

Assessment of Rheological Properties and Three-Dimensional Root Canal Filling Quality of Obturating Materials in Primary Teeth

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ABSTRACT

Objective: Rheology of four pulpectomy materials for primary teeth obturation was compared, and the relationship between flow behavior and 3-dimensional obturation quality on CBCT was tested.

Study Design: In vitro study

Place and Duration of Study: This study was conducted at the Pediatric and Preventive Dentistry Department, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research (DMIHER) Sawangi (Meghe) Wardha 442001, Maharashtra, India from August 2024 to August 2025.

Methods: Endoflas, Metapex, Metapaste, and Zinc Oxide-Eugenol were tested. Apparent viscosity of six samples of each material was measured with a strain-controlled rheometer following ISO 6876 standard at 2 minutes and at a later anchor point after mixing and/or extrusion. Eighty extracted primary mandibular second molars were prepared with standardized access, working length, instrumentation, irrigation, and syringe obturation with uniform technique. CBCT evaluation of obturation quality was performed 24 hours post-obturation with blinded evaluation by two independent scorers with high inter-rater agreement. One-way ANOVA for multiple means at $\alpha = 0.05$ was used for statistical analysis.

Results: Significantly different viscosities were measured for the four materials at both points ($p < 0.0001$). Endoflas showed the highest initial viscosity, while ZOE showed the lowest viscosity among the tested materials. CBCT evaluation showed the highest quality of obturation with Endoflas (91%), then with Metapex (87%), ZOE (74%), and Metapaste (68%).

Conclusion: Rheology of the tested pulpectomy materials for primary teeth obturation is strongly correlated with the quality of obturation, with the materials with the best rheology, Endoflas and Metapex, showing the best quality.

Key Words: Pulpectomy; Primary teeth; Root canal obturation; Rheology; Cone-beam computed tomography

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INTRODUCTION

The goal of a pulpectomy of primary teeth is to maintain the integrity of the dental arch, chewing, and

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speech, and to guide the permanent successors' eruption. For long-term success, chemomechanical debridement and a three-dimensionally optimal obturation with minimal space for microbes and possible reinfection are required^{1,2}. Primary molar roots are technically challenging because of their complex canal anatomy, small dentinal walls, and physiological root resorption, making the procedure more difficult than in permanent teeth^{2,3}. Therefore, the material and the application method are critical for the predictability of the procedure's success^{1,4}.

The optimal material for obturating primary teeth would be biocompatible, antimicrobial, and seal the canal hermetically, and resorb physiologically without impeding exfoliation^{1,3,5}. Zinc oxide-eugenol paste has traditionally been used for the procedure, but some disadvantages of ZOE include the slow resorption of the extruded material and tissue irritation. To overcome some of the disadvantages of ZOE, calcium hydroxide-iodoform has also been proposed for the procedure, but the application may be variable and may interfere with the continuity of the obturation material^{1,6,7}.

Rheological properties of the paste, especially viscosity and time-dependent viscosity, determine the apical passage, canal wall contact, and minimum space for microbes for the obturation material when delivered at a clinically realistic pressure⁸. If the paste is too viscous, coronal advancement may be impeded and apical space may be left unfilled, while if the viscosity is too low, the risk of extrusion increases and the space may still be left unfilled if the material separates and moves unevenly within the canal's complex anatomy^{8,9}. Nevertheless, the most common evaluation of the obturation procedure for primary teeth has been based on two-dimensional radiographs, which may not be entirely accurate because of superimposition of the canal's anatomy and the obturation material^{9,10}. Three-dimensional non-destructive evaluation of the canal and the obturation material has become possible with the advent of CBCT and has become a common practice for evaluating the success of the procedure in experimental endodontic studies^{9,11,12}.

The current in vitro study compares the rheological properties of the most common materials for the procedure and relates the viscosity profiles of the materials to the three-dimensional obturation success evaluated by CBCT and a standard syringe application method.

METHODS

This in vitro study was conducted 12 months after receiving ethical clearance from the institution for the use of extracted primary teeth from August 2024 Till August 2025.

Specimen Selection: Eighty primary mandibular second molars, which had at least two-thirds root length remaining and minimal apical resorption, were used for the study. These teeth were excluded if they had fractures, perforations, significant resorption, or calcifications. These teeth were stored in 0.1% thymol at 4°C.

Access, Instrumentation, and Canal Preparation: Standardized access cavities were prepared using water-cooled diamond burs. The working length was taken 1 mm short from the visible apex using a size 10 K-file. The canal was then instrumented using ProTaper rotary files, where SX was used for coronal flaring, and S2 was used to the working length at 300 revolutions per minute using an ENDO-MATE TC2 handpiece. Sodium hypochlorite at 1% concentration, alternating with normal saline, was used for irrigation via a 27-gauge needle. The canal was dried using paper points. The rotary files were discarded after using six canals to reduce file fatigue¹³.

