ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 9, Issue – 1, January – 2026, Page No. : 68 – 77

Comparative Analysis of the Effectiveness of Various Triphala Concentrations as A Final Irrigating Solution on Smear Layer Removal Using Various Needle Designs and Influence on Microhardness of Root Dentin: An in-Vitro Study

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Citation of this Article: Dr Subindas A S, Dr Jayalakshmi K B, Dr Shibani Shetty, Dr Soumya B, “Comparative Analysis of the Effectiveness of Various Triphala Concentrations as A Final Irrigating Solution on Smear Layer Removal Using Various Needle Designs and Influence on Microhardness of Root Dentin: An in-Vitro Study”, IJDSIR- January – 2026, Volume – 9, Issue – 1, P. No. 68 – 77.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

This study aimed to evaluate and compare the smear layer removal efficacy and the effect on dentin microhardness of different concentrations of Triphala (3%, 5%, and 10%) when delivered using two distinct needle designs. Ninety standardized mandibular premolars were biomechanically prepared and randomly divided based on needle design into open-ended and side-vented groups, each containing five subgroups (n = 9). The experimental groups received 3%, 5%, or 10% Triphala prepared in 10% dimethyl sulfoxide as final irrigants following irrigation with 3% sodium hypochlorite. Seventeen percent EDTA and saline were used as positive and negative controls, respectively. Smear layer removal was evaluated using scanning electron microscopy, while dentin microhardness was assessed using the Vickers hardness test.

The results showed that 17% EDTA exhibited the highest smear layer removal but caused the greatest reduction in dentin microhardness. Triphala demonstrated a concentration-dependent effect, with 10% Triphala showing smear layer removal efficacy comparable to

EDTA, particularly when delivered using side-vented needles, which achieved superior apical cleaning. All Triphala concentrations resulted in significantly less microhardness reduction than EDTA, with 3% Triphala preserving dentin hardness most effectively. Overall, 10% Triphala provided an optimal balance between effective smear layer removal and dentin preservation, suggesting its potential as a safer herbal alternative to EDTA in endodontic irrigation.

Keywords: Herbal irrigants; Triphala; Smear layer removal; Root dentin microhardness; Endodontic Irrigation; Needle Design

Introduction

Advancements in contemporary dentistry have significantly improved endodontic success through improved instrumentation, enhanced understanding of canal anatomy, and refined obturation techniques, thereby reducing the risk of under- or overfilling[1]. Effective management of pulpal and periapical diseases requires not only adequate canal enlargement for disinfection and obturation but also proper management of dentinal tubules along the canal walls [2].

Mechanical root canal preparation inevitably produces a smear layer that occludes dentinal tubules and compromises treatment outcomes [1]. This amorphous layer, approximately 2–5 µm thick, extends into dentinal tubules and consists of inorganic dentin particles (<0.5–1.5 µm) and organic components such as pulp tissue remnants, odontoblastic processes, microorganisms, and their by-products [3–5]. Smear plugs may penetrate up to 40 µm and, under certain conditions, as deep as 110 µm due to capillary action and adhesive forces [3,6]. The smear layer reduces irrigant penetration, harbors microorganisms, interferes with sealer adhesion, and serves as a reservoir for bacteria that may penetrate dentinal tubules up to 200 µm (7–11). Its unpredictable thickness and high water content further complicate removal[9]. Hence, effective smear layer removal is critical for achieving a hermetic seal and long-term treatment success[1]. Chemical irrigants such as sodium hypochlorite (NaOCl), chlorhexidine gluconate (CHX), and EDTA are widely used[12]. Although 5.25% NaOCl offers strong antimicrobial and tissue-dissolving properties [13], it has notable drawbacks including cytotoxicity and inability to remove the smear layer completely [14,15]. Chemical irrigants can alter dentin’s organic and inorganic components, reducing microhardness and weakening tooth structure, particularly with higher NaOCl concentrations and EDTA chelation [16–18]. These limitations have driven interest in biocompatible alternatives.

