# Sealing Ability of ProRoot MTA and MTA-Angelus Simulating a One-Step Apical Barrier Technique- An *in vitro* Study

Nikita Lolayekar* / Sham S Bhat ** / Sundeep Hegde***

*Endodontic treatment of the pulpless tooth with an immature root apex poses a special challenge for the clinician due to lack of an apical stop against which to compact an interim dressing of calcium hydroxide, or the final obturation material. A one-visit apexification protocol with MTA (Mineral Trioxide Aggregate) has be seen as an alternative to the traditional treatment practices with calcium hydroxide [Ca(OH)2]. The aim of this study was to investigate the use of MTA as a 5mm apical barrier by comparing sealing ability of ProRoot MTA to that of MTA-Angelus. 50 freshly extracted Maxillary and Mandibular single canal sound human incisor teeth were used in this study, which were decoronated to standardized 10mm root lengths. The root segments were prepared to simulate the clinical situation of an open apex with Gates Glidden burs # 5-1 and randomly assigned into 2 experimental groups of 20 samples each (Group A: ProRoot MTA, Group B: MTA-Angelus) and 10 root segments were used as control (Group C) where no apical barrier was used. After obturation the coronal portion of all samples were sealed with Glass Ionomer and stored at 37ºC and 100% humidity for 4 weeks. The root segments were then double coated with nail varnish except for the apical 1mm and apical ends of all root segments were suspended vertically in methylene blue dye for 48 hours at room temperature. After removal from the dye, the samples were sectioned longitudinally and linear dye penetration was measured using a Grid and stereomicroscope. The measurements were tabulated and statistically analyzed. The mean percentage of dye leakage for Group A was 55.5% and for Group B was 53.25%. The results showed no statistically significant difference in the sealing ability of ProRoot MTA and MTA-Angelus when used as apical barriers.*

***Keywords:*** *mineral trioxide aggregate, apexification, apical barrier*
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## INTRODUCTION

Endodontic treatment of the pulpless tooth with an immature root apex poses a special challenge for the clinician. The main difficulty encountered is the lack of an apical stop against which to compact an interim dressing of calcium hydroxide ($Ca(OH)_2$), or the final obturation material. In these situations the unpredictability of the result, the difficulty in creating a leak-proof temporary restoration for the duration of treatment, and the difficulty in protecting the thin root from fracture may lead to complications when using traditional ($Ca(OH)_2$ -based) apexification techniques. Furthermore, given the increased mobility of today's society, lengthy treatment protocols are fraught with problems, and may not be followed through to completion. This may lead to ultimate failure of the case.[1]

Mineral Trioxide Aggregate (MTA) has been introduced for use in endodontics. Current literature supports its efficacy in a multitude of procedures including apexification. A one-visit apexification protocol with MTA can be seen as an alternative to the traditional treatment practices with $Ca(OH)_2$.

Materials previously considered for apical barriers include dentin chips, freeze-dried cortical bone/dentin, calcium phosphate and calcium hydroxide which are efficient in creating a barrier for obturation in one appointment but do not provide a well sealed environment. Thus Mineral Trioxide Aggregate has been advocated for use as an apical barrier because of its sealing capabilities, ability to set in the presence of moisture, its biocompatibility and ability to induce hard tissue formation.[2]

Therefore the purpose of this study was to evaluate root end sealing ability of two commercially available MTA: ProRoot MTA(Dentsply Maillefer, Dentsply Tulsa Dental,

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USA) and MTA-Angelus (ANGELUS Dental Solutions, Brazil).

**MATERIALS AND METHOD**

50 freshly extracted Maxillary and Mandibular single canal sound human incisor teeth were used in this study. They were cleaned of calculus, soft tissue tags, attached bone or other debris by ultrasonic scaling. The teeth were stored in saline (Nirlife, Nirma Ltd., India) until further use. The inclusion criteria selected:

1. Sound teeth (without caries)
2. Teeth without any resorption due to periodontal reasons
3. Teeth without root fractures and
4. Teeth with complete root formation.

The teeth were decoronated to standardized 10mm root lengths with micromotor handpiece (NSK, Japan)and diamond discs (Diamant 0.15mm, Dentaurum, Germany).

