ORIGINAL ARTICLE

Comparative Evaluation of Mineral Trioxide Aggregate, Biodentine, and Calcium Phosphate Cement in Single Visit Apexification Procedure for Nonvital Immature Permanent Teeth: A Randomized Controlled Trial

Anjali Yadav[1], Rakesh K Chak[2], Richa Khanna[3]

Abstract

Aim and objective: This study assesses the efficacy of mineral trioxide aggregate (MTA), biodentine, and calcium phosphate cement (CPC) as single visit apexification agents for nonvital immature permanent teeth, both clinically and radiographically.

Materials and methods: The study was conducted as a double-blinded randomized, controlled clinical trial after approval of the Institutional Ethical Committee of King George's Medical University, Lucknow, Uttar Pradesh, India, the approval letter (Ref. no. 81st ECM II B-Thesis/P24). A total of 60 patients in the age group of 6–15 years, fulfilling all the inclusion and exclusion criteria were enrolled for the study. Patients were randomly divided into three groups having 20 in each group.

Results: On the basis of present study, it can hence, be inferred that clinical success for MTA, biodentine and calcium phosphate cement in apexification was 100%. The radiographic outcomes of calcium phosphate cement showed better results as compared to MTA and biodentine at 9 months of follow-up periods.

Conclusion: These finding suggest that calcium phosphate cement can be used as a substitute for MTA and biodentine because of its comparable clinical and superior radiographic success.

Keywords: Biodentine, Calcium phosphate cement, Image J software (1.46 r), Mineral trioxide aggregate, Single visit apexification.

International Journal of Clinical Pediatric Dentistry (2020): 10.5005/jp-journals-10005-1830

Introduction

Young permanent teeth may lose their vitality as a consequence of traumatic dental injury or dental caries. These teeth are characterized by incomplete root formation and apical closure. The canal with incomplete apex formation is termed a "blunderbuss" canal. The term indicates the internal shape of the canal which with greater width toward the apex than toward the cervical part.[1] In Blunderbuss canals, however, walls of the canal diverge and flare, especially greater in the buccolingual direction. This leads to the formation of a funnel-shaped apex that is wider than the coronal portions of the canal.[2] Incomplete development of tooth can be the product of pulp undergoes necrosis resulting from dental caries or any dental traumatic injury, occurring before root growth and development are complete, that is before Stage 4 given by Cvek.[3] Clinically, in endodontics, the term "open apex" describes an unusually wide apical foramen, where achieving an apical "stop" during canal preparation or obturation is extremely difficult, if not impossible. It has been described by various authors by the minimum ISO file size which passes freely through the apical foramen. The files reported to indicate the size of an open apex are ISO 40, ISO 45, ISO 60, ISO 80, or ISO 100.[4–8] Traumatic injuries in young permanent teeth are quite common and are reported to affect approximately 30% of the pediatric population.[2] Majority of the traumatic incidents occur before root formation is complete, that is usually in the age group range of 8–12 years, with most commonly involving maxillary anterior teeth.[9] Management of these nonvital or necrotic immature permanent teeth involves a choice between two approaches—apexogenesis or apexification. Apexogenesis is defined as a "vital pulp therapy procedure which is performed to encourage continued physiological development and formation of the root end".[10] Apexification, however, 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".[10] Alternate treatment approaches were suggested by Morse et al. They include customized cone technique for the open apex, the shortfill technique-obturating short of the apex, or periapical surgery. The use of calcium hydroxide in apexification was introduced by Kaiser and Frank in 1960. Since then it has been used with great success in the immature root apex.[11]

[1,3]Department of Paediatric and Preventive Dentistry, King George's Medical University, Lucknow, Uttar Pradesh, India

[2]Department of Pedodontics, King George's Medical University, Lucknow, Uttar Pradesh, India

Corresponding Author: Rakesh K Chak, Department of Pedodontics, King George's Medical University, Lucknow, Uttar Pradesh, India, Phone: +91 7355039996, e-mail: anjali.gudiya010@gmail.com

How to cite this article: Yadav A, Chak RK, Khanna R. Comparative Evaluation of MTA, Biodentine and Calcium Phosphate Cement in Single Visit Apexification Procedure for Nonvital Immature Permanent Teeth: A Randomized Controlled Trial. Int J Clin Pediatr Dent 2020;13(S-1): S1–S13.

Source of support: Nil

Conflict of interest: None

Calcium hydroxide, however, has also been associated with several drawbacks like multi-visit technique, failure to control the reinfection, and a cervical fracture.[12,13] These disadvantages led to the introduction of "one visit apexification procedures", where a biocompatible material is nonsurgically condensed into the open apex area of the root end.[14]

The search for superior alternatives has led to the introduction of mineral trioxide aggregate (MTA) as a very promising material for apexification in a single visit. Mineral trioxide aggregate has a very good sealing ability and promotes periradicular tissue regeneration.[15] A significant drawback of MTA is the long setting time (approximately 2 hours and 45 minutes) with difficult handling.[16]

The single visit apexification technique or the apical barrier technique has therefore witnessed the introduction of other newer materials. Biodentin is one such alternative. It is a calcium silicate-based cement exhibiting physical and chemical properties similar to various Portland cement derivatives.[17] It is a bioactive dentin substitute used for the repair of root perforation, root-end filling material, and apexification. It has a shorter setting time as compared to MTA which makes it more user-friendly.[18,19]

Another new material, calcium phosphate cement (CPC) cement has received a lot of attention in recent years due to its similarity to bones and teeth with respect to its chemical composition. Calcium phosphate cement has demonstrated osteoconductivity and also resorption and replacement similar to bone.[20] Therefore, there is some level of evidence for all these materials used for the single visit apexification technique. However, there is a lack of evidence in the form of randomized control trials that compare these materials. Hence, the present study was planned to compare, two newer materials (biodentine and CPC) as alternatives to MTA in single visit apexification technique for nonvital young permanent teeth in children and adolescents.

Materials and Methods

The study was conducted as a double-blinded randomized, controlled clinical trial after approval of the Institutional Ethical Committee of King George's Medical University, Lucknow, Uttar Pradesh, India, the approval letter (Ref. no. 81st ECM II B-Thesis/P24). Patients within the age group of 6–15 years having nonvital immature permanent teeth indicated for endodontic therapy, secondary to caries or trauma, were screened for inclusion. Inclusion of the patients in the study was performed through a thorough screening-taking history and examination (clinical and radiographical). Patients in the age group of 6–15 irrespective of gender and socioeconomic status of the patients presenting with nonvital immature permanent teeth as a consequence of trauma or dental caries were included. Other inclusion criteria considered were nonvital permanent teeth with radiographic evidence of immature root end development, clinically restorable teeth. Exclude from immature nonvital permanent teeth presenting with signs/symptoms of internal/external resorption, moderate to severe mobility, periodontal bone loss, lack of restorability. Immature nonvital permanent teeth with associated developmental abnormalities. Patients with a history of systemically debilitating diseases like uncontrolled diabetes, immunosuppression, severe asthma, etc. Patients with systemic conditions, syndromes, congenital malformation, blood dyscrasias or known allergy to any of the dental materials to be used were excluded. Screened teeth with root fractures, unrestorable remaining crown structure, and were not included in the present study. The patients/parents of all screened and selected patients were informed about the treatment procedure and written consent was obtained.

The enrollment of the study involved an assessment of 70 young permanent teeth for eligibility according to the inclusion criteria. Out of 70 teeth, 10 teeth were excluded (7 teeth, finally did not meet the inclusion criteria and 3 patients/parents refused to participate). Sixty teeth with open apex were finally selected that fulfilled the inclusion criteria.

The finally selected teeth were randomly divided into three groups depending on the type of different material used in the single visit apexification procedure. Each group consisted of 20 selected teeth.

Group I—MTA (control group).
Group II—Biodentine (experimental group).
Group III—CPC (experimental group).

Selected were randomized in the group by using envelop draw method. After obtaining informed written and verbal consent from the guardians, the patients enrolled for the present study were randomly allotted to one of the three groups by the envelope draw method. A total of 60 envelopes were used, divided into three groups of 20 envelopes each for group I, group II, and group III, respectively. The patients were instructed to pick up any envelope randomly. The envelopes contained information in the form of coded alphabets, regarding the type of material chosen for apexification procedure.

