ORIGINAL RESEARCH

Clinical and Radiographic Evaluation of Various Herbal Products Used with Zinc Oxide as an Obturating Material in Primary Teeth: An *In Vivo* Study

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Abstract

Aim: To compare the clinical and radiographically mixture of zinc oxide with *Aloe vera*, *Curcumin* and neem as an obturating material for pulpectomy.

Materials and methods: The study comprised of age group 4–8 years children requiring endodontic treatment for at least a single primary molar tooth. Sixty primary molar teeth from 43 children were divided equally and randomly into four study groups. The materials used for obturation were zinc oxide powder (ZnO) and Eugenol (ZOE) (group I), ZnO and *Aloe vera* Gel (group II), ZnO and *Curcumin* Powder (group III), ZnO and neem extract (group IV). They were evaluated clinically and radiographically at immediate postoperative and then at 1-, 3-, 6-, and 9-month intervals.

Results: At the end of 9 months, the Chi-square test revealed 100% success rate for recovery of pain in group I and III, 66.66% in group II and 93.3% in group IV. The success rates for absence of abscess and for periradicular radiolucency in group I, III, and group IV were 100% and 66.6% for group II. The success rate for periapical radiolucency in group I and group III was 100%, in group II 66.6% and in group IV 93.35%. The success rate for all the groups shows 100% success in terms of pathological root resorption.

Conclusion: Zinc oxide eugenol has proven to be the best obturating material. ZnO with *Aloe vera* showed a success rate which is significantly lower than the other medicaments. ZnO with *Curcumin* and ZnO with neem had shown promising clinical and radiographical results.

Clinical significance: ZnO with *Curcumin* and ZnO with neem can be used as a root canal filling material in primary teeth with further follow-up studies.

Keywords: *Aloe vera*, *Azadirachta indica*, *Curcumin*, Pulpectomy, Zinc oxide eugenol.

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Introduction

As primary teeth are the best space maintainers, teeth with infected pulps should be retained until exfoliation whenever possible.[1,2] Among the many ways of reducing or eliminating bacteria are adequate root canal debridement, antimicrobial irrigants, and antibacterial filling materials.[2] The antimicrobial properties of these filling materials used in primary teeth contribute significantly to the clinical success of endodontic therapy by inhibiting residual bacteria not removed by mechanical debridement.[2,3] The most popular root canal filling material for primary teeth is zinc oxide–eugenol (ZOE).[2,4] However, it has certain disadvantages, such as slow resorption, irritation to the periapical tissues, necrosis of bone and cementum that may lead to anterior crossbite, palatal eruption, or ectopic eruption of succedaneous tooth.[5] The second most used root canal filling material is Metapex which is a silicone oil-based calcium hydroxide with 38% iodoform. However, Iodoform may provoke the periapical tissues, which may lead to cemental necrosis and sometimes hollow tube effect.[6]

Herbal products have been used since ancient times in medicine, involving both Eastern and Western medicinal traditions.[7] Historically, *Aloe vera* has been used for medicinal purposes in several cultures as it has got anti-inflammatory, antibacterial, antifungal, antiviral, moisturizing, wound healing and pain relief properties.[2,8] *Curcumin*/turmeric is the principle *Curcuminoid* of the popular Indian spice turmeric, which is a member of the ginger family *Zingiberaceae* and is extensively used as spices, food preservative, medicament, and coloring material.[3] *Curcumin* after continuous exploration reported to exhibit antibacterial, antiviral, antifungal, antimicrobial, anti-inflammatory, antioxidant, antiallergic, antidiabetic, anticancer, anticoagulant, hypotensive, hepatoprotective, antiulcer, and hypocholesterolemic effects.[9] *Curcumin* or *diferrolylmethane* ($C_{21}H_{20}O_6$) the main yellow bioactive component of turmeric has a wide spectrum of biological actions, and this provides a basis for

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exploring its endodontic applications.[10] In dentistry, *Curcumin* had been introduced in mouthwashes and intracanal medicaments.[11,12] *Azadirachta indica* is a commonly found medicinal tree in India and its adjoining countries. It has various medical uses, such as immunomodulatory, antifungal, antihyperglycemic, antiulcer, antimalarial, anti-inflammatory, antibacterial, antiviral, and antioxidant.[2] The barks as well as the twigs have been used in India since historical times for dental care as routine oral hygiene measure and for battling gingivitis and preventing cavities.

