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Review Article

REMOVAL OF INTRACANAL MEDICAMENTS – A REVIEW

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ABSTRACT

Although some authors have questioned the benefit of placing inter-appointment intracanal medicaments, calcium hydroxide is still widely and routinely used due to its perceived benefits in disinfecting the root canals, and in rendering the soft tissue debris more susceptible to dissolution by subsequent use of sodium hypochlorite irrigant in the next appointment. After fulfilling its purpose, and prior to root canal obturation, removal of the medicament dressing is mandatory, as its remnants may mechanically block the apical area of the root canal system and also affect the viscosity, working time, integrity, dentin tubule penetration, and adhesion of root canal sealers. The removal of medicaments from the root canal space is challenging, because it should ideally be placed deep and densely, so that its biological effects can be exerted in close proximity to the appropriate tissues.

Keywords: Intracanal Medicaments, Intracanal Irrigants, Ultrasonics, Passive Irrigation, Canal Brush.

INRODUCTION

Most root canals contain viable microorganisms after completion of chemo-mechanical preparation at the end of the first appointment[1]. Inter-appointment antimicrobial medication acts to inhibit proliferation and eliminate surviving bacteria, as well as minimize ingress through leaking restorations[2]. Role of intracanal medicaments becomes more relevant in the treatment of pulpal necrosis and apical periodontitis[1].

The most widely and routinely used intracanal medicament is calcium hydroxide [$Ca(OH)_2$] because it controls bacteria in the canal environment, renders the necrotic tissue susceptible to solubilizing action of sodium hypochlorite (NaOCl) at the next appointment, achieves a more thorough instrumentation due to longer overall time used for treatment, promotes drying of weeping periapical lesions, enables apexification, treats root resorption, and has good biocompatibility[1,2].

Types

The various intracanal medicaments used in endodontics are[1,2]

1. Calcium hydroxide;
2. Chlorhexidine digluconate;
3. Triple-antibiotic paste (Metronidazole+Ciprofloxacin+Minocycline);
4. Corticosteroid-antibiotic paste: Ledermix;
5. Phenolic compounds: phenol, para-monochlorophenol, thymol, cresol;
6. Formocresol (Formaldehyde);
7. Halogens: chloramine-T, IKI (Iodine-Potassium-Iodide);
8. Bioactive glass;

Newer irrigants like Propolis has also been used as intracanal medicament[3].

NEED FOR REMOVAL OF INTRACANAL MEDICAMENTS

Before root canal obturation, the medicament that has been applied to the root canal should be removed. Medicament residue on canal walls hinders sealer penetration into dentinal tubules[4], and leads to unfavourable interaction between sealer and medicament[5].

$Ca(OH)_2$ reduces canal permeability by interacting with dentin, thus promoting formation of calcium-carbonate particles and interfering with sealing ability of endodontic cement[6]. $Ca(OH)_2$ has been proven to interact with the commonly used zinc oxide eugenol (ZnOE) containing sealer. The sealer layer in contact with $Ca(OH)_2$ exhibits gradual reduction in viscosity, with resultant resistance to placement of gutta-percha cone and inability of placement upto working length within root canals. Clinically, this effect is manifested as rapid setting reaction and reduced flow. Additionally, the set sealer will be poorly cohesive and granular. The reason for this is the preferential interaction of $Ca(OH)_2$ with eugenol leading to formation of calcium-eugenolate, with unreacted residual eugenol. Spectroscopy has shown this to be a disorganized layer. Presence of such remnants in critical (apical) areas affects clinical performance of the sealer[5,6].

Porkaew *et al.* has reported that teeth dressed with $Ca(OH)_2$ paste and then obturated, have significantly less leakage than unmedicated controls. This finding was explained on the possibility of residual $Ca(OH)_2$ being incorporated into the sealer during obturation, which may lead to decreased sealer permeability. Additionally, $Ca(OH)_2$ is transported or mechanically forced into the dentinal tubules, thus blocking them and reducing dentinal permeability[7].

Kim *et al.* has contradicted this theory reasoning that reduced dentin permeability is unrelated to improved apical seal because leakage occurs at three interfaces, namely, between the sealer and dentin, within the sealer itself, and between the sealer and gutta-percha cone. Additionally, calcium-eugenolate is more soluble, less sealing, and leads to greater film thickness[8].