All the selected permanent teeth, after thorough clinical and radiographical examinations, were subjected to electric and thermal pulp vitality tests. The presence of pain, swelling, sinus, and mobility was recorded before the commencement of treatment.

Clinical Procedure (Common to All Groups)

All the selected patients were subjected to local anesthesia sensitivity tests followed by administration of local anesthesia. The selected tooth was isolated with a rubber dam. All carious enamel and dentin were removed and coronal access was gained using a sterile no. 330 high-speed bur with water spray to expose the pulp chamber and gain unobstructed straight-line access to the apical region of the tooth. The root canal was gently cleaned with hand files and pulp tissue was extirpated. The root canal was irrigated with 0.5% sodium hypochlorite followed by irrigation with 0.9% normal saline. It was then dried with sterile paper points. Working length was measured with the conventional intraoral periapical radiographic method using paralleling technique. Calcium hydroxide powder mixed with distilled water to a creamy consistency was placed in the root canal using a lentulospiral, as an intracanal medicament. The access cavity was sealed with a temporary restoration. The patient was recalled after 7–14 days for subsequent appointments. If the tooth was symptomatic, intracanal medicament was replaced, the canal was sealed temporarily, and the patient was instructed to report after 7–14 days for a subsequent appointment. If the patient remains asymptomatic after 7–14 days of the first visit or after the second visit of medicament change, the next visit consisted of plug formation. In each group, the intracanal medicament was removed by hand instrumentation, and the canal was irrigated with 0.9% normal saline. The root canal was dried using sterile paper points.

Mineral Trioxide Aggregate Plug Formation (Group I)

Handling of MTA was performed according to the manufacturers' instructions. A metal spatula was used for mixing one sachet of

MTA with one drop of distilled water on a sterile glass slab. After 30 seconds of mixing, the mixture was homogeneous with a consistency similar to wet sand. The mix was carried and condensed using a finger plugger, lightly with a moistened sterile cotton pellet to ensure a thickness of 3–4 mm in the apical end of the root canal. All recommendations of the manufacturer were followed. After the MTA was condensed, excess MTA on the canal walls was gently wiped with moist cotton. Another moist cotton pellet was placed over it and the canal was sealed with a temporary restoration (Cavit, 3M ESPE, Seefeld, Germany). Placement of MTA at the apex was confirmed radiographically.

The patient was advised to avoid food and drinks for 1 hour to ensure the setting of temporary restoration. The patient was recalled after 24 hours.

Biodentine Plug (Group II)

Mixing of biodentine was done according to the manufacturers' instructions. Biodentine capsule was taken and gently tapped on the hard surface to loosen the powder. Then, the capsule was opened and placed on the white capsule holder. After that, single-dose container of liquid was detached and gently tapped. The container cap was twisted to open. Five drops of liquid from a single-dose dispenser were poured into capsule. The capsule was closed and placed on the mixing device. Mixing was done for 30 seconds. Biodentine mixture was prepared. The mix was carried and condensed in the apical end of the root canal, using a finger plugger, lightly to ensure a thickness of 3–4 mm. After biodentine was condensed, excess biodentine on the canal walls was gently wiped with moist cotton and the canal was sealed with a temporary restoration (Cavit, 3M ESPE, Seefeld, Germany). The placement of biodentine at the apex was confirmed radiographically.

The patient was advised to avoid food and drinks for one hour to ensure the setting of temporary restoration. The patient was recalled after 24 hours.

Calcium Phosphate Cement Plug (Group III)

Calcium phosphate cement has two components—calcium phosphate powder and setting liquid. These two parts were mixed and putty-like consistency was obtained. After mixing it was usable for 3–5 minutes. The mix was carried and condensed using a finger plugger and condensed lightly to ensure a thickness of 3–4 mm. After CPC was condensed, excess CPC on the canal walls was gently wiped with moist cotton and the canal was sealed with a temporary restoration (Cavit, 3M ESPE, Seefeld, Germany). The placement of CPC was confirmed radiographically.

The patient was advised to avoid food and drinks for 1 hour to ensure the setting of temporary restoration. The patient was recalled after 24 hours.

Obturation

After apical plug formation, lateral condensation technique was used with zinc oxide eugenol sealer and tailor-made gutta-percha (Dentsply Maillefer, USA) for obturation of the root canal on the following visit. After cleaning and drying the access cavity, it was etched for 45 seconds, rinsed with distilled water for 20 seconds, air-dried, and restored with a composite restoration. An intraoral periapical radiograph was taken postoperatively using similar standardized conditions as preoperatively. Depending on the remaining coronal structure, the patient was recalled for composite restoration or post-core build-up followed by porcelain fused to metal crown or directly porcelain fused to metal crown restoration.

Primary Outcomes' Assessment

The patient was recalled at 1, 3, 6, 12, and 15 months postoperatively for clinical and radiographical evaluation. Observations were performed by two independent observers (faculty members of the Department of Paediatric and Preventive Dentistry, King George's Medical University). Clinical and radiographic criteria for assessing teeth were explained along with a calibration process on three initial cases to the two observers, blinded to the intervention groups.

Radiographic Assessment Criteria

Radiographic assessment was performed through digital radiographs taken immediately postoperatively and at 1, 3, 6, and 9 months of follow-up. The parameters observed were periapical radiolucency (PAR) area measurement, PDL widening, and extent of material at the apex.

Analysis of digital radiographic images was done using the Image J 1.46r software (Wayne Rasband, National Institute of Health, USA). The area of interest (periapical lesion) in the digital radiographs of both the test and control group was selected using the selection tools of the software and the cumulative histogram was observed. The changes in the mean grayscale values of the area selected were used to determine the healing of the lesion.

All the clinical and radiographical observations were carried out by two independent observers, blind to the intervention used. In case of disagreement in observations, the lesions were re-evaluated; a consensus was reached and accepted as the final measure. The data so obtained were subjected to statistical analysis (Tables 1 and 2).

Results

A total of 60 patients in the age group of 6–15 years, fulfilling all the inclusion and exclusion criteria were enrolled for the study. Patients were randomly divided into three groups having 20 in each group.

Demographic Characteristics

The age of patients in group I, group II, and group III groups ranged from 6 to 15 years, respectively, with (mean ± SD) 9.95 ± 1.61, 9.90 ± 1.62, and 9.95 ± 1.70 years, respectively. Comparing the mean age of the three groups, the ANOVA test revealed similar age distribution among the groups ($p = 0.994$), i.e., they did not differ statistically.

Overall Clinical Score

The post-intervention (1, 3, 6, and 9 months) presence of clinical signs and symptoms (pain, tender on percussion, swelling, abscess

Table 1: Group-wise distribution of patients

Group I MTA	*Group II Biodentine*	*Group III calcium phosphate cement*
$n = 20$	$n = 20$	$n = 20$

Table 2: Demographic characteristics of participants in all three groups

Demographic characteristics	*Group I (n = 23) (%)*	*Group II (n = 23) (%)*	*Group III (n = 23) (%)*	*p value*
Age (in years)				
Mean ± SD	9.95 ± 1.61	9.90 ± 1.62	9.95 ± 1.70	0.994
(Range)	(6–15)	(6–15)	(6–15)	
Sex				
Male	12 (60.0)	11 (55.0)	13 (65.0)	0.812
Female	8 (40.0)	9 (45.0)	7 (35.0)	

Table 3: Overall clinical outcomes score over the final follow-up time periods of 9 months

	Baseline				*1 Month*				*3 Months*				*6 Months*				*9 Months*			
	No. (%)				*No. (%)*				*No. (%)*				*No. (%)*				*No. (%)*			
Parameter	*Group I (n = 20)*	*Group II (n = 20)*	*Group III (n = 20)*	*p value*	*Group I (n = 20)*	*Group II (n = 20)*	*Group III (n = 20)*	*p value*	*Group I (n = 20)*	*Group II (n = 20)*	*Group III (n = 20)*	*p value*	*Group I (n = 19)*	*Group II (n = 20)*	*Group III (n = 20)*	*p value*	*Group I (n = 17)*	*Group II (n = 19)*	*Group III (n = 18)*	*p value*
Pain	10 (50.0)	12 (60.0)	14 (70.0)	0.435	0 (0.0)	0 (0.0)	0 (0.0)	0.376	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA
Tenderness to percussion (TTP)	12 (60.0)	10 (50.0)	9 (45.0)	0.627	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	1 (5.0)	0.376	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA
Swelling	4 (20.0)	6 (30.0)	4 (20.0)	0.689	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA
Abseess/ fistulous tract	9 (45.0)	11 (55.0)	10 (50.0)	0.819	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	1 (5.0)	0.376	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA
Tooth mobility	5 (25.0)	5 (25.0)	4 (20.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	0 (0.0)	NA

formation, tooth mobility) of the three groups (group I, group II, and group III) are summarized in Table 3.

