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SCIENTIFIC ARTICLES

Sealing Ability of a Mineral Trioxide Aggregate for Repair of Lateral Root Perforations

Seung-Jong Lee, DDS, MS, Mehdi Monsef, DMD, and Mahmoud Torabinejad, DMD, MSD

Amalgam, IRM, and a mineral trioxide aggregate were tested for repair of experimentally created root perforations. Fifty sound, extracted mandibular and maxillary molars were used in this study. A perforation was created on the mesial root surface at about a 45-degree angle to the long axis of each tooth. The tooth was then placed into a saline-soaked "Oasis" to simulate a clinical condition. After placing the repair materials into the perforations, the teeth were kept for 4 wk in the Oasis model. The perforation sites were then stained with methylene blue for 48 h, sectioned, and examined under a dissecting microscope.

The results showed that the mineral trioxide aggregate had significantly less leakage than IRM or amalgam ($p < 0.05$). The mineral trioxide aggregate also showed the least overfilling tendency while IRM showed the least underfilling tendency.

Root perforation is one of the procedural accidents which can occur as a result of a misdirected bur during access preparation or during preparation of a post space. In addition, excessive flaring of the cervical portion of curved roots in molars can also cause lateral root perforations. Periodontal tissue reaction to experimentally induced perforations in animals (1, 2) and accidental root perforations in humans has been studied (3–6). In general, it appears that the prognosis for root perforations in the apical two thirds of the roots is much better than that in the cervical third (2, 4).

Perforation repair can be achieved intracoronally and/or by external surgical approach. Nonsurgical intracoronal approach usually precedes surgical repair. The important factor in both approaches is achieving a good seal between the tooth and the repair material. This can be affected by the location and size of the perforation, operator skill, and by the physical and chemical characteristics of the repair material.

The effectiveness of several materials has been evaluated in molar perforations in experimental animals. Amalgam has been one of the most widely used materials for this purpose. ElDeeb et al. (1) found that the use of amalgam in furcation perforations was superior to that of Cavit or calcium hydroxide in dogs. Other investigators have reported similar results in clinical studies (5, 7).

Pastes like Cavit or zinc oxide-eugenol cement have also been widely investigated for perforation repair. In a clinical evaluation of patients, Harris (6) reported 89.3% favorable responses with the use of Cavit as a repair material. Jew et al. (2), in their animal experiment, concluded that when Cavit was used immediately to seal "noncoronal" perforations fibrous encapsulation occurred. Zinc oxide-eugenol (9) and reinforced zinc oxide-eugenol cements like super EBA cement (10) have also been tested for perforation repairs.

Recently, Dazey and Senia (8) compared the sealing ability of a reinforced light curing calcium hydroxide (Prisma VLC Dycal), amalgam, and Ketac-Silver. Although they found that the VLC Dycal was significantly better than the other materials, a question still remains about how to use the curing light in inaccessible operation fields. Calcium hydroxide (4, 11) and hydroxyapatite (12) have also been recommended for large furcation perforations.

Extrusion of the filling material (5) is a potential problem in repairing root perforations. This usually occurs during condensation of filling material into the perforation site. Extrusion of filling material can cause traumatic injury to the surrounding periodontal ligament, resulting in inflammation and delay in repair. Hemorrhage control is another factor which can affect sealing ability of the repair material. Presently, available restorative materials are recommended for use in dry fields only.

Recently a new cement, mineral trioxide aggregate (MTA), has been developed at Loma Linda University to seal communications between the tooth and the external surfaces. The principle compounds present in this material are tricalcium silicate, tricalcium aluminate, and tricalcium oxide silicate oxide. In addition to the trioxides, there are a few other mineral oxides which are responsible for the chemical and physical properties of this aggregate. The powder consists of fine particles which are hydrophilic and set in the presence of water.

Hydration of the powder results in a colloidal gel which solidifies to a hard structure in less than 4 h. The character-

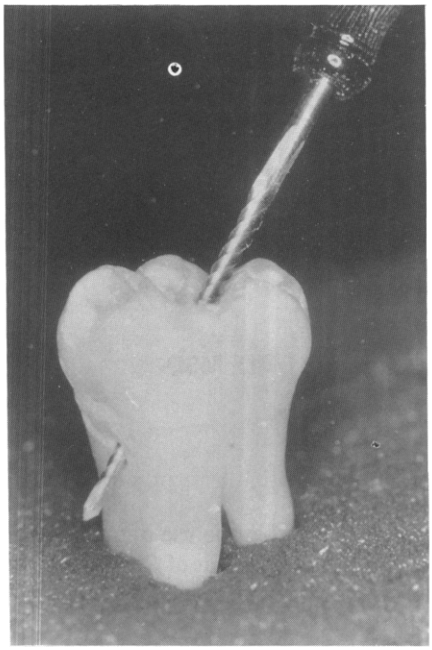

FIG 1. A perforation was made on the mesial root surface at about a 45-degree angle to the long axis of the tooth. The perforation site was enlarged by a #80 K file 5 mm beyond the root surface.

istics of the aggregate depend on the size of the particles, the powder to water ratio, temperature, presence of water, and entrapped air. Several pilot studies have shown that this material prevents dye leakage.

