Journal of Medical and oral biosciences
ISSN (Online): 3007-9551
ISSN (Print): 3007-9543

JMOB
Open Access DOAJ

IRAQI Academic Scientific Journals

Type: Research article
Publish online: 30 / 05 / 2026

Evaluation of the Apical Microleakage using Zinc Oxide Eugenol via three Different Obturation Techniques (Reamer, Tuberculin syringe and Modified Disposable Syringe) in Primary Teeth An In Vitro Study

Dhuha Najm Abdulhussein [1*] ,

[1*] AL-Iraqia University, College of Dentistry, Department of Clinical Sciences, Iraq
E-mail: dhuha.n.abdulhussein@aliraqia.edu.iq
ORCID : https://orcid.org/0000-0002-5037-1075

OPEN ACCESS

ARTICLE INFO

Received: 12 / 03 /2026
Revised: 15 / 04/ 2026
Accepted: 30 / 04 / 2026
Publish online: 30 / 05 / 2026
Plagiarism percentages at publication: 13 %
AI percentages at publication: 7 %

Reviewers:
1. Prof Dr. Aseel Haidar Mohammad Jawad Al Haidar / College of Dentistry/ University of Baghdad
Email: dr.aseelhaider@codental.uobaghdad.edu.iq
2. Prof. Dr. Mohammed Nahidh
College of dentistry/ University of Baghdad
Email: m_nahidh79@codental.uobaghdad.edu.iq
.

* Corresponding Author: Dhuha Najm Abdulhussein
Email: dhuha.n.abdulhussein@aliraqia.edu.iq

CITATION

Dhuha Najm Abdulhussein. (2026). Evaluation of the Apical Microleakage using Zinc Oxide Eugenol via three Different Obturation Techniques (Reamer, Tuberculin syringe and Modified Disposable Syringe) in Primary Teeth An In Vitro Study. JMOB. 3 ;(2): 39-54.
https://doi.org/10.58564/jmob.156

Abstract

Maintenance of primary dentition is important for a preventing arch-length discrepancy. Therefore, successful root canal treatment is important for keeping such teeth until natural exfoliation occurs. This research was conducted to quantitatively assess the sealing ability and time taken for obturation with Zinc Oxide Eugenol via different three obturation methods. Thirty-six extracted anterior primary teeth samples were included in this study. Canals were prepared by K-files (15–45) and obturated by ZOE. The teeth were divided randomly into three experimental groups (n=12), randomly as follows: Group I (Modified Disposable Syringe), Group II (Reamer Technique) and Group III (Tuberculin Syringe). The dye extraction technique was utilized for microleakage evaluation, and obturation time was recorded for each sample. All results were statistical analyze, and $P < 0.05$ was considered to be significant. The mean microleakage of the modified disposable syringe group was lower than microleakage amounts in the tuberculin syringe and reamer groups with no statistical difference ($p > 0.05$). In terms of obturation duration, using the modified disposable syringe technique, the time was less than the tuberculin group with no statistical significance difference, and less compared to that of the reamer technique group with a statistical significance difference ($p < 0.05$). In conclusion, modified disposable syringe that used in this study was the most acceptable obturation method when ZOE was used to obturate the primary teeth. It has a better apical seal and saves up on chair time, which is of high importance in successful pediatric practice.

Keywords: Apical microleakage, Dye extraction, Obturation duration, Primary teeth, Pulpectomy, Zinc oxide eugenol.

Introduction

Oral health is a part of general systemic health and an essential determinant of quality of life (1). Deciduous dentition is very important for mastication, phonation, esthetics, and

psychology of children (2). In addition, they are natural space holders which provide a path of eruption for the permanent successors and maintain the integrity of dental arch (3, 4). Although they are essential, people still hold a mistaken belief that primary teeth need no professional care simply because they are temporary (5). This lack of attention of the primary teeth results in premature loss of these teeth, which is still a significant clinical problem in many areas. Thus, endodontic treatment of pulpally involved primary teeth is a preferred therapy in the dental practice for preventing arch space loss (6). Pulp therapy in primary dentition is classified as vital and non-vital treatment, both aimed at maintaining the teeth until their physiological exfoliation. The success of such treatments is predicated upon good diagnosis and careful case selection, as well as maintaining an effective coronal seal (7). In teeth with irreversible pulpitis, pulpal necrosis or dentoalveolar abscesses, non-vital pulp therapy, more specifically a complete pulpectomy is the treatment of choice (8). Aseptic instrumentation, and dense filling of the root canal space play an important role in the success of pulpectomy procedure of necrotic primary teeth. The technique is of considerable importance for successful obturation. Several obturation methods have been reported in the pediatric endodontic literature (9). The pulpectomy is the total removal of coronal and radicular pulp tissue, with debridement, disinfection and filling of root canals using a resorbable pulp-filling material (10). Moreover, pulpectomy is beneficial for retained primary molar teeth (11). If the tooth is removed in advanced stage with a progressive root resorption and an excessive infraocclusion, retain molar may act as an occlusal support for the dentition over many years (12). However, even with progress in pediatric endodontics, there is no specific agreement on the best materials or treatment protocols and techniques for use in clinical practice. A lack of consensus on how to proceed with pediatric endodontic treatment creates a situation where clinicians sometimes choose the approach with which they are most comfortable or familiar (13). Though evidence-based practice is stressed in modern dentistry, clinical experience also plays a role for therapeutic decisions, and they should be combined. Hence, it is important for professionals to assess the efficiency of the materials and techniques currently available (14,15). A factor that influences the success of root canal therapy is the obturation quality which leads to good sealing of root canal system. Different methods that have been used are the amalgam plugger, endodontic pressure syringe, incremental filling technique, jiffy tube, disposable local anaesthetic syringe, insulin syringe, tuberculin syringe, motor-driven lentulo-spiral, NaviTip system, and Pastinject (12,16-17). Apical leakage, defined as the passage of dye or bacteria through the interface (the border) between the filling material and canal wall, is still a prevailing issue in endodontics as it can significantly undermine treatment success. In spite of the introduction of new innovative technology in endodontics, apical leakage has been observed to play a role in clinical failures (18). A hermetic tight root canal obturation, in case of necrotic primary teeth is a must for successful pulpectomy. Thus, the study of different obturation techniques for sealing ability is essential (9). In primary teeth, it has also been shown that obturation methods are successful with many types of sealers and the same is true in permanent teeth (19). The apical sealing properties of root-filling materials have been assessed using a number of methodologies: dye penetration, dye extraction, radioisotope penetration, bacterial leakage, electrochemical analysis and fluid filtration. Among them, the dye penetration technique is based on immersion of samples in a dye solution like 2% methylene blue and observing them under a stereomicroscope (20,21). In contrast, the dye extraction method includes soaking samples in dye and subsequent acid to remove all of the dye from the interface. A spectrophotometer measures subsequently the optical density of