Evaluation of Clinical Out Comes over Different Follow-up Time Periods

Pain as Clinical Outcome

The clinical outcome of pain in the three groups over the follow-up periods are summarized in Table 4. The pain was present in 10, 12, and 14 cases of group I, II, and III, respectively, at baseline. After successive follow-up periods, the pain was not present in any case of group I, II, and III at 1, 3, 6, and 9 months.

Tender to Percussion (TTP) as Clinical Outcome

The clinical outcome of tender to percussion (TTP) in the three groups over the follow-up time periods are summarized in Table 5. Tender to percussion was present in 12, 10, and 9 cases of group I, II, and III, respectively, at baseline. After that TTP was present in one case of group III in the 3rd month. However, no significant difference was observed ($p = 0.362$) among the groups in the 3rd month. Tender to percussion was absent in all the groups at 1, 6, and 9 months.

Swelling as Clinical Outcome

The clinical sign of the presence of swelling in the three groups over the follow-up periods is summarized in Table 6. The swelling was present in 4, 6, and 4 cases of group I, II, and III, respectively, at baseline. After that, the swelling was absent in all the groups at 1, 3, 6, and 9 months.

ABSCESS (with or without Sinus Tract) as a Clinical Outcome

The clinical sign of abscess formation in the three groups over the follow-up time periods are summarized in Table 7. The swelling was present in 9, 11, and 10 cases of group I, II, and III, respectively, at baseline. After that, the abscess was present in one case of group III in the 3rd month. However, no significant difference was observed ($p = 0.362$) among the groups in the 3rd month. An abscess was absent in all the groups at 1, 6, and 9 months.

Tooth Mobility as a Clinical Outcome

The clinical sign of tooth mobility in the three groups over the follow-up periods are summarized in Table 8. The tooth mobility was present in 5, 5, and 4 cases of group I, II, and III, respectively, at baseline. After that, the tooth mobility was absent in all the groups at 1, 3, 6, and 9 months.

Overall Clinical Outcome

The clinical sign scores (0/1/2/3/4) of the three groups (group I, group II, and group III) are summarized in Table 9. Initially, at baseline, none of the subjects in group I, 2 (10%) in group II and 1 (5.0%) in group III had a clinical score of 0. Maximum cases had a clinical score of 2 (i.e., two clinical signs). No significant difference was observed in the clinical score of the three groups at baseline ($p = 0.460$).

At 1 month, all the subjects in group I, II, and III had a clinical score of 0 while at 3 months, 1 (5.0%) subject of group III had a clinical score of 2. However, no significant difference was observed in the clinical scores of the three groups at 3 months ($p = 0.362$).

At 6 and 9 months, all the subjects in group I, II, and III had clinical scores of 0 (Fig. 1).

Table 4: Comparison of pain as clinical outcome among the three groups over the follow-up time periods

Time period	*No. in groups I, II, and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	10 (50.0)	12 (60.0)	14 (70.0)	1.667	0.435
1 Month	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
3 Months	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
6 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

NA, not applicable

Table 5: Comparison of TTP as clinical outcome among the three groups over the follow-up time periods

Time period	*No. in groups I, II and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	12 (60.0)	10 (50.0)	9 (45.0)	0.934	0.627
1 Month	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
3 Months	20, 20, 20	0 (0.0)	0 (0.0)	1 (5.0)	2.034	0.362
6 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

NA, not applicable; TTP, tender to percussion

Table 6: Comparison of swelling as a clinical outcome among the three groups over the follow-up time periods

Time period	*No. in groups I, II, and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	4 (20.0)	6 (30.0)	4 (20.0)	0.745	0.689
1 Month	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
3 Months	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
6 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

NA, not applicable

Table 7: Comparison of abscess as a clinical outcome among the three groups over the follow-up time periods

Time period	*No. in groups I, II, and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	9 (45.0)	11 (55.0)	10 (50.0)	0.40	0.819
1 Month	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
3 Months	20, 20, 20	0 (0.0)	0 (0.0)	1 (5.0)	2.034	0.362
6 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

NA; not applicable

Table 8: Comparison of tooth mobility as a clinical outcome among the three groups over the follow-up time periods

Time period	*No. in groups I, II, and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	5 (25.0)	5 (25.0)	4 (20.0)	0.186	0.911
1 Month	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
3 Months	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
6 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

NA, not applicable

Table 9: Overall clinical score change among the three groups overall follow-up time periods

		Group I		Group II		Group III			
Overall clinical score		*No.*	*(%)*	*No.*	*(%)*	*No.*	*(%)*	χ^2	*p value*
Baseline	0	0	0.0	2	10.0	1	5.0	7.74	0.46
	1	8	40.0	3	15.0	5	25.0		
	2	6	30.0	8	40.0	7	35.0		
	3	4	20.0	3	15.0	6	30.0		
	4	2	10.0	4	20.0	1	5.0		
1 Month	0	20	100.0	20	100.0	20	100.0	NA	NA
3 Months	0	20	100.0	20	100.0	19	95.0	2.03	0.362
	2	0	0.0	0	0.0	1	5.0		
6 Months	0	19	100.0	20	100.0	20	100.0	NA	NA
9 Months	0	17	100.0	19	100.0	18	100.0	NA	NA

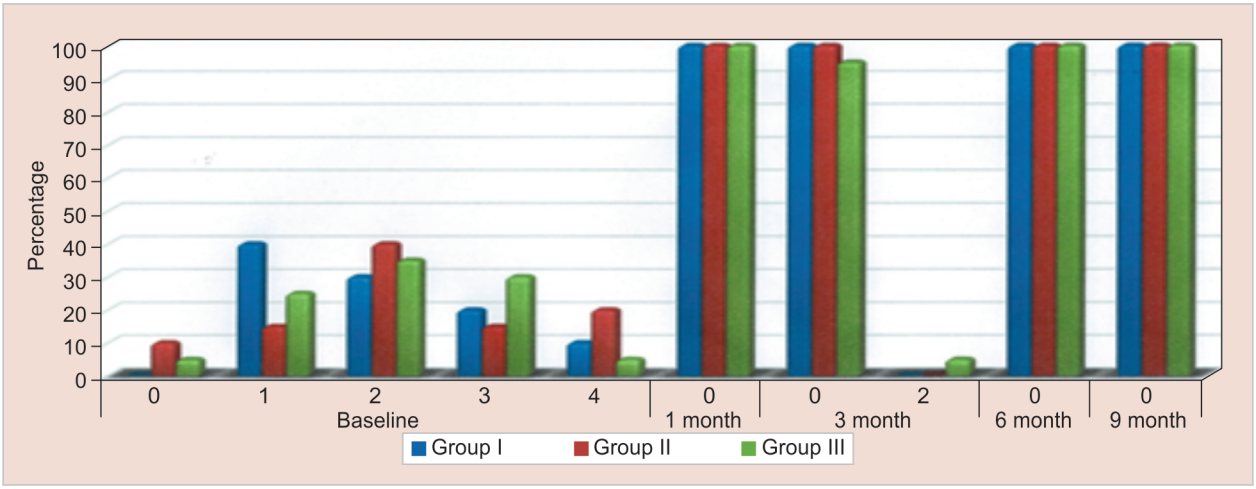


Fig. 1: Overall clinical outcomes changes among the three groups over all follow-up time periods