Although an apical plug with $Ca(OH)_2$ has been advocated for its prolonged antimicrobial activity after filling of the canal space[9], it is preferable to remove it as it might enhance apical leakage, because $Ca(OH)_2$ is believed to be diluted in contact with tissue fluids[10].

Barbizam *et al.* reported lower bond strength values between Epiphany™ sealer (a resin-based sealer) and dentin after use of $Ca(OH)_2$ medicament, suggesting that $Ca(OH)_2$ residues left in the canal space could have interfered with sealer adhesion to root dentin[11]. Renovato *et al.* has suggested that $Ca(OH)_2$, being of basic character, promotes neutralization of acid monomers within the sealer, reducing its ability to hybridize dentine. These changes led to a decrease in the area of contact between sealer and dentine during obturation, thus affecting bond strength[12].

FACTORS AFFECTING REMOVAL EFFICIENCY OF MEDICAMENTS

1. *Variations in root canal morphology:* Various anatomical complexities of the root canal system pose challenges to cleaning and shaping. Removal of $Ca(OH)_2$ residues from irregular canal walls is difficult[13]. In straight root canals, it was shown that recapitulation with master apical file (MAF) in combination with irrigation resulted in improved removal of $Ca(OH)_2$ when compared to irrigant flush alone[14]. Rotary NiTi-instruments facilitated removal of $Ca(OH)_2$ from curved root canals without affecting root canal anatomy[15].

2. *Irrigating solution used:* NaOCl is ineffective in removing $Ca(OH)_2$ as it lacks chelating ability; it merely removes superficial debris[1,16]. Chelators like EDTA neutralizes $Ca(OH)_2$ residues, but these residues must then be flushed out with NaOCl, or a neutral agent likes saline[17,18].

3. *Medicament formulation (physical state, concentration, excipients used):* Physical state of the medicament may affect its removal. Calt *et al.* found the removal of Temp Canal to be very difficult due to its hardness[4].

According to Lambrianidis *et al.*, $Ca(OH)_2$ content or concentration has no influence on its removal efficiency from root canal walls. But the vehicle used to mix $Ca(OH)_2$ paste is important for complete retrieval: Methyl cellulose vehicle resists removal from root canals when retrieved with 17% EDTA. This was probably due to interactions between methylcellulose and EDTA[5].

Nandini *et al.* found that particulate form of $Ca(OH)_2$ in distilled water was easily removed, but Metapex (oily vehicle: silicone oil) resists dissolution in water and hence was retained in the canal. Both EDTA and citric acid chelators efficiently removed $Ca(OH)_2$ powder in distilled water. Also, citric acid performed better compared to EDTA in removal of Metapex because EDTA chelates calcium ions in water, but citric acid can penetrate silicone oil better than EDTA[19]. $Ca(OH)_2$ combined with an oily vehicle is difficult to remove and leaves residues on canal walls[20]

4. *Factors pertaining to chelating agents:*

a) Application time: There is no clear-cut recommendation as to duration of application of chelating agents. Generally, each canal is rinsed for atleast 1 min. Prolonged exposure to strong chelators like EDTA may weaken root dentin[21], as dentin hardness and elastic modulus are functions of dentin mineral content[22].

Chelating activity of EDTA is observed at 1-4 min, reducing beyond 5 min[23]. But Teixeira *et al.* reported that EDTA has similar chelation efficiency at 1, 3 and 5 min[18].

For citric acid, there is a trend of saturation of demineralizing ability after 60s.[24] da Silva *et al.* reported good results in terms of smear layer removal when applied to root canals for 30s[16]. Citric acid has a time-dependent action because, as the decalcification increases with time (3-10 min.), the physico-chemical properties of the original acid is not preserved in the salt (substrate/dentin + acid = salt). Beyond 15 min, chelation is not observed[24].

Etidronic acid (1-hydroxyethylidene-1,1-biphosphonate/ HEBP) is a relatively slow chelator[25]. De-deus *et al.* found that complete smear layer removal was achieved only after 300s of etching[26].

b) pH and concentration of solution: EDTA is more effective at neutral pH than alkaline pH[27,28]. EDTA has a self-limiting action; this is explained on its ability for complex formation and protonation: EDTA has special affinity for chelation in the ratio 1:1, and its action ceases once EDTA molecules are used up[25]. Protonation, manifested as decreased pH, leads to a fall in demineralizing power of EDTA over time[29].