the prepared solution, making it possible to calculate dye diffusion through filling edges (22,23).

Several obturating materials and techniques have evolved to provide an ideal apical seal with minimum voids (24). Zinc oxide eugenol (ZOE) paste, calcium hydroxide [Ca $(OH)_2$] paste, iodoform and combinations of these are the most commonly used materials for obturation of primary teeth (25). However, of these, ZOE continues to be the most commonly used material for pulpectomy in deciduous teeth. ZOE has been the considered the suitable material of choice because of its antibacterial, anti-inflammatory properties, easily available, and, costly effective since it was introduced in 1930s (26, 27). Reported success rates for ZOE are 65% to 85% (21). In deciduous teeth, the complex anatomy of the root canal system possess a major challenge for complete debridement through mechanical shaping and irrigation. Successful treatment depends upon thorough cleaning and shaping, accompanied by obturation of the entire canal system (19). Variability in treatment recommendations among general dentists and pediatric specialists has been reported. In some cases, the obturation procedures remains incomplete because of lack of knowledge by operator or cooperation of the child (28,29). Consequently, this study was conducted to compare the apical microleakage and duration using ZOE as an obturating agent in primary teeth. Obturation techniques (modified disposable syringe, reamer and tuberculin syringe) will be compared together using 2% methylene blue as the tracer.

Materials and Methods

Ethical approval

This in-vitro experimental study was performed under ethical approval of the ethical committee (Approval No. ESA & HER-16-12-2025) at College of Dentistry, Al-Iraqia University.

Sample size estimation

The sample size was estimated with G*Power software (version 3.1.9.7; University of Kiel, Germany). On the basis of a two-sided alpha error probability of 0.05 and power of 0.80 with a large effect size (f = 0.55) among three experimental groups, the total sample size was set to be 36 teeth (12 teeth per group).

Sample Selection and Criteria

The samples consisted of 150 primary maxillary anterior teeth collected from (5-10 year's old) patients over a period of six months, among which only 36 were included in the study. Indications for extraction were orthodontics (serial extraction), dental caries (unrestorable teeth), and avulsion due to trauma. Parents or guardian of the pediatric patients gave their informed consent before sampling. The inclusion criteria were established according to the protocols of Bawazir and Salama (20), as adapted by Irzooqee et al., (2023) (22): Straight roots, root length at least, two-thirds intact, the length (measured from incisal edge to apex) is (15–22 mm), apical diameter no more than a size 30 K file (Dentsply Maillefer, Switzerland) to standardize the samples and avoid high variability (22). Any sample out of these inclusion criteria were excluded from this research. Root resorption can affect the

position of the apex foramen; as such, in each tooth, the apex was analyzed under microscope to verify a centered apical foramen that does not affected with resorption and limit bias on study results.

Sample Preparation

All experimental group interventions were administered by the same operator to reduce variability. The remaining soft tissue was then carefully removed from root surface using a sharp curette (Medesey, Italy). Afterwards, all teeth were placed in a 0.1% thymol (DBH, England) solution for 24 hours and subsequently in tap water which was changed daily until the beginning of this study (23). All samples were used within 6 months as recommended by OSHA (21). After marking the roots of each tooth 10 mm from the apex with a marker pen (22), and then fixated into a bench vice they were cross-sectioned perpendicular to their long axes with a diamond disc bur (Horico Dental, Berlin, Germany) mounted on straight handpiece using water cooling flow (23).

Randomization

In this study, randomization was used to classifying the patients into 3 study groups according to the obturation technique (each / n = 12) (modified disposable syringe, reamer and tuberculin syringe) by using the "Random sequence Generator" tool (https://www.random.org/ sequences).