Materials Used: There were four different materials used, namely, Endoflas, which is a zinc oxide-eugenol paste combined with iodoform, Metapex, which is a calcium hydroxide/iodoform premixed paste, Metapaste, which is a calcium hydroxide premixed paste, and a conventional zinc oxide-eugenol mix prepared from zinc oxide powder and eugenol.

Rheological assessment: Six separate samples of each material (n=24) were tested in a strain-controlled rheometer (MCR 92; Anton Paar, Austria) with a parallel plate geometry (8mm plates with a 0.50mm gap). Each sample (0.025 mL) was subjected to steady-shear testing according to ISO 6876 for flow measurements. Apparent viscosity measurements were recorded at an initial point and subsequently at an anchor point to measure the reduction in viscosity with time.

Obturation procedure: After preparation, all samples were obturated using a standardized syringe technique. For all samples in each group, the syringe needle was positioned close to the working length of the canal and gradually removed while dispensing a continuous syringe stream of obturating material without warm compaction.

CBCT acquisition and analysis: Samples were scanned 24 hours post-obturation with standardized CBCT settings (Field of View 5 x 5 cm, voxel size 90µm). Multi-planar reconstruction images were used to classify samples as underfilled, appropriately filled, or overfilled. Two calibrated examiners analyzed samples in blind fashion to group allocation. Inter-examiner agreement was recorded using intra-class correlation coefficient.

Statistical analysis: Data analysis was performed using SPSS software version 26. Normality of viscosity values was tested using the Shapiro-Wilk normality test. For group comparison, one-way ANOVA was used to compare the results among the groups. Significance was set at p<0.05.

RESULTS

Rheological results: Apparent viscosity varied significantly among the four materials at the initial as well as the later anchor points (ANOVA, p<0.0001). Initially, the highest viscosity values were recorded in Endoflas (mean=12.4543×10⁶ mPa·s), followed by Metapex (mean=1.9836×10⁶ mPa·s), Metapaste (mean=1.0002×10⁶ mPa·s), and ZOE (mean=0.4341×10⁶ mPa·s) (Table 1). All materials demonstrated a significant reduction in viscosity over time (paired t-tests, p<0.0001), indicating time-dependent behavior. At the later anchor point, the highest viscosity values were recorded in Metapaste (mean=0.0263×10⁶ mPa·s), followed by Metapex (mean=0.0114×10⁶ mPa·s), Endoflas (mean=0.0092×10⁶ mPa·s), and ZOE (mean=0.0014×10⁶ mPa·s) (Table 1; Figure 1).

CBCT-based assessment of obturation quality: CBCT results demonstrated that the four materials varied significantly with regard to the continuity and quality of obturation (Table 2). Endoflas demonstrated the highest percentage of appropriately obturated root canal spaces (91%), followed by Metapex (87%), ZOE (74%), and Metapaste (68%). (Figure 1)

Table No. 1: Rheological measurements (apparent viscosity) of the tested obturating materials (n=6 per group).

Material	Mean Initial ($\times 10^6$ mPa·s)	SD Initial	Mean Final ($\times 10^6$ mPa·s)	SD Final	P (initial vs final)
ZOE	0.4341	0.0179	0.0014	0.0001	<0.0001
Metapaste	1.0002	0.0188	0.0263	0.0012	<0.0001
Metapex	1.9836	0.0573	0.0114	0.0006	<0.0001
Endoflas	12.4543	0.5425	0.0092	0.0003	<0.0001

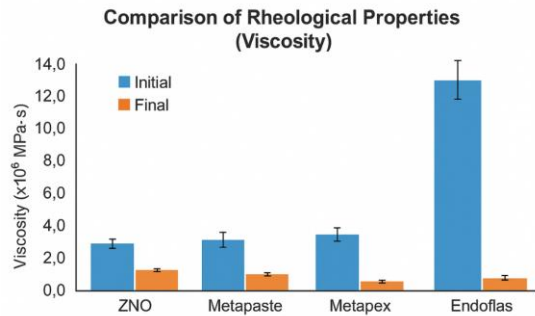


Figure No.1: All four materials exhibited a dramatic drop in viscosity from the initial to the final value, with Endoflas starting at the highest and ZOE at the lowest, and final values clustering near zero. Metapaste remained relatively high at the end.

Table No. 2: CBCT-based assessment of canal filling adequacy (n=20 teeth per group).