Table 10: Intragroup comparison of PAR mean from baseline to different follow-up time periods in group I

	Group I			
PAR mean	*Mean diff. from Pre Op.*	*SD*	*t value*	*p value*
Baseline	–	–	–	–
1 Month	6.0	18.2	−1.02	0.322
3 Months	7.8	21.1	−1.11	0.283
6 Months	17.2	21.3	−2.92	0.009
9 Months	26.3	21.0	−5.35	<0.001

Table 11: Intragroup comparison of PAR mean baseline to different follow-up time periods in group II

	Group II			
PAR mean	*Mean diff. from Pre Op.*	*SD*	*t value*	*p value*
Baseline	–	–	–	–
1 Month	12.8	31.0	−3.32	0.004
3 Months	24.0	23.1	−3.71	0.001
6 Months	24.9	24.8	−3.33	0.004
9 Months	31.4	25.3	−3.92	0.001

Evaluation of Radiographic Outcomes over Different Follow-up Time Periods

PAR as Radiographic Outcome

The intragroup comparison of PAR mean values (Table 10) from baseline to various follow-ups in group I revealed that significant differences were found at 6 months and 9 months when compared with baseline ($p < 0.05$).

The intragroup comparison of PAR mean values (Table 11) from baseline to various follow-ups in group II revealed that significant differences were found at all the follow-ups when compared with baseline ($p < 0.05$).

The intragroup comparison of PAR mean values (Table 12) from baseline to various follow-ups in group III revealed that significant differences were found at all the follow-ups except 1 month when compared with baseline ($p < 0.05$).

The intergroup comparison of PAR mean values (Table 13) revealed that at baseline and 1 month, no significant difference was observed in PAR (mean) values among the groups, while significant differences were observed at 3 months ($p = 0.009$) with minimum PAR for group I (mean 115.0 ± 22.9) and maximum for group III (mean 134.3 ± 22.4).

Again at 6 months, significant differences were observed ($p = 0.011$) with minimum PAR for group I (mean 124.0 ± 23.3) and maximum for group III (mean 146.0 ± 28.2).

At 9 months, highly significant differences were observed ($p < 0.001$) with minimum PAR for group I (mean 133.5 ± 22.6) and maximum for group III (mean 165.8 ± 17.6) (Fig. 2).

Periodontal Ligament Widening (PDL Widening) as Radiographic Outcome

The radiographic sign of periodontal ligament widening in the three groups over the period is summarized in Table 14. At baseline, sign of periodontal ligament widening was seen in 17 (85%) cases in each group, which was reduced after 3 months and then was seen in 10 (50%) cases of each group. After 6 months and onward, no sign of periodontal ligament widening was seen in any case. No significant difference was observed among the group in proportion of periodontal ligament widening at any follow-up time.

Extent of Material at Apex as Radiographic Outcome

The radiographic sign of the extent of material at the apex in the three groups are summarized in Table 15. The extent of grade 0 was seen in 14 (70.0%) cases in each group, extent of grade I was seen in 4 (20.0%) cases, and extent of grade II was seen in 2 (10.0%) cases in each group (Figs 3 to 5).

Discussion

Conventionally $Ca(OH)_2$ was used in apexification procedures after root canals disinfection. It was associated with reported predictable apexification procedure outcomes but needed multiple visits for the medicament to be efficacious, resulting in delayed endodontic treatment. Other limitations of $Ca(OH)_2$ apexification include increased risk of tooth fracture as prolong usage of this alkaline material desiccates the tooth and also renders the organic portion brittle. These disadvantages of the multi-visit $Ca(OH)_2$ apexification led to the development of a new procedure termed as "one visit apexification".[21]

One-visit apexification is defined as a "nonsurgical condensation of a biocompatible material into the apical end of the root canal". The concept of one visit apexification is about creating an apical barrier that would facilitate the canals to be obturated instantly and no effort to induce apexogenesis is required.[22]

The treatment of young permanent teeth with open apex invites a multitude of techniques and materials. Much work has been undertaken by researchers in this field and we aimed to add to the existing literature by comparing MTA, biodentine, and CPC in a single visit apexification procedure for nonvital immature permanent teeth. The study was designed as a randomized, double-blind, single-center, interventional, comparative, prospective study.

Recruitment for the study included a screening of child patients from 6 to 15 years of age which were indicated for endodontic treatment in young permanent teeth. The selected age group corresponds to the open apex stage of root development as described by Cvek.[23] Walton and Torabinejad et al.[24] have described apexification criteria to be: immature teeth with pulp necrosis, teeth must be ultimately restorable, root length must be approximately half or more established, no vertical or horizontal root fractures, no radiographic evidence of replacement resorption. All these criteria were strictly adhered to during enrolling teeth in this study. Only subjects free from any systemic diseases were inducted into the trial. A comprehensive medical history, including symptoms, thorough clinical and radiographic assessment, and pulp tests required for clinical assessment of pulpal necrosis was done on each enrolled subject. If the nature of pain was throbbing and the tooth tender on percussion, pulpal necrosis with apical periodontitis or acute abscess was expected, if the pain was spontaneous, severe, and long-lasting, this diagnosis was almost a certainty.[25] Rubber dam for isolation was first proposed by Sanford Christie Barnum in 1864 and the introduction of clamps specific for each tooth was done by Dr Delous Palmer in 1882.[26] There are many advantages of rubber dam such as protection of patient against aspiration of an instrument, prevention of laceration of soft tissue from rotary or hand instrument, improved accessibility, and visibility, retraction of soft tissue to some extent, and also to prevent cross-infection.[27] Rubber dam isolation was hence, used in the present study for each tooth. Most of the bacteria are instantly killed when they come in direct contact with sodium hypochlorite

Table 12: Intragroup comparison of PAR mean baseline to different follow-up time periods in group III

	Group III			
PAR mean	*Mean diff from Pre Op.*	*SD*	*t value*	*p value*
Baseline	–	–	–	–
1 Month	3.6	26.3	−0.45	0.659
3 Months	13.2	21.4	−3.34	0.003
6 Months	24.9	24.6	−3.54	0.002
9 Months	44.7	19.1	−5.55	<0.001

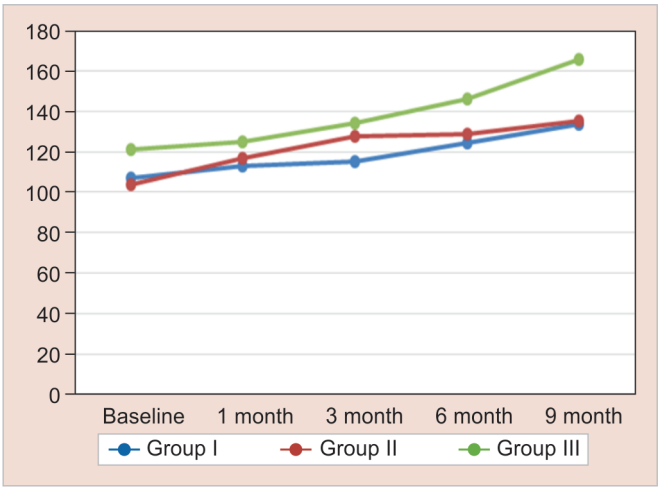


Fig. 2: Intergroup comparison of PAR mean among the groups

Table 13: Intergroup comparison of PAR mean among the groups over the follow-up time periods