Due to disadvantages of ZOE and Metapex, they are not considered as ideal root canal filling material; hence, there is a need for continuous research for ideal obturation material. In recent years, phytodentistry is an emerging branch in dentistry. It generally implies the use of medicinal plants and their products for treating disease directly or indirectly. Previous in vitro studies have conducted ZOE, zinc oxide powder mixed with *Morinda citrifolia* extract, *Aloe vera* extract, and neem extract as a root canal filling material in primary teeth and concluded that they respectively showed varied antimicrobial activity against the microorganisms *S. aureus, P. aeruginosa*, and *C. albicans*.[13–15]

To improve the properties and success rate, ZOE has been tried with many compounds, but the addition of these compounds neither increased the success rate nor made the material more resorbable as compared to ZOE alone. Eugenol causes irritation in the periapical region, and it sets into hard mass when mixed ZnO powder. Whereas ZnO powder, if mixed with *Aloe vera* gel, has advantages such as it does not set, its ease of placement, and easily retrievable nature.[14] In the past, zinc oxide powder and *Curcumin* had proved to be excellent antimicrobial agents and anticancer agents, both on their own as well as in combination. Together, they have potential as alternatives/supplements to antibiotics and traditional anticancer drugs.[16] Zinc oxide powder and neem have been developed as a therapeutic agent with antioxidant, enzyme inhibition and strong antibacterial potential against antibiotic-resistant bacteria that can be safely administered.[17] So, in this study, we have chosen ZnO powder with *Aloe vera* gel, ZnO powder with *Curcumin* and distilled water; ZnO powder with neem extract to evaluate its efficacy as an obturating material.

To the best of our knowledge, there seems to be no study in the literature that has conducted *Aloe vera*, neem, and *Curcumin* with ZnO powder as an obturating material in a single study. Therefore, it seems necessary to conduct an in vivo study to compare the ZOE and different herbal products with antibacterial properties as obturating material in primary teeth.

Materials and Methods

This study was single-blinded randomized control trial as patients were blinded about the allocation procedure among the groups. Due to variation in the radiopaque nature of the different obturation materials, clinician was not blinded. Sample size was calculated using G power software with the help of mean and standard deviation obtained from the literature.[3] Prior to the beginning of the study, ethical clearance was obtained from the Ethical Committee with number IDST/IERBC/2015-18/13 and was conducted from July 2016 to July 2017 (13 months). The study comprised of children requiring endodontic treatment in at least a single primary molar tooth. Sixty primary molar teeth in 43 children were selected based on inclusion and exclusion criteria. The inclusion criteria were children with age group between 4 and 8 years, attending the outpatient Department of Pediatric and Preventive Dentistry with good general health, primary molars with the presence of deep carious lesions or teeth having carious exposure which are indicated for pulpectomy, teeth that were in a restorable condition, radiographic evidence of deep carious lesion or lesion with radiographic pulp exposure and at least 2/3rd of root length present and having adequate bony coverage, presence, or absence of intra-radicular or periradicular radiolucency not involving permanent tooth bud. Exclusion criteria were medically compromised children, history of hospitalization and any systemic medical condition requiring antibiotic intake during the study period, the presence of pathologic mobility or mobility due to physiologic exfoliation, non-restorable primary molars and radiographically obliteration of root canal, the presence of internal resorption or pathologic external resorption, perforated pulpal floor, root resorption of more than a one-third of its length.

Detailed treatment procedure and its outcome were explained to the patient and their parents/guardians, and a written informed consent was obtained from them prior to the participation in the study. The materials used in the study were zinc oxide powder (ZnO) and Eugenol (ZOE) as group I, ZnO and *Aloe vera* gel as group II, ZnO and *Curcumin* Powder as group III, ZnO and neem extract as group IV. Total sample sizes were 60 primary molars that were divided equally and randomly in the above four study groups with 15 cases in each group.