Endodontic Procedure

Instrumentation technique

All the teeth were subjected to standardized instrumentation. Canal patency was checked with a size 10 K-type file (Dentsply Maillefer, Switzerland) and then the remnant pulp was extirpated by barbed broach. The working length was radiographically determined and canals prepared with K-files until size 50 (30). Irrigation was done during instrumentation with a 27-gauge needle (Sinalident, China) advanced up to 1.5 mm short of the working length. After each file, 2.5% NaOCl was irrigated with a volume of 1 mL between the files. The canals were irrigated with 2 mL of 2.5% NaOCl after instrumentation. According to the protocol described by Kale et al. (2024), 1 mL of 17% EDTA (Produits Dentaires, Vevy, Switzerland) was used for the irrigation during a minute and then followed by an irrigation with 2.5% NaOCl (3 ml) then, a final rinse with distilled water in 5mL (21). A paper point was used to dry the prepared and irrigated canals (31).

Obturation Techniques

The canals were dried and obturated with a slow setting ZOE (Switzerland) using three methods. Complete obturation of the canal space in all the specimens till the working length was verified for all teeth and radiographs were taken to verify that obturation material filled the apical third, (Figure.1). Samples were categorized into three groups, based on the obturation technique used:

Figure.1: X-ray film of a sample obturated with Modified Disposable Syringe

Group I: Modified Disposable Syringe Technique

A disposable syringe was modified through connecting a disposable tip (Meta Biomed). The syringe was filled about 1 ml with ZOE combination by aspiration which was prepared by mixing one scoop of the powder and three drops of liquid to produce a thin, easily injectable and flowable mixture. The syringe then, tapped several times on a hard surface to ensure that all air was removed. The disposable was attached and flow of material confirmed. A rubber stop was fixed to the predetermined working level. The tip was placed into the canal prepared for later when resistance to the walls of canal, it was withdrawn gradually delivering material (9, 22).

Group II: Reamer Technique

The canals were sealed with an endodontic reamer (size 30) in this study group. To get a medium consistency, two scoops powder was mixed with one drop liquid according to the manufacturer's recommendation. The reamer was coated with ZOE and inserted five to seven times into the canal working length vibrationally rotating clockwise, until the canal's orifice appeared filled with paste, (Figure.2) (4,32).

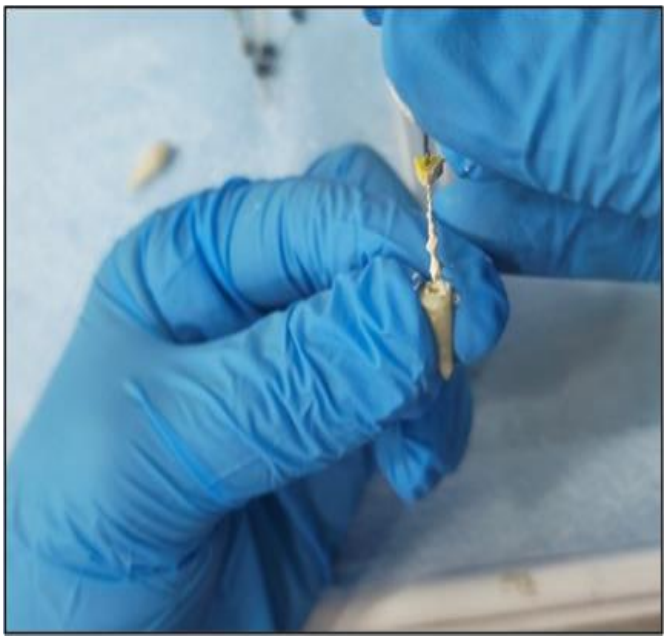

Figure. 2: Obturation manually with a size 30 file

Group III: Tuberculin Syringe Technique

Tuberculin syringe (Dispo Van, HMD Ltd., India) containing ZOE which was prepared and mixed the same as group I, was introduced into the canal. The plunger was gradually depressed to load the material and simultaneously withdrawn with the needle. Afterward wet cotton was used to compact material at tooth canal orifice. Length control was accomplished using a rubber stopper on each instrument. Following obturation, glass ionomer cement was used to restore all the samples occlusally. They were then incubated at 37 °C and 100% humidity for 24 hours to ensure the complete setting of the obturating material. The root surface of all experimental specimens was painted with (2 layers) of nail polish except (1 mm) around the apical foramen before immersion in methylene blue dye (33, 34).

Assessment of Microleakage and Time

Dye Extraction Evaluation

For the Dye extraction test, the dye extraction method was used for evaluation of all samples in each group. Two weeks after obturation, Individual teeth were suspended in a glass vial filled with neutralized buffer solution containing 2% methylene blue dye (BDH, UK) for 24 hours and then the teeth were washed with water for 30 min. The nail polish was then removed utilizing a surgical blade and a polishing disc (23,35). The samples were then kept for three days in 4 mL of 65% nitric acid. The solution was centrifuged by a Sigma 3-16L (Osterode, Germany) at 4,000 rpm for 7 min. For each sample, 2 ml of the supernatant was placed in a plastic cuvette. With an automatic spectrophotometer, the optical density of the solution was measured, using as a blank concentrated nitric acid at 550 nm (23, 36).

Obturation Time Measurement

The time for obturation of the canals was measured in minutes by a digital chronometer for each sample. Then the comparison of these values was carried between groups to perform inter-group analysis.

Statistical Analysis

Data were recorded into Microsoft Excel and analyzed by SPSS software (version 22, Chicago, Illinois, USA). Intergroup comparisons were performed using one-way ANOVA with Bonferroni and Tukey post-hoc test. $P < 0.05$ was considered to indicate statistical significance.