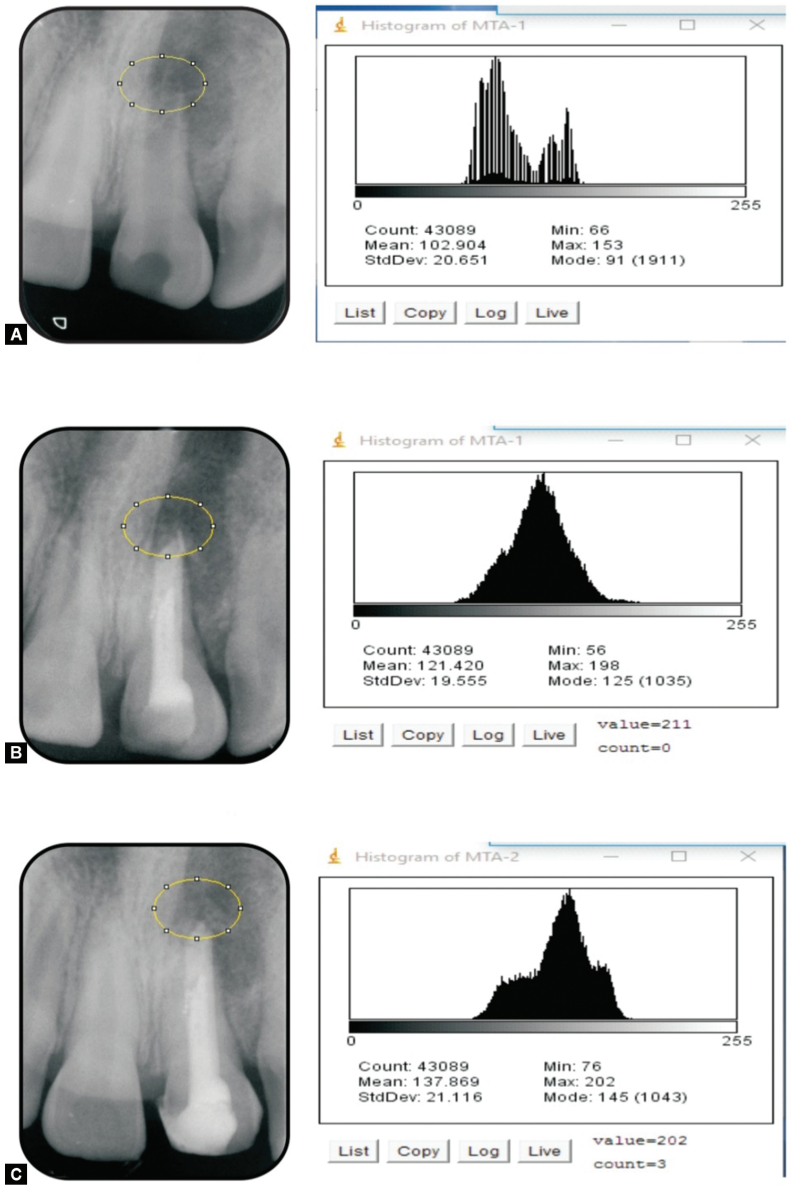
	Group I		*Group II*		*Group III*			
PAR mean	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*F value*	*p value*
Baseline	107.2	19.2	103.8	31.1	121.1	20.4	2.851	0.066
1 Month	113.2	17.2	116.6	30.9	124.7	31.1	0.944	0.395
3 Months	115.0	22.9	127.8	10.1	134.3	22.4	5.128	0.009
6 Months	124.4	23.3	128.7	16.1	146.0	28.2	4.910	0.011
9 Months	133.5	22.6	135.2	17.8	165.8	17.6	17.431	<0.001

Table 14: Comparison of periodontal ligament widening as a radiographic outcome among the three groups over the follow-up time periods

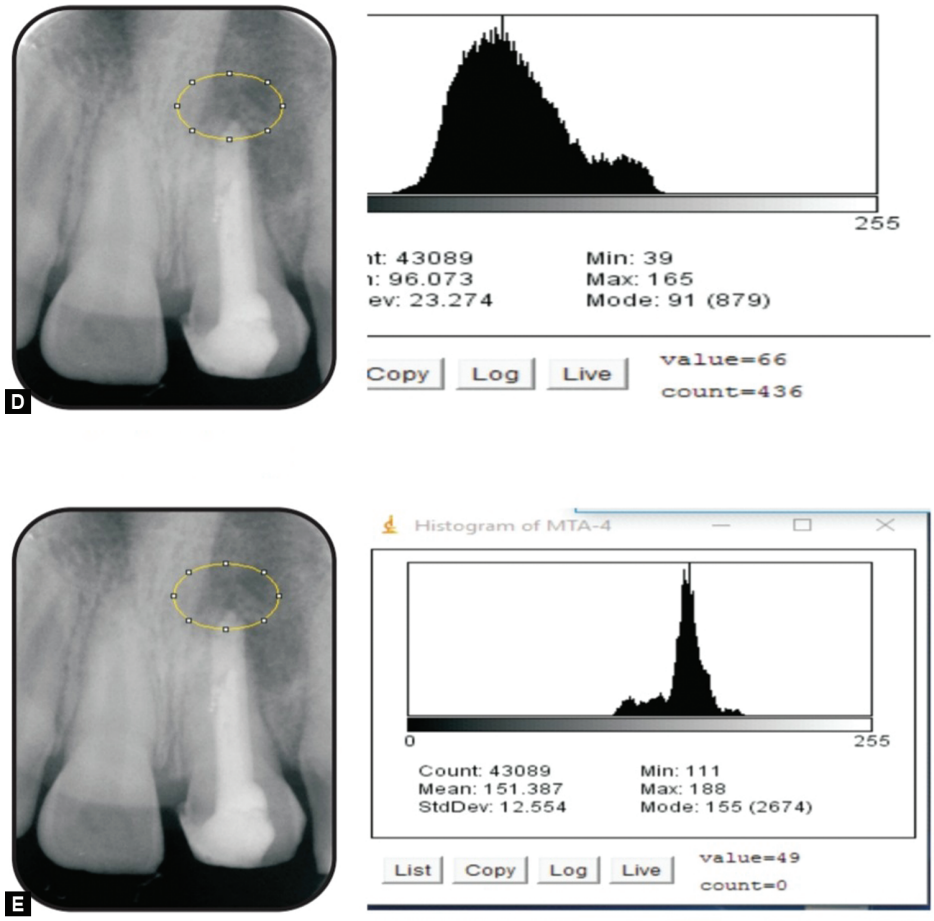
Time period	*No. in groups I, II, and III*	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
Baseline	20, 20, 20	17 (85.0)	17 (85.0)	17 (85.0)	0.0	1.000
3 Months	20, 20, 20	10 (50.0)	10 (50.0)	10 (50.0)	0.0	1.000
6 Months	20, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
9 Months	19, 20, 20	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
12 Months	17, 19, 18	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA

Table 15: Comparison of extent of material at apex among the three groups

Extent of material at apex	*Group I, N (%)*	*Group II, N (%)*	*Group III, N (%)*	χ^2	*p value*
0	14 (70.0)	14 (70.0)	14 (70.0)	0.000	1.000
1	4 (20.0)	4 (20.0)	4 (20.0)		
2	2 (10.0)	2 (10.0)	2 (10.0)		



Figs 3A to C: Radiographic evaluation in group-I (MTA). (A) Preoperative radiograph; (B) 1 month follow-up; (C) 3 months follow-up