Method of Preparation of the Materials for Obturation

A. Preparation of Zinc Oxide and Eugenol Obturating Material

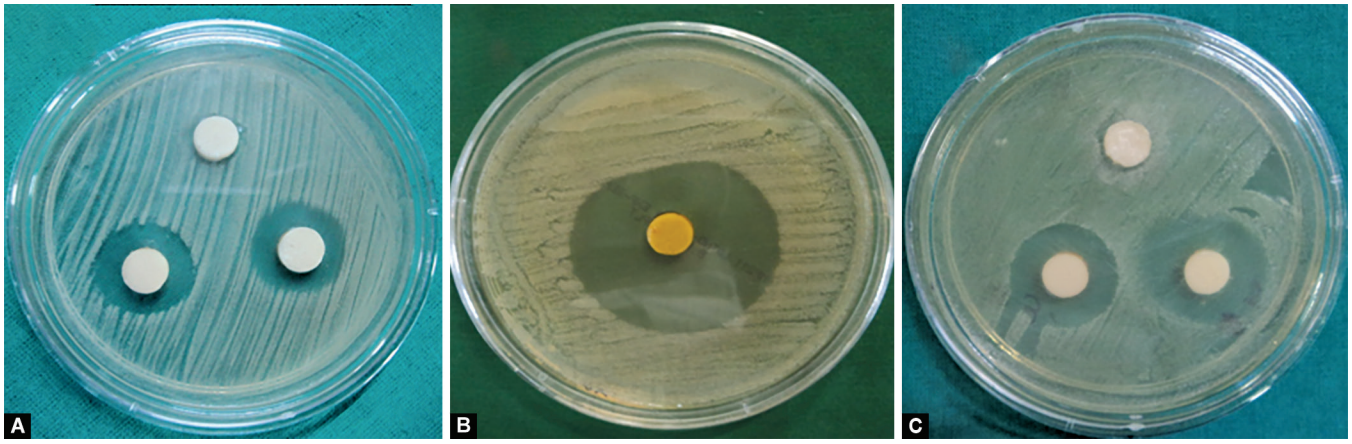
The commercially available zinc oxide powder and eugenol (Deepak Enterprise, Mulund, Mumbai, Maharashtra, India) were used for the obturation in group I. ZnO and eugenol were dispensed on a cool glass slab and mixed with a stainless steel spatula. The ratio of ZnO powder to eugenol were 0.4 gm/mL to form a paste-like consistency that could be inserted into the pulp canals with lentulo spiral (size 25, Dentsply, Maillefer, Switzerland) mounted in a slow speed contra-angle handpiece (1000 rpm).[18]

B. Preparation of Zinc Oxide and Aloe Vera Gel

Fresh leaves of *Aloe vera* were collected from the garden and authenticated in Department of Botany, Aligarh Muslim University, India. Then they were soaked in distilled water for 8 hours to extract aloine. The *Aloe vera* leaves were cut into pieces and were liquefied, sieved, filtered with negative pressure to obtain the gel. They were then sterilized by gamma ray and stored at 4°C in Eppendorf tubes.[13] Minimum bactericidal concentration (MBC) was calculated using agar diffusion method in the Department of Microbiology, IDST Dental College, Ghaziabad, India. MBC of *Aloe vera* was found to be 500 mg/mL (Fig. 1A). ZnO and *Aloe vera* gel were mixed on a glass slab using a stainless steel spatula. The mixing ratio of ZnO powder (1 gm) and *Aloe vera* was 1:2 to form a gel-like consistency suitable for obturation.[14]

C. Preparation of Zinc Oxide and Curcumin

Raw *Curcumin*/turmeric (Gmac Exim Private Limited, Bhavnagar, India), in pure form was procured from the local shop and authenticated in the Department of Botany, Aligarh Muslim University, India. Then they were ground into a powder in grinding machine and stored in an amber color airtight container. ZnO powder (1 gm) and *Curcumin* (1 gm) in 1:1 ratio with 0.8 mL of distilled water (same as ZOE mixture) were mixed on a glass slab with a stainless steel spatula to form a paste-like consistency that was kept in accordance with the MIC value of *Curcumin* against



Figs 1A to C: Zone of inhibition of: (A) Zinc oxide powder mixed with *Aloe vera* extract; (B) Zinc oxide powder mixed with *Curcumin*; (C) Zinc oxide powder mixed with neem extract against *E. faecalis* after 24 hours

