DOI: 10.7860/JCDR/2022/58307.16879

Review Article

Dentistry Section

Smear Layer Removal Efficacy of Natural Root Canal Irrigants- A Literature Review

SEEMA DESHMUKH[1], INDIRA MYSORE DEVRAJ[2], ARUNDHATI BANERJEE[3]

ABSTRACT

An efficient chemomechanical preparation is essential for the success of endodontic treatment. There are various methods of instrumentation and irrigation, the canals are instrumented with either hand files or rotary. Chemical agents are used for irrigation during instrumentation to completely sterilise the canals. A lot of natural products are also used as irrigating agents as they have a lot of antimicrobial, anti-inflammatory, antioxidant and other biological properties. Several commonly used irrigants come with certain disadvantages. Certain chemicals like sodium hypoclorite can be toxic and weakens the dentine microstructure, but by using natural agents these side effects can be prevented. Less toxic and more biocompatible products are being increasingly used such as apple vinegar, citrus fruits, miswak, tulsi, chitosan, neem, turmeric, triphala etc. The natural preparations are derived from roots, seeds, leaves of plants preparations or shells of animals. This narrative review is aimed at highlighting various natural agents which can be considered as a potential adjunct for endodontic treatment.

Keywords: Antioxidants, Chemical debridement, Dentin hardness, Pulp tissue

INTRODUCTION

A strong association between the basic science of microbiology and the clinical science of successful endodontic practice has been identified and endorsed in literature [1]. In order to produce a sterile environment and a hermetic seal, root canal treatment relies on the elimination of infected pulpal tissues, bacteria, and their toxins. Chemomechanical preparation involves the utilisation of a chemical solution in conjunction with mechanical instrumentation to clean the root canal system [2]. The elimination of pulp remnants, microbial toxins and germs accomplished by chemomechanical debridement, is necessary for the success of root canal therapy [3]. Irrigation and instrumentation are used to achieve acceptable root canal cleaning [4]. During the instrumentation process, huge amounts of dentin debris combine with vital and necrotic pulp tissue remains, forming a smear layer with microorganisms and microbial toxins adhering to the root canal wall [4]. In the year 1975, McComb and Smith were the first to report the formation of a smear layer on instrumented root canals. According to the researchers this layer is made up of dentin fragments, bacteria, odontoblastic processes and necrotic pulp tissues [5].

Despite the proliferation of irrigants and irrigation techniques, the ever-difficult and problematic smear layer elimination needs to be looked upon. The smear layer's effect, its clinical implications of bacterial contamination is a highly debated subject among scientists who are continually in disagreement in Endodontics [6]. There is evidence in the literature that microorganisms and their metabolites present in the smear layer contribute to the endodontic treatment's ultimate outcome, either directly or indirectly. Persistent infections in these canal spaces are the main cause of many treatment failures. The obturated root canal system's apical and coronal closure is greatly improved by removing the smear layer [6]. Various methods like hand filing, rotary with EDTA, sodium hypochlorite and saline irrigation for removing intraradicular smears have been suggested [6]. Regardless of instrumentation, 35% or more of the root canal surfaces remain uninstrumented [6]. As a result, irrigation is an important aspect of root canal debridement since it enables cleaning beyond what root canal instrumentation alone can provide. Irrigants can help eliminate the smear layer from the root wall in addition to disinfecting it [7].

EDTA and sodium hypochlorite are the most commonly utilised irrigants for debridement and removal of the smear layer. Despite their tissue toxicity and dentine erosive effects, they serve as a standard reference. Erosion can sometimes be severe enough to expose the calcospherites' spherical surface [1]. As a result, a variety of novel root canal irrigants have been explored and tested for their capacity to effectively debride and remove the smear layer [1]. Ideally irrigant should have antimicrobial activity, can mechanically flush out debris from the canal, should be non toxic and biocompatible, should dissolve necrotic and vital pulp tissues, serve as lubricant, remove smear layer and have low surface tension to enable better penetration into dentin tubules [8].

Irrigation solutions are classified according to their common use [7].

A) Instrumentation auxiliary chemicals (these are substances that are utilised during instrumentation but do not require optimal physical properties, only chemical properties) like Sodium Hypochlorite (NaOCl), Ethylenediaminetetraacetic acid (EDTA), Chlorhexidine (CHX), etc.

