Solvents in Non-Surgical Endodontic Retreatment

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Non-surgical endodontic retreatment is a reliable conservative option for managing post-treatment apical periodontitis. However, effective microbial control, based on the maximization of filling removal and disinfection protocols, is not yet predictable. Traditional gutta-percha solvents, which are indistinctively used for both the core and sealer filling materials, became obsolete due to unprecedented advances in endodontic technology. Nonetheless, microtomography, scanning electronic microscopy findings, and histobacteriological analysis tend to confirm the persistence of filling materials and the lack of association between root canal enlargement and superior disinfection. There is a controversy regarding the most suitable clinical protocols surrounding the shaping procedures and the supplementary disinfection steps.

Keywords: endodontics ; filling materials ; gutta-percha ; solvents ; non-surgical endodontic retreatment ; sealers

1. Introduction

Non-surgical endodontic retreatment (NSER) is a conservative option for managing persistent apical periodontitis (AP) associated with root-filled teeth, or where a new disease has emerged after root canal filling. Its main objective is to reduce the interradicular bacterial load to levels that are compatible with periapical healing, relying on maximum filling removal, repreparation through the most complete and canal-centered shaping techniques, and disinfection protocols [1]. However, the current therapy still focuses on the main root canal.

Reducing old filling remnants is crucial, as they may harbor intraradicular biofilms, the main cause of post-treatment AP [2]. The relative difficulty of NSER is related to variables such as the design of the retreatment/instrumentation systems, the age and type of the root canal filling, and previous preparation errors, besides the complex root canal anatomy [3]. After regaining access to the apical foramen, chemo-mechanical preparation (repreparation) aims to further remove filling residues and disrupt persisting adhered biofilms. Current retreatment techniques include rotary files, ultrasonic instruments, heat, laser, hand files, and solvent solutions [3]. Although their combination is generally required, removing the bulk of the obturations has greatly improved with the development of nickel–titanium (NiTi) rotary systems.

Two main strategies have been proposed to optimize disinfection before the new filling: (i) a further apical enlargement, with the risk of weakening the root structure; or (ii) using adjunctive procedures, such as sonic/ultrasonic processes or recently developed finishing instruments, to activate the standard sodium hypochlorite (NaOCl) irrigating solution. Nonetheless, microtomography, scanning electronic microscopy findings, and histobacteriological analysis tend to confirm the persistence of filling materials and the lack of association between root canal enlargement and superior disinfection.

2. Moment of Use

Traditionally, solvents were applied at the initial stages of the NSER, when fillings are more compact, through the deposition of a few drops into the space created by the coronal filling removal [3]. The main objective was to soften gutta-percha, enabling the initial penetration of the file into the remaining obturation [4]. Some researchers reported a negative impact of the solvents' deposition (chloroform and eucalyptol) in the medial and apical parts of the retreated ex-vivo canals, with reduced the filling remnants in the root canal surfaces of the nonsolvent groups [5]. Different methodologies, such as the type and moment of solvent deposition (before/after repreparation), may have influenced the results.

Flooding the canal with solvent after removing the bulk of the remaining gutta-percha, and further enlargement, have also been investigated. One of the studies assessed the effect of xylene (1 min) on cleaning the root canal with paper points; the outcome was comparable to 2.5% ultrasonically activated NaOCl [6]. In turn, Fruchi et al. [7] emphasized the cleaning performance of the reciprocating instruments with xylene (1 min) and concluded that, even with passive ultrasonic agitation (PUI), the solvent did not improve filling removal. Similarly, Barreto et al. [8] also showed no improvement with PUI with OOil or NaOCl. Contrarily, Ferreira I et al. [9][10] showed promising results, advising specific solvents (MEK/TCE and MEK/OOil) as an additional step after the conventional repreparation and NaOCl/EDTA treatment. Due to their high dissolution rate in short periods, the same solvent mixtures might also be considered, to assist with the initial penetration of well-compacted obturations.

3. Solvent Agitation

The goal of combining solvents with ultrasonic agitation (UA) was for endodontic instruments to reach difficult-to-access areas, enhancing their effectiveness, as with the current irrigating protocol [11]. Moreover, the apical root canal, which is considered a "critical zone" due to its strategic position for microorganisms, remains a challenge for several instrumentation techniques or irrigating/dressing proposals [12].

SEM assessments found no improvement in root canal walls cleanliness using PUI with EndoSolv R as a final step after further enlargement (repreparation), independent of the root canal thirds; thus, its efficacy remains unclear [13]. Additionally, with contradictory outcomes, a few ex-vivo studies with microtomography quantified the volume of the remnants of filling materials after retreatment protocols with solvent agitation. Barreto et al. [8] found no significant differences between static NaOCl, PUI/NaOCl, and PUI/OOil, but stressed that all groups showed a significant reduction in filling residuals (gutta-percha and epoxy resin-based sealer). The lack of superiority of the solvent group was justified with the formation of a paste that penetrated the dentinal tubules and canal irregularities, making its removal harder. Fruchi Lde et al. [7] concluded that solvent agitation (PUI for 1 min, with xylene) slightly increased filling material removal, but without statically significant results.

On the other hand, in vitro studies assessing the dissolution rate using a sample weight comparison concluded that UA increased the efficacy of solvents such as eucalyptol and OOil. However, independent of the solvent, the greatest dissolution was obtained with the ZOE sealer [14]. Another study [15] with chloroform and eucalyptol corroborated an increased efficiency of solvents in the dissolution of sealers with UA, although with a significant decrease concerning the mineral trioxide aggregate sealer (MTA Fillapex). Ferreira I et al. [16] also reported a positive impact of UA on solvent efficacy, which was first evidenced with MEK over an epoxy resin-based sealer (AH-Plus). Similarly, traditionally milder solvents, such as OOil, were clearly improved via UA with regard to gutta-percha dissolution [17].