According to Sousa *et al.*, pH of citric acid is more important than concentration for chelating ability. It is not an effective chelator at neutral pH[29]. Sterrett *et al.* reported that this phenomenon may be due to balance between decrease in pH and increase in viscosity of the solution caused by increase in constituent concentration. At high concentrations, citrate monopolizes such a large portion of the solvent that the amount of solvent available for Ca^{2+} diffusion is dramatically reduced[30].

c) Volume of solution: It has been recommended that 5-10 mL of the chelator irrigant be used for each canal[31].

d) Reaction by-products: Citric acid decalcifies the dentin, leading to precipitation of calcium-citrate crystals, which appear as debris under scanning electron microscope (S.E.M.)[32]. NaOCl oxidizes EDTA leading to formation of intermediate by-products (glioxilic acid, ethylenediaminetriacetic acid[33]). The significance of these reaction products remains unknown, but could potentially interfere with S.E.M. analysis in determining the extent of medicament removal.

e)Apical-third of root canal: Chelator efficiency decreases significantly from coronal part towards apical. This is because, towards the apex, tubule density and hence the dentin permeability decreases. Also, apical dentin is often sclerosed, more and non-uniformly mineralized[17].

MEDICAMENT REMOVAL TECHNIQUES

***Manual* (Figure 1a).**

Before obturation, $Ca(OH)_2$ removal is routinely accomplished by either sodium hypochlorite or saline and/or instrumentation in a reaming motion with a small endodontic instrument, or with the master apical file.[5] Irrigants are delivered by the conventional method of syringe irrigation.

The most commonly described method is instrumentation along with irrigation by sodium hypochlorite and EDTA, combined with the use of 'master apical file' at working length.[5,14,34] Instrument motion performed to disrupt and loosen the medication are up-and-down filing/oscillation with #15 K-file[14] and #40 H-file[34].

Instrumentation with a file, one size larger than the one used to the working length has also been performed.[7]

***Machine-assisted* (Figure 1b).**

Different devices have been used for activation of the intracanal solution, so as to improve the mechanical flushing action of the irrigant.

The various devices/techniques that have been used for medicament removal are: pressure alternation devices[35-38], rotary brush agitation[36,39], NiTi rotary instrument[15,40], ultrasonic[15,35,37,39] and sonic irrigation devices [41-43], and Er:YAG laser[44].

***Chemical [Endodontic irrigants]* (Figure 1c).**

The most frequently used irrigant is sodium hypochlorite.[14,16,45,46] Neutral agents like saline has also been used.[5,38,47]

Chelating agents which have been assessed for their medicament removal efficiency are EDTA[16,33,34], citric acid[19,34,48], maleic acid[48,49], and peracetic acid[50]. Other chelators that have the potential for use in $Ca(OH)_2$ removal are Etidronic acid (1-hydroxyethylidene-1,1-biphosphonate/ HEBP)[25,26], Tetracycline-hydrochloride, MTAD & Tetraclean.

Combinations – Advantages & Drawbacks.

Importance of final irrigant after the use of working solution: EDTA emulsifies, neutralizes and holds $Ca(OH)_2$ debris in suspension[51], but if these residues are not removed, they may interfere with sealing efficiency.[17,18] Hence the need arises for the mechanical flushing action afforded by NaOCl or saline.

EDTA alone or prior to NaOCl irrigation has caused reduction in dentin microhardness. Combination of tetracycline-hydrochloride and NaOCl exhibited less dentin softening in comparison.[52,53]

Use of irrigation in combination with filing has proven to be more efficient in cleaning the root canals than manual filing unassisted by irrigants.[14]

Association with wetting agent: Salgado *et al.* has shown superior results of $Ca(OH)_2$ removal by EDTA-T (EDTA + 0.2% sodium lauryl sulphate biological detergent), than by NaOCl, EDTA-C and citric acid irrigants.[14] On the contrary, Zehnder *et al.* showed that the association of wetting agents with EDTA may be detrimental to its calcium-chelating ability.[54] This finding was supported by De-Deus *et al.* who reported that EDTA-C (EDTA + Cetavlon) had a weaker effect than EDTA.[55,56]

Previous studies done to assess efficiency of various methods of intracanal medicament removal are shown in Table 1.