Triphala, a traditional Ayurvedic formulation used for over 2,000 years [19,20], consists of Amalaki, Bibhitaki, and Haritaki and contains tannins, quinones, flavonoids, gallic acid, and vitamin C [3,21]. It exhibits strong antimicrobial activity[22], substantivity at 10% concentration [23], and chelating ability due to citric acid content [27]. Studies show 5% Triphala performs comparably to 17% EDTA, while 10% shows enhanced efficacy and 3% offers superior biocompatibility [3,28]. Triphala also causes less reduction in dentin microhardness than NaOCl and EDTA [29].

Irrigant delivery influences efficacy; side-vented needles improve distribution and reduce apical extrusion compared to open-ended needles [30,31]. SEM and Vickers microhardness testing are reliable methods for evaluating smear layer removal and dentin hardness [32–34]. Therefore, this study aimed to compare different Triphala concentrations on smear layer removal and dentin microhardness using two distinct needle designs.

Methodology

Study Method

The methodology of this study is divided as:

- Preparation of 10% dimethyl sulfoxide solution
- Preparation of 3, 5, and 10% triphala solution in 10% dimethyl sulfoxide
- Grouping of samples

Preparation of 10% Dimethyl sulfoxide: 30 ml of pure dimethyl sufoxide and 270ml of distilled water was measured in a measuring cylinder. 30 ml of 100% Dimethyl sulfoxide was carefully added to 270ml of distilled water and gently stirred using glass stir rod to prepare 300ml of 10% Dimethyl sulfoxide.

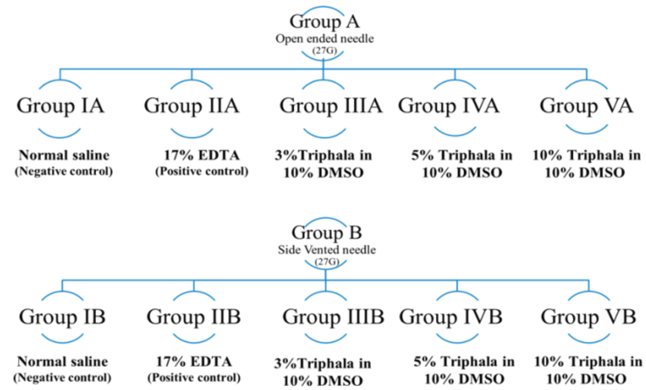
Preparation of 3% Triphala solution in 10% Dimethyl sulfoxide: 3g of Triphala powder is weighed in digital weigh (Lenon digital pocket scale) and added to 100ml of 10% Dimethyl sulfoxide to prepare 3% Triphala solution.

Preparation of 5% Triphala solution in 10% Dimethyl sulfoxide: 5mg of Triphala powder is weighed in digital weigh (Lenon digital pocket scale) and added to 100ml of 10% Dimethyl sulfoxide to prepare 5% Triphala solution

Preparation of 10% Triphala solution in 10% Dimethyl sulfoxide: 5mg of Triphala powder is weighed in digital weigh (Lenon digital pocket scale) and added to 100ml of 10% Dimethyl sulfoxide to prepare 10% Triphala solution.

Freshly extracted, non-carious permanent human mandibular first premolars were cleaned using 3% sodium hypochlorite and stored in 0.9% physiological saline until use. The teeth were decoronated below the cementoenamel junction to obtain a standardized root length of 10 mm. Working length was established 1 mm short of the apical foramen, and a glide path was prepared using a #15 K-file. Root canals were instrumented using nickel–titanium rotary files up to size 30 with a 6% taper in a crown-down manner.

Samples were randomly divided into two groups based on needle design (open-ended or side-vented).



One milliliter of irrigant was used after each instrument. The apical foramen was sealed to create a closed system. Final irrigation consisted of 5 ml of the respective irrigant over 3 minutes with dynamic activation, followed by 10 ml of distilled water.