Results

Microleakage

Data representing the microleakage measurements of the dye's extraction that seeped into the samples of each group were tested for normality of distribution. The Shapiro-Wilk test results at $p > 0.05$ showed that microleakage was consistently distributed among groups. Descriptive statistics of the microleakage of the dye are shown in Figure. 3. The microleakage was detected in all three study groups. The lowest mean value (0.162) was shown in group I (Modified Disposable Syringe group), then the group II (0.206), while the highest mean value was found in group III (Tuberculin syringe group) (0.216). A one-way ANOVA test was carried out to identify the presence of statistically significant difference among groups. The result of ANOVA revealed no significant difference as $p > 0.05$ among groups, as shown in Table 1.

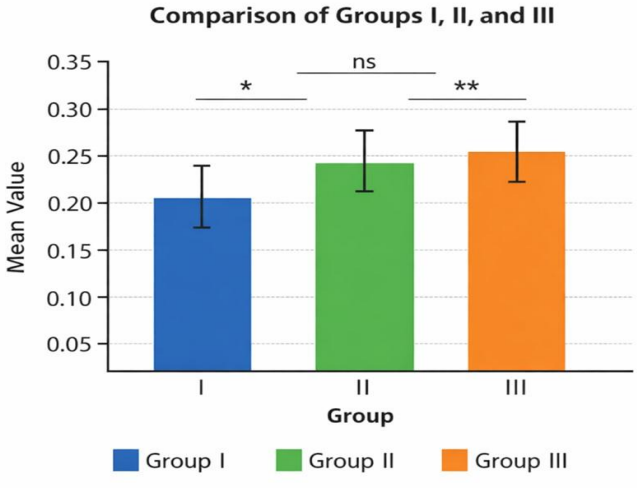

Figure. 3: Bar graph showing the mean microleakage value among groups

Time

Time taken for obturation of each root canal was recorded and intergroup comparison was made. Obturation with modified disposable syringe consumed least time (mean =3.95)

followed by tuberculin syringe (mean =6.26), and obturation time was maximum with reamer (mean = 4.50). One-way ANOVA revealed a statistically significant difference in obturation time among the groups. F (2,33) = 17.92, p < 0.001 (Table 2, 3 and 4).

Table. 1: Descriptive statistics of the optical density among the experimental groups.

Groups	**Mean**	**±SD**	**±SE**	**Minimum**	**Maximum**
I	0.162	0.064	0.0185	0.064	0.281
II	0.206	0.0613	0.0177	0.071	0.292
III	0.216	0.0618	0.0178	0.079	0.302

I: Modified pressure syringe, **II:** Reamer, **III:** Tuberculin syringe,
SD: Standard deviation. **SE:** Standard Error.

Table 2: Descriptive statistics of the time in minutes among the experimental groups

.

Groups	Mean	±SD	±SE	Minimum	Maximum
I	3.95	1.075	0.31	2.5	5.4
II	6.26	0.69	0.20	5.2	7.3
III	4.50	1.04	0.30	2.6	6.1

I: Modified pressure syringe, **II:** Reamer, **III:** Tuberculin syringe,
SD: Standard deviation. **SE:** Standard Error.

Table. 3: Multiple comparisons of obturation time among groups using Tukey post-hoc test.

Groups		Mean Difference	p-value
I	II	-2.31	0.001*
	III	-0.55	0.216
II	III	1.76	0.001*

I: Modified disposable syringe, **II:** Reamer, **II:**Tuberculin syringe, *Significant, p<0.05