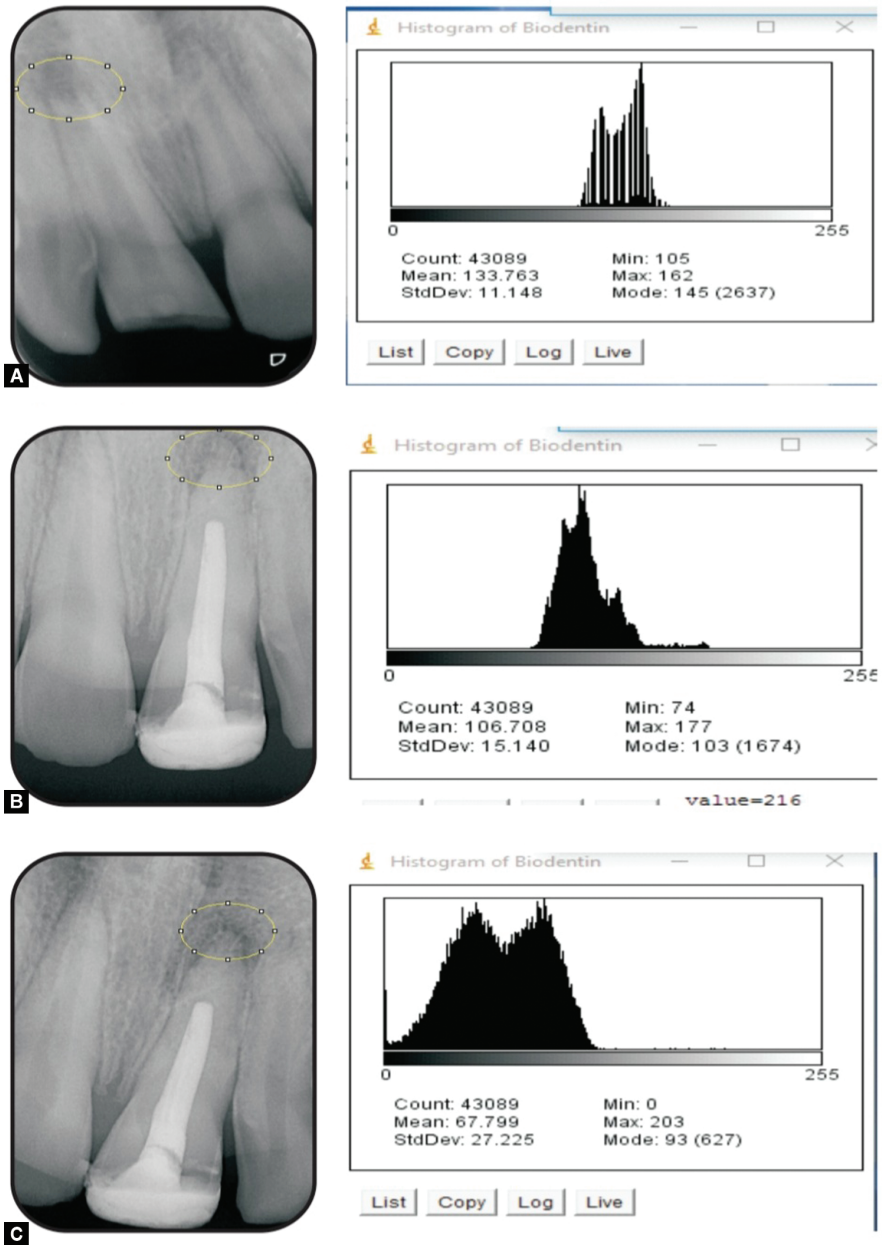


Figs 3D and E: Radiographic evaluation in group-I (MTA): (D) 6 months follow-up; (E) 9 months follow-up

solution. Additionally, it also dissolves pulpal remnants, collagen, and most organic component of dentine. NaOCl is so prevalent as an endodontic irrigant to dissolve vital organic tissue and nonvital tissue or debris of the root canal that it is difficult to imagine a successful irrigation sequence without it.[28] In the present study, irrigation was done with a 0.5% conc. of sodium hypochlorite. The most commonly used obturation technique throughout the world by dental practitioners is the cold lateral condensation technique. Advantages of this technique are the controlled gutta-percha positioning inside the canal and its relatively cheaper cost.[29,30] This technique results in gutta-percha cones oriented and aligned closely together with a cohesive sealer cementing them together.[31] Filled composite resin was used for restoration after obturation with a base layer of glass ionomer cement which acted as a barrier and prevented composite from coming in direct contact with the zinc-oxide eugenol that was used in cold lateral condensation. Single-visit apexification with MTA is a good option for the multi-visit procedure with $Ca(OH)_2$. The advantages of one visit apexification were cited as a reduction in the total therapy time, decreased fracture risk, and the early placement of an apical seal so that early coronal and intra-radicular restoration is made possible. Khalaf[32] compared MTA and biodentine in apexification and concluded that both MTA and biodentine can be employed in successful apexification procedures for immature nonvital permanent teeth. Another bioactive cement is CPC that sets as hydroxyapatite when moistened.[33] Brown and Chow[34] discovered CPC, used for root surface desensitization, furcation sealing, and apical sealing materials. It is superior to pure calcium hydroxide because of its self-setting ability, good compressive strength, and biocompatibility. Calcium phosphate cement is also being used as bone filler material. It is a bioactive agent due to its osteoconductive and osteotransductive properties.[35] In the present study, digital radiography was used to assess radiographic outcomes. Standard digital radiographs were taken at baseline, 1, 3, 6, and 9 months by paralleling technique at pre-set parameters. In the present study, it was observed that clinical outcomes of MTA, biodentine, and CPC in single visit apexification procedure were 100%.

The radiographic sign of periodontal ligament widening was found to be linked with external root resorption, and periapical bone loss on radiographs. In the present study, periodontal ligament widening, at baseline was seen in 17 (85%) cases in each group, which was reduced after 3 months and then was seen in 10 (50%) cases of each group. After 6 months and onward, no sign of periodontal ligament widening was seen in any case. No statistical difference was noticed among the groups in the proportion of periodontal ligament widening at any follow-up time.

In our study, a radiographic sign of the extent of material at an apex in the three groups was also assessed. Grade 0 was seen in 14 (70.0%) cases in each group, grade I was seen in 4 (20.0%) cases and grade II was seen in 2 (10.0%) cases in each group. No significant difference was observed in the extent of material (*p* value 1.000).

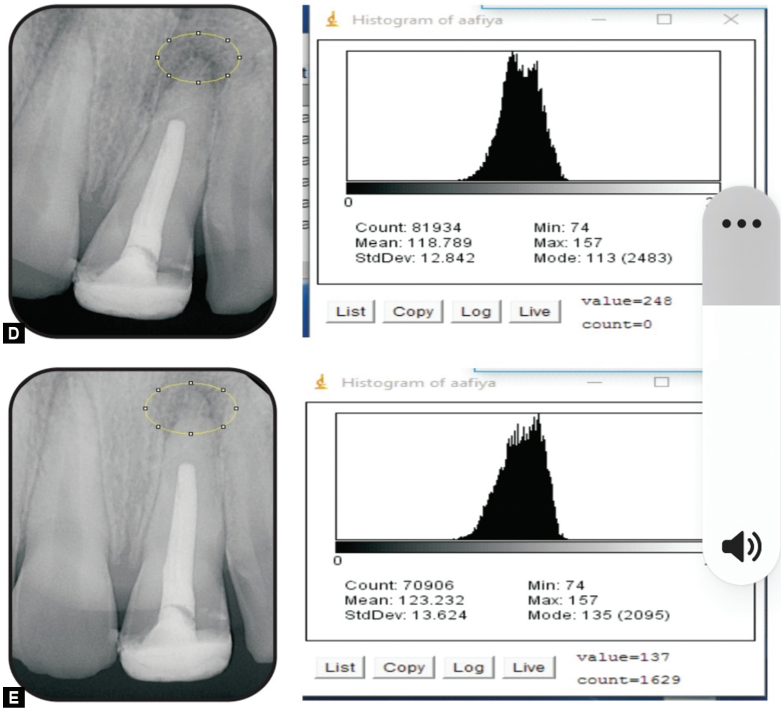


Figs 4A to C: Radiographic evaluation in group-II (biodentine): (A) Preoperative radiograph; (B) 1 month follow-up; (C) 3 months follow-up

In the present study, the difference in mean grayscale changes as observed on histogram analysis of digital radiographs of the three groups became apparent. The analysis of the periapical lesion region's radiographic density on the radiograph was measured via the histogram tool of Image J software, using a 256 gray tone scale, where "0" indicates the black color and "255" the white one. The radiographic image file was imported in Image J software (1.46 r), then the oval area for examination was marked through the selection tool. The marked area, height, and width were adjusted to similar settings (height-327, width-273, $X = 274$, $Y = 326$) for every radiographic examination to ensure standardization. The selected area from the radiograph was duplicated, brightness and contrast level were kept constant (minimum display value 52, maximum display value 204) for all the images and all radiographic image types, used in 32-bit. The selected area was then analyzed through the histogram tool. Gray tone differences were considered as a value of radiographic density.

These values can also be measured with the help of different software available such as Gimp 2.8.18 (GNU Image Manipulation Program) and Adobe Photoshop software (Adobe Systems).