Material	Teeth (n)	Estimated canals*	Adequately filled canals (%)
ZOE	20	60–80	74
Metapex	20	60–80	87
Metapaste	20	60–80	68
Endoflas	20	60–80	91

*Each mandibular primary second molar typically has 3–4 canals.

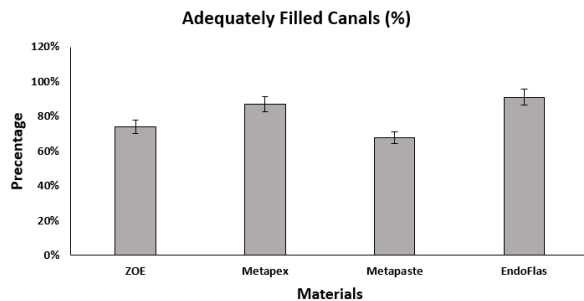


Figure No. 2: Proportion of adequately filled canals by material on CBCT analysis (Endoflas and Metapex highest; Metapaste lowest).

DISCUSSION

This study established a correlation between differences in paste rheology and three-dimensional obturation outcomes in primary molar teeth. It found that the

material with the highest initial viscosity, Endoflas, and the combination with Metapex produced the most consistent three-dimensional obturation outcomes on CBCT. It also found a correlation with more inadequate three-dimensional obturation outcomes with ZOE and Metapaste, specifically with apical short fill and dispersed voids.

Viscosity is a measure of resistance to deformation under shear stress and is a factor in apical advancement when used with a syringe or needle. Previous studies on endodontic materials have emphasized the flow behavior of endodontic materials and have stressed the importance of this factor in endodontic treatment. Flow behavior is clinically important but cannot be predicted based on composition alone^{14,15}. In this study, all materials had a marked reduction in viscosity over time. This finding is consistent with previous studies and underscores the need to standardize time in material use in endodontic treatment and in material comparisons. In addition, despite having the highest initial viscosity, Endoflas had a marked reduction in viscosity at the later time point. This finding might explain the easy handling of this material in endodontic treatment and the dense three-dimensional adaptation to the root canal.

The study found a correlation with previous studies on three-dimensional obturation outcomes in primary molar teeth and with the sensitivity of primary molar endodontic treatment outcomes to instrumentation and material handling techniques. It found that pediatric rotary instruments improved the consistency of shaping outcomes and produced a more homogeneous three-dimensional obturation outcome compared with a manual instrument approach. This study used a standardized approach with pediatric rotary instruments and found material differences in three-dimensional obturation outcome continuity consistent with clinical and systematic reviews on endodontic treatment outcomes with different materials. The systematic reviews found similar short-term outcomes with different materials but a trend toward favorable radiographic outcomes with Endoflas and calcium hydroxide/iodoform formulations in selected contexts. CBCT showed clear advantages over 2D radiographs for the evaluation of the obturation quality and the location of underfilling, particularly within the apical third where overlap can obscure the presence of these defects on periapical radiographs^{16,17,18}. Since voids and apical discontinuities can facilitate microleakage, the

three-dimensional evaluation of the obturating materials strengthened the internal validity of the in vitro comparisons, possibly providing an explanation for the material variability reported¹⁹.

Clinical application of the data needs to be viewed with some caution, as the outcome of a successful pulpectomy of a primary tooth has multiple determinants, including disinfection, coronal sealing, and biological responses. However, rheological profiling offered a useful, mechanistic alternative to clinical outcome, potentially informing the choice of material for syringe delivery systems used for obturation. Antimicrobial properties and biocompatibility were also important, with variable antimicrobial properties of the pediatric obturating materials reported by in vitro investigations, potentially impacting the outcome of infected canals^{20,21,22}.

Shortcomings of the Study: This was an in vitro evaluation, and only the viscosity properties of the materials were examined, and it is proposed that further investigations be carried out to evaluate the viscoelastic, thixotropic, and dimensional stability properties of the materials. A single syringe system was used to evaluate the materials, and this allowed for the isolation of the rheological properties of the materials.

CONCLUSION

In the context of this in vitro investigation, the rheological properties of the obturating materials for primary teeth were found to be differentiated according to the three-dimensional quality of obturation. Endoflas and Metapex, which have balanced viscosity and time-dependent flow properties, were found to have the highest CBCT-based rates of well-filled canals. ZOE was more commonly associated with apical underfilling, and Metapaste was found to have the highest percentage of discontinuous void patterns. The inclusion of rheological properties in the assessment of the obturating materials may aid in the evidence-based selection of the obturating materials in pediatric endodontics.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Mohamed Tharwat Salama, Punit Fulzele
Drafting or Revising Critically:	Mohamed Tharwat Salama, Punit Fulzele
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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REFERENCES