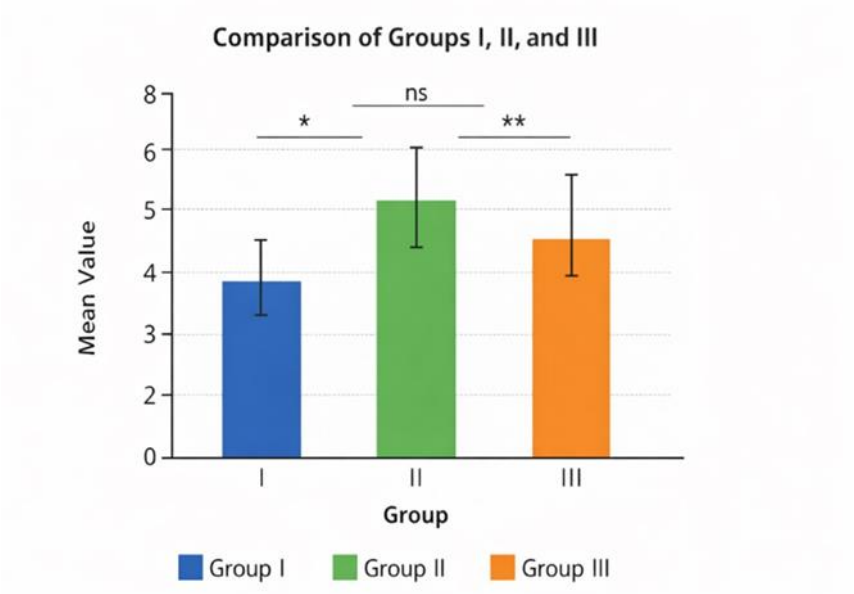

Figure 4: Bar graph showing the mean obturation duration value among groups

Discussion

The primary goal of obturation is to eliminate pathways of leakage from apical and coronal directions, as well as to eliminate bacteria often seen within dentinal tubules (35). For anatomical standardization, extracted primary anterior teeth were collected and used in the present study (21). Methylene blue dye was used in this research because it allows accurate quantitative measurement of penetration by linear methods. Its molecular size is similar to bacterial by product such as butyric acid which can leak out of infected root canals to irritate periapical tissues (37). Moreover, methylene blue is easy to manipulate, economical, rapid in application, high staining and not absorbed by dentinal hard tissues and therefore, it is the ideal dye for this study (38). To ensure complete setting of the obturation filling material, the samples were dyed 14 days after obturation. The dye penetration is till date considered to be the most commonly used means for assessment of sealing ability but it has critical problems. This is by cutting the root randomly into two halves without determining which side shows the most penetration of dye, and this can result in underestimation, as well as inconsistent results. In addition, leak detection with this approach is qualitative rather than quantitative (38). While, the dye extraction dissolution technique is a well-established method for measuring the amount of absorbed dye following acid dissolution of the tooth substrate. So, the optical densities are estimated by spectrophotometer to get a quantitative score. This methodology has been used in endodontic studies for several years, as it is remarkably straightforward, cost-effective and allows one to correct each absorbed dye value within the specimen. Unlike the dye penetration technique, which is based on sectioning and linear measurements, the method of dye extraction reduces human errors and estimates volumetric leakage with higher reliability (18). Microleakage in the form of bacterial contamination, by-products, fluids and chemicals into the root canal system continues to be a leading cause of unsuccessful endodontic therapy (35). It's critical to maintain the marginal seal for long duration to reduce or eliminate as possible problems that can be faced clinically like marginal discoloration and secondary caries related to microleakage (39). Performing root canal

filling of primary teeth with a hermitic seal is particularly difficult, as such teeth demand both resorbable and non-condensable filling material (40). Accordingly, the sealing capability was largely dependent upon the obturation technique, the efficiency of smear layer elimination during irrigation, and the adaptation of the filling material the canal walls (41). To improve the results, smear layer removal is performed; using 17% EDTA that was included in the irrigation regimen of this study (42). The findings of this study revealed that there was no significant difference between reamer and modified disposable syringe techniques ($P>0.05$), but the mean value of microleakage in modified disposable syringe technique was lower than the reamer group. Tuberculin Syringe procedure showed higher mean microleakage than the other two techniques. Using the modified disposable syringe had various advantages: transparent tip enables to observe material flow directly, there is no possibility of it breaking, tips can be cut to length. Moreover, disposable syringes allow reduced risk of cross contamination (9). Despite that the microleakage mean was lower than the other study groups, it is possible that some voids were created inside the roots during the obturation as on modified disposable syringe air goes through the barrel during fill up with material and these may be cause of this microleakage (9). Simultaneously, the reamer technique had a greater microleakage than modified disposable technique. The present finding was also similar to that of Sharma et al. 2023 who found that poor proportion of optimal filled root canals was achieved with reamer technique (4). Despite, cavities were not assessed in this study, it could be concluded that the microleakage may perhaps due to the formation of the voids as minor irregularities in small numbers and sizes during the obturation of canals and repeated removing and reinserting of the hand instrument (43,44). Possible reasons for the differences in studies might be related to the material type used for obturation, the technique of obturation and method of evaluation (22). A significant difference between groups regarding time consumed with each obturation technique to fill the root canal was found. The time was longer with reamer. This might be because of the fact that in reamer the increasing portion fillings was performed 5-7 times until the canal orifice was already full with obturating material, this is in conjunction with Ochoa-Romero et al., 2011 (45). Although the current study was carried out in vitro, and thus the time data do not exactly represent clinical performance since however obturation in vivo is influenced by clinical factors such as gingival hemorrhage, patient cooperation, and anatomical variation which increase obturation time. Nevertheless, the results might provide an insight into which method would consume less obturating time to be recommended for use in vivo as it is well known that time is an important factor while managing a pediatric patient.

Study Limitations

This study has several limitations. Firstly, only straight single-rooted primary anterior teeth were included in the study and therefore may not be extrapolated to other root canal anatomies. Furthermore, Only ZOE was the filling material used; therefore, other obturating materials might not yield the same results. The research was performed in a laboratory setting that may not mimic clinical environments. Despite the efforts to mimic the oral environment but, conditions such as the continuous cleansing action of saliva, sudden temperature changes during the experiment and pH alterations through time could not be achieved. So, differences in saliva amount and composition and delivered irrigation treatments could also affect the result of treatment and need to be more investigated. Furthermore, the long-term sealing ability is uncertain, and although the dye extraction

method measured leakage at short times only. Further studies are recommended for comparison of other obturating materials, irrigation protocols and their clinical long-term adaptation to root canal walls.

Conclusion

Obturating primary teeth with ZOE utilizing modified disposable syringe technique has exhibited less apical microleakage, also the obturation time was the less; it could be a potential alternative to tuberculin syringe technique and reamer technique with better sealing ability.

Clinical Significance of the research

Regarding the results of this research, it could be concluded that choosing an obturation technique that limits microleakage while being timesaving for primary teeth is of primary importance for pedodontist. Modified Disposable Syringe technique showed the lowest microleakage and shortest obturation time among the tested techniques, thus can be a potential choice for pediatric endodontic practice. Minimization of microleakage associated with prevention of reinfection and guaranteeing the success in long-term pulpectomies, whereas lesser time consumed during treatment progresses patient compliance that is a significant aspect when dealing with pediatric patients. These results help to make selecting techniques that promote a more effective and efficient outcome in primary teeth endodontics an evidence-based decision.

Declarations

Acknowledgment

The author would like to express her thanks and gratitude to all who contributed to this research and to its publication.