For microhardness evaluation, specimens were mounted in acrylic and tested using a Vickers hardness tester at 400 µm from the canal lumen with a 200 g load for 15 seconds. For SEM analysis, roots were split, dehydrated, and evaluated at ×2000 magnification using Caron et al.'s smear layer scoring system [55].

Table 1: Scoring criteria of smear layer by Caron et al

Score	Evaluation
1	No smear layer and dentinal tubules open
2	Small amounts of scattered smear layers and dentinal tubules open

3	Thin smear layer and dentinal tubules partially open (characteristic image of crescent)
4	Partial covering with a thick smear layer
5	Total covering with a thick smear layer.

Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., will be used to perform statistical analyses.

Descriptive Statistics

Descriptive analysis of all the explanatory parameters will be done using frequency and proportions for categorical variables.

Inferential Statistics

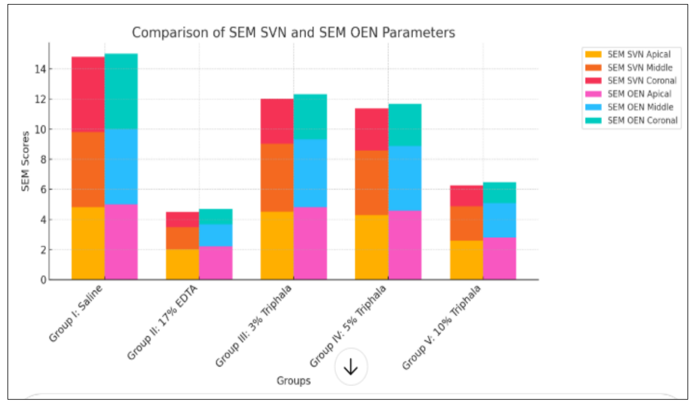
Unpaired t test and One way ANOVA will be used to compare the differences between the groups .The level of significance will be set at P<0.05.

And any other relevant test, if found appropriate during the time of data analysis will be dealt accordingly

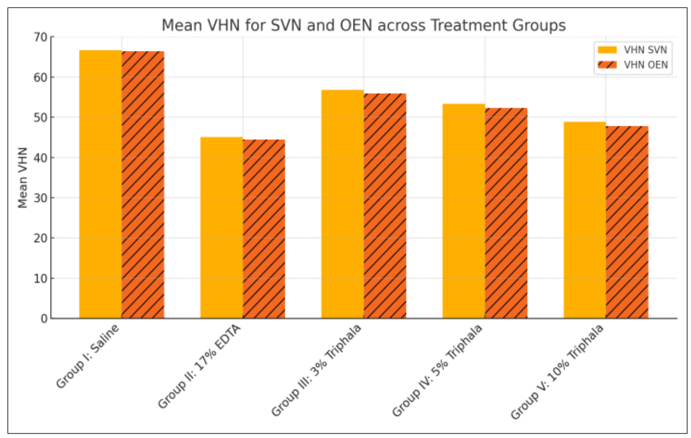
Result

Group I (saline) showed the poorest smear layer removal with the highest scores (mean = 5.0) across all root thirds. Group II (17% EDTA) demonstrated the best smear layer removal, particularly in the coronal third (mean = 1.000), followed closely by Group V (10% Triphala). Smear removal efficacy of Triphala increased with concentration. Microhardness values were highest in the saline group (VHN = 66.722 for SVN; 66.411 for OEN) and lowest in the EDTA group (45.111 for SVN; 44.433 for OEN). Among Triphala groups, 3% Triphala preserved dentin hardness better than 5% and 10%. Statistically significant differences were observed for smear layer removal and microhardness among all groups for both needle designs ($p < 0.001$), with high F-values for coronal regions ($F = 5318.105$), confirming the superior efficacy of EDTA and 10% Triphala.