Based on the results of PAR value (PAR) measured, it was found that at 1 month of the follow-up period, all three groups showed the same results. At 3 months, biodentine showed better results than MTA and CPC but at 9 months of the follow-up period, CPC showed greater periapical healing than MTA and biodentine. A similar comparison with CPC has not been reported in the literature. Mineral trioxide aggregate and biodentine have been, however, compared and the results of the present study are in concordance to them.



Figs 4D and E: Radiographic evaluation in group-II (biodentine): (D) 6 months follow-up; (E) 9 months follow-up

Based on the present study, it can hence, be inferred that clinical success for MTA, biodentine, and CPC in apexification was 100%. The radiographic outcomes of CPC showed better results as compared to MTA and biodentine at 9 months of follow-up periods.

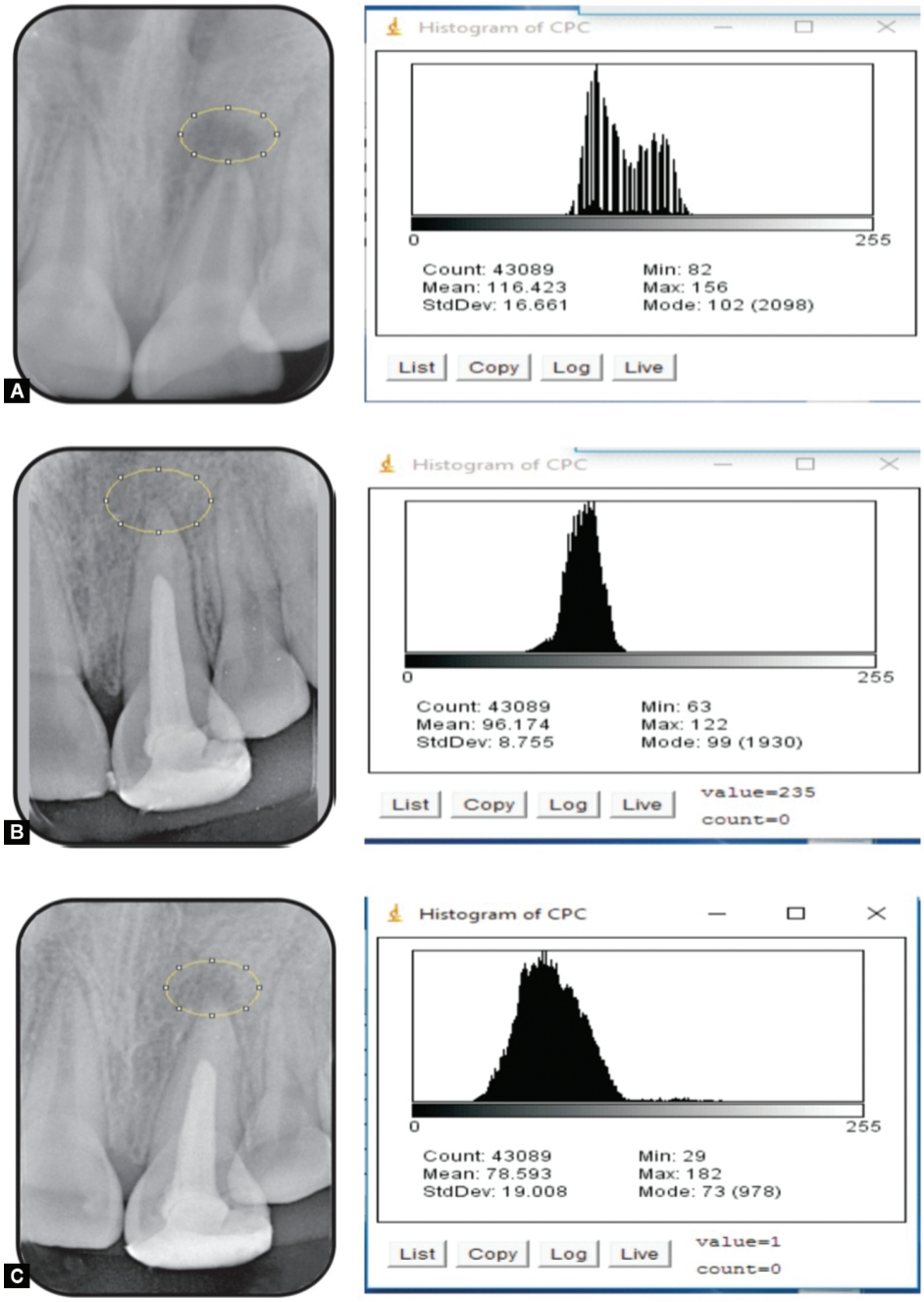
These findings suggest that CPC can be used as a substitute for MTA and biodentine because of its comparable clinical and moderately superior radiographic success. Further evidence may be generated in randomized controlled clinical trials with longer follow-up periods.

Conclusion

Conclusions are drawn from the comparative evaluation of different biocompatible materials—MTA, biodentine, and CPC in a single visit apexification procedure for young permanent teeth. Clinically, the success rate of MTA, biodentine, and CPC was 100% in 9 months of the follow-up period. Radiographically, the success rate of biodentine is better than MTA and CPC in 3–6 months of the follow-up period. Whereas, CPC performed superiorly than biodentine and MTA, in 9 months of the follow-up period.

