A comparative evaluation of ProRoot mineral trioxide aggregate and Portland cement as a pulpotomy medicament

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ABSTRACT

Introduction: Recently, some studies have compared mineral trioxide aggregate (MTA) with portland cement (PC), concluding that the principle ingredients of PC are similar to those of MTA. The purpose of the present study was to evaluate the biocompatibility of PC as a pulpotomy medicament.

Materials and Methods: Thirty premolars that scheduled for extraction for therapeutic reasons were randomly assigned to two experimental groups: ProRoot MTA (PMTA) and PC. After isolation and pulp exposure, pulpotomy was carried out and pulps were dressed with PMTA and PC. After 6 months, the teeth were extracted and prepared for histological analysis based on Cox et al. criteria. The data were analyzed by Z-test of proportion with 1% of allowed error.

Results: No statistically significant difference was found between the two groups with respect to inflammatory response, soft tissue organization, and dentine bridge formation (P > 0.05). Conclusions: PC was associated with similar favorable biological response to pulpotomy treatment as PMTA. The findings of this study support the idea that PC can be considered a cheaper substitute to MTA.

KEYWORDS: Portland cement, ProRoot mineral trioxide aggregate, pulpotomy

Introduction

Vital pulp therapy is the treatment of choice for treating reversible pulpal injuries in both primary and permanent teeth for maintaining pulp vitality and function. Rationale of this treatment is based on the healing ability of the healthy pulp. Pulpotomy is a vital pulp therapy in which a portion of vital coronal pulp tissue is removed surgically and the remaining radicular dental pulp is covered with a suitable material that protects the pulp from further injury and promotes healing.[3] Calcium hydroxide based materials have been extensively used as a pulpotomy medicament because of their potential to induce dentin

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How to cite this article: Bhagat D, Sunder RK, Devendrappa SN, Vanka A, Choudaha N. A comparative evaluation of ProRoot mineral trioxide aggregate and Portland cement as a pulpotomy medicament. J Indian Soc Pedod Prev Dent 2016;34:172-6.
bridge formation. However, the presence of tunnel defects in the dentinal bridges beneath CH has been described. Mineral trioxide aggregate (MTA) has recently received much attention as a good substitute for calcium hydroxide-based materials.[6]

MTA is a bioactive material which has the ability to create an ideal environment for healing, standing as the most promising substitute to other materials.[3] The United States Patent No. 5,415,547 and 5,769,638 for MTA states that the base material for MTA is portland cement (PC) and bismuth oxide has been added to make the mix radiopaque. PC is classified as hydraulic cement, which normally is, composed of 65% lime (calcium + magnesium oxide), 20% silica, 10% alumina and ferric oxide, and 5% other compounds.[4]

The first study which used ordinary PC as a reference material to MTA published in 2000.[9] Since then, numbers of studies used PC as material of reference showed that the only difference between PC and MTA materials is the bismuth oxide.[6]

Regarding the healing effects, it was observed that the osteoblast-like cells had similar growth and matrix formation when growing on set PC[7] while other authors noted that PC allowed dentin bridge formation after pulpotomy on dogs[8] and induced calcite crystal granulations deposition when placed in dentin tubes that were implanted subcutaneously in rats. Moreover, it has been demonstrated that PC and MTA have a similar effect on pulp cells when used as a direct pulp capping materials in rats[9] as well as comparable antibacterial activity.[5]

Concerns notwithstanding, clinical use of PC has been carried out in clinical cases in which PC was applied as a medicament after pulpotomy[10] and an apical plug for apexification.[11]

Considering the similarities in the properties of MTA and PC, the objective of this study was to evaluate the biocompatibility of PC compared with ProRoot MTA (PMTA).

Materials and Methods

Teeth selection
Teeth were obtained from 8 patients reporting to the department of orthodontics ranged from 12 to 18 years of both genders. Sample consisted of thirty noncarious human premolars which were scheduled for therapeutic extraction. All experimental procedures were carried out according to the protocol approved by the Ethic Committee of Research conducted after the approval from Ethical Committee in accordance with the declaration of Helsinki. Consent forms were prepared according to WHO informed parental consent form for research involving children for clinical studies. The patients were asked to read and sign a consent form allowing the clinical procedure. Complete enumeration method was used for selecting the subjects during that period and were further randomly divided by systematic allocation method into two groups (15 teeth each/group).

Cavity preparation and pulp exposure
In both the groups, rubber dam isolation was used. Under local anesthesia, the teeth were excavated using handpiece with bud bur; the opening of the pulp chamber was conducted with carbide bur, followed by irrigation with saline solution. The coronal pulp tissue was removed manually with an evacuator, and controlled bleeding of the remaining pulp tissue was obtained using slight pressure with sterile cotton pellet.

