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Review

Removal of the Previous Root Canal Filling Material for Retreatment: Implications and Techniques

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Abstract: Adequate removal of the previous filling material may be pivotal to a favorable outcome of root canal retreatment of teeth with post-treatment periodontitis in order to permit the access of irrigants and medicaments to persistent bacteria. However, even with recent technological advances, including the introduction of specially designed instruments, no technique has been shown to predictably promote complete filling removal. Supplementary approaches used after chemomechanical preparation, including the use of finishing instruments, ultrasonics and laser, have shown promising results in enhancing root canal cleaning and disinfection. This narrative review addresses the importance and implications of maximal filling removal during retreatment and discusses the effectiveness of different techniques and supplementary approaches used for this purpose.

Keywords: filling removal; gutta-percha; non-surgical endodontic retreatment; root canal sealers

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1. Introduction

The ultimate goal of root canal treatment is to prevent or treat apical periodontitis (AP) [1]. Consequently, the development or persistence of clinical signs and symptoms of AP following treatment indicates an unsuccessful outcome. The disease associated with root canal-treated teeth can be termed post-treatment AP and is managed by nonsurgical root canal retreatment, periradicular surgery or extraction. Because both primary and post-treatment AP share the same etiology, i.e., intraradicular infection, the same basic antimicrobial treatment principles and practice can be applied to approach both conditions.

Numerous epidemiological studies revealed that one of the most important risk factors for post-treatment AP is the technical quality of the previous treatment [2–7]. Teeth with low-quality treatment exhibit normal periradicular tissues in less than 40–50% of the cases, while a successful outcome is observed in about 85–95% of the adequately treated teeth [8,9].

It is apparent that even some well-treated teeth can fail. Teeth with persistent lesions after root canal treatment are eligible for retreatment or surgery [8]. The primary cause of post-treatment disease in well-treated teeth is usually bacteria located in areas of difficult access to intracanal antimicrobial procedures [10].

The success rate of retreatment in teeth with post-treatment AP, in turn, ranges from about 60% to 85% [11–15]. The lower rate of healing when compared to the initial treatment is likely related to the following: limited access to residual bacteria, which can be more complicated because of the need to completely remove the previous filling material; difficult to access to residual bacteria located in areas distant from the main canal lumen; and resistance of residual bacteria [8].

Because of the intraradicular location of most persistent/secondary bacterial infections [16,17], intracanal management by retreatment has great potential to promote healing. For this, disinfection of the entire canal system should be one of the most important goals of retreatment. A favorable outcome of non-surgical endodontic retreatment in teeth with post-treatment disease will depend on proper infection control [18], including not only the main root canal but also difficult-to-reach areas, including lateral and apical ramifications, isthmuses, recesses and dentinal tubules. In this context, adequate removal of the previous filling material is of fundamental importance for disinfection during retreatment, as it permits the access of irrigants and medicaments to residual bacteria [19].

Removal of the previous filling material is the first intracanal phase during retreatment, and should ideally be complete to expose areas of the root canal system where infection foci may exist. However, even with recent technological advances, which included the development of different instruments specially designed for retreatment, no technique has been shown to predictably promote thorough filling removal. This problem is even more critical in the apical canal region, especially in the presence of curvatures and anatomic irregularities [20,21].

Understanding the importance of attaining complete filling removal during retreatment as well as the variables and technical issues that may influence it is of paramount relevance for clinicians to improve the outcome. The purpose of this narrative review is to address diverse aspects of root canal filling material removal during retreatment.

1.1. The Importance of Complete Filling Removal

The actual impact of the amount of residual filling material on the outcome of root canal retreatment is unknown and it is very difficult to evaluate in the clinical setting, as the potential methods for evaluation, such as periapical radiographs and cone-beam computed tomography (CBCT) may not have sufficient resolution to exhibit small filling remnants on the canal walls. These evaluations have usually been performed in ex vivo studies using either direct observation under the microscope [22–24] or micro-computed tomography [21,25–29], which has a much higher resolution than radiographs and CBCT [30]. However, it is possible to infer the consequences of leaving residual material during retreatment. Histobacteriological studies have clearly demonstrated the intracanal location of bacteria in teeth with post-treatment AP, including irregularities and recesses in the main canal lumen, dentinal tubules, isthmuses and ramifications [17,31,32]. If the residual filling material covers some of these areas, bacteria may be physically protected and will remain unaffected by the antimicrobial substances used during retreatment [10]. If the unaffected bacteria are those that are actually causing periradicular inflammation, then the retreatment outcome will be compromised [18].

