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Repair of Root Perforations Using Mineral Trioxide Aggregate: A Long-term Study

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Root perforations adversely affect the prognosis of teeth. Inadequacy of the repair materials has been a contributing factor to the poor outcome of repair procedures. Mineral trioxide aggregate (MTA) is a relatively new material that is being successfully used to repair perforations. The purpose of this study was to evaluate the success rate of root perforation repairs using MTA. A list of all of the perforation repairs completed with MTA at an endodontic residency program was obtained. Sixteen cases were included that met the criteria for this study. Pretreatment, immediate posttreatment, and at least 1 year follow-up radiographs were evaluated in a double-blind manner to determine the presence or absence of any pathologic changes adjacent to the perforation site. The results showed that all 16 cases demonstrated normal tissue architecture adjacent to the repair site at the recall visit. Teeth with existing lesions showed resolution of the lesion, and teeth without preoperative lesions continued to demonstrate absence of lesion formation at the follow-up visit. Based on the results of this study, MTA provides an effective seal of root perforations and shows promise in improving the prognosis of perforated teeth that would otherwise be compromised.

Root perforation is an undesirable incident that can occur at any stage of root canal therapy. Although caries or resorptive processes may cause perforations, most root perforations are induced iatrogenically. According to the Washington study, root perforations result in endodontic failures accounting for approximately 10% of all failed cases (1).

Many materials have been used to repair perforations; they include amalgam (2), Cavit (SPE America 3M, Norristown, PA) (3), Super-EBA (HI Bosworth Co, Skokie, IL) (4), glass ionomer (5), and others. The success rate of these materials has been variable. Amalgam has been the most commonly used perforation repair material. However, studies have demonstrated that it has poor sealing ability, resulting in inflammation and inadequate regeneration of periradicular tissues (6). Alhadainy and Himel (7) compared the sealing ability of Cavit, glass ionomer, and amalgam, and found that glass ionomer provides a better seal because of its ability to adhere to dentin. In this study, Cavit also outperformed amalgam, possibly because of Cavit's hydrophilic nature and ease of placement compared with amalgam.

In addition to providing a good seal, the material of choice for repair of root perforations must be biocompatible, nontoxic, insoluble in the presence of tissue fluids, and capable of promoting regeneration of the periradicular tissues. Mineral trioxide aggregate (MTA) has been recommended as a repair material for root perforations (8). The biocompatibility of MTA has been demonstrated in vitro (9) and by being implanted in the mandible and tibia of guinea pigs (10).

In a dye leakage study, Lee et al. (11) investigated the sealing ability of MTA in lateral perforations and reported that MTA allowed significantly less leakage than IRM or amalgam. Nakata et al. (12) compared the sealing ability of MTA and amalgam in furcal perforations of extracted human teeth using an anaerobic bacterial leakage model. Their results showed that MTA allows significantly less leakage of *Fusobacterium nucleatum* past the furcation repairs compared with amalgam. According to Torabinejad et al. (13), the reduction in bacterial leakage of MTA is a result of its sealing ability rather than any antimicrobial properties of the material. Their study has shown that MTA does not have any significant effect on bacterial growth of facultative or anaerobic bacteria.

One of the major consequences after repair of root perforations has been the inflammatory reaction in the surrounding tissues. MTA not only has been shown to be biocompatible to the surrounding tissues but also has demonstrated the ability to allow regeneration of these hard tissues. In a human osteoblast model, Koh et al. (14) found that MTA stimulated upregulation of cytokines, such as interleukin-1α, interleukin-1β, and interleukin-6, which are involved in bone turnover. In addition, the results of another study showed that MTA stimulates propagation of human osteoblasts by offering a biologically active substrate for the cells (15). Historically, materials used to repair root perforations have been associated with the formation of a fibrous connective tissue capsule in contact with the adjacent bone at best. In fact, formation of a periodontal defect has been a more common finding adjacent to the majority of previously used materials. A characteristic that differentiates MTA from other materials is its ability to promote regeneration of cementum, thus facilitating the regeneration of the periodontal apparatus.

A search of the literature revealed two short-term studies that evaluated the clinical efficacy of MTA as a perforation repair material. Arens and Torabinejad (16) reported on two cases in which MTA had been used to repair furcal perforations. The first case showed bone regeneration after 3 months. Continued healing was observed radiographically at 6 and 12 months. The second case had similar findings, with radiographic evidence of resolution of a lesion in the furcation region at 9 and 12 months. In a similar case report using MTA to repair perforations, Schwartz et al. (17) found radiographic evidence of resolution of a furcal lesion and absence of any clinical symptoms 6 months after the repair procedure. The purpose of this report is to present a series of cases with longer follow-up demonstrating the response of periradicular tissues to MTA when used to repair root perforations in humans.

MATERIALS AND METHODS

A cross-referenced list was obtained of all patients seen at the Loma Linda University endodontic residency program who were treated with MTA. From this list, patients were chosen based on the following criteria: presence of a root perforation that had been repaired with MTA with accompanying radiographs documenting the tooth at the time of treatment and a minimum of 1 year of postoperative follow-up. All patients from the list meeting these criteria were included in the study. There were 16 patients who met these criteria.

