11 - ORIGINAL ARTICLE
MATERIALS TESTING

Portland cement with additives in the repair of furcation perforations in dogs[1]

Cimento Portland com aditivos na reparação de perfurações radiculares em cães

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ABSTRACT

PURPOSE: To evaluate the use of Portland cements with additives as furcation perforation repair materials and assess their biocompatibility.

METHODS: The four maxillary and mandibular premolars of ten male mongrel dogs (1-1.5 years old, weighing 10-15 kg) received endodontic treatment (n=80 teeth). The furcations were perforated with a round diamond bur (1016 HL). The perforations involved the dentin, cementum, periodontal ligament, and alveolar bone. A calcium sulfate barrier was placed into the perforated bone to prevent extrusion of obturation material into the periradicular space. The obturation materials MTA (control), white, Type II, and Type V Portland cements were randomly allocated to the teeth. Treated teeth were restored with composite resin. After 120 days, the animals were sacrificed and samples containing the teeth were collected and prepared for histological analysis.

RESULTS: There were no significant differences in the amount of newly formed bone between teeth treated with the different obturation materials (p=0.879).

CONCLUSION*:* Biomineralization occurred for all obturation materials tested, suggesting that these materials have similar biocompatibility.

Key words: Biocompatible Materials. Calcium Sulfate. Dental Cements. Furcation Defects. Dogs.

RESUMO

OBJETIVO: Avaliar o uso de cimentos Portland aditivados na reparação de perfurações radiculares e a biocompatibilidade destes materiais.

MÉTODOS: Oitenta pré-molares, quatro da arcada dentária superior e quatro da arcada inferior de 10 cães machos, sem raça definida, com idade em torno de um a um ano e meio, pesando entre 10 e 15 kg foram submetidos a tratamento endodôntico, sendo realizadas perfurações nas furcas com broca de diamante 1016 HL. A cavidade envolveu dentina e cemento, como também periodonto e o osso alveolar. Na porção óssea da obturação, barreira de sulfato de cálcio foi utilizada evitando extravasamento do cimento para o espaço periodontal. Foi realizada a distribuição randomizada dos cimentos MTA (controle), Portland tipo II, Portland tipo V e Portland branco estrutural nas obturações. Os dentes foram restaurados com resina composta. Após 120 dias realizou-se eutanásia, retirada dos dentes, preparação e análise histológica.

RESULTADOS: Entre os cimentos não houve diferença estatística significante quanto à neoformação óssea (p=0,879).

CONCLUSÃO: Ocorreu biomineralização com os diferentes cimentos usados no estudo, sugerindo que estes são similares em termos de biocompatibilidade.

Descritores: Materiais Biocompatíveis. Sulfato de Cálcio. Cimentos Dentários. Defeitos da Furca. Cães.

Introduction

Root perforation is defined as an artificial opening usually of iatrogenic etiology, connecting the pulp cavity with periradicular tissues and alveolar bone. It can also be caused by pathological conditions, such as caries process and resorption[1]. The pulp chamber floor is the part of the tooth where most perforations occur. Furcation perforations have poor prognosis because of the lack of obturation materials with adequate properties[2].

The advent of mineral trioxide aggregate (MTA) has changed this scenario because of its favorable chemical and biological properties[3]. At present, MTA is the most indicated material for the repair of root canals. It is also used in endodontic surgery, direct pulp capping, apexification, root resorption, lateral root perforations, and furcation perforations[4]. The major components of MTA are tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetra-calcium aluminoferrate, bismuth oxide (radiopaque agent), and calcium sulfate dihydrate (gypsum)[5]. Despite its widespread use, MTA has some disadvantages, including low resistance to compression over the long-term and high cost[4,6]. Both mechanical resistance and cement integrity are desirable properties of materials subjected to high occlusal loads, such as obturation materials for furcation perforations[7].

Portland cement is the most common cement used in civil engineering applications. The major components of ordinary (Type I) Portland cement, which are similar to those of MTA[8], consist of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetra-calcium aluminoferrate, and calcium sulfate dihydrate[9]. Studies comparing the properties of MTA and Type I Portland cement have reported that their pH[10,11], antimicrobial activity[12], biocompatibility[13], and low resistance to compression[14] are similar.