E. faecalis, that is, 293 µg (Fig. 1B) in the Department of Microbiology, IDST Dental College, Ghaziabad, India.[19–21]

D. Preparation of Zinc Oxide and Neem

Mature, fresh *A. indica* (Neem) leaves were collected from the garden, washed in distilled water, and were authenticated in the Department of Botany, Aligarh Muslim University, India. The leaves were macerated in mortar with pestle for 1–2 minutes followed by 50 mL of absolute ethanol. The mixture was then filtered through a muslin cloth to separate the coarse residue. Filtration was done twice to obtain the desired extract. The alcoholic part was removed by water bath from the extract and stored in airtight amber colored container. Preparation of neem extract according to MIC value against *E. faecalis*, that is, 500 µg (Fig. 1C) was obtained in the Department of Microbiology, IDST Dental College, Ghaziabad, India.[22] ZnO powder (1 gm) with 0.4 mL of neem leaf extract (same as ZOE mixture) was used for mixing to form a paste-like consistency for obturation.[15]

Clinical Protocol

The standard protocol for pulpectomy was performed. Saline water and 2.5% sodium hypochlorite were used as irrigating solution during and after instrumentation. The canals were dried using sterile paper points and obturation was done with appropriate materials selected for all four groups, respectively using lentulo spirals (size 25, Dentsply, Maillefer, Switzerland) in a slow speed contra-angle handpiece (1000 rpm). The tooth was restored immediately using Glass Ionomer cement (3M Espe Ketac Molar) followed by stainless steel crowns (3M Espe SS crown). Post-obturation intra-oral periapical radiograph was obtained.

Criteria for Clinical Evaluation at 1, 3, 6, and 9 Months

The numerical value of score for absence of pain, abscess, and mobility was given as 0 whereas its presence was considered as 1.

Criteria for Radiographic Findings at 1, 3, 6, and 9 Months

The numerical value of score for the absence of periradicular and furcal radiolucency was given as 0. Its presence was considered as 1 whereas its presence but no change in size was considered as 1, decrease in size as 2 and increase in size was considered as 3. Absence of development of pathological radiolucency was scored as 0, its presence as 1 and increase in size as 2. The absence of root resorption was scored as 0 and its presence was scored as 1. The presence of any one or more of the above clinical and radiographic criteria was considered a failure.

Statistical Analysis

The data were analyzed with IBM SPSS statistics software 23.0 Version. To describe about the data, descriptive statistics for each parameter that includes numbers and percentage for discrete or categories data and for continuous data, are present in the form of Table. Chi-square test was used for the significance in categorical data and the probability value ≤0.05 was considered as significant.

Results

Table 1A depicts the assessment of pain at different time intervals in which preoperative pain was present in all groups and 100% recovery at immediate postoperative treatment. At the end of 1 month, 2 (13.3%), 4 (26.7%), 3 (20%), and 0 patients in the groups I, II, III, and IV, respectively. Overall, at the end of 1 month, 9 out of 60 patients had pain. At the end of 1 month, three patients had severe pain, along with abscess, mobility, and periapical radiolucency due to which they had to be extracted, so only 12 teeth were available for evaluation in group II. At 3 months of follow-up 2 (16.7%) out of 12 patients reported with pain in group II and pain was absent in all the remaining patients of group I, III, and IV. At the end of 6 months, there was no pain in all the groups. At the end of 9 months, 1 (6.7%) patient reported mild pain in group IV. At the end of 9 months, the overall success rate in group I and III was 100%, 66.66% in group II and 93.3% in group IV. The *p*-value was 0.206, 0.051, and 0.438 for 1, 3, and 9 months, respectively which were non-significant for the assessment of pain in all the four groups.

Table 1B showed assessment of abscess at different time intervals, in which abscess was present preoperatively in 4 (26.7%) patients in group I and IV and 3 (20%) patients in group II. At 1 month recall, abscess was present in 3 (20%) in group II. At 3 months, 2 (16.7%) patients out of 12 patients reported with abscess in group II. No group showed any presence of abscess after 6 months and 9 months. The overall failed cases were 5 out of the 60 teeth treated with pulpectomy. The overall success rate was 100% at the end of 9 months for all the groups. *p*-value was 0.188 and 0.051 for preoperative and 3 months, respectively which was non-significant for the assessment of abscess in all the four groups. *p*-value was *0.024 at 1 month follow-up which is significant for the assessment of abscess in all the four groups.