All patients had been seen at University Dental Clinic for endodontic treatment and subsequently treated for repair of a perforation defect at various levels on the root surface. Sixteen pretreatment and posttreatment and recall radiographs were evaluated in a double-blind manner by three independent examiners to determine the presence or absence of any pathologic changes adjacent to the perforation site. The size and location of the perforations and the existence and type of a final restoration were noted to address possible confounding factors. Three radiographs were examined for each tooth. The first radiograph examined was the preoperative film exposed before the repair of the perforation defect. The second radiograph was the film exposed immediately after the repair of the perforation. The third radiograph was the follow-up film taken at least 1 year after the repair procedure. The results were recorded as presence or absence of a periradicular lesion. A lesion was defined as any radiolucency adjacent to the repair site exceeding double the width of a normal periodontal ligament space. All 16 cases were also clinically evaluated to determine the presence or absence of a periodontal defect in the area of the perforation. Periodontal pocket measurements were noted from the follow-up examination.

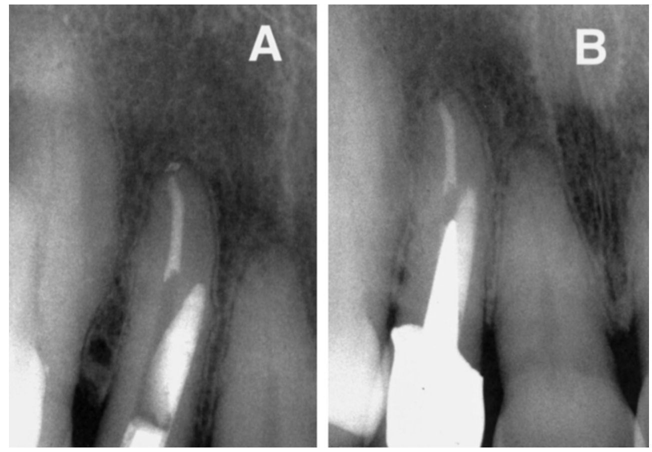

FIG 1. Radiographs of the maxillary right lateral incisor with a lateral perforation. *A*, Postoperative radiograph taken immediately after the repair of the perforation. *B*, Radiograph taken 18 months after perforation repair.

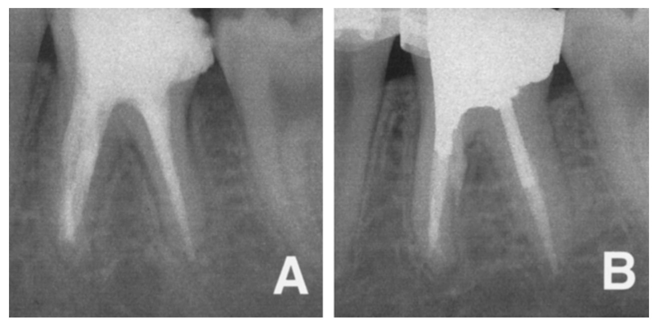

FIG 2. Radiographs of the mandibular left first molar with a strip perforation on the distal aspect of the mesial root. *A*, Postoperative radiograph taken immediately after the repair of the perforation. *B*, Radiograph taken 15 months after perforation repair.

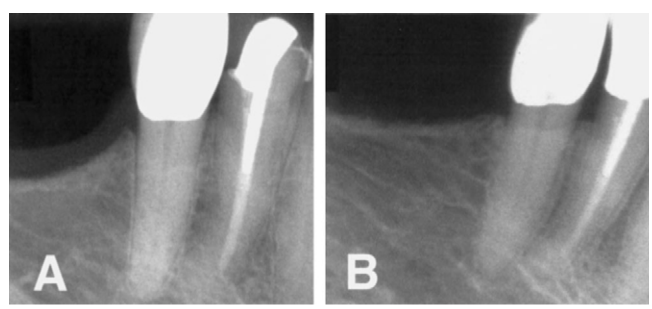

FIG 4. Radiographs of the mandibular right first premolar with a perforation at the apical region of the mesial root. *A*, Postoperative radiograph taken immediately after the repair of the perforation. *B*, Radiograph taken 15 months after perforation repair.

RESULTS

Of the 16 clinical cases that were included in this study, five were classified as lateral perforations (Fig. 1), five as strip perforations (Fig. 2), three as furcal perforations (Fig. 3), and three as apical perforations (Fig. 4). None of the teeth had pocket measurements greater than 3 mm. Seven of these patients presented with radiolucent lesions at the time of repair. The follow-up radiographs ranged from 12 to 45 months. All of the cases with evidence of preoperative radiolucency demonstrated resolution at the follow-up appointment. The length of time elapsed for the repair of the perforation in these cases ranged from 12 to 45 months. The remaining nine teeth did not present with a radiographic lesion at the site of the perforation at the time of repair (Fig. 3) and did not develop radiolucent lesions at these sites at the time of follow-up. The time lapse between the date of repair and follow-up for these cases ranged from 12 to 43 months. Overall the average time lapse between the immediate postoperative and the follow-up radio-

