Solomonov (15) found that hand condensation of calcium hydroxide was better retained in root canals than lentulo-placed paste or commercial injected paste. It is conceivable that the manufacturer's recommended powder:liquid ratio of 3:1 for MTA may not be the most favorable for the ultrasonic placement and was a potential cause of voids that resulted with this technique. The manufacturer's recommended ratio of powder to liquid for MTA was strictly adhered to for this study. Further research is warranted to determine if the MTA samples of varying lengths would react differently if tested using other experimental models.

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