Material placement
PC (EN 197-1: 2000, type CEM I) was mixed with bismuth oxide (80:20) and was kept for dry heat sterilization at 170°C (340°F) for 1 h in hot air oven.[12] One of the major concerns for this cement was the arsenic content of the cement; the cement was sent for laboratory testing, and the methodology employed for analysis of arsenic was based on ISO 9917-1 standard. Arsenic quantification was performed using an atomic absorption spectrophotometer (model 1475; Varian, Victoria, Australia) equipped with a hybrid generator. The total arsenic content in the cement is 0.64 ppm which was below the ISO specified limits.[13]

Either PMTA (Dentsply, Tulsa Dental, Tulsa, OK, USA) or PC (EN-197-1: 2000, type CEM I) was applied into the pulp chamber with a spatula. The subjects were blinded to the type of material placed in the pulp chamber. A layer of reinforced zinc oxide eugenol (IRM® Dentsply Ind. eCom. Ltda., Petropolis, RJ, Brazil) was placed prior restoration with resin-modified glass ionomer cement (VITREMER®, 3M/ESPE, St. Paul, MN, USA). An immediate postoperative radiograph was taken.

Histological preparation
Following postoperative interval of 6 months, the teeth were extracted and subjected to histological examination. The extracted teeth were injected with formalin from the apical foramen with minimum pressure and stored in formalin for overnight fixation. Decalcification was obtained using 5% HCL + 5% HNO3 for 2-4 weeks. Subsequently, the tooth was embedded in paraffin wax and 5 μm sections were obtained and stained with hematoxylin and eosin. The observer evaluating the histologic section was blinded to all the procedure involved. Histologic evaluations were made under a light microscope (Carl Zeiss, Oberkachen, Germany) at ×400 magnification based on the criteria previously established [Table 1]. The data obtained were subjected to statistical analysis. Z-test of proportion was applied with 1% of allowed error.
Results

The results of histological observation are summarized in Table 2.

1. **Inflammatory cell response:** 11 out of 15 teeth in MTA group had a score of 1 and 4 teeth had a score of 2 while 10 out of 15 teeth in white PC (WPC) group had a score of 1 and 5 teeth had a score of 2. Comparing both the groups for score 1 ($P = 0.7285$) and score 2 ($P = 0.6838$).

2. **Soft tissue organization:** 7 out of 15 teeth in MTA group had a score of 1 and 2 teeth had a score of 2 and 6 teeth had a score of 3 while 8 out of 15 teeth in WPC group had a score of 1 and 7 teeth had a score of 3. Comparing both the group for score 1 ($P = 0.7504$) and score 2 ($P = 0.1481$) and score 3 ($P = 0.708$).

3. **Dentinal bridge formation:** 7 out of 15 teeth in MTA group had a score of 1 and 2 teeth had a score of 2 and 6 teeth had a score of 3 while 8 out of 15 teeth in WPC group had a score of 1 and 7 teeth had a score of 3. Comparing both the group for score 1 ($P = 0.7504$) and score 2 ($P = 0.1481$) and score 3 ($P = 0.708$).

However, no statistically significant difference was found between PMTA and WPC for any of the histological criteria.

Discussion

It is estimated that over 24 million endodontic procedures are performed on an annual basis. An ideal endodontic repair material will adhere to the tooth structure, maintain a sufficient seal, are insoluble in tissue fluids, dimensionally stable, radiopaque, and exhibit biocompatibility.

MTA is a biomaterial that has been investigated for endodontic applications since the early 1990’s. MTA is biocompatible, the US Federal Drug Administration approved material, with a range of applications in endodontic therapy.[14]

A comparative analysis of MTA and PC using plasma emission spectrometry showed that except for no detectable quantity of bismuth in PC, significant difference did not exist between the other 14 elements in both PC and MTA. According to its manufacturer’s material safety data sheet, ProRoot™ MTA has in its composition of 75% PC, 20% bismuth oxide, and 5% dehydrated calcium sulfate while MTA-Angelus® is composed of 80% PC and 20% bismuth oxide.[6]

PC is the worldwide covenant designation for one of the most widely employed materials in construction. PC is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other compounds. The European Union standard for PC, EN 197-1 regulates the industrial production of cement. EN 197-1 makes a distinction of the materials into five groups of cement (CEM I-V). Out of the 5 types and 3 subtypes, only CEM I is pure PC.[4] The cement (BS EN 197-1:2000, type CEM I) had similar physical, mechanical, and chemical properties of PC comparable to ProRoot MTA.[15] In our study, EN 197-1 CEM-I ISO 9001-2001 type of cement has been used for the study. After the chemical analysis, the cement was prepared