B) Irrigating chemicals (Irrigating substances have appropriate physical features, such as a lower tension surface and reduced viscosity, and are used during irrigation aspiration procedures) such as Saline, Distilled Water, NaOCl, Mixture of Tetracycline, Acid and Detergent (MTAD) etc [7].

Need for Newer Root Canal Irrigants

In light of the safety concern, antibiotic-resistant bacteria, and no or minimal potential side effects, researchers are trying to rekindle their search for herbal alternatives [1]. Due to the antioxidant, anti-inflammatory, immune-modulatory, antibacterial, antifungal, antiviral, antioxidant, anticarcinogenic, and radical scavenging activity of the active ingredients, natural compounds such as herbal extracts are gaining great significance as endodontic irrigants [8]. Natural herbal medicines are being evaluated and used frequently as part of dental treatment methods due to their simplicity of availability, cost-effectiveness, and biocompatibility [6]. Researchers have been looking for safer and more patient-friendly herbal alternatives due to the progressive development in antibiotic-resistant strains, the side effects produced by the introduction of synthetic medications, and the risks linked with irrigants such as sodium hypochlorite [6].

NATURAL ROOT CANAL IRRIGANTS

Citrus Aurantifolia

Water, 6-8% citric acid, 2% potassium citrate, and other components make up 88% of *C. aurantifolia*. Citric acid is a basic ingredient in C. aurantifolia, thus researchers looked into it for a possible role in removing the endodontic smear layer; nevertheless, the results were mixed. Citric acid generally removes smear layer when used in higher concentration and for longer duration. But again long duration might bring about etching of the root canal dentine [9]. Citric acid, a weak organic acid, found in citrus fruits has been used on periodontal disease and instrumentation-affected root surfaces in the past to enhance cementogenesis and speed healing [10]. Early investigations found that using 6% citric acid as a final flush in instrumented root canals did not entirely eliminate the smear layer [11]. A 1 mol L^{-1} citric acid solution was just as effective as EDTA at eliminating the smear layer [10].

Furthermore, the role of natural fruit juices, such as Citrus aurantifolia (*C. aurantifolia*), on exposed root dentin surfaces in eliciting dentinal hypersensitivity has been proven, and it is associated to the elimination of the existing smear layer on the exposed dentin [9]. *C. aurantifolia* was quite effective at removing the smear layer, as seen by Scanning Electron Microscopy (SEM) images of the root canal walls, which revealed cleaner canal walls in all three thirds [11], but the smear layer could not be completely removed from the apical 3rd with sodium hypochlorite solution tested [4].

Apple Vinegar

Apple vinegar has been recommended as an irrigant in the chemomechanical process because of its promising outcomes that are similar to EDTA [3]. Although it has a high quantity of maleic acid, it has a good biocompatibility [4]. Apple vinegar is a powerful chelating agent that also has a bactericidal impact on bacteria. On investigating the performance of apple vinegar versus 17% EDTA in eliminating smear layer and it was found that apple vinegar was more successful in removing smear layer when used for one minute as a final rinse without changing the calcium level of intraradicular dentin [3]. The presence of maleic acid in apple vinegar explains these outcomes [3]. Maleic acid is a mild organic acid found in grapes, cherries, watermelons, and in vegetables such as broccoli and carrots. It has smear layer removal characteristics when used as an acid etchant in restorative dentistry [12]. The results of a study demonstrated that 7% maleic acid was more effective than 17% EDTA and a diode laser combination in removing smear layer [13].

Castor Detergent+Papain Enzyme

Papain is a debris removing enzyme. It exclusively affects the damaged tissues, as healthy tissues lack the 1-antitrypsine plasmatic antiprotease that prevents proteolysis. Castor oil comes from the seeds of the Ricinus communis plant and is a phytotherapeutic polymer [14]. The presence of chelating agent increases the proteolytic activity of papain enzyme in this solution, as Chu CM et al., (2002) discovered that when heavy metal chelating agents are present, papain activity is boosted and activated [15].

The MCP solution (which contains 20% sodium castorate and 4% papain enzyme) is a single solution that removes organic and inorganic waste through chelation and proteolysis. The MCP solution has the capacity to partially remove both. EDTA and NaOCL are unable to cause smear layer removal entirely without causing dentin erosion, but MCP solution was able to partially cause smear layer removal without causing dentin erosion [14].