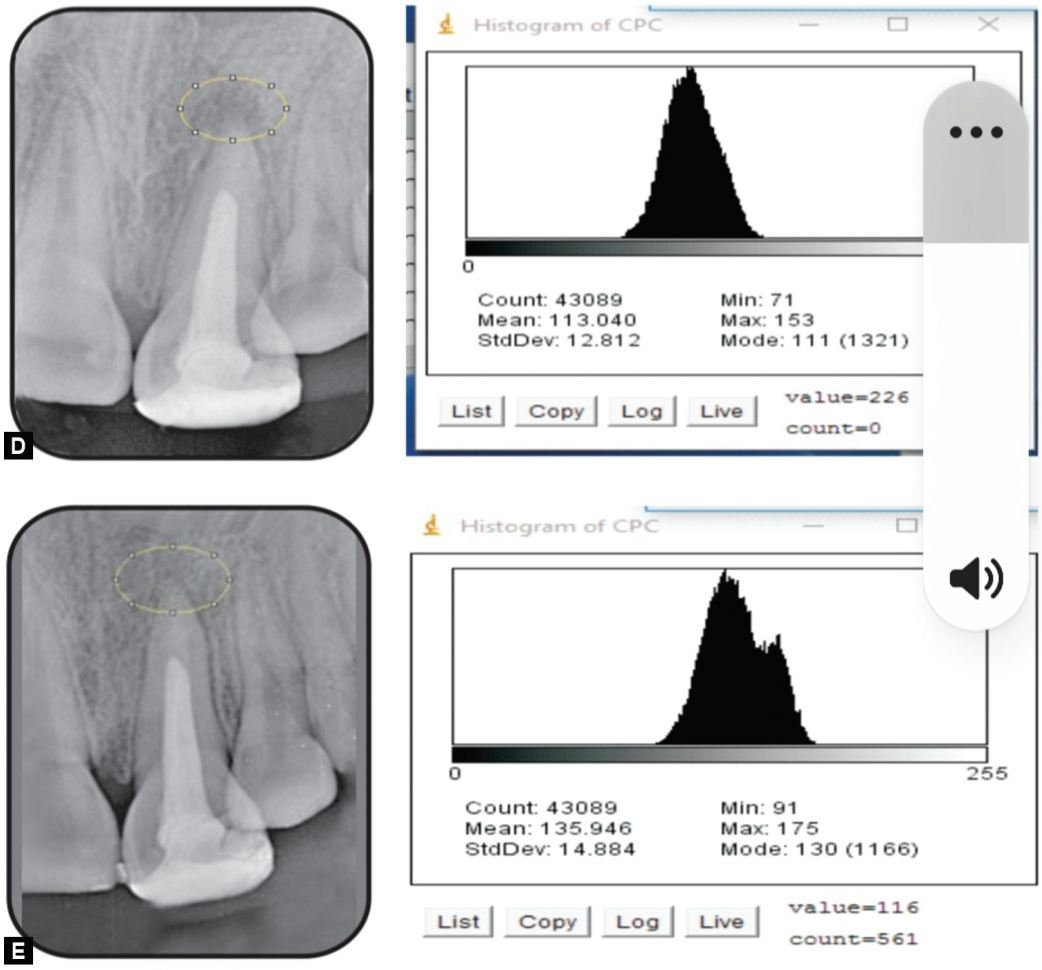
References

1. Weine FS. Textbook of endodontics. 6th ed., 2004.
2. Maroto M, Barbería E, Planells P, et al. Treatment of a non-vital immature incisor with mineral trioxide aggregate (MTA). Dent Traumatol 2003;19(3):165–169. DOI: 10.1034/j.1600-9657.2003.00106.x.
3. Cvek MA. Clinical report on partial pulpotomy and capping with calcium hydroxide in permanent incisors with complicated crown fracture. J Endod 1978;4(8):232–237. DOI: 10.1016/S0099-2399(78)80153-8.
4. Mente J, Hage N, Pfefferle T, et al. Mineral trioxide aggregate apical plugs in teeth with open apical foramina: a retrospective analysis of treatment outcome. J Endod 2009;35(10):1354–1358. DOI: 10.1016/j.joen.2009.05.025.
5. Hassel V, Natkin E. Induction of root end closure. ASDC J Dent Child 1970;37(1):57–59.
6. Sarris S, Tahmassebi JF, Duggal MS, et al. A clinical evaluation of mineral trioxide aggregate for root-end closure of non-vital immature permanent incisors in children—a pilot study. Dent Traumatol 2008;24(1):79–85. DOI: 10.1111/j.1600-9657.2006.00485.x.
7. El-Ayouti A, Dima E, Löst C. A tactile method for canal length determination in teeth with open apices. Int Endod J 2009;42(12):1090–1095. DOI: 10.1111/j.1365-2591.2009.01636.x.
8. Friend LA. Treatment of immature teeth and non-vital pulps. J Br Endod Soc 1967;1(2):28–33. DOI: 10.1111/j.1365-2591.1967.tb01202.x.
9. Moore A, Howley MF, O'Connell AC. Treatment of open apex teeth using two types of white mineral trioxide aggregate after initial dressing with calcium hydroxide in children. Dent Traumatol 2011;27(3):166–173. DOI: 10.1111/j.1600-9657.2011.00984.x.
10. Andreasen JO, Bakland LK, Matras RC, et al. Traumatic intrusion of permanent teeth. part. An epidemiological study of 216 intruded permanent teeth. Dent Traumatol 2006;22(2):83–89. DOI: 10.1111/j.1600-9657.2006.00421.x.
11. Pace R, Giuliani V, Pini Prato L, et al. Apical plug technique using mineral trioxide aggregate: results from a case series. Int Endod J 2007;40(6):478–484. DOI: 10.1111/j.1365-2591.2007.01240.x.
12. Bastone EB, Freer TJ, McNamara JR. Epidemiology of dental trauma: a review of the literature. Aust Dent J 2000;45(1):2–9. DOI: 10.1111/j.1834-7819.2000.tb00234.x.
13. Yassen GH, Chin J, Mohammedsharif AG, et al. The effect of frequency of calcium hydroxide dressing change and various pre- and inter operative factors on the endodontic treatment of traumatized immature permanent incisors. Dent Traumatol 2012;28(4):296–301. DOI: 10.1111/j.1600-9657.2011.01089.x.
14. Leonardo MR, Bezerra da Silva LA, Leonardo RT, et al. Histological evaluation of therapy using a calcium hydroxide dressing for teeth with incompletely formed apices and periapical lesions. J Endod 1993;19(7):348–352. DOI: 10.1016/S0099-2399(06)81361-0.
15. Torabinejad M, Chivian N. Clinical application of mineral trioxide aggregate. 1999;25(3):197-205. DOI:10.1016/S0099-2399(99)80142-3.



Figs 5A to C: Radiographic evaluation in group-III (CPC): (A) Preoperative radiograph; (B) 1 month follow-up; (C) 3 months follow-up

16. Felippe MCS, Felippe WT, Marques MM, et al. The effect of renewal of calcium hydroxide paste on the apexification and periapical healing of teeth with incomplete root formation. Int Endod J 2005;38(7):436–442. DOI: 10.1111/j.1365-2591.2005.00959.x.
17. Witherspoon DE, Ham K. One-visit apexification: technique for inducing root-end barrier formation in apical closures. Pract Proced Aesthet Dent 2001;13(6):455–460.
18. Islam I, Chng HK, Au. Y. Comparison of the physical and mechanical properties of MTA and Portland cement. J Endod 2006;32(3):193–197. DOI: 10.1016/j.joen.2005.10.043.
19. Saidon J, He J, Zhu Q, et al. Cell and tissue reactions to mineral trioxide aggregate and Portland cement. Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2003;95(4):483–489. DOI: 10.1067/moe.2003.20.
20. Wang X, Sun H, Chang J. Characterization of Ca_3SiO_5/$CaCL_2$ composite cement for dental application. Dent Mater 2008;24(1):74–82. DOI: 10.1016/j.dental.2007.02.006.
21. Huang GT. Apexification: the beginning of its end. Int Endod J 2009;42(10):855–866. DOI: 10.1111/j.1365-2591.2009.01577.x.
22. Morse DR, O'Larnic J, Yesilsoy C. Apexification: review of the literature. Quintessence Int 1990;21:589–598.
23. Cvek M, Nord CE, Hollender L. Antimicrobial effect of root canal debridement in teeth with immature root. A clinical and microbial study. Odontol Review 1976;27:1–10.
24. Walton RE, Torabinejad M. Management of incompletely formed roots. In: Principles and practice of endodontics. 3rd ed., Philadelphia, Pa: WB Saunders; 2002. pp. 388–404.



Figs 5D and E: Radiographic evaluation in group-III (CPC): (D) 6 months follow-up; (E) 9 months follow-up

25. Shikha D, Mukunda KS, Arun A, et al. Apexification: a review. J Dent Sci Res 2012;3:41–44.
26. Ahmad IA. Rubber dam usage for endodontic treatment: a review. Int Endod J 2009;42(11):963–972. DOI: 10.1111/j.1365-2591.2009.01623.x.
27. Iglesias AM, Urrutia C. Solution for the isolation of the working field in a difficult case of root canal therapy. J Endod 1995;21(7):394–395. DOI: 10.1016/S0099-2399(06)80978-7.
28. Heling I, Chandler NP. Antimicrobial effect of irrigant combinations within dentinal tubules. Int End J 1998;31(1):8–14. DOI: 10.1046/j.1365-2591.1998.t01-1-00124.x.
29. Kerkes K, Tronstad L. Long term results of endodontic treatment performed with a standardized technique. J Endod 1979;5(3):83–90. DOI: 10.1016/S0099-2399(79)80154-5.
30. Levitan ME, Himel VT, Luckey JB. The effect of insertion rates on fill length and adaptation of a thermoplasticized guttapercha technique. J Endod 2003;29(8):505–508. DOI: 10.1097/00004770-200308000-00004.
31. Leduc J, Fishelberg G. Endodontic obturation: a review. Gen Dent 2003;51:232–233.
32. Khalaf MS. Apexification of traumatically injured teeth: a comparison between biodentine and mineral trioxide aggregate. Int J Sci Res (IJSR) 2017;6(12):1181–1184. DOI: 10.21275/ART20178908.
33. Dos Santos LA, Carrodéguas RG, Rogero SO, et al. α-Tricalcium phosphate cement: "In vitro" cytotoxicity. Biomaterials 2002;23(9):2035–2042. DOI: 10.1016/S0142-9612(01)00333-7.
34. Brown WE, Chow LC. A new calcium phosphate setting cement. J Dent Res 1983;61:672–676.
35. Al-Sanabani JS, Madfa AA, Al-Sanabani FA. Application of calcium phosphate materials in dentistry. Int J Biomater 2013;2013:876132. DOI: 10.1155/2013/876132.