Table 1A: Assessment of pain among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	15/15 (100%)	0/15	0/15	15/15 (100%)	2/15 (13.3%)	13/15 (86.7%)	0/15	15 /15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	15/15 (100%)	0/15	0/15	15/15 (100%)	4 /15 (26.7%)	11/15 (73.3%)	2/12 (16.7%)	10/12 (83.3%)	0/12	12 /12 (100%)	0/12	12/12 (100%)
III	15/15 (100%)	0/15	0/15	15/15 (100%)	3/15 (20%)	12/15 (80%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0	15/15 (100%)
IV	15/15 (100%)	0/15	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	1/15 (6.7%)	14/ 15 (93.3%)
Chi-square	–		–		4.575		7.773		–		2.716	
p-value	–		–		0.206		0.051		–		0.438	

Table 1B: Assessment of abscess among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	4/15 (26.7%)	11/15 (73.3%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	3/15 (20%)	12/15 (80%)	0/15	15/15 (100%)	3/15 (20%)	12 /15 (80%)	2/12 (16.7%)	10/12 (83.3%)	0/12	12/12 (100%)	0/12	12/12 (100%)
III	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
IV	4/15 (26.7%)	11/15 (73.3%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
Chi-square	4.787		–		9.474		7.773		–		–	
p-value	0.188		–		*0.024		0.051		–		–	

Table 1C: Assessment of mobility among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	0/15	15/15 (100%)	0/15	15/15 (100%)	3 /15 (13.3%)	12/ 15 (86.7%)	2/12 (16.7%)	10/12 (83.3%)	0/12	12/12 (100%)	0/12	12/12 (100%)
III	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
IV	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	1/15 (6.7%)	14/15 (93.3%)
Chi-square	–		–		6.207		10.951		–		2.716	
p-value	–		–		0.102		*0.012		–		0.438	

Table 1C depicts the assessment of mobility at different time intervals, in which mobility was absent preoperative and postoperatively in all the groups. At the end of 1 month, mobility was absent in group I, III, and IV but it was present in 3 (20%) patients in group II. At 3 months, mobility was seen in 2 (23.1%) out of 12 patients in group II. At 6 months, no mobility was seen in any patient in any group. At the end of 9 months, 1 (6.7%) of the patients reported with the presence of mobility in group IV. The overall success rate for group I, group II, and group III at the end of 9 months was 100%, and 14 (93.7%) patients for group IV. *p*-value for the assessment of mobility were 0.102 and 0.438 for 1 and 9 months, respectively which were non-significant, and it was *0.012 for 3 months which is significant.

Table 2A presents the assessment of size of periradicular radiolucency at different time intervals, in which preoperative periradicular radiolucency was present in 5 (33.3%) patients in group I, 3 (20%) in group II, and 4 (26.7%) in group III and IV. At the interval of 1 month, radiographical examination showed periradicular radiolucency was unchanged for group I and II and decreased in size, that is, 3 (20%) patients in group III and 1 (6.7%) in group IV. At 3 months, periradicular radiolucency was reduced, that is, 4 (26.7%) patients in group I, 2 (15.4%) out of 12 patients in group II, 2 (13.3%) patients in group III and remained unchanged, that is, 1 (6.7%) patient in group IV. At 6 months, periradicular radiolucency was only present in 1 (9.1%) of patients in group II. The overall success at the end of 9 months for group I, group II,

Table 2A: Assessment of size of periradicular radiolucency among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	5/15 (33.3%)	10/15 (66.7%)	5/15 (33.3%)	10/15 (66.7%)	5/15 (33.3%)	10/15 (66.7%)	4/15 (26.7%)	11/15 (73.3%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	3/15 (20%)	12/15 (80%)	3/15 (20%)	12/15 (80%)	3/15 (20%)	12/15 (80%)	2/12 (16.7%)	10/12 (83.3%)	1/12 (9.1%)	11/12 (90.9%)	0/12	12/12 (100%)
III	4/15 (26.7%)	11/15 (73.3%)	4/15 (26.7%)	11/15 (73.3%)	3/15 (20%)	12/15 (80%)	2/15 (13.3%)	13/15 (86.7%)	0/15	15/15 (100%)	0/15	15/15 (100%)
IV	4/15 (26.7%)	11/15 (73.3%)	4/15 (26.7%)	11/15 (73.3%)	1/15 (6.7%)	14/15 (93.3%)	1/15 (6.7%)	14/15 (93.3%)	0/15	15/15 (100%)	0/15	15/15 (100%)
Chi-square	0.682		0.903		12.667		8.067		4.165		–	
p-value	0.877		0.825		0.178		0.527		0.244		–	