Recent experimental studies have compared the performance of MTA with those of Type I Portland cement and white ordinary Portland cement in pulp capping in dogs[10,15], and their effects on the submucosal connective tissue in rats[13] and subcutaneous connective tissue in guinea pigs[16]. The findings of these studies support the idea that Type I and white ordinary Portland cements have the potential to be used in the same clinical applications as MTA. The components of MTA are similar to those of Type I Portland cement, with the addition of bismuth oxide as a radiopaque agent[13,14]. Type I Portland cement and MTA have low resistance to compression[17], and the addition of bismuth oxide to MTA increases its porosity and friability over time[6].

On the other hand, Type II, Type V, and white Portland cements have excellent physical properties, including high resistance to compression, due to the presence of additives in their composition[17]. Additives used in the different types of Portland cements include slag from charcoal blast furnace in Type II cement, blast-furnace slag in Type V cement, and pozzolans/volcanic ash in white cement[18]. However, further experimental studies on the use of Portland cements with additives as a repair material for root perforations are required to evaluate the biocompatibility of these materials.

Materials used in the repair of root perforations remain in close contact with periradicular tissues. A major problem associated with the use of obturation materials is the difficulty to maintain them within the perforation. The lack of a barrier at the moment of condensation of the obturation material results in extrusion of this material into the periradicular space and alveolar bone. This adversely affects bone regeneration because sealers are not absorbed by the body. In order to remediate this problem, some authors have suggested the use of a matrix of calcium sulfate dihydrate (plaster of Paris) in the osseous portion of the perforation[19-22]. Calcium sulfate dihydrate acts as a barrier preventing the extrusion of the obturation material and allows regeneration of bone and periodontal ligament[19-22].

The use of Portland cements with additives as obturation materials may be an alternative for the repair of furcation perforations due to their high resistance to compression. Thus, we considered opportune to carry out a histological analysis of the regeneration of bone and periodontal ligament in furcation perforations repaired using a calcium sulfate barrier and Portland cements with additives (white, Type II, or Type V Portland cement) as obturation materials. MTA was used as a control obturation material.

Methods

This study was performed at Laboratory of Surgical Techniques of Sapucai Valley University (UNIVAS), Pouso Alegre-MG, Brazil. It was approved by the Ethics Research Committees of the Sao Paulo Federal University (UNIFESP) and UNIVAS. All animals received humane care in strict compliance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures and in accordance with local laws and regulations. Adequate measures were taken to minimize pain or discomfort of the animals.

The four maxillary and mandibular premolars of ten male mongrel dogs aged 1-1.5 years and weighing 10-15 kg (n = 80 teeth) were used in the study. The animals were obtained from the dog pound of the Center of Zoonoses Control of Pouso Alegre-MG, Brazil. The dogs were selected by a veterinarian who was also responsible for the care of the animals pre- and postoperatively.

A pilot study was carried out previously to determine the required surgical procedures, characteristics of the perforations, amount of obturation material needed, and aspects of the clinical evolution of the animals[22]. The endodontic procedures are fully described in the preceding paper[22].

Before surgery, the dogs were pre-anaesthetized intramuscularly with 2 ml of xylazine hydrochloride (Rompun, Bayer, Sao Paulo, Brazil). Next, the animals were anaesthetized intravenously with sodium thiopental (12.5 mg/kg) and intubated. Infiltration anesthesia (1 ml of 1% lidocaine with adrenaline) was administered to the periapical region of the teeth included in this study.

The endodontic treatment was performed using the crown-down technique with nickel-titanium rotary instruments. The canals were obturated using medium gutta-percha cones and AH-Plus sealer with warm vertical condensation. The furcations were perforated with a round diamond bur (1016 HL) in a water-cooled high-speed handpiece. The length of the perforations (10 mm) was defined by the cusp apex and an annular groove in the shank of the dental bur. The perforations involved the dentin, cementum, periodontal ligament, and alveolar bone. The mean length of the osseous portion of the perforation was 4 mm. Calcium sulfate dihydrate was placed into the perforated bone using an amalgam carrier. A Schilder plugger #5 was used for condensation of the calcium sulfate barrier, creating a space for the obturation material[22].