Orange Oil

The major component of orange oil is d-Limonene [16]. Orange peel extract is made up of 88% water, 6–8% citric acid, 2% potassium citrate, and other ingredients. Citric acid is the main ingredient, thus researchers looked into it for a possible role in removing endodontic smear layer; nevertheless, there was mixed outcome. In comparison to the control group, orange peel extract had a lower efficacy in removing smear layers. The lesser efficacy could be due to irrigants not reaching the deeper apical region due to the high surface tension of the oil-based nature of orange peel extract irrigant, or it could be due to irrigants not reaching the required number of acid metabolites for elimination [8].

Green Tea Polyphenol

Catechins (polyphenols) are important ingredients of green tea extract, which have increased action against a wide range of microorganisms and have also been discovered to be a good chelating agent [9] but showed less smear layer removal efficacy, possibly due to the lack of acid metabolites required for removal [16].

Salvadora Persica

Salvadora persica (S. persica) or miswak, is a Salvadoraceae family member that has been used to supply toothbrushes [17]. It is also known as the toothbrush tree. Even when used without any other tooth cleaning treatments, S. persica has been scientifically demonstrated to be effective in preventing tooth decay [18].

The 5 mg/mL S. persica solution out performed the 1 mg/mL solution significantly. Furthermore, the 5 mg/mL S. persica solution was just as effective at removing the smear layer from the coronal third of the canal wall as 17% EDTA. The acid component of S. persica (stearic acid), may react with calcium in the dentin and act as a chelating agent, could explain its smear layer removing capacity [17].

Tea Tree Oil

Tea tree oil, also known as *Melaleuca alternifolia*, is a native Australian plant whose oil has a variety of qualities that make it ideal for use in dentistry. It has antibacterial and antifungal properties. It has a modest solvent activity and hence, has the potential to be used in root canal therapy. Although its high surface tension does not completely remove the smear layer from all the regions of the root canal. Hence, it is better to switch to a non oily tea tree oil extract because a material with a lesser surface tension would be more useful [19].

Turmeric

Turmeric has a wide range of biological effects, including antioxidant, anti-inflammatory, antifungal, and antibacterial properties [20]. *Curcuma longa* (turmeric) aqueous extract, on the other hand, showed good antifungal activity against *Candida Albicans* [21]. Turmeric had diffuse but adequate antibacterial action against E. faecalis in this trial as well [22]. Turmeric can also help to reduce smear layer and is a potential root canal irrigant that can be used in conjunction with other irrigating treatments to effectively remove smear layer [21]. Turmeric, being a biocompatible substance, might be thought of as a good alternative to the often employed chemical irrigants [20].

Chitosan

Chitosan is a amino-polysaccharide co-polymer of glucosamine and N-acetylglucosamine formed by alkaline partial deacetylation of chitin derived from crab and shrimp shells. It is a natural polysaccharide with biocompatibility, bioadhesion, biodegradability, and a-toxicity to human cells, as well as a high chelating property for various metal ions and a low cost, making it a popular alternative to sodium hypochlorite [23]. The chelating property of chitosan reported, suggests that it acts on the inorganic portion of the smear layer, allowing it to be removed more easily.Under SEM, 0.2% chitosan

was found to be effective in removing the smear layer in all three regions (coronal, middle, and apical) of the root surface [19].

Morinda citrifolia

Morinda Citrifolia Juice (MCJ) offers a wide spectrum of medicinal properties, including antibacterial, antiviral, antifungal, and analgesic properties. It has also been discovered to be a herbal irrigant that, when administered at a concentration of 6%, is efficient in removing smear layers. Because it is a biocompatible antioxidant with minimal side effects, the use of MCJ as root canal irrigant could be beneficial. Milder acids in MCJ may be responsible for its stated ability to remove smear layers. The pH of MCJ at 6% concentration is 3.5. With either watering method, MCJ 6 % proved ineffective in removing the smear layer [24].

Terminalia chebula

Terminalia chebula, often known as kadukka, is a medicinal plant. One of the key ingredients in Triphala is *Terminalia chebula*, which has antiviral and antibacterial properties, and its fruits are high in citric acid, which may help with smear layer removal. It is used to cure oral illnesses because it includes hydrolysable tannins such as gallic acid, chebulic acid, corilagin and chebulagic acid. Tannic acid can be adsorbed to dental hydroxyapatite, which is linked to the surface of bacterial cells, causing protein denaturation and bacterial cell lysis [25].