Table 2B: Assessment of development of postoperative pathological radiolucency among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	5/15 (33.3%)	10 /15 (66.7%)	5/15 (33.3%)	10/15 (66.7%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	3/15 (20%)	12/15 (80%)	3/15 (20%)	12/15 (80%)	3/15 (20%)	12/15 (80%)	2/12 (16.7%)	10/12 (83.3%)	0/12	12/12 (100%)	0/12	12/12 (100%)
III	4/15 (26.7%)	11/15 (73.3%)	4/15 (26.7%)	11/15 (73.3%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
IV	4/15 (26.7%)	11/15 (73.3%)	4/15 (28.6%)	11/15 (71.4%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	1/15 (6.7%)	14/15 (93.3%)
Chi-square	0.682		5.980		6.207		16.364		–		3.051	
p-value	0.877		0.113		0.400		*0.012		–		0.384	

Table 2C: Assessment of pathological root resorption among the four groups at different time intervals

	Pre-op		*Post-op*		*1 month*		*3 months*		*6 months*		*9 months*	
Groups	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
I	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
II	1/15 (6.7%)	14/15 (93.3%)	1/15 (6.7%)	14/15 (93.3%)	1/15 (6.7%)	14/15 (93.3%)	0/12	12/12 (100%)	0/12	12/12 (66.7%)	0/12	12/12 (100%)
III	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
IV	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)	0/15	15/15 (100%)
Chi-square	3.051		–		3.051		–		–		–	
p-value	0.384		–		0.384		–		–		–	

group III, and group IV were 100%. *p*-values for the assessment of periradicular radiolucency were 0.877, 0.825, 0.178, 0.527, and 0.244 for preoperative, post-operative 1 month, 3 months, and 6 months, respectively, which were non-significant for all the four groups.

Table 2B presents the assessment of development of postoperative pathological radiolucency at different time intervals, in which preoperatively and immediate postoperatively, pathological radiolucency was present in 5 (33.3%) patients in group I, 3 (20%) in group II, 4 (26.7%) in group III and group IV, respectively. Radiographically, periapical radiolucency was seen at the interval of 1 month in 3 (20%) patients in group II and at the interval of 3 months, it was reduced to 2 (16.6%) out of 12 patients in the same group. No development of any postoperative pathology was seen at the end of 6 months in any of the groups but at the end of 9 months, 1 (6.7%) patient showed radiolucency in group IV. The overall success rate was 100% for group I, group II and group III, and 14 (93.35%) in group IV. *p*-value for preoperative and postoperative pathological radiolucency, were 0.877, 0.113, 0.400, and 0.348 at 1 month, 3 months, and 9 months, respectively which were non-significant in the assessment of development of postoperative pathological radiolucency. *p*-value was *0.012 for 3 months which was significant for the assessment of development of postoperative pathological radiolucency.

Table 2C showed assessment of development of postoperative pathological root resorption at different time intervals, in which preoperative pathological root resorption were present in 1 (6.7%)

patient in group II that remained unchanged at the end of 1 month. The success rate at the end of 3 months, 6 months, and 9 months for all the groups showed 100% success in terms of pathological root resorption. The results were non-significant for the assessment of pathological root resorption among the four groups at different time intervals, that is, *p*-value was 0.384 at the end of 1 month.

Overall, ZOE has proven its ability as the best obturating material in primary teeth as there is a 100% clinical and radiographical success. Zinc oxide with *Aloe vera* showed only 66.7% success rate which is significantly lower than the other medicaments. Zinc oxide with *Curcumin* and neem had shown promising clinical and radiographical results and further studies are recommended to prove their long-term efficacy as obturating materials in primary teeth.