A great majority of these studies have assessed the removal of $Ca(OH)_2$ and its various formulations. Limited studies have been performed on other intracanal medicaments.

CONCLUSION

No technique has completely removed medicaments from the root canal walls. It is the appropriate use of mechanical instrumentation combined with the use of chelating agents, followed by final flushing with sodium hypochlorite that enables adequate cleanliness of root canal walls. Agitation of the irrigant solution with mechanical devices seems to improve the removal efficiency of intracanal medicaments.

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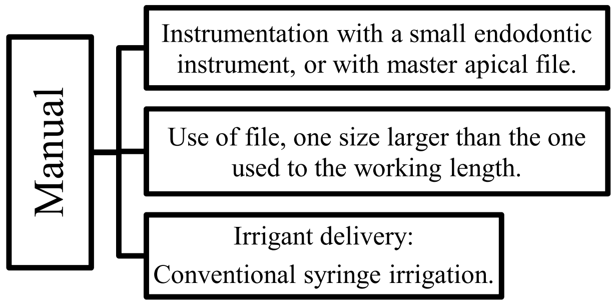

Figure 1a: Manual techniques of medicament removal.

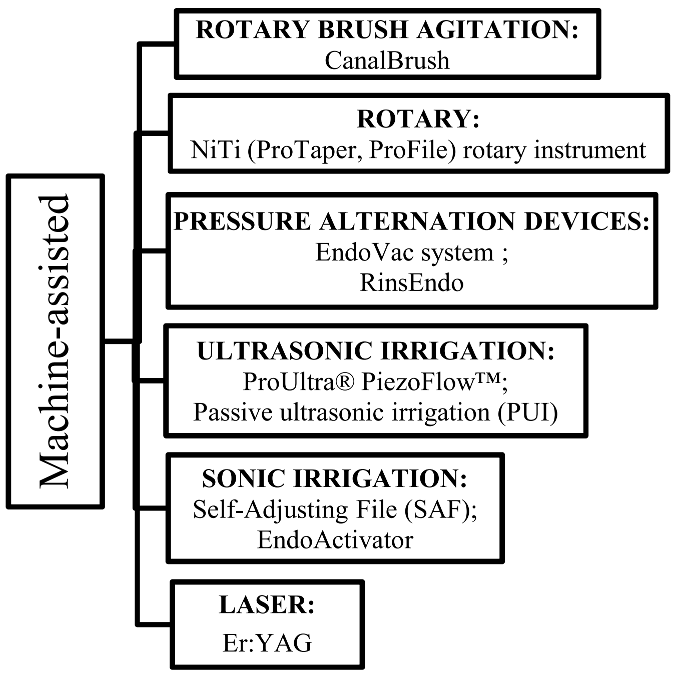

Figure 1b: Machine-assisted techniques of medicament removal.

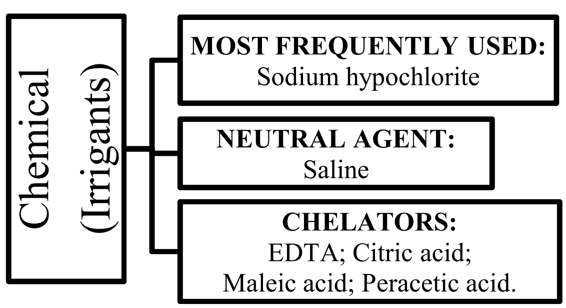

Figure 1c: Chemically-aided techniques of medicament removal.

TABLE 1: VARIOUS STUDIES DONE TO ASSESS EFFICIENCY OF INTRACANAL MEDICAMENT REMOVAL.