Triphala

Triphala (TPL) is a classic ayurvedic herbal composition. It is made up of three medicinal plants: *Terminalia chebula*, *Terminalia bellerica* and *Phyllanthus emblica*. Tannins and other phenolic compounds are found in *Phyllanthus emblica*. It also contains flavanoids and ascorbic acid. The cleaning effect of TPL strongly relates to these acid components [25]. No irrigation solution tested could completely remove smear layer from apical thirds [4]. Irrigating solutions containing 0.005% TPL are effective [1]. Triphala showed enhanced smear layer clearance and moderate apical third erosion [1].

Neem Leaf

With its antioxidant and antibacterial qualities, neem leaf extract has been shown to be effective against *Candida albicans* and *Enterococcus faecalis*, making it a potential root canal irrigation agent [16]. It had the highest amount of smear layer removal efficiency compared to all the other groups in the study due to the presence of acid metabolites, flavanoids [16]. Nimbin, nimbidin, and nimbidol, which are active ingredients in neem leaf extract, demonstrated significant smear layer removal efficacy. Neem leaf extract has significant antibacterial efficiency against E. faecalis and significant smear layer removal efficacy when compared to 17% EDTA [26]. It is discovered that neem leaf extract was effective in removing smear layers. Due to the presence of acid metabolites, flavanoids, neem leaf extract displayed the maximum degree of smear layer removal efficacy in the present investigation [27].

German Chamomile

The analgesic, anti-inflammatory, antispasmodic, antibacterial, and sedative qualities of German chamomile have been used for medical reasons for centuries. Chamomile is beneficial as a mouthwash for treating mild infections and mouth irritations, and it is also found in several toothpastes. G. chamomile preparations, on the other hand, were said to clean the coronal and middle third of the brain better. GCE is a dried flower extract of the *Matricaria recutita* plant, also known as "German chamomile." This extract possesses antibacterial properties, as well as anti-inflammatory and antioxidant properties. Chamazolene, alpha-bisabolol, and acids such aschlorogenic acid, capric acid, caprylic acid, o-coumaric acid, p-coumaric acid, dihydroxybenzoic acid, and other components have been discovered through chemical study of GCE [28]. With a pH of 7.6, it also contains acids such capric acid, o-coumaric acid, p-coumaric acid, dihydroxybenzoic acid, and caprylic acid. Chamomile's cleansing effect could be due to these acid components [28]. When used with either continuous or syringe and needle irrigation systems, GCE 6 % proved successful in removing the smear layer. The severe demineralization observed with 17 % EDTA did not occur with GCE 6 % [24].

Tulsi

Eugenol (70%), Oleanolic acid, Aerosol acid, element (11%), caryophyllene, and germacrene are the main constituents of *Ocimum sanctum* (Tulsi), a plant native to India. The anti-inflammatory, immunological modulatory, antibacterial, antifungal, antiviral, antioxidant, and anticarcinogenic activities of the ingredients of these commonly used herbal irrigants are well-documented. Tulsi's active components, such as eugenol, ursolic acid, carvacrol, and oleanolic acid, demonstrated comparable antibacterial effectiveness. Eugenol (l-hydroxy2-methoxy-4-allylbenzene), an active ingredient discovered in *Ocimum sanctum* L., has been found to be responsible for tulsi's therapeutic properties [26]. Tulsi has antibacterial, anti-inflammatory, and antioxidant effects, according to studies [26,29].

In comparison to tulsi, NaOCl exhibited the less efficacy, and the difference in smear layer elimination was determined to be highly significant. Tulsi irrigants can be used efficiently as irrigants in primary teeth because they can eliminate the smear layer. This could be attributed to the extracts' active components. In apical slice, almost all of the dentinal tubules were open. Due to the presence of acid metabolites, flavanoids, tulsi leaf extract demonstrated the largest level of smear layer removal efficacy compared to all the other groups in investigation by Sharma K and Dhawan R [27].

Passion Fruit Juice

Antimicrobial activities have been discovered in Passion Fruit Extract (PFE) irrigant. In the coronal and middle thirds of the root, 30% PFE caused less erosion and statistically significant smear layer reduction. Smear layer removal was effective in all three thirds of the root when coupled with 17 % EDTA [30].