Type II, Type V and white Portland cements and MTA-Angelus were used as obturation materials; MTA was used as a control. The allocation sequence of the obturation materials to the right or left maxillary or mandibular premolars was obtained using the Random Generator for Microsoft Excel 4.0. Only one type of obturation material was assigned per tooth. The obturation material was placed into the preparation using an amalgam carrier and condensed with a Schilder plugger #5. The teeth were restored with light-cured composite resin. Analgesics (acetyl salicylic acid, 25 mg/kg) and non-steroidal anti-inflammatories (ibuprofen, 20 mg/kg) were administered postoperatively every 12 hours.

The dogs were sacrificed by anesthetic overdose 120 days after the surgical procedure. For the preparation of histological slides, samples containing the treated teeth were cut, identified, and immersed in a decalcifying solution (558 ml of 10% formaldehyde and 42 ml of 65% nitric acid) for 15 days. Following, the specimens were washed in running water for 24h, embedded in paraffin, and cut along the proxi-proximal direction to expose the obturation material and areas adjacent to the furcation (Figure 1). Then, 6µm serial sections were cut with a microtome and stained with hematoxylin-eosin.

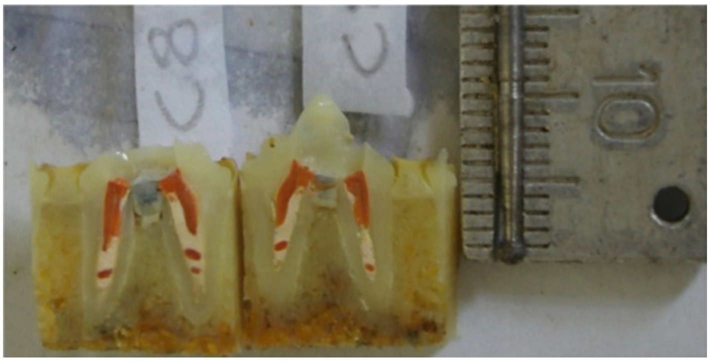

FIGURE 1 – A maxillary second premolar cut along the proxi-proximal direction and placed beside a H1016 bur and a ruler for scale. The length of the perforations was defined by the cusp apex and the groove in the burr shank. Note the cement in the dental portion of the perforation.

Histological analysis was performed simultaneously by two pathologists blinded to the type of cement used to repair the teeth. Structures were identified and quantified using morphometric and stereological analysis integrated with digital image processing (Figures 2A and 2B). A 10 x 10 square grid containing 100 points was created with Microsoft Power Point[23]. The grid was placed over the digital images and grid points positioned on the obturation material, newly-formed bone, and inflammatory infiltrate were counted (Figures 2C and 2D).

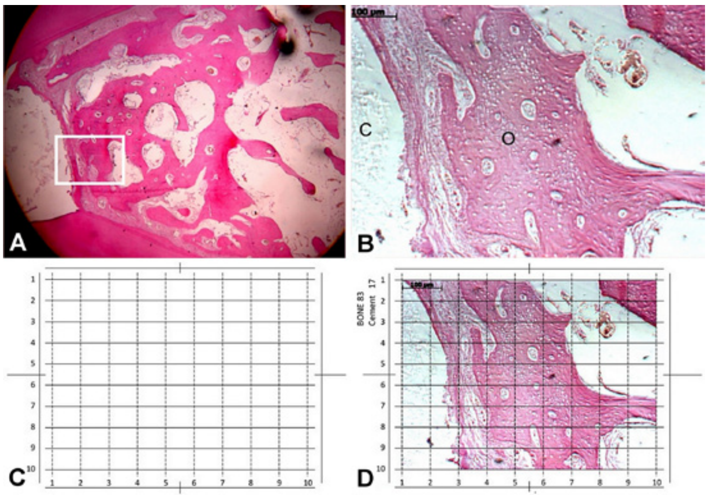

FIGURE 2 – (**A**) Micrograph of a furcation perforation treated with white Portland cement. Image detail shows the obturation cement and newly formed bone. Hematoxylin and Eosin stain, magnification 5x. (**B**) Enhanced image detail showing the obturation cement (*C*) and newly formed bone (*O*). (**C**) Image of the 10 x 10 square grid containing 100 points used in the study. (**D**) Grid placed over the digital image for counting grid points positioned on the structures identified in the image.