Sl No	Authors(s)	Year	Parameter tested	Medicament (Formulation)	Medicament removal technique	Assessment of removal	Results/Conclusions
1.	Porkaew *et al.*[7]	1990	Removal efficiency	CH (CH USP, Calasept, Vitapex)	Canal enlargement to next file size &NaOCI irrigation	S.E.M; energy dispersive X-ray analysis.	Incomplete removal.
2.	Guignes *et al.*[57]	1991	Removal efficiency of pharmaceutical & commercial forms.	CH (pharmaceutical &commercial forms)	-	S.E.M.; X-ray microanalysis.	CH removal is difficult but no significant difference in elimination between the 2 forms.
3.	Lambrianidis *et al.*[5]	1999	Effect of different CH preparations on removal efficiency	CH (Calxyl, Pulpdent paste, chemically pure CH in distilled water)	Saline + #25 file + saline; NaOCl + #25 file + NaOCl; NaOCI + #25 file + tetrasodium EDTA	Percentages of overall canal surface area.	Incomplete removal - all methods (25-45% CH residues); CH content - little effect on removal; Excipients (methyl cellulose in Pulpdent) resists removal.
4.	Keneee*t al.*[15]	2006	Removal efficiency of combinations of NaOCl, EDTA, hand filing, rotary, or US.	CH (Calasept)	5.25% NaOCl with 27 gauge slot-tipped needle; MAF + 17% EDTA + 5.25% NaOCl; MAF + Profile.04file + 5.25% NaOCl; MAF + EIE(US) with #15 Zipperer file + 5.25% NaOCl	Percentages of overall canal surface area.	Incomplete removal - all methods; Addition of rotary/US to hand filing & irrigation results in cleaner canals; Irrigant only methods - not different from each other; Rotary instruments facilitated removal of CH from curved canals without affecting root canal anatomy.
5.	Lambrianidis *et al.*[10]	2006	Removal efficiency of instrumentation + irrigation with NaOCl & EDTA.	CH & CHX (CH/CHX gel; CH/CHX solution; CH/saline pastes)	MAF + 1% NaOCl + 17% EDTA + 1% NaOCl (with/without patency with #10 H-file)	Specimens scanned, 6x magnification; scoring system.	Incomplete removal - all methods. CH/CHX gel - more residue; CH/CHX solution - less residue; Patency file facilitated removal in apical-third of the straight canals.
6.	van der Sluis*et al.*[58]	2006	Removal efficiency with PUI + NaOCl/water from artificial standardized groove in apical root canal.	CH (Ultracal XS paste)	PUI with 2% NaOCl; PUI with water; CI with 2% NaOCl.	LM (40x); 4-grade scoring system.	PUI with 2% NaOCl more effective than PUI with water or CI with 2% NaOCl/water.
7.	Nandini *et al.*[19]	2006	Removal efficiency of CH in 2 different vehicles by 2 chelators combined with US agitation.	CH (pure CH powder in distilled water; Metapex)	17% EDTA/10% CA combined with US agitation	Volumetric analysis using spiral CT.	Vehicle used to prepare CH paste is important in its retrieval; Metapex (CH + silicone oil) more difficult to remove than CHpowder in distilled water; 17% EDTA & 10% CA removed CH in distilled water efficiently, 10% CA better than EDTA in removing Metapex.
8.	Salgado *et al.*[14]	2009	Removal efficiency	CH (CH + 1% lidocaine anesthetic solution)	0.5% NaOCl; EDTA-C; CA; EDTA-T; MAF + NaOCl & lubricant (RC-Prep, Glyde File Prep or Endo-PTC) + EDTA-T	S.E.M.; 5-grade scoring system.	Best cleanliness - EDTA-T & MAF + NaOCl + EDTA-T; In straight root canals, recapitulation with master apical file (MAF) + irrigation resulted in improved CH removal compared to irrigant flush alone.
9.	Taşdemir *et al.*[39]	2010	Removal efficiency	CH (Calcicur)	2.5% NaOCl; 17% EDTA + NaOCl; 2.5% NaOCl + US agitation; 2.5% NaOCl + CanalBrush	Percentages of overall canal surface area.	Incomplete removal - all methods. CanalBrush& US agitation of NaOCl- significantly more effective than irrigant only methods.
10.	Rödig*et al.*[34]	2010	Removal efficiency	CH (Calxyl paste)	CI by 30 gauge needle (irrigants- 20% EDTA; 10% CA; 1% NaOCl, 10% CA + 1% NaOCl, 20% EDTA + 1% NaOCl; water)	LM (30x); 4-grade scoring system.	EDTA & CA - cleanest canals; NaOCl & water - least effect; Irrigant combination - no improvement.