Nutmeg

The main constituents of Nutmeg have been found to be terpenes, alpha pinene, beta pinene, trimyristin, myristic acid, neolignan (myrislignan), alkyl benzene derivatives (myristicin, elemicin, safrole, etc.,), and macelignan. NaOCl had less efficacy in comparison with nutmeg and the difference in the smear layer removal was found to be highly significant [31].

Phytic Acid

Phytic acid (IP6, inositol hexakisphosphate) is a primary phosphorus storage form found in bran and plant seeds, and it plays a role in a range of cellular functions. It possesses a lot of negative charges, which makes it a good chelator for multivalent cations like calcium (Ca^{++}), iron and magnesium [32]. It also has antiplaque and cariostatic properties. In comparison to EDTA, phytic acid causes smear layer removal and has been shown to be more biocompatible and less cytotoxic. It is discovered that phytic acid was more successful than EDTA at removing the smear layer from NaOCl-treated dentin surfaces and instrumented root canals, with no adverse effects on pulpal cells. The pH of a 1 % phytic acid solution was found to be around 1.2, which could explain why calcium ions were extracted more efficiently [32]. Result of various studies [3,4,9-14,16,17,20,23-28,31,32] are presented in [Table/Fig-1].

Year	Author	Irrigants used	Method of assessment	Conclusion
2000	Di Lenarda R et al., [10]	Citric acid (Citrus aurantifolia) and NaOCl.	SEM	1 mol L^{-1} citric acid solution was as effective in removing smear layer as EDTA.
2010	Ballal NV et al., [12]	Maleic acid (Apple vinegar) and EDTA	SEM	Results showed that all the three concentrations of maleic acid were better than EDTA (RC- prep) in removing smear layer.
2010	Prabhakar J et al., [25]	Triphala and green tea polyphenol to 2.5% sodium hypochlorite (NaOCl) solution	SEM	The efficacy of Triphala to remove smear layer was superior to NaOCl alone but less than NaOCl combined with EDTA.
2012	Hasheminia SM et al., [13]	17% EDTA, 5% maleic acid (Apple vinegar), and Nd:YAG laser	SEM	There was no significant difference between smear layer removal of 17% EDTA and 5% maleic acid.
2012	Balto H et al., [17]	Ethanolic Salvadora persica extract and EDTA	SEM	The 5 mg/mL S. persica solution was as effective as 17% EDTA in removing the smear layer from the coronal third of the canal wall.
2014	Zakarea NAA et al., [14]	Mixture of (castor detergent and papain enzyme) MCP	SEM	Solution had the ability to remove the smear layer partially at the three levels of a root canal without dentin erosion.
2015	Chhabra N et al., [9]	C. aurantifolia and Sapindus mukorrossi extracts	SEM	The combination of two extracts in 2:1 ratio was slightly better than 1:1 ratio and the smear layer removal efficacy was further improved when accompanied with sonic agitation.
2016	Chhabra N et al., [11]	Citrus aurantifolia and Sapindus mukorossi extracts	SEM	Experimental irrigant proves to be an effective alternative to various synthetic irrigants
2017	Sowjanyaa J et al., [28]	Ethylenediaminetetraacetic acid, Triphala, and German chamomile	SEM	The most effective removal of smear layer occurred with the use 17% EDTA as a final rinse followed by the use of Triphala. G. chamomile did not produce satisfactory results
2017	Jagzap JB et al., [32]	17% EDTA, Q-MIX, and Phytic acid	SEM	17% EDTA showed promising results in coronal and middle third of root canal followed by QMIX and then phytic acid.
2017	Sebatni MA and Kumar AA [16]	Green tea extract, orange oil, and neem leaf extract	SEM	The canals treated with neem leaf extract exhibited significant smear layer removal when compared to those treated with orange oil, sodium hypochlorite, and green tea extract
2018	Kumar A et al., [26]	Azadirachta indica (neem) and Ocimum sanctum (tulsi) extract	q PCR method and SEM	Neem leaf extract has a significant antimicrobial efficacy against E. faecalis and significant smear layer removal efficacy compared to 17% EDTA
2018	Sulgante S et al., [20]	Curcuma longa (Turmeric) and citric acid	SEM	EDTA (17%) and NaOCl (3%) were most efficient in smear layer removal at all the levels compared to citric acid and turmeric
2019	Saha S et al., [24]	6% German chamomile extract (GCE) and 6% Morinda citrifolia juice (MCJ), in removal of smear layer.	SEM	The most effective smear layer removal in the coronal part was observed with SAF-EDTA and SAF-GCE, followed by WO-EDTA
2020	Karteek BS et al., [4]	Salvadora persica (S.persica), Triphala, Citrus aurantifolia (CA) on smear layer removal	SEM	17% EDTA was better in all the sites (coronal, middle, apical) when compared with S.persica (5mg/mL), Triphala (5mg/mL) and Citrus aurantifolia (5mg/mL) extracts.
2020	Abdelghany ME et al., [3]	Apple Vinegar and 17% EDTA	SEM	Apple vinegar presented similar smear layer removal efficiency from intraradicular dentin compared to 17% EDTA when used as final rinse
2020	Badr M and Elhafez E [23]	Salvadora persica (miswak-siwak) and chitosan) versus Saline and NaOCl	SEM	Saline and NaOCl groups showed the highest mean values then Chitosan group, whereas Siwak had the least value.
2020	Mali S et al. [31]	Myristica fragrans – Nutmeg, Terminalia chebula –Myrobolan, Ocimum sanctum-tulsi, and 2.5% Sodium Hypochlorite (NaOCl) on the removal of the smear layer	SEM	All herbal extracts were found to be significantly effective than 2.5% NaOCl.
2020	Ranjitha GR, et al., [8]	Neem extract, Orange peel extract, Tulsi extract 5.25% Sodium Hypochlorite	SEM	Neem extract can be considered as an efficient smear layer removal irrigant in the apical third of the root canal.
2020	Sharma K and Dhawan R [27]	Neem leaf extract, tulsi leaf extract, green tea extract	SEM	Highest smear layer removal efficacy was seen with neem extract in canals treated.