The root segments were then prepared to simulate the clinical situation of an open apex with Gates Glidden burs # 5-1. The burs were used in a crown-down manner until a #1 bur could pass through the apical foramen.

The segments were then prepared with Flexofiles until an ISO size 90 file (Mani Inc, Japan) could be visualized 1mm past the apex. Sodium hypochlorite (Endoclean, Vardhman Surgicraft Denticare Division, India)was used as irrigant throughout the procedure.

The 50 root segments included in this study were randomly assigned into 2 experimental groups of 20 samples each and 10 root segments were used as control:

Group A: ProRoot MTA was placed as 5mm apical barriers.
Group B: MTA-Angelus was placed as 5mm apical barriers.
Group C: Control group: no material was placed as apical barrier.

All materials were manipulated as *per* manufacturer's instructions.

The MTA used in both the groups was mixed on a paper pad with distilled water in 3:1 powder water ratio. When the mixture exhibited putty like consistency after about 30 seconds of mixing, it was immediately placed as apical barriers. A plugger followed by a wet cotton pellet was used to condense the material gently at the simulated open apex.

Radiographs were taken to verify the placement of the apical barriers (Figure 1).

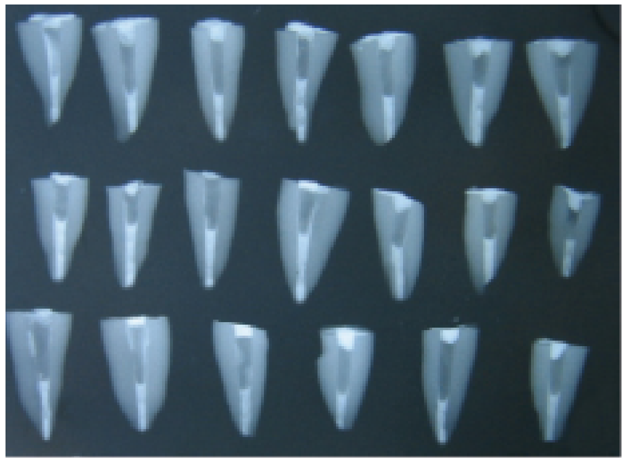

**Figure 1.** Radiograph showing placement of apical barriers

**Group A**

White ProRoot MTA was placed as 5mm apical barriers and moistened cotton pellet was placed in the root canals till the material set and the coronal portion sealed with IRM. After 24 hours, the IRM (Caulk, Dentsply, USA)and cotton pellet were removed and the canals dried and obturated with guttapercha (Dentsply Maillefer, Dentsply France SAS) and zinc oxide eugenol sealer (Deepak Enterprise, Dental Products of India, India).

Coronal portion of all samples were then sealed with Glass Ionomer (Fuji IX).

**Group B**

White MTA-Angelus was placed as 5mm apical barriers and all the root segments were obturated with guttapercha and zinc oxide eugenol sealer on the same day.

Coronal portion of all samples were sealed with Glass Ionomer (Fuji IX, GC Corporation, Japan).

**Group C**

In 10 of the prepared root segments used as control, no material was placed as apical barrier. All the samples were obturated with guttapercha and zinc oxide eugenol sealer. Coronal portion of all samples were then sealed with Glass Ionomer (Fuji IX).

Radiographs were taken of samples in all 3 groups to verify the obturation and all root segments were stored at 37ºC and 100% humidity for 4 weeks.

**Measurement of Dye leakage**

The root segments from all groups were double coated with nail varnish except for the apical 1mm and apical ends of all root segments were suspended vertically in methylene blue dye (Loflers Methylene Blue, B.N. Laboratory, Mangalore, India)for 48 hours at room temperature.

After removal from the dye, the teeth were washed with tap water and then sectioned longitudinally with diamond discs along the long axis of the teeth with the sections passing through the obturated root canals and apical barriers. These sections revealed the filling material between the two axial walls of the root canals.

Linear dye penetration was then measured from apical root surface to the most coronal extent of dye penetration in units, on a scale of 0 to 100 using a Grid and a stereomicroscope (Magnus, India) at 20X magnification (Figure 2).