Ethics statement

This study was conducted in accordance with the ethical standards and guidelines outlined in the journal's "Ethics Approval" section.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests

The author declares that she has no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' Contributions

DNA: designed the study, performed the statistical analysis, and drafted the manuscript; contributed to the design of the study and critically revised the manuscript; contributed to assembling the statistical dataset and performed the analyses; contributed to the writing of the manuscript. The author read and approved the final manuscript.

References

1. Riolina A, Hartini S, Suparyati S. Dental and oral health problems in elementary school children: A scoping review. Pediatric Dental Journal. 2020;30(2):106–14. DOI:10.1016/j.pdj.2020.04.001

2. Ahmadi F, Triwinarto A (2019): Analysis descriptive stunting in Indonesia Health Research Basic, Ann Trop & Public Health; 22(11): S357A. DOI: http://doi.org/10.36295/ASRO.2019.221159

3. Chandrasekhar S, Prasad MG, Radhakrishna AN, Saujanya K, Raviteja NVK, Deepthi B, Ramakrishna J. A comparative In vivo efficacy of three spiral techniques versus incremental technique in obturating primary teeth. J Indian Soc Pedod Prev Dent. 2018 Jan-Mar;36(1):71-75. doi: 10.4103/JISPPD.JISPPD_365_16. PMID: 29607843.

4. Sharma K, Maria R, Durga Dutta S, Semwal M, Srija K, Pawar M, Dagli N, Niranjan Mehta D. Evaluation of obturation techniques in primary teeth among Indians. Bioinformation. 2023 Dec 31;19(13):1324-1328. doi: 10.6026/973206300191324. PMID: 38415036; PMCID: PMC10895539.

5. Achmad H, Armedina RN, Timokhina T, Goncharov V V, Sitanaya R, Riyanti E. Literature review: Problems of dental and oral health primary school children. Indian Journal of Forensic Medicine & Toxicology. 2021;15(2). 4117-4124. DOI:10.37506/ijfmt.v15i2.15019

6. Redwan AK, Alhazmi HA, Alharthi SA, Alharbi JJ. Parents' Knowledge and Awareness About the Importance of Primary Teeth and Space Maintainers in Saudi Arabia: A Cross-Sectional Study. Cureus. 2024 Jun 6;16(6):e61836. doi: 10.7759/cureus.61836. PMID: 38975367; PMCID: PMC11227340.

7. Sanusi SY, Al-Bataynehb OB. Pulp Therapy of Primary Dentition; its Relevance despite Insufficient Histological Evidence: A Review. Iran Endod J. 2023;18(1):15-40. doi: 10.22037/iej.v18i1.34931. PMID: 36751408; PMCID: PMC9900146.

8. Guimarães ME, Jorge RC, Duarte ML, Bedran NR. Pulp therapy in primary teeth with irreversible pulpitis or necrosis: a literature review. Revista, Latino americana. 2025;15:e-246692. https://doi.org/10.47990/m8j6yp38

9. Nagarathna C, Vishwanathan S, Krishnamurthy NH, Bhat PK. Primary Molar Pulpectomy Using Two Different Obturation Techniques: A Clinical Study. Contemp Clin Dent. 2018 Apr-Jun;9(2):231-236. doi: 10.4103/ccd.ccd_826_17. PMID: 29875566; PMCID: PMC5968688.

10. Jena A. Pulpectomy: A Comprehensive Review. (2020). *Indian Journal of Forensic Medicine & Toxicology, 14*(4), 9321-9324. https://doi.org/10.37506/ijfmt.v14i4.13267

11. Ali A, Fadhil N, Al-Maroof A. Evaluation of technical quality and procedural errors of root canal treatment performed by undergraduate and postgraduate dental students: A retrospective radiographic analysis. Medico-Leg Update. 2020;20(3):787–92.

12. Priyadarshini P, Gurunathan D. Comparative evaluation of quality of obturation using endoflas and endoflas powder with aloevera gel as obturating materials in primary mandibular molars: a double blinded randomized controlled trial. J Complement Med Res. 2020;11(3):203–13. DOI: 10.5455/jcmr.2020.11.03.27

13. Casaña Ruiz MD, Martínez LM, Miralles EG. Update in the Diagnosis and Treatment of Root Canal Therapy in Temporary Dentition through Different Rotatory Systems: A Systematic Review. Diagnostics (Basel). 2022 Nov 13;12(11):2775. doi: 10.3390/diagnostics12112775. PMID: 36428835; PMCID: PMC9689064.

14. Coll JA, Vargas K, Marghalani AA, Chen CY, AlShamali S, Dhar V, Crystal YO. A Systematic Review and Meta-Analysis of Nonvital Pulp Therapy for Primary Teeth. Pediatr Dent. 2020 Jul 15;42(4):256-461. PMID: 32847665.

15. Silva Junior MF, Wambier LM, Gevert MV, Chibinski ACR. Effectiveness of iodoform-based filling materials in root canal treatment of deciduous teeth: a systematic review and meta-analysis. Biomater Investig Dent. 2022 May 19;9(1):52-74. doi: 10.1080/26415275.2022.2060232. PMID: 35615468; PMCID: PMC9126566.