In teeth with an inadequate or absent coronal restoration, saliva may seep into the canal and bacteria may colonize the interface between the filling material and the dentinal wall [33–37]. If the previous material is not completely removed for retreatment, these areas will remain contaminated and may serve as a reservoir of bacteria to induce or maintain AP [38].

One of the many challenges for the clinician during retreatment is to completely remove the previous filling material, especially in curved and well-filled canals [39]. The resistance imposed by the material makes its removal difficult, increasing the risk of procedural accidents such as ledges, perforation and instrument fracture. Furthermore, unlike gutta-percha, which is usually confined to the main canal, the endodontic sealer may penetrate into the dentinal tubules. Although this is required for a fluid-tight seal, the depth of sealer penetration and the blockage of the dentinal tubules can add an extra challenge to canal retreatment. Once the sealer penetrates into dentinal tubules, its total removal during retreatment is physically impossible [40].

Non-surgical endodontic retreatment can be divided into two phases: filling removal and re-instrumentation. Considering that canal enlargement during re-instrumentation also helps remove the previous filling material, evaluations of canal cleaning after retreatment should always take into account both phases, that is, the whole procedure. Different retreatment techniques have been proposed, with the most recent ones based on engine-driven nickel-titanium instruments. Some systems have been specially designed for use in retreatment.

1.2. Effectiveness of Different Protocols

Numerous nickel-titanium (NiTi) instrument systems for root canal preparation have been introduced into the market over the years. Unfortunately, most of them are released without sufficient information regarding their mechanical and geometric properties and, even worse, without any demonstration of their effectiveness. As for retreatment, rotary NiTi instruments have been used for both removal of the previous filling material and re-instrumentation [41]. Depending on the system, it is even possible to perform both steps simultaneously [42].

Chemical solvents (chloroform, xylol or eucalyptol) have traditionally been used in association with manual or rotary instruments to facilitate instrument penetration into the filling mass. In addition, the solvent may contribute some antimicrobial effects [43], though the magnitude and relevance of this property remain questionable, given the small amount of substance used and the fact that more potent antimicrobial agents, such as sodium hypochlorite, will be used next in the procedure and in much higher volumes. A study evaluated the influence of a solvent (eucalyptol) in enhancing the removal of filling material for retreatment of Vertucci's type II mandibular molars [21]. The Mtwo instrument system (VDW) was used for filling removal, with or without a solvent, and then the residual filling volume was assessed by micro-computed tomography. Findings revealed that the amount of material removed from the canal, including the isthmus area, was 83.2% without solvent and 83.8% with solvent, with no significant difference [21]. Other studies have confirmed these findings, not showing superior removal of filling material when using solvents [44,45]. Besides, the formation of a thin layer of chemically softened gutta-percha on the root canal wall may impair further cleaning and disinfection. This, along with solvent toxicity and unproved effectiveness, may discourage the use of these substances during retreatment [46,47].

Regardless of the retreatment technique, studies have shown that the complete removal of filling material is not commonly achieved [28,48,49], especially in the apical portion of root canals (Figures 1 and 2) [19,42,50]. The mean percentage of residual filling material has been demonstrated to range from 0.02% [51] to 43.9% [52] of the initial filling volume, with the great majority of studies reporting values below 10%. For this reason, supplementary approaches have been recommended to enhance filling material removal [42,50] and improve root canal disinfection [53–57] (see below).