Graph 1:

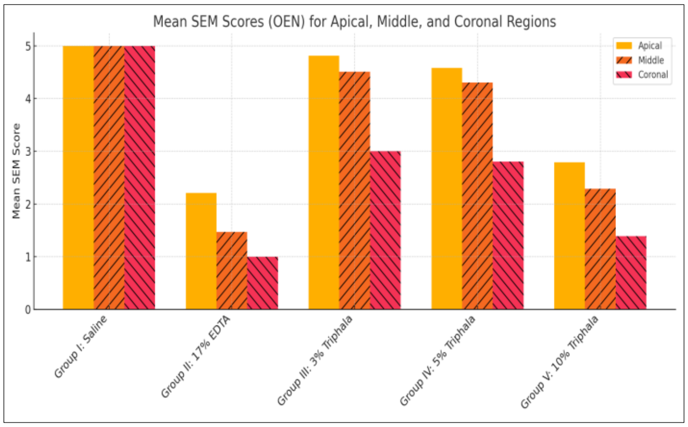


Graph 2:

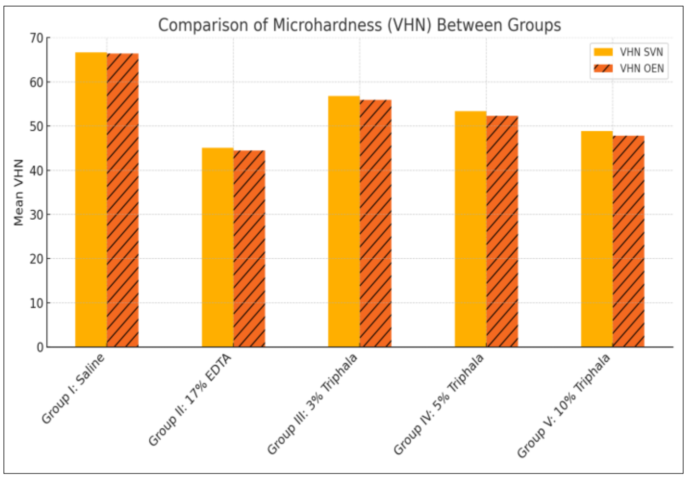


Graph 3:

Graph 4:



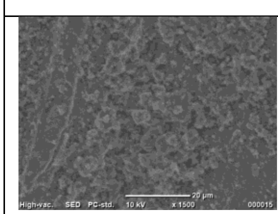
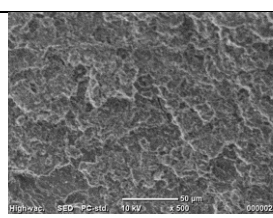
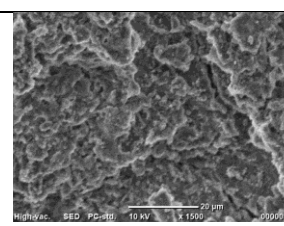
Graph 5:



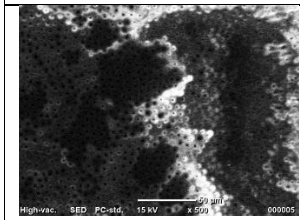
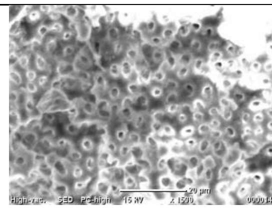
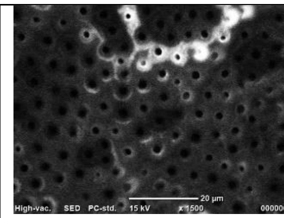
Discussion

Recent evidence supports smear layer removal to enhance canal sealing, reduce bacterial load, improve disinfection, and promote better bonding of filling materials, thereby improving long-term endodontic success [56]. The smear layer, composed of organic and inorganic debris produced during instrumentation, occludes dentinal tubules and restricts irrigant penetration, necessitating its removal for optimal treatment outcomes [30]. While chemical irrigants are effective, concerns regarding toxicity, allergic reactions, and antibiotic resistance have encouraged the exploration of biocompatible herbal alternatives [3].