Because MEK had little effect on gutta-percha dissolution, studies with the MEK/TCE and MEK/OOil associations have confirmed previous findings and a clear benefit of UA in filling dissolution [18]. The suggested protocol assessed in ex-vivo studies with microtomography, including MEK/TCE, and claimed to target the most common filling materials: gutta-percha and epoxy resin-based sealer (AH-Plus). These performances was reported as being similar to a further enlargement to the next file size, thus preventing an excessive reduction in the thickness of the root canals [10]. The researchers also found that the benefit of solvent agitation was independent of the device, whether ultrasonic or XP-endo Finisher R [9]. The specificity and synergism of the solvents in the mixture, their moment of use, and the exposure time, as well as sonic/ultrasonic agitation, were given as explanations for the performance obtained.

4. Effects on Dentin Structure

During NSER, solvents are inevitably in contact with dentin for some time. For a long time, investigations have highlighted a decrease in enamel and dentin hardness, due to the significant softening effects of chloroform, xylene, and halothane, with a time-dependent effect [19]; however, others do not confirm these findings [20][21]. Recent protocols suggest longer periods of dentin exposure to solvents after removing the bulk of the obturations. Some apprehension has, thus, arisen as to whether solvents can alter the dentin surface's chemical composition, with potential changes in its microhardness, and consequences on the bond strength of the sealers [21][22]. A recent systematic research [23], including push-out assessments, has stressed that the heterogeneity of the studies prevented a reliable conclusion from being reached. However, chloroform and xylene seemed to raise further concerns.

Despite reducing dentin's hardness, the novel solvent proposals of MEK and ethyl acetate are reported as being preferred over chloroform, which caused the most significant decrease [24]. A different experimental design associating MEK with the specific co-solvents TCE and OOil significantly increased dentin hardness after NaOCl and EDTA treatment [25]. Regarding direct dentin exposure, the MEK/TCE group showed no significant differences from the control (saline). MEK/OOil produced a significant hardness increase, independently of being used directly or after the NaOCl/EDTA standard final irrigating protocol.

The effect of solvent agitation on dentinal structure, per se, has been scarcely studied, and with ambiguous results. UA was reported to elicit a decline in dentin hardness when using MEK, ethyl acetate, and chloroform [24]. On the other hand, a study with the solvent mixtures MEK/TCE and MEK/OOil found no evidence of UA causing an additional decrease in dentin's hardness [25]. Findings from endodontic irrigating solutions such as NaOCl, chlorhexidine, or EDTA also tend to diverge. Investigations on EDTA's effect on dentin microhardness found that diode laser agitation caused higher hardness reduction than EDTA alone. However, there were no significant differences with UA or photon-induced photoacoustic streaming [26][27]. The different methodologies and chemistries regarding the compounds might explain the contradictory outcomes.

5. Antimicrobial/Antibiofilm Activity

AP is currently recognized as a biofilm-induced disease [28]. This causal link explains the increased resistance of endodontic intra-radicular infections to conventional disinfection procedures associated with the number of unprepared areas where root canal microorganisms, in planktonic and especially biofilm form, may persist [28][29]. These are considered to be the main causes of treatment failure. Moreover, the awareness that bacterial biofilms occur with particular relevance in the apical portion is crucial for the treatment, indicating the importance of primary and post-treatment AP therapeutics [30].

Research focusing on the antimicrobial properties of conventional gutta-percha solvents, such as halothane, eucalyptol, and OOil, has not been deep. The reported assays are almost exclusively against planktonic bacteria, such as *Enterococcus faecalis* (*E. faecalis*) and *Staphylococcus aureus* (*S. aureus*). In general, findings agree upon a stronger degree of antibacterial activity that is associated with the most cytotoxic solvents; OOil, for example, shows no antibacterial activity against the species mentioned [31]. Ex vivo studies emphasize that chloroform reduces intracanal levels of cultivable *E. faecalis* during endodontic retreatment [32]. By also stressing the role of *E. faecalis* as being the prime etiological agent of post-treatment infection, Subbiya A et al. [33] highlighted that RC Solve, a derivative of OOil, had superior antibacterial activity compared to xylene and EndoSolv E, which has tetrachloroethylene as its major compound. That study considered the minimal inhibitory concentration against *E. faecalis* ATCC and a clinical isolate from a failed root canal.

Maximum antimicrobial activity against *E. faecalis* biofilm has been reported with the association of a surfactant, such as cetrimide, and with chloroform, eucalyptol, or OOil. Although the combinations with cetrimide achieved a 100% kill rate, cytotoxicity assessments or the dissolution efficacy of the suggested associations were missing [34]. Biofilm removal strategies include its disruption via chemo-mechanical preparation with specific shaping techniques, and antimicrobial irrigating solutions/dressings. Increased concern over its resistance to conventional antimicrobial drugs should be considered [35][36].

Supplementary procedures for activating the final irrigating protocol with NaOCl with recent devices, such as ultrasonics or XP-endo Finisher R, have been suggested [4][37]. However, microorganisms are reported to regrow after NaOCl treatment. Although the final exposure with the chelating EDTA had an additional antimicrobial effect, researchers claim there is a flaw in its ability to completely eliminate resistant biofilms, such as *C. albicans*, the most prevalent fungi isolated from persistent endodontic infections [38][39]. A recent study highlighted that the association of MEK/OOil could eradicate *C. albicans* biofilm cells remaining after the conventional NaOCl and EDTA final irrigating protocol [38].

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