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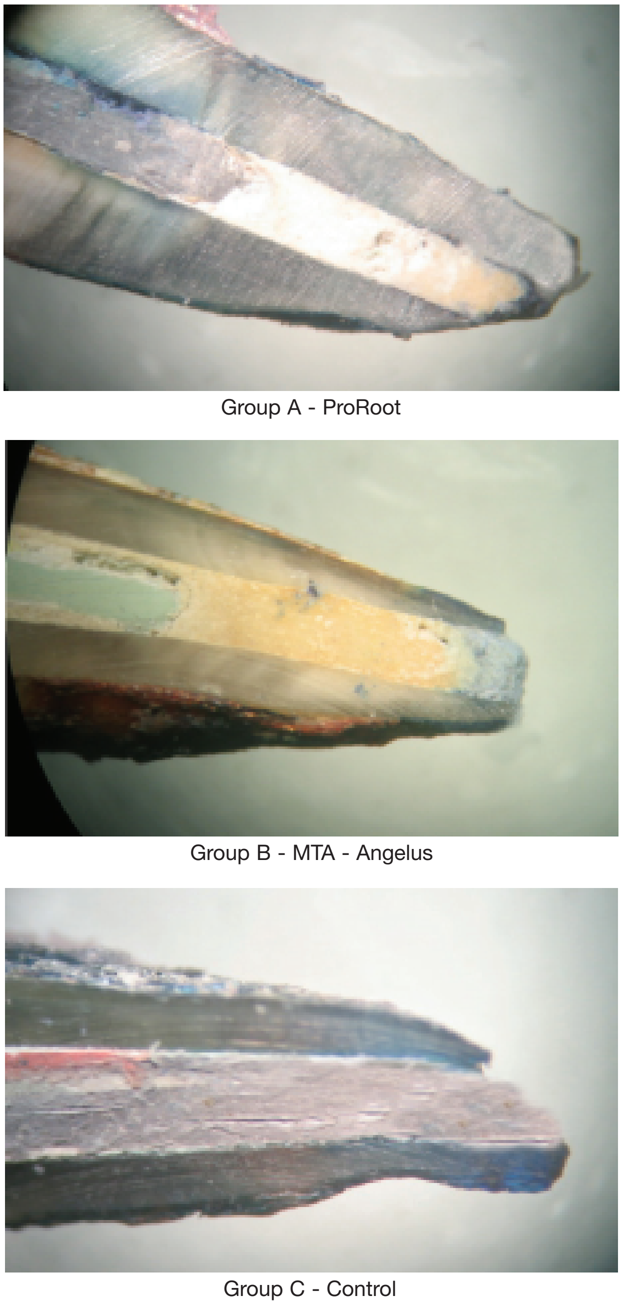


**Figure 2**. Microscopic images showing dye leakage

## RESULTS

After assessing the extent of linear dye penetration, the data so obtained from all the samples was analyzed statistically using the Students unpaired't' test for comparison (Table 1).

According to the results obtained, the control group showed complete dye penetration whereas the experimental groups revealed different degrees of microleakage.

In group A: 6 of the 20 samples showed no dye leakage, the mean percentage of dye leakage being 55.5%.

In group B: 4 of 20 samples showed no dye leakage, the mean percentage of dye leakage being 53.25%. Group A and Group B did not differ significantly from each other (P= 0.870) (Table 2).

**Table 1.** Statistical Analysis

**Group Statistics**

| | GROUP | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| VARIABLE | MTA Angelus | 20 | 10.650 | 7.415 | 1.658 |
| | Pro-Root MTA | 20 | 11.100 | 9.715 | 2.172 |

**Independent Samples Test**

| | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 95% Confidence Interval of the Difference | |
| | t | df | P-value | Mean Difference | Std. Error Difference | Lower | Upper |
| VARIABLE Equal variances assumed | -.165 | 38 | .870 | -.450 | 2.733 | -5.982 | 5.082 |