Discussion

Successful endodontic treatment involves not only thorough debridement of the root canal system but also perfect obturation by using a material which is biocompatible and has strong antibacterial properties. At present, there is no such ideal material to meet all the requirements.[2,23,24] Cox and Hembree stated in their study that zinc oxide alone has no inhibitory effect against microorganisms and that the antimicrobial activity of ZOE could be due to the free eugenol which is generally released from the set materials.[25] In contrast, Spencer found that zinc oxide when used exclusive of eugenol had an antimicrobial action.[26]

In the recent days, naturally available herbs were continuously explored and their usage in dentistry is emerging.[3] In this study, clinical and radiographic evaluation, and comparison of four different obturation materials ZOE, ZnO with *Aloe vera*, ZnO with *Curcumin*, and ZnO with neem were done. In the present study, group I (ZOE) showed no clinical and radiographical evidence of any recurrence of abscess or pathological mobility at 9 months and thus a 100% success rate was observed that were in accordance with Wasnik, whereas it was greater than Barr (82.3%), Gould (82.5%), Coll (86.1%).[2,27–29]

Herbal compounds have gained popularity in recent years due to their safety, efficacy, cultural acceptability, easy availability, increased shelf life, cost-effectiveness and lack of microbial resistance. Herbs have strong antimicrobial, anti-inflammatory, and antioxidant properties because they contain a variety of active phytochemicals, including flavonoids, terpenoids, lignans, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, curcumins, phthalides, and phytochemicals with biocompatible properties. This has led to a rise in the use of herbs in dentistry.[30]

ZnO mixed with *Aloe vera* gel has been used as a pulpectomy medicament and was found to be effective.[2] Due to its anti-inflammatory, antibacterial, antifungal, antiviral, moisturizing, and pain-relieving characteristics, *Aloe vera* gel has been utilized for numerous medicinal as well as preventive purposes. The antimicrobial effects of *Aloe vera* have been attributed to the plant's natural anthraquinones which imparts analgesic, antibacterial, antifungal, and antiviral benefits.[31,32] *Aloe vera* contains vast phytochemical classes, such as anthraquinones, chromones, anthrones, phenolic compounds, flavonoids, tannins, steroids, and alkaloids which contribute to their different pharmacological activities. In the present study, group II showed a clinical success rate of 67% whereas on radiographic examination, there was an increase in size of periradicular radiolucency and root resorption were seen in three teeth and were extracted to relieve the symptoms. Thus at 6 months, only twelve teeth were left for the evaluation. Radiographic examination revealed periapical radiolucency in one tooth which remained till the end of study; this variation may be because of the variable chemical composition of *Aloe vera* plant at different locations. Khairwa reported a clinical success rate of 93% and radiographical success of 73% of zinc oxide with *Aloe vera* as an obturating material, whereas in the present study, the success rate was found to be only 66.6% both clinically and radiographically.[14]

Curcumin has shown to kill several pathogenic gram-positive bacteria such as *Staphylococcus aureus, Staphylococcus epidermidis*, and *Enterococcus*.[3,33] Possession of useful properties, pharmacological safety, and negligible cost make *Curcumin* an attractive agent to explore it for its potential therapeutic applications in various endodontic procedures.[34] *Curcumin* [1,7-bis-(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-Dione] is a phytochemical obtained from the dried rhizomes of *Curcuma longa L* which contribute to their different pharmacological activities. Hence, in the present study, *Curcumin* was used as an adjuvant to zinc oxide powder for primary tooth obturation. Akram in his study stated that anti-inflammatory action of *Curcumin* is due to combination of three different properties, firstly, it lowers the production of inflammation inducing histamine, secondly, it increases and prolongs the action of the body's natural anti-inflammatory hormone cortisol and finally it flushes toxins present in the form of cellular wastes.[35] On clinical and radiographic evaluation, group III showed clinical success rate of 93% which was in accordance with the finding of Purohit and Hugar.[36,37] Zinc oxide with *Curcumin* was able to restore all the previously abscessed teeth back to health.