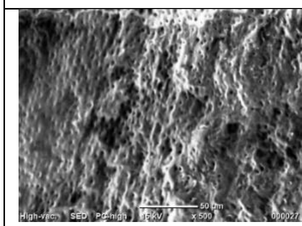
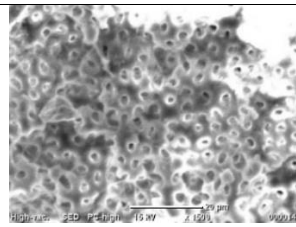
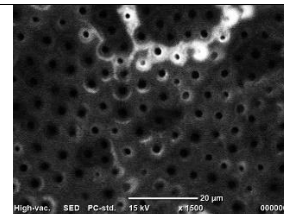
This in vitro study evaluated the smear layer removal efficacy of different Triphala concentrations, their effect on dentin microhardness, and the influence of needle design. Triphala was selected due to its phytochemical composition, including tannins, citric acid, gallic acid, and chebulinic acid, which provide antimicrobial and chelating properties essential for smear layer removal [18]. Three concentrations (3%, 5%, and 10%) were prepared using 10% DMSO to enhance dentinal penetration of phytochemicals [57,58]. Saline served as a negative control, showing minimal microhardness reduction [59], while 17% EDTA acted as the gold standard positive control for smear removal [60], despite its known dentin-weakening effects [44].

Group 1		
		
Apical	Middle	coronal

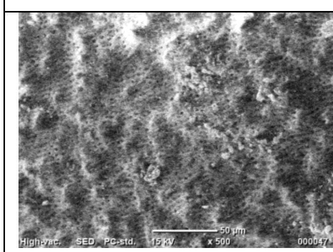
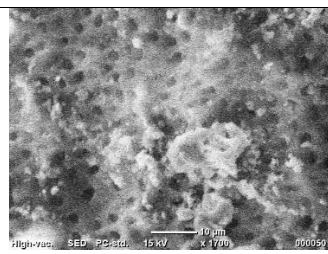
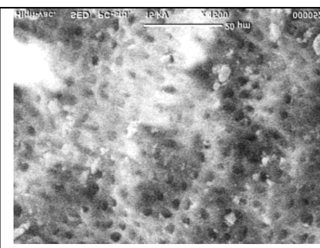
SEM images in negative control group

Group II		
		
Apical	Middle	coronal

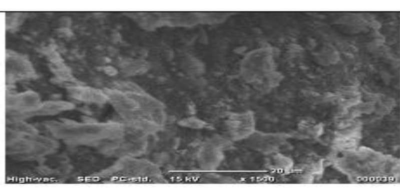
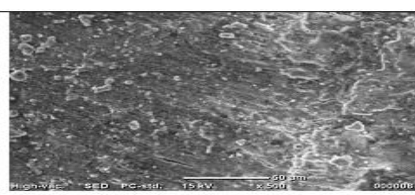
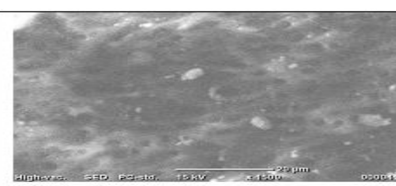
SEM images in Positive control group

Group V		
		
Apical	Middle	coronal

SEM images in 10% Triphala group

Group IV		
		
Apical	Middle	coronal

SEM images in 5% triphala group

Group III		
		
Apical	Middle	coronal

SEM images in 3% triphala group

Conclusion

Within the limitations of this in vitro study, 10% Triphala demonstrated the most effective smear layer removal among the tested herbal concentrations, showing results comparable to 17% EDTA in the coronal and middle thirds, with a clear concentration-dependent improvement over 5% and 3%. In terms of dentin microhardness, 3% Triphala preserved dentin hardness best, followed by 5% and 10%, whereas 17% EDTA caused the greatest reduction, indicating a higher risk of dentin weakening. Side-vented needles enhanced irrigant distribution, particularly in the apical third, and minimized apical extrusion compared to open-ended needles. Overall, 10% Triphala offers a favorable balance between smear layer removal and dentin preservation, supporting its potential use as a safer, biocompatible final irrigant in clinical endodontic practice.

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