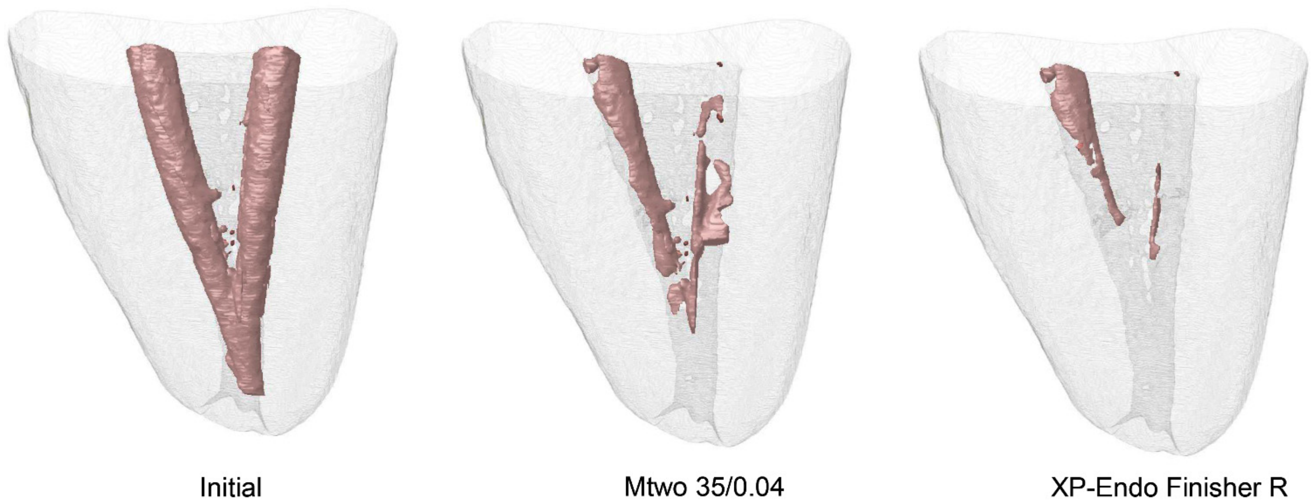

Figure 1. Microcomputed tomographic images of the apical segment of a mesial inferior molar root (class II of Vertucci, with isthmus) subjected to retreatment. **Left**, initial microtomographic scan performed after root canal obturation. **Middle**, post-preparation image obtained after retreatment with the Mtwo system (final instrument 35/0.04) in both canals. **Right**, final image after using the XP-Endo Finisher R.

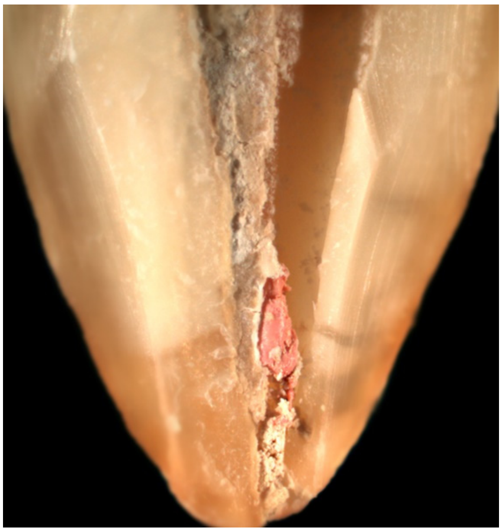

Figure 2. Image obtained in a stereomicroscope (16×) after root canal retreatment in a lower incisor. The system used was the Universal ProTaper (final instrument F4).

1.3. Main Variables Influencing Filling Material Removal

1. Anatomy. The outcome of non-surgical endodontic retreatment can be affected by the tooth type; studies revealed that multi-rooted teeth have a significantly lower percentage of success than premolars and anterior teeth [58,59]. Certainly, the complex internal anatomy, including isthmuses and ramifications, as well as the occurrence of curvatures can make the retreatment of infected teeth more difficult. Root canals that are oval or flattened in cross-section also pose additional difficulties to proper cleaning and disinfection [60]. Rotary or reciprocating instrumentation often produces a circular and centered preparation, with limited lateral action on the recess areas of oval /flattened canals [61,62]. Although brushing or circumferential filling might help overcome this problem, a high percentage of the canal surface still remains unprepared in these teeth [63,64].

2. Coronal access. Adequate coronal access is expected to influence the filling material removal. Studies reported that minimally invasive access cavities resulted in a greater amount of filling remnants compared to conventional cavities [65,66].

3. Instrument. A systematic review concluded that NiTi instruments specially designed for retreatment do not have advantages over conventional techniques with regard to filling material removal [49]. Although these instruments may more easily penetrate into the filling mass and reduce the procedure time, they have been shown not to be essential for better material removal [41,49]. On the other hand, the use of hybrid techniques and larger preparation diameters are associated with greater cleaning [49]. Studies have shown that differences in taper, tip and cross-sectional shape, as well as the operation mode and the number of instruments used, usually failed to promote significant differences in filling removal [28,41,48,50,67].

4. Quality of filling. A prospective study with long-term follow-up showed that the outcome of endodontic retreatment was significantly better in teeth, with previous obturation ranked as inadequate [15]. Conceivably, thorough removal of the previous filling material in these cases is more predictable. This increases the possibility of further antimicrobial procedures to reach the residual infection.

5. Canal enlargement. Larger preparation sizes are associated with greater filling material removal [42]. The final size of the preparation in retreatment should incorporate the diameter of the previous preparation along the entire canal length. This is justified not only for maximum filling material removal, but also to promote proper cleaning and disinfection [68,69]. In addition, a prospective cohort study [70] reported a high success rate (89%) for the retreatment of lower molars using contemporary techniques and preparation sizes of 0.35–0.40 mm, with tapers varying from 0.04–0.06 mm/mm. Nevertheless, it is important to emphasize that excessive

enlargement should be avoided, especially in the pericervical area, in order not to weaken the root, which could predispose the tooth to fracture.