11.	Kuga *et al.*[40]	2010	Removal efficiency by 2 types of rotary with NaOCl /EDTA.	CH (CH + propylene glycol in 1:1 ratio; paste consistency)	NiTirotary #25, 0.06 taper (K3 Endo) + 17% EDTA; NiTi rotary F1 (ProTaper) + 17% EDTA; NiTi rotary #25, 0.06 taper + 2.5% NaOCl; NiTi rotary F1 + 2.5% NaOCl	S.E.M.	ProTaper F1 better than K3 Endo # 25, 0.06 taper, regardless of irrigant used.
12.	Balvedi *et al.*[47]	2010	Removal efficiency by manual/PUI of CH in different vehicles.	CH (CH powder; CH + saline; CH + PEG; CH + PEG + CPMC)	MAF + saline; MAF + #25 K (US) file + saline	LM (5x); Percentage of overall canal surface area.	Incomplete removal - all methods; Neither CI nor PUI methods were efficient.
13.	Victorino *et al.*[3]	2010	Removal efficiency of experimental propolis & CH.	CH & Propolis paste (A70D,D70D).	K-file + 1% NaOCl + 17%EDTA	S.E.M.	Removal of experimental propolis pastes from root canals was difficult, similar to that observed for CH paste.
14.	Wiseman *et al.*[59]	2011	Removal efficiency of sonic & PUI.	CH	Rotary + PUI; rotary + sonic irrigation	Micro-CT scanning to determine volume & percentage of CH removal.	Rotary + PUI results in less CH remnants compared with rotary + sonic irrigation.
15.	Rödig*et al.*[37]	2011	Removal efficiency of US &RinsEndo® in removing CH &Ledermix from simulated root canal irregularities.	CH (Calxyl) &Ledermix paste.	PUI/RinsEndo® + 1% NaOCl	LM (30×); 4-grade scoring system	Incomplete removal – all methods; significantly less Ledermix paste was detected compared with CH.
16.	da Silva *et al.*[60]	2011	Removal efficiency of different CH pastes.	CH (CH + 0.2% CHX solution; CH + PG; CH + antibiotic paste + distilled water; CH + antibiotic paste + PG)	1% NaOCl + MAF; 1% NaOCl + patency with K-file #10; US; 17% EDTA-T	S.E.M.; 3-grade scoring system; 3 points on canal walls chemically analyzed (EDX) to investigate calcium ion remnants.	Apical dentin wall remained equally covered by CH regardless of vehicle; Less remnants in group of CH with antibiotic paste & PG (maybe because less quantity of CH was used due to its association with antibiotics).
17.	da Silva *et al.*[16]	2011	Removal efficiency	CH (CH in saline 1:1.5 w/v)	2.5% NaOCl/ 17% EDTA-T/ 10% CA/ 37% PA + MAF + saline	S.E.M.	17% EDTA-T & 37% PA – more effective than NaOCl & CA in apical-third.
18.	Rao*et al.*[61]	2012	Removal efficiency of irrigant + US.	CH (Apex-cal; Rccal)	#25 H file to loosen the medication; #25K (US) file passively activated with 10 mL of irrigant (SmearClear; 10% CA; 5% EDTA; 3% NaOCl)	LM (12.5x)	Smear Clear & CA – more effective than EDTA & NaOCl. No difference in removal efficiency of Apex Cal & RC Cal.
19.	Gorduysus *et al.*[45]	2012	Removal efficiency with CanalBrush technique.	CH (chemically pure CH in distilled water 1:1)	MAF + 2.5% NaOCl + 17% EDTA; MAF + 2.5% NaOCl + 17% EDTA + CanalBrush	S.E.M.; 4-grade scoring system.	CanalBrush led to packing effect through apex; importance of re-instrumentation + NaOCl/EDTA combination.
20.	Kaptan *et al.*[44]	2012	Removal potential of Er:YAG laser in combination with EDTA & NaOCl.	CH	17% EDTA + 5% NaOCl; 17% EDTA + 5% NaOCl + Er:YAG laser	Percentage of overall canal surface area.	Laser did not improve CH removal by CI with NaOCl & EDTA.
21.	De Faria-Júnior *et al.*[46]	2012	Removal efficiency of CH in different vehicles.	CH (CH in silicone oil; CH in 2% CHX; CH in PG)	Saline + MAF + 2.5% NaOCl.	S.E.M.	Association of CH with different vehicles did not influence the persistence of residues on root canal walls.
22.	Ballal *et al.*[48]	2012	Removal efficiency of 2 CH preparations by chelators with US agitation.	CH (CH + iodoform + silicone oil; CH + PG)	10% CA, 17% EDTA or 7% MA in combination with US agitation	Volumetric analysis using spiral CT.	7% MA & 10% CA superior to 17% EDTA in CH + iodoform + silicone oil removal; CH + PG fully removed by all irrigants.
23.	Sağsen *et al.*[50]	2012	Removal efficiency	CH	17% EDTA; 2.5% NaOCl + 17% EDTA; 1% PAA; 0.5% PAA	S.E.M.	In apical-thirds, 1% PAA was superior to other irrigants; no difference among the other irrigants.
24.	Türker *et al.*[36]	2013	Removal efficiency	CH (Calcicur)	CI, rotary CanalBrush, Endo Vac SAF (irrigant; 2.5% NaOCl).	S.E.M.	SAF & Endo Vac significantly better than Canal Brush & CI in apical-third.