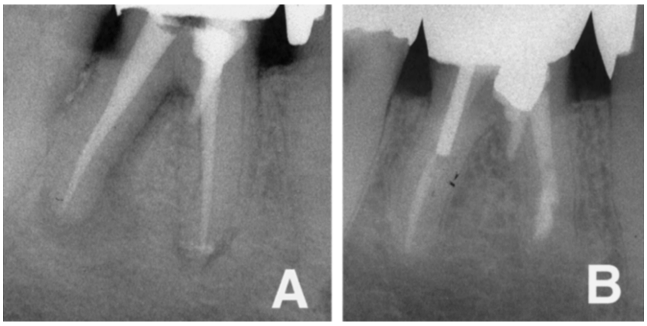

FIG 3. Radiographs of the mandibular right first molar with a perforation of the furcation region. *A*, Postoperative radiograph taken immediately after the repair of the perforation. *B*, Radiograph taken 45 months after perforation repair.

graphs was 25 months. Table 1 demonstrates the results of this study.

DISCUSSION

Although MTA is one of the most researched materials in dentistry, showing remarkable results, the majority of the published data are based on in vitro and animal studies. Research must be continued to evaluate clinical outcomes in human subjects. The importance of clinical data is substantiated by recent trends in evidence-based dentistry. In this article, we present a series of cases that have demonstrated consistent healing with the use of MTA as a perforation repair material. The availability of this material may require re-evaluation of previous guidelines regarding prognosis of perforated teeth.

It has been speculated that the important factors in determining the success of a perforation repair procedure are the location of the perforation, time lapse between the occurrence of the perforation and repair, the ability of the material to seal the perforation site, and the biocompatibility of the repair material (18). A perforation in the cervical third of the root or in the floor of the pulp chamber has had a poorer prognosis than one at the apical or middle third of the root (18). Furcal perforations have had a diminished prognosis because of the closer proximity to the oral environment, which has a higher potential to cause a periodontal defect (19). A perforation of the pulpal floor of a tooth causes damage to the periodontal ligament with a subsequent inflammatory reaction. If the perforated region is exposed to bacterial contaminants from the oral environment for a substantial period, a downward proliferation of epithelium may occur. This can result in breakdown of bone and, ultimately, loss of the tooth. However, it has been shown that if the perforation is repaired without delay, the prognosis is greatly improved (18, 19). The main goal in management of perforations is to arrest the inflammatory process and the subsequent loss of tissue attachment by preserving healthy tissues at the site of the perforation. If a lesion is already present, it is important to restore tissue reattachment. Until the advent of MTA, repair materials had not been able to achieve this regenerative process.

Any material or technique may have certain properties that must be considered during its clinical use. MTA is a fine powder primarily composed of tricalcium silicate, tricalcium aluminate, tricalcium oxide, and silicate oxide that, upon hydration, forms a colloidal gel that solidifies in approximately 3 h (20). Therefore, when used as a root repair material, although the periradicular tissues provide some moisture from the external surface of the material, to assure proper setting, moisture must also be provided from the internal aspect of the root using a moist cotton pellet.

In previous studies, investigators have tried to demonstrate insertion of Sharpey fibers into the repair material. However, the re-establishment of the periodontal apparatus depends greatly on regeneration of cementum over the root defect. Once the cementum has covered the repaired site, periodontal ligament reestablishment is more predictable. Based on the outcome of the cases presented in this article, MTA is an excellent material for the repair of perforations at various levels of the root. Comparison of the results of this report with the results of reports on root perforations repaired with other materials shows a marked improvement in the prognosis of teeth repaired with MTA. Further studies are needed to determine the prognosis of root perforations repaired with MTA after longer observation periods.

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TABLE 1. Perforation repair cases

Case (Tooth)	Type of Perforation	Repair Date	Presence of Lesion	Recall Date	Presence of Lesion	Time Lapse Repair–Recall, Months
1(28)	Apical	05/18/99	No	08/23/00	No	15
2(19)	Furcal	12/12/96	No	07/01/98	No	19
3(30)	Strip	05/01/95	No	05/06/96	No	12
4(32)	Apical	08/23/96	Yes	04/06/99	No	32
5(12)	Lateral	05/08/96	No	08/17/99	No	39
6(19)	Strip	05/21/98	Yes	05/03/99	No	12
7(19)	Strip	08/04/98	Yes	09/28/00	No	25
8(5)	Lateral	08/25/98	Yes	11/18/99	No	15
9(30)	Strip	01/29/96	Yes	08/20/99	No	43
10(3)	Furcal	01/26/95	Yes	11/25/96	No	22
11(15)	Apical	01/11/96	Yes	05/24/99	No	40
12(19)	Strip	09/20/93	Yes	12/8/94	No	15
13(30)	Furcal	11/13/95	Yes	8/17/99	No	45
14(10)	Lateral	12/06/95	No	12/04/96	No	12
15(19)	Lateral	12/01/94	No	10/30/97	No	34
16(7)	Lateral	10/12/95	No	04/06/97	No	18

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