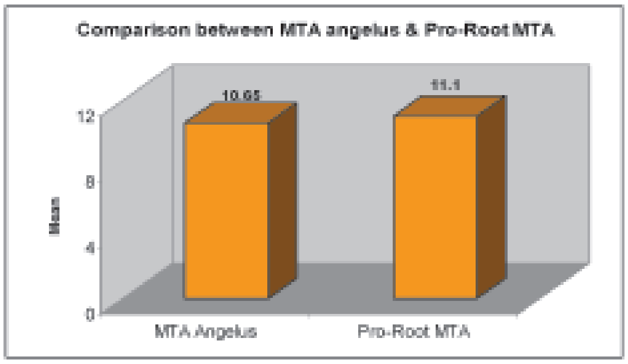


**Table 2.** Graph representing mean dye leakage with MTA-Angelus and ProRoot MTA

## DISCUSSION

The completion of root development and closure of the apex occurs up to 3 years after eruption of the tooth. The treatment of pulpal injury during this period poses a significant challenge for the clinician. Depending upon the vitality of the affected pulp, two approaches are possible – apexogenesis or apexification.

- Apexogenesis is 'a vital pulp therapy procedure performed to encourage continued physiological development and formation of the root end'.
- Apexification is defined as 'a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incomplete root in teeth with necrotic pulp'.[3]

In children, dental caries and trauma are the most common challenges to the integrity of a tooth as it matures. Both insults can render the dental pulp non-vital. It the dental pulp is damaged before development of the root length and closure of the apical foramen, normal root development is altered or halted completely.[4]

In such teeth, due to lack of apical constriction, hermetic

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seal of the root canal system during obturation is not possible. For such cases, the management technique has been apexification involving induction of a calcific barrier at the apex, with calcium hydroxide root canal dressings, which facilitate obturation of the root canal.[5]

The requisite 1-2 year for multi visit apexification with $Ca(OH)_2$ before permanent canal obturation may however, present serious problems for patients and dentists:

- The stop formation is variable, sometimes unpredictable and occasionally unsatisfactory.
- That may handicap obtaining informed consent accurately, predicting a fee and explaining problems as they develop.
- Youthful patients and parents maybe unable to co-operate with critical recalls because of vicissitudes in child guardianship and changes of residence, employment and insurance.
- The intermittent need for a large lingual access to pack fresh $Ca (OH)_2$ to stimulate apical growth could delay placing a permanent restoration resulting in esthetic concerns.
- The temporary seal may fail, causing re-infection and prolonged treatment.
- Stop-loss calculations arise if the cost of treatment increases with uncertainties about completion.
- A larger number of radiographs are necessary to closely monitor apical growth, periapical health and treatment procedures. Public awareness and sensitivity to radiation hygiene have increased as hazard tolerances have decreases.[6]
- Andreasen *et al* showed that the fracture strength of immature teeth is markedly decreased following long-term calcium hydroxide treatment. [7]

The advantage of a material that promotes the immediate formation of an artificial apical plug and that maintains the capability to induce apexification with time means that the definitive root filling can be placed immediately after the material sets.[8]

Successful apexification depends on the formation of a hard tissue barrier by cells that migrate from the healing periradicular tissues to the apex and differentiate under the influence of specific cellular signals to become cells capable of secreting a cementum, osteocementum or osteodentin organic matrix.[9]

In the past, techniques for management of the open apex in non-vital teeth were confined to custom fitting the filling material, paste fills and apical surgery. A number of authors[10, 11] have described the use of custom fitted gutta-percha cones, but this is not advisable as the apical portion of the root is frequently wider than the coronal portion, making proper condensation of the guttapercha impossible. Sufficient widening of the coronal segment to make its diameter greater than that of the apical portion would significantly weaken the root and increase the risk of fracture.[3]

The disadvantages of surgical intervention include:[3]

- The difficulty of obtaining the necessary apical seal in the young pulpless tooth with its thin, fragile, irregular walls at the root apex.
- These walls may shatter during preparation of the retro-cavity or condensation of the filling material.
- The wide foramen results in a large volume of filling material and a compromised seal.
- Apicoectomy further reduces the root length resulting in a very unfavorable crown root ratio.
- The limited success enjoyed by these procedures resulted in significant interest in the phenomenon of continued apical development or establishment of an apical barrier, first proposed in the 1960s.[12, 13]

The standard ways for achieving an apical stop are creating a shelf or a tapering funnel or a combination of the two. However there are clinical situations for which standard diminishing techniques are not adequate:

- There may be the absence of a natural canal constriction at the apex
- A restricted cervical access
- The impracticality of tapering a narrow canal in a long thin root with more than one bend
- Immature root canal anatomy or external resorption of the apex.
- Complications such as overzealous trephination, root perforations and apicoectomy maybe present.