Statistical analysis of the collected data was performed using the two-sample Poisson test. Because the response data were measured as a Poisson variable, the one-way analysis of variance (ANOVA) was conducted using Tukey's transformation. All statistical tests were performed at a significance level of 5% ($p<0.05$).

Results

There were no significant differences in the mean number of points counted over the newly-formed bone among the four types of obturation materials (p = 0.879), as shown in Table 1 and Figure 3. Also, no significant differences were found in the mean number of points counted on the inflammatory infiltrate among the four types of obturation materials (p = 0.741), as shown in Table 2 and Figure 4.

TABLE 1 – Number of grid points counted on newly formed bone shown in digital images of histological sections of teeth treated with the different types of repair materials.

Repair Material	N	Mean count	SD
MTA	20	5.520	3.519
Type II Portland cement	20	5.050	3.392
Type V Portland cement	21	5.051	3.371
White Portland cement	19	5.781	3.320

N = number of teeth treated with each repair material; SD = standard deviation.

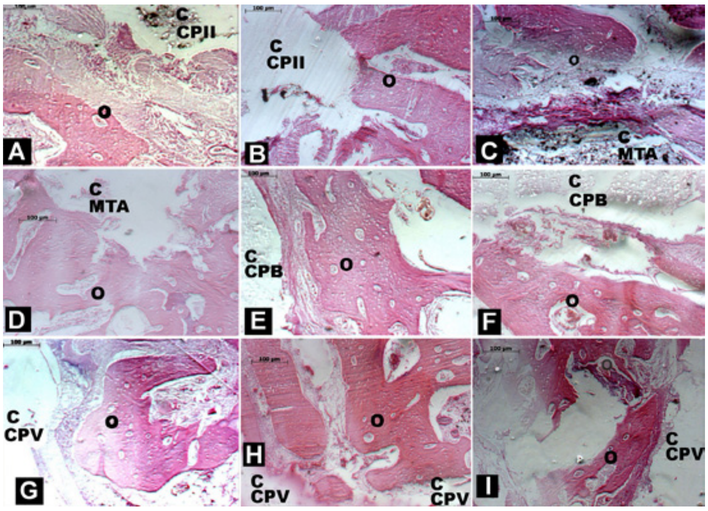

FIGURE 3 – Micrographs of furcation perforations treated with the different cements showing the repair material (*C*) and newly formed bone (*O*). (**A**, **B**) Furcation perforations treated with Type II Portland cement (*CPII*). (**C**, **D**) Furcation perforations treated with mineral trioxide aggregate (*MTA*). (**E**, **F**) Furcation perforations treated with white Portland cement (*CPB*). (**G**, **H**, **I**) Furcation perforations treated with Type V Portland cement (*CPV*). Hematoxylin and Eosin stain, magnification 5x.

TABLE 2 – Number of grid points counted on inflammatory infiltrate shown in digital images of histological sections of teeth treated with the different types of repair materials.

Repair Material	N	Mean count	SD
MTA	20	5.027	3.904
Type II Portland cement	20	5.661	3.675
Type V Portland cement	21	5.674	3.605
White Portland cement	19	4.555	3.691

N = number of teeth treated with each repair material; SD = standard deviation.