25.	Ahmetoğlu *et al.*[41]	2013	Removal efficiency	CH (MM-paste)	SAF, PUI, CI	S.E.M.	Incomplete removal - all methods; PUI significantly better than SAF & CI.
26.	Faria*et al.*[42]	2013	Removal efficiency	CH (Calen)	SAF, ProTaper rotary	S.E.M., 5-grade scoring system.	Incomplete removal - all methods; No difference between SAF & ProTaper.
27.	Maalouf *et al.*[38]	2013	Removal efficiency of 2 CH preparations.	CH (CH powder + water; Pulpdent)	CI/ US/ RinsEndo® + saline	Percentage of overall canal surface area.	Incomplete removal - all methods; In apical-third, RinsEndo® & US most effective when mixed powder was used.
28.	Yücel*et al.*[35]	2013	Removal efficiency	CH (Cals-In + saline)	EndoVac, ProUltra®PiezoFlow™, CI by 30-gauge slot-tipped needle	S.E.M., 5-grade scoring system.	EndoVac&PiezoFlow - cleanest canals with no statistical difference; CI - insufficient.
29.	Nainan *et al.*[49]	2013	Removal efficiency of 3 CH preparations using chelators.	CH (CH in distilled water + barium sulfate for radio-opacity; Apexcal; Metapex)	17% EDTA; 7% MA	Volumetric analysis using spiral CT.	CH in distilled water &Apexcal (in PEG) were efficiently removed by 17% EDTA & 7% MA. 7% MA removed Metapex (in silicone oil) better than 17% EDTA.
30.	Khaleel *et al.*[43]	2013	Removal efficiency	CH	Irrigation (2.5% NaOCl + 17% EDTA + 2.5% NaOCl) with no agitation; irrigant agitation by ProTaper; agitation by EndoActivator tip size 25/.04; agitation by US file 25/.02	Percentage of overall canal surface area.	Sonic & US agitation more effective than ProTaper rotary & CI.

Ultrasonic Irrigation
US = Ultrasonic
SAF = Self-Adjusting File
S.E.M. = Scanning Electron Microscopy
LM = Light microscopy
EDX= Energy Dispersive X-ray microanalyzer.
CH = Calcium hydroxide
EDTA = Ethylenediaminetetraacetic acid
CA = Citric acid
MA = Maleic acid
PAA = Peracetic acid
NaOCl = Sodium hypochlorite
CHX = Chlorhexidine
PEG= Polyethylene glycol
PG = Propylene glycol
PA = Phosphoric acid
CPMC = Camphorated paramonochlorophenol
Antibiotic paste: contains ciprofloxacin & metronidazole.
CI = Conventional Irrigation (syringe)
PUI = Passive Ultrasonic Irrigation
US = Ultrasonic
SAF = Self-Adjusting File
S.E.M. = Scanning Electron Microscopy
LM = Light microscopy
EDX= Energy Dispersive X-ray microanalyzer.

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