A. indica (neem) has antimicrobial properties due to the presence of alkaloids, glycosides, saponins, flavonoids, steroids, antiquinone, and tannic acid. Nimbidin and nimbolide in neem leaves have antibacterial and antifungal properties. Neem contains many chemically diverse and structurally complex phytochemicals, such as limonoids, flavonoids, phenols, catechins, gallic acid, polyphenols, and nimbins which contribute to their different pharmacological activities. Previous *in vitro* studies have shown antimicrobial activity of neem extract against *E. faecalis* and *S. mutans*.[2,38]

Hedge studied the antibacterial efficacy of 2% sodium hypochlorite, propolis, neem leaf extract and liquorice against *E. faecalis* and *C. albicans* and concluded that neem leaf extract showed the highest zone of inhibition for both organisms.[39] Group IV showed 93% success rate both clinically and radiographically. A possible reason for some failure seen in *Curcumin* and neem could be attributed to the limited formation of lateral and apical seal in the canals as these medicaments do not set into a hard mass like zinc oxide and eugenol.

Endodontic microflora comprises of a huge number of variable bacterial species, and in some cases, it might be difficult to find a single medicament that would inhibit all the species. As zinc oxide with *Aloe vera* stays in a gel-like form, therefore, some percolation of *Aloe vera* can be expected in periapical area. The failure of a greater number of cases in group II could be attributed to the consistency of the material. Turner suggested that the polysaccharides found in *Aloe vera* gel were not stable and can show disintegration during the extraction of the gel from the leaf, thus compromising its anti-inflammatory properties.[40] Radiographically, maximum reduction of periapical pathology was observed in group IV. In the present study, ZnO–Neem combination was accomplishing healing at a faster rate than other combinations.

Zinc oxide eugenol obturated teeth showed fast reversal of preoperative symptoms and good healing. Wasnik and Reddy concluded that the sealers with a ZOE combination show greater inhibitory effect against the microorganisms found in root canals.[2,41] Radiographically, slight reduction of periapical radiolucency was seen in all the groups, but it did not disappear completely, though clinically teeth appeared symptomless, the reason being that the changes in radiographs took time to appear in spite of complete and uneventful healing of bone and periodontium. Bommareddy concluded that healing pattern of periapical lesions was dependent on the initial size of the radiographic lesion.[3]

Curcumin (Group III) showed good clinical success as none of the teeth showed any abscess or mobility in this group. Bommareddy and Chamele concluded that there was 50% reduction in *E. faecalis* colony count, when turmeric extract was used as an intra-canal medicament in primary teeth.[3,33] In our study, statistically significant difference in the success rate of zinc oxide with *Aloe vera* was found when compared with the use of zinc oxide with eugenol, *Curcumin*, and neem. The difference in the outcome between zinc oxide and eugenol, *Curcumin* and neem were found to be statistically insignificant.

In the present study, ZOE has proven its efficacy to be used as the standard medicament for root canal obturations. Among *Aloe vera*, *Curcumin* and neem, *Aloe vera* showed the maximum number of failure cases, control of infection by *Aloe vera* was found to be inadequate in already existing abscesses. The amount of *Aloe vera* required to inhibit the growth of intracanal microbes might be insufficient in the present study. *Curcumin* and neem have shown promising results when used as root canal obturating material in the present study. Another possible reason for some failure seen in *Curcumin* and neem could be attributed to the limited formation of lateral and apical seal in the canals as these medicaments do not set into a hard mass like zinc oxide and eugenol do. Hence, ZnO with *Curcumin* and ZnO with neem can be considered as a root canal filling material in primary teeth.

The limitation of this study could be that the phytochemical composition of herbal plants may alter due to the natural environment and location, hence it could give different results. Additionally, in vivo studies are required to state the specific antimicrobial activity and the advantages and disadvantages of any of the test filling materials. Furthermore, clinical and histological studies with longer follow-up till the period of tooth exfoliation to ascertain the efficacy these treatment modalities are recommended.

Conclusion

Zinc oxide eugenol has proven its ability as the best obturating material in primary teeth. Zinc oxide with *Aloe vera* showed significantly lower success than the other two herbal medicaments. Zinc oxide with *Curcumin* and neem had shown promising clinical and radiographical results and could be considered as an alternative root canal filling material but further in vivo studies in a larger sample size are recommended to prove their long-term efficacy as obturating materials in primary teeth.

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