[Table/Fig-1]: In-vitro studies with natural root canal irrigants.
EDTA: Ethyelenediamine tetraacetic acid; RC-prep: Root canal preparation; NaOCl: Sodium hypochlorite SEM: Scanning electron microscopy; SAF-EDTA =Self-adjusting file EDTA; SAF-GCE=Self- Adjusting file German chamomile extract; WO-EDTA = Wave one (WO)-EDTA

CONCLUSION(S)

Citrus aurantifolia, apple vinegar, Salvadora persica, nutmeg, tulsi, neem, German chamomile, triphala are mild acidic or contain acid metabolites which can be useful for dissolving smear layer. Many of them for example Morinda citrifolia, green tea, additionally contains antioxidant properties which contributes to better removal of the smear layer. Moreover, the chelating of papain, green tea has also proved to be quite beneficial. Despite the fact that only a few natural products have been proven to be effective. Different combinations and concentrations may improve their efficacy and use for biofriendly smear layer removal. Additional animal models and in-vivo studies are need to be conducted. Natural extracts' effect on the long-term prognosis of endodontic treatment needs to be explored through further research.

REFERENCES

[1] Paul J, Prakash V, Mensudar R, Sukumaran VG, Subbiya A, Mitthra S. Evaluation of three root canal irrigants in their ability to remove smear layer with significantly least erosio-ansem analysis. Smear layer removal. Int J Aquat Sci. 2021;12(3):03.

[2] Alharbi A, Aliuddin S, Alharbi TA, Alharbi S, Alanzi AO, Alharbi AA. Herbal endodontic irrigants. Int J Prev Clin Dent Res. 2017;4(4):311-14. Doi: https://doi.org/10.5005/jp-journals-10052-0133.

[3] Abdelghany ME, Kamel WH, Bastawy HA. Efficacy of Apple vinegar as final irrigating solution in removing smear layer using XP-Endo finisher file. Al-Azhar Dent J Girls. 2020:7(1):95-103. Doi: https://doi.org/10.21608/adjg.2019.7841.1117.

[4] Karteek BS, Reddy KS, Prasad SD, Reddy MS, Jain A, Lakshmi C. Evaluation of efficacy of three herbal extracts on smear layer removal during root canal preparation using scanning electron microscope: An in vitro study. Int J Dent Sci Innov Res. 2020,3(4):240-53.

[5] Alamoudi RA. The smear layer in endodontic: To keep or remove-an updated overview. Saudi Endod J. 2019;9(2):71-81.