### Table 1: Scores used for histological findings based on Cox et al. criteria

| Scores | Inflammatory cell response |
|--------|----------------------------|
| 1      | None or few scattered inflammatory cells present in the pulp beneath the exposure site |
| 2      | Polymorphonuclear leukocytes (acute) or mononuclear lymphocytes (chronic) in an inflammatory lesion |
| 3      | Severe inflammatory lesion appearing as an abscess or dense infiltrate involving one third or more the coronal pulp |
| 4      | Completely necrotic pulp |

| Scores | Soft Tissue Organization |
|--------|--------------------------|
| 1      | Normal or almost normal tissue morphology below the exposure site and throughout the pulp |
| 2      | Lack of normal tissue morphology below the exposure site, with deeper pulp tissue appearing normal |
| 3      | Loss of general pulp morphology and cellular organization below the exposure site |
| 4      | Necrosis in at the coronal third of the pulp |

| Scores | Dentinal Bridge Formation |
|--------|---------------------------|
| 1      | New barrier tissue directly adjacent to some portion of the restorative material |
| 2      | New dentin bridge some distance from the material interface |
| 3      | No evidence of any dentin tissue formation in any of the tissue sections |

### Table 2: Statistical evaluation of histopathological results after capping with PMTA and WPC

| Groups | Inflammatory cell response | Soft tissue organization | Dentinal bridge formation |
|--------|----------------------------|--------------------------|---------------------------|
|        | n (%) Score 1 | n (%) Score 2 | n (%) Score 3 | n (%) Score 1 | n (%) Score 2 | n (%) Score 3 | n (%) Score 1 | n (%) Score 2 | n (%) Score 3 |
| PMTA   | 11 (75%) | 4 (25%) | .. | 7 (47%) | 2 (13%) | 6 (40%) | 7 (47%) | 2 (13%) | 6 (40%) |
| WPC    | 10 (66%) | 5 (33%) | .. | 8 (53%) | .. | 7 (47%) | 8 (53%) | .. | 7 (47%) |
| Z-test | 0.347155 | 0.407309 | .. | 0.318063 | 1.446359 | 0.37451 | 0.318063 | 1.446359 | 0.37451 |
| p Value | 0.7285 | 0.6838 | .. | 0.7504 | 0.1481 | 0.708 | 0.7504 | 0.1481 | 0.708 |

Result: NS NS .. NS NS NS NS NS NS
for the study, and it has been stated that PC in its natural state is slightly radiopaque, but it fails to meet the ISO 6876/2001 requirement for radiopacity. To overcome this disadvantage, Húngaro Duarte et al. in 2009 evaluated the mixed ratio of 20% radiopacifier and 80% WPC by weight and concluded that PC/bismuth oxide presented the highest radiopacity values. Similarly, in our study, 80 g of PC (EN 197-1:2000, type CEM I) was mixed with 20 g of bismuth oxide by weight and a homogeneous mix was prepared; the prepared material was kept for dry heat sterilization at 170°C (340°F) for 1 h in hot air oven. In addition, it is stated that the process of cement manufacture requires 15,000°C temperature and due to the high alkalinity of PC, generally, the commercially available samples are found to be sterile.

PC has been found to promote the precipitation of a layer of “bone-like” hydroxyapatite which underpins its ability to integrate with living tissue. The dissolution of portlandite and formation of calcite were also observed on contact with simulated body fluid. In our study, pulpotomy was performed on human teeth using MTA and PC in terms of inflammatory response, soft tissue organization, and dentin bridge formation. Z-test of proportion was done and no statistically significant difference was found between both the groups.

The study compared the success of PC based on calcific bridge formation. In our study, out of 15 teeth, 8 teeth in the PC revealed dentine bridge formation; dentine formation is a sign or consequence of attempted repair processes within the pulp tissue. In the present study as seen in Figures 1 and 2, none of the teeth with dentine bridges had other concomitant radiographic or clinical signs of failure, and therefore, the presence of dentine bridge was categorized as a success.

The biological reaction of the pulp to PC was good and no significant difference was seen as the mechanism of action of MTA and PC are similar. As both the materials have calcium hydroxide, calcium hydroxide has a direct effect on the precapillary sphincters resulting in less plasma outflow, which in turn favors a calcific response in the involved tissue. Calcium hydroxide also increases the action of pyrophosphatase enzyme which is Ca^{2+} dependent. This enzyme transforms pyrophosphatase into orthophosphates which increases energy utilization and therefore favors a defense mechanism.

The reaction of calcium from calcium hydroxide with carbon dioxide from the pulp tissue produces calcite crystal when any of these materials is used. The primary calcific bridge is found as an early barrier between pulp tissues and the cavity which allows the pulp to organize its cellular elements and forms the permanent dentin bridge.

The response of material such as PC is the formation of a dentin barrier, resulting from the recruitment and proliferation of undifferentiated cells, which may be either stem cells or dedifferentiated and transdifferentiated mature cells. Once differentiated, the cells synthesize a matrix that undergoes mineralization. The extracellular matrix components can induce either reactionary dentin formation or formation of dentin barriers.

Our study confirmed many preexisting factors; strong indicators exist suggesting that PC is biocompatible, has good sealing ability, and can be made radiopaque without significantly altering its properties.

**Conclusion**

In conclusion based on the results of this study PC may serve as an effective and less expensive MTA substitute.
Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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