The purpose of this study was to compare the sealing ability of the MTA with that of amalgam and IRM in experimentally induced lateral perforations in extracted human teeth.

MATERIALS AND METHODS

Fifty sound, extracted mandibular molars were used in this study. The teeth had been preserved in normal saline after extraction until their use in this experiment.

A standard coronal access cavity was prepared on the occlusal surface of each tooth using high-speed burs with water spray. After locating the mesial canals with an endodontic explorer and/or a #10 file, a perforation was made from one of the mesial canal orifices toward the mesial surface of the root with a slow-speed #2 long shank round bur at about a 45-degree angle to the long axis of each tooth. The perforation site was enlarged with a #80 Kerr file until the file's tip extruded 5 mm beyond the root surface (Fig. 1). Perforations were thoroughly irrigated with normal saline. Any visible debris was removed using a spoon excavator.

The prepared teeth were then placed in a saline-soaked Oasis, a material widely used for flower arrangements. This setup provided a model simulating a clinical condition in which underfilling or overfilling of the repair materials is not observable (Fig. 2).

The teeth were then randomly divided into four groups and the perforations were repaired as follows: group 1—15 teeth with amalgam; group 2—15 teeth with IRM; and group 3—15 teeth with MTA. The perforations in five teeth (group 4) were not repaired and served as positive controls.

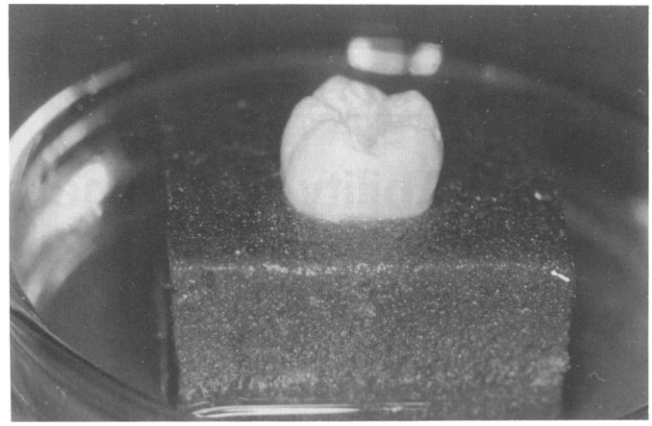

FIG 2. Prepared tooth was placed in the saline-soaked "Oasis."

FIG 3. A ground tooth showing IRM-filled perforated site.

Using a Messing gun, amalgam and IRM were placed into the perforation sites through the coronal access cavities in small increments. Gentle force was used to condense the filling materials. After repair of each perforation, the access cavity in each tooth of group 1 and 2 was filled with the same material as had been used to seal the perforation.

In group 3, the MTA powder (three parts) was mixed with water (one part) into a putty consistency and was placed into the perforations using a Messing gun. A small cotton pellet was used to condense the material into the perforation sites. The access cavities were also filled with the same paste.

The teeth were kept in Oasis for 4 wk. The entire surface of each tooth, except 1 to 2 mm around the perforation site, was double coated with nail varnish. The teeth from all groups were placed in methylene blue for 48 h. To determine the depth of dye penetration, each tooth was ground parallel to its long axis to expose the filled perforated site using a large diamond bur in a high-speed handpiece under water spray (Fig. 3).

All sections were evaluated under a dissecting microscope (Wolfe Co. Carolina Biological Supply Co., Burlington, NC). The lengths of dye penetration in coronal and apical interfaces between the filling materials and the tooth structure were measured separately at ×20 power using an ocular micrometer. Linear dye penetration was measured independently by two observers from the external root surface of each tooth into the access cavity. A two-way analysis of variance was used to determine the statistical difference between the three groups.

RESULTS

Dye penetrated the whole length of the perforation sites in positive controls. Dye penetration in perforated areas took place not only on the exposed surfaces but into the open dentinal tubules as well.

Both IRM and amalgam demonstrated a considerable amount of dye penetration. Average linear penetration for IRM was 1.30 mm with a range of 0 to 2.3 mm, and for amalgam, 1.52 mm with a range of 0.5 to 2.5 mm (Fig. 4). The MTA showed the least degree of dye leakage, averaging 0.28 mm with a range of 0 to 0.8 mm. There was no significant statistical difference between the IRM and amalgam group, while the MTA leaked significantly less than the other two materials ($p < 0.05$).

The measurements of overfilling and underfilling at the perforation sites are shown in Tables 1 and 2. IRM showed the highest rate of overfilling followed by amalgam and the MTA (Table 1). Amalgam showed the highest underfilling tendency followed by the MTA and IRM (Table 2). When the lengths of dye penetration were measured in underfilled or overfilled sites in each group, the MTA still had the least dye penetration. This was statistically significant ($p < 0.05$) compared with dye penetration of IRM and amalgam.