A variety of special techniques will always be an advantage in these non standard situations. The plug stop is one such aid that involves the extra step of packing a biocompatible material, such as calcium hydroxide, dentin chips or tricalcium phosphate, to provide an immediate apical stop in cases where diminishing taper techniques are not feasible.[6]

Single visit techniques using apical barriers have been proposed as alternatives to the long term calcium hydroxide apexification procedure which enables immediate obturation of the root canal.[5]

Coviello and Brilliant evaluated clinical healing in single-visit cases in which gutta-percha was condensed against immediately placed apical barriers of tricalcium phosphate and calcium hydroxide. Their results were compared to multi visit calcium hydroxide apexification. After 9 months all treatment techniques were effective and showed equal clinical success.[14] Pitts *et al* showed no significant difference in periapical inflammation healing after 1 month in root canals of feline teeth filled with apical plugs of either dentin chips or calcium hydroxide. After 9 months virtually all the calcium hydroxide was missing from the teeth. In addition all the teeth showed calcification, resembling cellular cementum, in all but one specimen and granulation tissue of various stages of organization within the reduced lumina of the canals.[15] Hammarstrom *et al* demonstrated that even thought direct contact of calcium hydroxide with periapical tissues helped to induce cemental and osseous repair by alteration of pH, it also caused limited necrosis. Thus, while calcium



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hydroxide may facilitate osseous repair, a barrier material with better tissue biocompatibility is desirable for use in the single-visit apexification procedure.[16]

The idea of single visit apexification is not new and has been discussed and tested for many years. The success rate varies for different materials.[17] Various materials like Super-EBA, IRM, osteogenic protein-I, silver amalgam and MTA have been tried out as apical barriers out of which MTA was found to be the most effective.[5]

A material like MTA with a high biocompatibiliy is a viable option, but is said that it still needs further testing. This material is osteoconductive, which may help the periapical tissue to adapt and heal. Its effectiveness has been shown in many case reports.[18]

Felippe *et al* demonstrated that the application of MTA immediately after root canal preparation favored the establishment of a normal periodontal ligament and formation of new bone and cementum. The MTA behaved in a similar manner to the calcium hydroxide paste, even in the presence of exudate and contamination observed at the time of preparation, and promoted the disinfection of the canal and stimulated the formation of an apical barrier of hard tissue. The histological responses observed in this study indicate that the MTA is a reliable material and should be considered effective in teeth with incomplete root formation. Its application results in predictable apical closure and reduction of the treatment time, number of appointments and radiographs, particularly in young patients.[8]

Villa P *et al* in their study suggested Mineral trioxide Aggregate for apexification because it provides an adequate seal in the root canal, and it appears to offer a biological active substrate that stimulates periodontal cell production.[19]

MTA-Angelus manufactured in Brazil was chosen because it presents a similar composition to ProRoot MTA according to the manufacturer. Duarte *et al*[20] have demonstrated that both materials release calcium and provide alkaline environment. Besides when used in direct pulp capping or pulpotomy both materials were biocompatible and effective to produce complete pulp healing. Menezes *et al* [21] also showed that the tissue reactions were identical for Pro-Root and MTA-Angelus.

The difference in the two materials lies in few of its properties (Table 3).

Because of potential discoloration effect of grey MTA, white MTA has been introduced into endodontic treatment for the same purpose. [24]

Bozeman *et al s*howed that white MTA had a significantly higher compressive strength than grey MTA at 24 hours and that grey MTA had a significantly longer time to final setting time compared to white MTA. Based on this study, the results suggest that white MTA is an effective substitute for grey MTA.[25] Hence white MTA was used for this study.