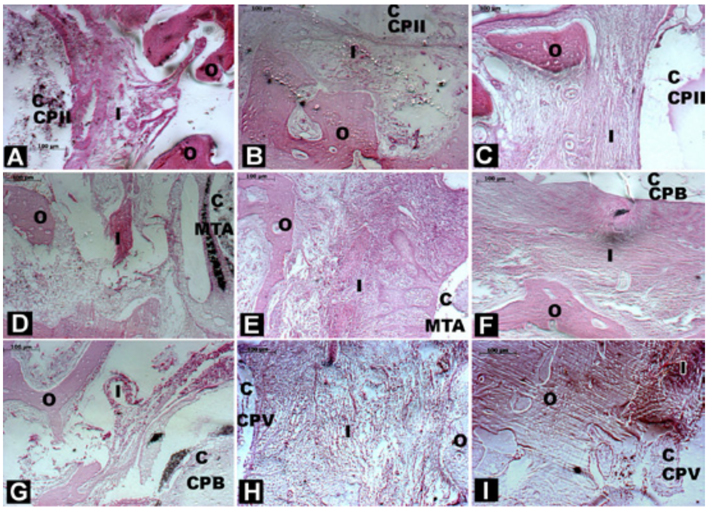

FIGURE 4 – Micrographs of furcation perforations treated with the different cements showing the inflammatory infiltrate (*I*) and newly formed bone (*O*). (**A**, **B**, **C**) Furcation perforations treated with Type II Portland cement (*CPII*). (**D**, **E**) Furcation perforations treated with MTA. (**F**, **G**) Furcation perforations treated with white Portland cement (*CPB*). (**H**, **I**) Furcation perforations treated with Type V Portland cement (*CPV*). Hematoxylin and Eosin stain, magnification 5x.

Discussion

The advent of MTA has changed the clinical concept of preservation of tooth structure. The components of MTA are similar to those of Type I Portland cement, with the addition of bismuth oxide[13,14]. Portland cement is used in civil engineering applications and can be grouped into two main categories: ordinary (Type I) Portland cement and Portland cements with additives[17].

Some studies have shown that the chemical and biological properties of Type I Portland cement and MTA are similar; both cements release calcium ions that lead to the formation of carbonate apatite, which promote biomineralization[15,24,25]. However, Type I Portland cement and MTA have low resistance to compression[6]. Mechanical resistance is one of the fundamental requirements for cements to be used in the repair of furcation perforations because obturation materials are subjected to high occlusal loads[7,26]. Therefore, the purpose of this study was to evaluate histologically furcation perforations repaired using three different types of Portland cements with additives, including natural pozzolans/volcanic ash and blast-furnace slag; MTA was used as a control material[17,19,22].

Extrusion of cement into the perforated bone occurs when the obturation material is condensed without the use of a barrier. This prevents the formation of a homogeneous interface between the newly formed bone, cementum/dentin and obturation material, as observed in the pilot study[22]. Because cements are non-absorbable materials, they prevent new bone formation and should not be used in bone repair[27]. On the other hand, calcium sulfate dihydrate is bioabsorbable and allows guided bone regeneration at the same time that serves as a barrier[20,22]. A calcium sulfate barrier was used to prevent extrusion of cement at the bone-cementum/dentin interface, ensuring that the obturation material would seal the furcation perforation and that complete bone regeneration would be achieved[27]. Calcium sulfate dihydrate is also a component of both the MTA and Portland cements. New bone formation was observed in the entire bone perforation on slides showing the interface between newly formed bone and obturation material, indicating that the three types of Portland cements and MTA had similar biocompatibility[20,22,27,28].

MTA is considered the gold standard; however, its mechanical resistance and radiopacity are parameters that should be evaluated prior to its use in the repair of furcation perforations. MTA has low resistance to compression because its composition is similar to that of Type I Portland cement[8,13,14]. Besides, the addition of bismuth oxide (radiopaque agent) to MTA has the effect of increasing its porosity and friability over the long-term[4,29]. The use of Portland cements with additives, which have high resistance to compression, may contribute to the long-term success of the repair of furcation perforations, because this is an area subject to high masticatory loads[7]. Moreover, professionals have been able to determine the presence of Portland cement in dental radiographs without the addition of a radiopaque agent.

Further studies are necessary to substantiate these findings and to determine whether Portland cements with additives can be used in the development of furcation perforation repair materials for clinical practice.

Conclusion

Biomineralization occurred for all different types of cement tested, with no significant differences among the obturation materials used.

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