[6] Susan AC, Bharathraj AR, Praveen M, Kumar NSM, Karunakaran JV. Intraradicular smear removal efficacy of triphala as a final rinse solution in curved canals: A scanning electron microscope study. J Pharm Bioall Sci. 2019;11:S420-28. Doi: https://doi.org/10.4103/JPBS.JPBS_55_19. PMID: 31198380.
[7] Vineet AS, Rajesh M, Sonali, Mukesh. A contemporary overview of endodontic irrigants-A review. J Dent App. 2014;1(1):105-15.
[8] Ranjitha GR, Mutha SR, Anithakumari R, Vikram R, Kumar N, Shivekshith AK. Comparative evaluation of smear layer removal efficacy of three herbal irrigants in the apical third of the root canal: An in vitro scanning electron microscopic study. SRM J Res Dent Sci. 2020;11:61-5. Doi: https://doi.org/10.4103/srmjrds.srmjrds_2_20.
[9] Chhabra N, Gyanani H, Kamatagi L. Smear layer removal efficacy of combination of herbal extracts in two different ratios either alone or supplemented with sonic agitation: An in vitro scanning electron microscope study. J Conserv Dent. 2015:18(4):374-78. Doi: https://doi.org/10.4103/0972-0707.164035. PMID: 26430300.
[10] Di Lenarda R, Cadenaro M, Sbaizero O. Effectiveness of 1 mol L-1 citric acid and 15% EDTA irrigation on smear layer removal. Int Endod J. 2000;33(1):46-52. Doi: https://doi.org/10.1046/j.1365-2591.2000.00273.x. PMID: 11307473.
[11] Chhabra N, Gyanani HC, Patel B, Gangaramani S, Desai K. A Novel combination of Herbs as chelating agents: An in vitro SEM evaluation. Orig Res Artic Indian J Conserv Endod. 2016;1(2):47-51.
[12] Ballal NV, Kundabala M, Bhat KS. Evaluation of the efficacy of various concentrations of maleic acid and edta in removal of smear layer- An sem study. Int J Clin Dent. 2010;3(4):225-34.
[13] Hasheminia SM, Birang R, Feizianfard M, Nasouri M. A comparative study of the removal of smear layer by two endodontic irrigants and nd:yag laser: A scanning electron microscopic study. ISRN Dent. 2012:2012:01-07. Doi: https://doi.org/10.5402/2012/620951. PMID: 22844605.
[14] Zakarea NAA, Mohamad TH, Taqa AA, Chumbley S, Al-Juaid S, Balto H. A newly prepared solution for the removal of the smear layer. Int J Dent Sci Res [Internet]. 2014:2(1):19-26.
[15] Chu CM, Awang B, Duduku K, Tie SH. Effect of ionic and non ionic surfactants on papain activity. Borneo Sci. 2002;12:71-77.
[16] Sebatni MA, Kumar AA. Smear layer removal efficacy of herbal extracts used as endodontic irrigants: An in vitro study. J Endod. 2021;29(1):35-38.
[17] Balto H, Ghandourah B, Al-Sulaiman H. The efficacy of Salvadora persica extract in the elimination of the intracanal smear layer: A sem study. Saudi Dent J [Internet]. 2012;24(2):71-77. Doi: https://doi.org/10.1016/j.sdentj.2012.01.002. PMID: 23960532.
[18] Salehi P, Danaie SHM. Comparison of the antibacterial effects of persica mouthwash with chlorhexidine on streptococcus mutans in orthodontic patients. J Pharm Sci (US). 2006;14:178-82.
[19] Mallika, Aggarwal N, Gupta P, Abrol A, Abrol N. Evaluation of the effect of different irrigant solutions on the smear layer removal on root canal dentine at coronal middle and apical root sections using SEM study. Int J Curr Res. 2019;11(04):2867-72.
[20] Sulgante S, Ratnakar P, Patil VS, Rairam S. Efficacy of chemical and herbal endodontic irrigants in smear layer removal from root dentin-A comparative in-vitro sem study. Int J Sci Res. 2018;7(6):285-88.
[21] Amalraj A, Pius A, Gopi S, Gopi S. Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives: A review. J Trad Comp Med. 2017;7(2):205-33. Doi: https://doi.org/10.1016/j.jtcme.2016.05.005. PMID: 28417091.
[22] Neelakantan P, Subbarao C, Subbarao CV. Analysis of antibacterial activity of curcumin against Enterococcus faecalis. Int J Curr Res. 2011;3(9):37-41