It is speculated that the elimination of tetracalcium alumino ferrite from the white formulation may have caused slight volumetric shrinkage of white MTA that accounts for increased leakage seen between the MTA and root dentin as

**Table 3.** Differences between ProRoot MTA and MTA-Angelus

| Properties | ProRoot MTA [22] | MTA-Angelus [23] |
|---|---|---|
| | The powder sets in the presence of moisture into a colloidal gel | When mixed to water it initially forms a gel which soon achieves a rigid set |
| pH | After mixing pH is 10.2 and rises to 12.5 at 3hours | Highly alkaline pH 12 |
| Setting time | 2h 45 minutes (+ 5minutes) It has a final setting time of 4 hours | Setting time: Initial: 10 minutes; final: 15 minutes. It is not necessary to wait for the final set to continue treatment procedures |
| Compressive strength | ~70 MPa at 21 days | 44.2 MPa after 28 days; which is very acceptable, considering that sites of application do not receive direct occlusal load |

showed that a 5mm barrier demonstrated significantly greater micro-hardness than the 2mm barrier. In this study we tested the sealing ability of white ProRoot MTA and MTA- Angelus as 5mm apical barriers.

MTA is condensed into root-end preparation against a base or physical barrier for support. Orthograde delivery is said to be more technique sensitive. Placement must be verified with radiographs and condensation is limited because of minimal resistance of the open apex. In addition to the difficulty in delivering the material to the apex, the irregularities and divergent nature of the anatomy may limit adaptation to the dentinal walls, creating marginal gaps at the dentinal interface.[17] Therefore after placement of MTA, radiographs were taken to verify the thickness of the barrier and its placement at the apex.

Due to the prolonged setting time of ProRoot MTA, these samples were obturated in 24 hours. The long hardening time of ProRoot MTA is said to reduce internal tensions and the incidence of marginal infiltration, but it forces to definitively fill the tooth in the following sitting.[26] MTA-Angelus on the other hand has a setting time of 15 minutes and hence all the samples could be obturated on the same day.

After obturation the coronal portions of all samples were sealed with GIC to prevent any chances of dye penetration from the coronal aspect. They were then stored at 37ºC and 100% humidity for 4 weeks to simulate a periapical environment.

Many techniques have been advised to test the sealing properties of restorative materials *in vivo* and *in vitro*. These techniques include use of dyes, chemical tracers, radioactive isotopes, neutron activation analysis, scanning electron microscopy and electrical conductivity. These studies have emphasized that margins of restorations are not fixed and inert with impenetrable borders and possess dynamic micro crevices which contain a busy traffic of ions and molecules. The use of dye is considered the easiest and most economical method for detecting microleakage.

Before placing the prepared samples in methylene blue

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dye, all the root segments except the apical 1mm were double coated with nail varnish to prevent dye penetration into the lateral and accessory canals.

Maximum linear extent of dye penetration was defined as the most coronal level of dye visible on the root canal walls or gutta-percha, regardless of whether it was continuous with the apical area. Dye penetration along the gutta-percha was defined as the maximum linear extent of dye penetration minus the distance from the tooth apex to the apical terminus of the guttapercha in accordance with a study done by Goodell *et al*. [27]

It has generally been considered that a potential root-end filling material should set as soon as it is placed in the root-end cavity without significant shrinkage. This condition would allow dimensional stability of the material after placement and less time for an unset material to be in contact with vital tissues. However, in general terms, the quicker a material sets the more it shrinks. This phenomenon may explain why ProRoot MTA in previous experiments had significantly less dye and bacterial leakage than other materials tested as root-end filling materials. [22]

The sealing capacity of MTA-Angelus has also been tested *in vitro* (dye penetration through a dentine-MTA cement interface). The low levels of dye penetration indicate that MTA-Angelus presents an effective sealing potential. Considering the larger dimensions of bacteria in comparison to those of dye molecules, bacterial infiltration is highly reduced, guaranteeing excellent marginal closing. [23]

## CONCLUSIONS

1. Statistically, there was no significant difference in the sealing ability of ProRoot MTA and MTA-Angelus when used as apical barriers (P=0.870).
2. Mineral Trioxide Aggregate with its additional properties such as biocompatibility and osteoconductivity is an ideal material for single visit apexification.

Based on the above findings it can be concluded that both ProRoot MTA and MTA-Angelus have similar sealing ability when used in a one-step apical barrier technique. The direct extrapolation of results to clinical situation needs to be undertaken only after further *in vivo* investigations.

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