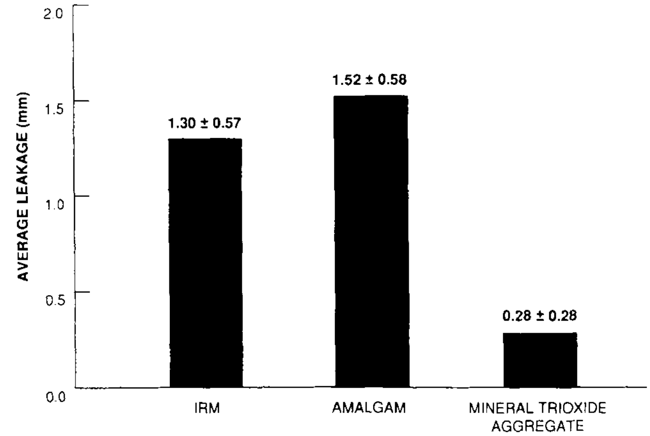

FIG 4. Amalgam showed the highest amount of dye leakage but its leakage was not significantly different than that seen in IRM. MTA allowed significantly less dye leakage compared with IRM or amalgam.

TABLE 1. Frequency of overfillings with IRM, amalgam, and MTA

	IRM	Amalgam	MTA
Incidence (%)	36.7	16.7	3.3
Average leakage when overfilled (mm)	1.32	1.56	0

TABLE 2. Frequency of underfilling with IRM, amalgam, and MTA

	IRM	Amalgam	MTA
Incidence (%)	16.7	36.7	30.0
Average leakage when underfilled (mm)	1.17	1.28	0.21

DISCUSSION

Amalgam and IRM demonstrated a considerable amount of dye leakage compared with the MTA. Though amalgam has been widely recommended for repair of furcation perforations (1, 5, 7), questions as to whether amalgam can provide an adequate seal for furcation repair (8) or retrograde fillings (13–15) have been raised. For the retrofilling procedures, cavity varnish has been recommended to enhance the sealing ability of the amalgam (16, 17). However, this is not always practical for an area with uncontrolled bleeding. Validity of the use of cavity varnish has been also questioned (18).

Reinforced zinc oxide-eugenol cements like IRM or EBA have been recommended for furcation repair or retrograde apical fillings. Some studies (11, 19) showed adequate seals with these materials, while others (20) demonstrated considerable dye penetration.

It is possible that the moisture present in the perforation sites reduces the sealing ability of these materials. Considering the fact that perforation sites are usually contaminated with blood or tissue fluid, these materials may not be suitable for repair of perforations. Eugenol present in them also can be irritating to the surrounding tissues.

The MTA showed significantly less dye penetration than amalgam or IRM. This material is composed mainly of mineral oxides which react with water to set. Because of its hydrophilic characteristic, moisture of the surrounding tissue acts as an activator of the chemical reaction in this material and does not pose a problem with its use in moist environments. In a pilot experiment, the MTA was placed in retrograde cavities contaminated with human blood and tested for dye penetration. The results showed minimal dye penetration between the MTA and the dentinal walls.

Extrusion of the repair material into the perforation site or underfilling are other considerations. In this experiment, the materials were placed with a Messing gun from the coronal access to simulate the clinical situation. Overextrusion occurred mostly in the IRM repair group, followed by amalgam, and then MTA. The reason for this might have been that the MTA is a hydrophilic powder which absorbs moisture and needs little condensation force. An assessment of the relationship between degree of dye penetration and extrusion of repair material showed no correlation between the two. The depth of dye penetration when overextrusion occurred was not significantly different from the overall dye penetration averages of the respective materials. One extrusion occurred in the MTA with no dye penetration.

The frequency of underfilling and the degree of dye penetration was also examined. The average depths of dye penetration were slightly higher than, but not significantly different from, the overall average depths of the respective materials. The distance between the root surface and the filling material when underfilling occurred was also measured for each material. Amalgam showed the largest distance at 0.85 mm, followed by IRM at 0.6 mm, and then MTA at 0.56 mm. Whether this discrepancy can act as an irritant to periodontal healing is beyond the scope of this experiment.

It seems that overfilling or underfilling with the material does not affect the sealing ability. However, tissue injury due to overfilling should be considered during perforation repair.

This study was performed to observe the degree of adaptability of the three materials onto the perforation walls using methylene blue dye as an indicator. Considering the fact that dye penetration may not always reflect the clinical situation, additional in vivo investigations are needed.

Dr. Lee is an associate professor of Yonsei University, Seoul, Korea and a former visiting faculty member of Loma Linda University, Loma Linda, CA. Dr. Monsef is an associate professor and director of Graduate Endodontics, at Mashad University, Mashad, Iran. Dr. Torabinejad is professor and Graduate Program Director of Endodontics, Loma Linda University School of Dentistry, Loma Linda, CA.

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