[23] Badr M, Elhafez E. Comparison of antibacterial effect and smear layer removal of herbal versus traditional irrigants- An in vitro study. Egypt Dent J. 2020;66(3):1863-71. Doi: https://doi.org/10.21608/edj.2020.28284.1104.
[24] Saha S, Singh R, Bhardwaj A, Vijaywargiya P, Billore J, Saxena D. Efficacy of smear layer removal by two Ayurvedic herbal irrigants, using continuous vs. syringe and needle irrigation. J Endod. 2019;31(1):72-77. Doi: https://doi.org/10.4103/endo.endo_28_18.
[25] Prabhakar J, Senthilkumar M, Priya MS, Mahalakshmi K, Sehgal PK, Sukumaran VG. Evaluation of antimicrobial efficacy of herbal alternatives (triphala and green tea polyphenols), mtad, and 5% sodium hypochlorite against enterococcus faecalis biofilm formed on tooth substrate: An in vitro study. J Endod [Internet]. 2010;36(1):83-86. Doi: https://doi.org/10.1016/j.joen.2009.09.040. PMID: 20003940.
[26] Kumar A, Sarthaj AS, Antony SM. Comparative evaluation of antibacterial and layer removal efficacy of two different herbal irrigants - An in vitro study. Int Health Res J. 2018;1(11):350-54. Doi: https://doi.org/10.26440/IHRJ/01_11/145.
[27] Sharma K, Dhawan R. Efficacy of herbal extracts in removal of smear layer: An in-vitro study Int. J. Sci. Res. 2021(2277):61-63.
[28] Sowjanyaa J, Thomas T, Chandana CS. Comparative evaluation of the efficacy of smear layer removal by ethylenediaminetetraacetic acid, Triphala, and German chamomile as irrigants- A scanning electron microscopy study. J Adv Pharm Educ Res. 2017;7(3):267-71.
[29] Ghonmode WN, Balsaraf OD, Tambe VH, Saujanya KP, Patil AK, Kakde DD. Comparison of the antibacterial effciency of neem leaf extracts, grape seed extracts and 3% sodium hypochlorite against E. faecalis – An in vitro study. J Int Oral Health 2013;5:61-66.
[30] Vinothini DV. Effect of passion fruit juice in removal of smear layer in root canal of ex vivo human teeth: A scanning electron microscopic study. Ann SBV. 2018;7(1):79-79. Doi: https://doi.org/10.5005/jp-journals-10085-7196.
[31] Mali S, Singla S. Tyagi P, Sharma A, Talreja N, Gautam A. Comparative evaluation of the efficacy of different herbal irrigants on the removal of smear layer of primary teeth: A SEM study. J Indian Soc Pedod Prev Dent. 2020:38:374-80.
[32] Jagzap JB, Patil SS, Gade VJ, Chandhok DJ, Upagade MA, Thakur DA. Effectiveness of three different irrigants- 17% ethylenediaminetetraacetic acid, Q-MIX, and phytic acid in smear layer removal: A comparative scanning electron microscope study. Contemp Clin Dent. 2017;8:459-63. Doi: https://doi.org/10.4103/ccd.ccd_524_17. PMID: 29042735.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Pediatric and Preventive Dentistry, JSS Dental College and Hospital, JSS Academy of Higher Education and Research, Mysuru, Karnataka, India.
2. Associate Professor, Department of Pediatric and Preventive Dentistry, JSS Dental College and Hospital, JSS Academy of Higher Education and Research, Mysuru, Karnataka, India.
3. Post Graduate Student, Department of Pediatric and& Preventive Dentistry, JSS Dental College and Hospital, JSS Academy of Higher Education and Research, Mysuru, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Mysore Devraj Indira,
JSS Medical Instituions Campus, Sri Shivarathreeswara Nagar, Bannimantap,
Mysore-570015, Karnataka, India.
E-mail: drindiramd@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jun 10, 2022
- Manual Googling: Aug 02, 2022
- iThenticate Software: Aug 24, 2022 (19%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Jun 07, 2022**
Date of Peer Review: **Jun 24, 2022**
Date of Acceptance: **Aug 26, 2022**
Date of Publishing: **Sep 01, 2022**