16. Manhas, S. ., Haritwal, V. ., Chaturvedi, Y. ., Vyas, D. ., Dalsania, R. ., & Chhibber, R. . (2020). Obturating Materials in Pediatric Dentistry : Literature Review. International Journal of Contemporary Research and Review, 11(08). https://doi.org/10.15520/ijcrr.v11i08.835

17. Goit A, Srivastava M, Ayodhi S, Vannala V, Shanmugaavel AK, Sooriaprakas C. Evaluation of Three Different Obturating Techniques in Primary Molar using Cone-Beam Computed Tomography: An In vitro Study. J Pharm Bioallied Sci. 2025 Jun;17(Suppl 2):S1233-S1235. doi: 10.4103/jpbs.jpbs_1666_24. Epub 2025 Jun 18. PMID: 40655777; PMCID: PMC12244907.

18. Nepal M, Shubham S, Tripathi R, Khadka J, Kunwar D, Gautam V, Gautam N. Spectrophotometric analysis evaluating apical microleakage in retrograde filling using GIC, MTA and biodentine: an in-vitro study. BMC Oral Health. 2020 Feb 3;20(1):37. doi: 10.1186/s12903-020-1025-9. PMID: 32013975; PMCID: PMC6998061.

19. Brar GS, Bajaj N, Bhola M, Brar JK. Clinical Evaluation of Root Resorption and its Correlation with Obturation Quality in Pulpectomized Deciduous Teeth with Different Obturating Materials: An In vivo Study. Contemp Clin Dent. 2019 Apr-Jun;10(2):243-248. doi: 10.4103/ccd.ccd_448_18. PMID: 32308285; PMCID: PMC7145250.

20. Bawazir OA, Salama FS. Clinical evaluation of root canal obturation methods in primary teeth. Pediatr Dent. 2006 Jan-Feb;28(1):39-47. PMID: 16615374.

21. Kale YJ, Misal S, Dadpe M, Dahake PT, Kendre SB. Comparative Evaluation of Microleakage of Zinc Oxide Eugenol and Endoflas as Obturating Materials Using Different Root Canal Irrigants in Primary Teeth: An *In Vitro* Study. Int J Clin Pediatr Dent. 2024 Nov;17(11):1252-1257. doi: 10.5005/jp-journals-10005-2755. Epub 2024 Dec 19. PMID: 39781383; PMCID: PMC11703773.

22. Irzooqee AF, Al Haidar AHMJ, Abdul-Kareem M. The Effect of Different Obturation Techniques in Primary Teeth on the Apical Microleakage using Endoflas: A Comparative In Vitro Study. Int J Dent. 2023 Mar 31;2023:4982980. doi: 10.1155/2023/4982980. PMID: 37033128; PMCID: PMC10081900.

23. Alani, Z. K., & Abd-alla, M. H. (2025). Effect of Root Dentin Moisture on the Apical Sealing Ability of Root Canal Sealers: In vitro Study. *Al-Rafidain Journal of Medical Sciences (ISSN 2789-3219)*, *8*(2), 122–127. https://doi.org/10.54133/ajms.v8i2.1910

24. Prabakar J, Jeevanandan G, Kengadaran S. In Vitro Evaluation of Viscosity, Depth of Penetration, Microleakage, and Shear Bond Strength of Conventional and Hydrophilic Sealants. Int J Clin Pediatr Dent. 2023 Sep-Oct;16(5):745-750. doi: 10.5005/jp-journals-10005-2684. PMID: 38162245; PMCID: PMC10753099.

25. Govindaraju L, Jeevanandan G, Veeraraghavan VP, El-Sherbiny M, Binshafi GB, Alkharji SK et al. An In-vitro Analysis of the Antimicrobial Efficacy of a Novel Obturating Material for Primary Teeth. Journal of International Dental and Medical Research. 2024;17(1):110-114.https://psau.sa.elsevierpure.com/en/publications/an-in-vitro-analysis-of-the-antimicrobial-efficacy-of-a-novel-obt/

26. Nalawade HS, Lele GS, Walimbe H. Outcome of zinc oxide eugenol paste as an obturating material in primary teeth pulpectomy: A systematic review. J Dent Res Rev 2017;4:90-6.DOI: 10.4103/jdrr.jdrr_65_17

27. Wasnik MB, Mittal R, Sajjanar A, Gahlod N, Khekade S, Shukla H. Comparative Evaluation of Antimicrobial Efficacy of Zinc Oxide Eugenol with Zinc Oxide Mixed with Three Herbal Products to be Used as Root Canal Filling Material: An In Vitro Study. Int J Clin Pediatr Dent. 2022;15(Suppl 1):S40-S46. doi: 10.5005/jp-journals-10005-2129. PMID: 35645491; PMCID: PMC9108819.

28. Hiremath MC, Srivastava P. Comparative evaluation of endodontic pressure syringe, insulin syringe, jiffy tube, and local anesthetic syringe in obturation of primary teeth: An in vitro study. J Nat Sc Biol Med 2016;7:130-5. DOI: 10.4103/0976-9668.184698

29. Bargale S, Davangere Padmanabh SK, Kariya PB, Shah S, Dave B. Knowledge, attitude, and practice regarding standardized treatment protocol for pulp therapy in deciduous dentition among general dental practitioners of Vadodara, Gujarat, India. J Indian Soc Pedod Prev Dent. 2019 Oct-Dec;37(4):327-332. doi: 10.4103/JISPPD.JISPPD_186_19. PMID: 31710005.

30. Govindaraju L, Jeevanandan G, Emg S, Vishawanathaiah S. Assessment of Quality of Obturation, Instrumentation Time and Intensity of Pain with Pediatric Rotary File (Kedo-S) in Primary Anterior Teeth: A Randomized Controlled Clinical Trial. Int J Clin Pediatr Dent. 2018 Nov-Dec;11(6):462-467. doi: 10.5005/jp-journals-10005-1558. PMID: 31303731; PMCID: PMC6611531.