- Manzoor DRR, Manzoor M. Obturating materials in pediatric dentistry: a review. *Int J Appl Dent Sci* 2021;7:175-182.
- Mah YJ. Consideration of primary molar root and root canal for pulpectomy treatment. *J Korean Dent Assoc* 2019;57:474-479.
- Sijeria P, Bhartia R, Kv NS, Kulkarni S, Singla S. Evaluation of root canal filling in primary teeth by volumetric analysis: In vitro study. *Int J Clin Pediatr Dent* 2018;11(5):386.
- Lourenço Neto N, Souza BK, Custodio ID, Duarte MA, Valarelli TM. Optimizing endodontic treatment in primary teeth: a literature review. *Rev Flum Odontol* 2023;42-51.
- Gasner NS, Brizuela M. Endodontic materials used to fill root canals. *InStatPearls [Internet]* Mar 19. StatPearls Publishing, 2023.
- Chonat A. Obturation materials in pediatric dentistry—past to present: a review. In: Rizvi SAA, editor. *Advanced Concepts in Medicine and Medical Research*. 2nd ed. B P International; 2023. p.141-151.
- Chopra V, editor. *Bioceramics in Endodontics*. John Wiley & Sons; 2024 Mar 12.
- Wiśniewski P, Krokosz S, Pietruska M, Zalewska A. Functional and bioactive performance of premixed bioceramic sealers with warm obturation: a scoping review. *Gels* 2025;11:932.
- Kadkhodayan S, Almeida FT, Lai H, Pacheco-Pereira C. Uncovering the hidden: a study on incidental findings on cbct scans leading to external referrals. *Int Dent J* 2024;74(4):808-15.
- Kumari K, Kumar A, Miglani R, Kumar R, Anwer N, Barma MD, et al. Comparative Three-Dimensional Analysis of Three Different Root Canal Obturation Techniques: An in Vitro Study. *Cureus* 2025;17(8).
- Musale PK, Mujawar SA. Evaluation of the efficacy of rotary vs. hand files in root canal preparation of primary teeth in vitro using CBCT. *Eur Arch Paediatr Dent* 2014;15(2): 113-120.
- Venkatesh E, Elluru SV. Cone beam computed tomography: basics and applications in dentistry. *J Istanb Univ Fac Dent* 2017;51(3 Suppl 1): S102-S121.
- Gomes BPF, Aveiro E, Kishen A. Irrigants and irrigation activation systems in Endodontics. *Braz Dent J* 2023;34(4):1-33.
- Kurt M, Hazar Bodrumlu E. Assessment of Root Canal Filling Capacity and Quality of the Root Canal Pastes. *Acta Stomatol Croat* 2025;59(1): 15-25.
- Elicherla SR, Bandi S, Venkata Saikiran K, Nunna M, Sai Sahiti P, Nuvvula S. Clinical and

- radiographic success of Endoflas compared with other root canal obturating materials in primary teeth: a systematic review. *Dent Res J (Isfahan)* 2022;19:72.
16. Girish Babu KL, Gururaj Hebbar K, Doddamani GM. Correlation between quality of obturation and outcome of pulpectomized primary molars following root canal instrumentation with pediatric rotary file systems. *Pediatr Dent J* 2024;34:27-34.
 17. Girish Babu KL, Kavyashree Gururaj Hebbar. Influence of root canal instrumentation file systems and obturating materials on the success of pulpectomized teeth: A secondary analysis from a randomized controlled trial. *Contemp Pediatr Dent* 2024;5(2):71-85.
 18. Khadilkar AS, Kapur A, Goyal A, Gauba K, Singh SK. Comparison of clinical performance of obturating materials in pulpectomies: a randomized clinical trial. *J Indian Soc Pedod Prev Dent* 2024;42:28-36.
 19. Gandhi M, Tandon S, Vijay A, Kalia G, Rathore K. Clinical Assessment of Various Obturating Techniques for Primary Teeth: A Comparative Study. *J Clin Diagn Res* 2017;11(7):ZC48-ZC51.
 20. Navit S, Jaiswal N, Khan SA, et al. Antimicrobial Efficacy of Contemporary Obturating Materials used in Primary Teeth- An In-vitro Study. *J Clin Diagn Res* 2016;10(9):ZC09-ZC12.
 21. Fabiane P, Faraco Junior IM, Estrela C. Antimicrobial activity of different root canal filling pastes used in deciduous teeth. *Materials Res* 2008;11:171-3.
 22. Coll JA, Vargas K, Marghalani AA, et al. A Systematic Review and Meta-Analysis of Nonvital Pulp Therapy for Primary Teeth. *Pediatr Dent* 2020;42(4):256-461.