31. Naji AN, Al-Gharrawi HA. Comparison of the sealing ability of GuttaFlow bioseal with different obturation systems (an in vitro study). J Int Dent Med Res. 2020;13(4):1632–6. https://www.semanticscholar.org/paper/Comparison-of-the-Sealing-Ability-of-GuttaFlow-with-Naji-Al-Gharrawi/4f8d3f6cf84fa8977458a132279ab0dc4f32193c

32. Mahajan N, Bansal A. Various Obturation methods used in deciduous teeth. Int J Med and Dent Sci 2015; 4(1):708-713. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://scispace.com/pdf/various-obturation-methods-used-in-deciduous-teeth-sb9qub33t3.pdf

33. Dou G, Wang D, Zhang S, Ma W, Xu M, Xia B. A retrospective study on the long-term outcomes of pulpectomy and influencing factors in primary teeth. J Dent Sci. 2022 Apr;17(2):771-779. doi: 10.1016/j.jds.2021.10.007. Epub 2021 Oct 21. PMID: 35756771; PMCID: PMC9201929.

34. Ge KX, Yu-Hang Lam W, Chu CH, Yu OY. Updates on the clinical application of glass ionomer cement in restorative and preventive dentistry. J Dent Sci. 2024 Dec;19(Suppl 1):S1-S9. doi: 10.1016/j.jds.2024.07.021. Epub 2024 Jul 27. PMID: 39807434; PMCID: PMC11725089.

35. Sah S, Mangat P, Kumar A, Sah N, Shivakumar GC, Di Blasio M, Cervino G, Minervini G. Stereomicroscopic evaluation of sealing ability of four different root canal sealers: an in-vitro study. BMC Oral Health. 2024 Feb 20;24(1):258. doi: 10.1186/s12903-024-03913-7. PMID: 38378554; PMCID: PMC10877889.

36. Razmi H, Bolhari B, Karamzadeh Dashti N, Fazlyab M. The Effect of Canal Dryness on Bond Strength of Bioceramic and Epoxy-resin Sealers after Irrigation with Sodium Hypochlorite or Chlorhexidine. Iran Endod J. 2016 Spring;11(2):129-33. doi: 10.7508/iej.2016.02.011. Epub 2016 Mar 20. PMID: 27141222; PMCID: PMC4841349.

37. Negi S, Adhikari HD, Mazumder D, Lakiang RD, Bhardwaj S. Comparative evaluation of microleakage after root-end resection by erbium, chromium: Yttrium-scandium-gallium-garnet (Er, Cr:YSGG) laser and carbide bur with or without

placement of mineral trioxide aggregate: An in vitro study. J Conserv Dent. 2019 Jul-Aug;22(4):391-395. doi: 10.4103/JCD.JCD_48_19. PMID: 31802826; PMCID: PMC6873605.

38. Muliyar S, Shameem KA, Thankachan RP, Francis PG, Jayapalan CS, Hafiz KA. Microleakage in endodontics. J Int Oral Health. 2014 Nov-Dec;6(6):99-104. PMID: 25628496; PMCID: PMC4295468.

39. Sahu D, Somani R, Rao BV, Nagarjuna P, Eshwara K, Lakshmi PVSD. Comparative evaluation of microleakage of various glass-ionomer cements: An: in vitro: study. International journal of preventive and clinical dental research. 2018;5(3):17–20. DOI: 10.4103/INPC.INPC_8_18

40. Öter B, Topçuog Lu N, Tank MK, Çehreli SB. Evaluation of Antibacterial Efficiency of Different Root Canal Disinfection Techniques in Primary Teeth. Photomed Laser Surg. 2018 Apr;36(4):179-184. doi: 10.1089/pho.2017.4324.

41. Yüksel BN, Demirel A, Ziya M, Kolçakoğlu K, Doğan S, Sarı Ş. The effects of various irrigation protocols on root canal wall adaptation and apical microleakage in primary teeth. Acta Odontol Scand. 2020 Jul;78(5):321-326. doi: 10.1080/00016357.2019.1709890.

42. Valizadeh M, Gheidari A, Daghestani N, Mohammadzadeh Z, Khorakian F. Evaluation of various root canal irrigation methods in primary teeth: a systematic review. BMC Oral Health. 2024 Dec 21;24(1):1535. doi: 10.1186/s12903-024-05164-y.

43. Kukreja P, Reddy PR, Hugar SM, Shigli A, Hugar SS. Comparative evaluation of efficiency of three obturation techniques for primary incisors—an in vivo study. International Journal of Oral Health and Medical Research. 2015;2(2):15–18. https://www.academia.edu/73435323/An_In_Vivo_Study

44. Monali S, Anandamoy B, Atul B. A cone-beam computed tomographic assessment of different obturation techniques in primary molars—an in vivo study. International Journal of Dental Science and Innovative Research. 2020;74(1):46–51. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ijdsir.com/uploads/pdf/16042496521009.pdf

45. Ochoa-Romero T, Mendez-Gonzalez V, Flores-Reyes H, Pozos-Guillen AJ. Comparison between rotary and manual techniques on duration of instrumentation and obturation times in primary teeth. J Clin Pediatr Dent. 2011 Summer;35(4):359-63. doi: 10.17796/jcpd.35.4.8k013k21t39245n8.