6. Patency. Foraminal patency and the extent of root canal cleaning as close as possible to the apical terminus were identified as factors that positively influence the root canal treatment/retreatment outcome [71–73]. This is because, in some infected teeth, the most advanced frontline of infection may be located close to or at the apical foramen. In addition, increasing the apical level of the root canal filling during retreatment also positively affected the outcome when compared to teeth in which such an increase was not observed [18]. This can be explained by the fact that the apical advance of root canal procedures during the retreatment of infected teeth can lead to better disinfection of the apical part of the canal, where the bacteria commonly associated with the post-treatment disease are usually located.

7. Irrigant agitation. It has been demonstrated that the removal of the filling material in the canal can be enhanced by supplementary approaches for agitation of sodium hypochlorite after canal preparation (see below).

8. Solvent. Its benefit is observed only in the initial stage of the retreatment as it may facilitate penetration of the instrument into the filling mass. As discussed above, solvents may impair proper cleaning because of the formation of a thin layer of soft gutta-percha, which can cover the canal wall [47,74]. With regard to filling removal, some studies have not observed greater benefits when a solvent was used [44,75,76].

9. Magnification. The use of magnification under abundant illumination is of utmost importance in many phases of endodontic treatment/retreatment and surgery. The impact of magnification on filling material removal is more evident in straight canals [23,77,78]. Furthermore, an improved retreatment outcome was observed when the operating microscope was used [15].

10. Type of filling material. The different types of filling materials may cause diverse levels of difficulty for removal during treatment. Of the most currently used materials, the greatest challenge has been reported for bioceramic sealers [67,79–82].

11. Age of filling. Although the effects of the root canal filling age and its impact on gutta-percha removal are not well known, a recent study using a tricalcium silicate sealer showed that filling removal was less effective in freshly filled canals than aged filled canals [83].

1.4. Retreatment with Hand or Engine-Driven Instruments

The results of different studies evaluating the removal of the filling material by hand and engine-driven instruments are conflicting. While some studies showed a better performance for hand instruments [51,84], others have not reported significant differences [28,85], and even others observed better results for engine-driven instruments [60,86]. A systematic review concluded that, unlike engine-driven instruments, retreatment with hand instruments was not associated with iatrogenic errors [49]. Hand instrumentation usually spends more time for retreatment when compared to rotary or reciprocating systems [28,84,87]. However, speed should not be the main factor when selecting one system over another. The difference in time is usually limited to only a few minutes and a longer action time also results in a longer retention time for antimicrobial irrigants, which can improve disinfection [88].

1.5. Retreatment with Rotary or Reciprocating Instruments

In general, studies comparing rotary and reciprocating systems for filing material removal during retreatment have shown a similar performance [28,48,67,86,89–94]. Because these systems are often compared in teeth with similar anatomy, under standardized irrigation conditions, working length and apical preparation sizes, the isolated effects of the operation mode on filling removal may not be of great significance. These findings are in line with many other studies that showed similar shaping [95–97] and disinfection [98–100] effects when using NiTi instruments in continuous rotation or reciprocation.

1.6. Canal Transportation during Retreatment

The safety of retreatment procedures is a matter of concern because of the risk of procedural accidents, including instrument fracture, zips, ledges and perforation. The occurrence of root canal transportation during filling removal and re-instrumentation has been evaluated, especially in curved canals and in the apical third [14,101]. Transportation can complicate proper cleaning, disinfection, and filling of the canal and, if unnoticed or not corrected, may evolve to more drastic accidents, including perforation and zips [102]. Furthermore, excessive dentin removal, especially in the most coronal parts of the root canal, may weaken the root structure and put the root at risk of fracture [103].

Studies have shown a high frequency of canal transportation during retreatment [45,101,104,105]. For instance, a recent study revealed the occurrence of apical transportation in all mesial canals from mandibular molars retreated with either rotary multifile or single-file NiTi systems [105]. In general, the studies show a similar performance of the different NiTi systems in terms of centralization, including when compared with manual instruments [45,101,104,105]. However, any conclusion about a specific retreatment system/technique is premature because of the restricted number of studies on the subject.

Many variables can interfere with canal transportation during retreatment, including canal anatomy, type of filling material, dentin hardness, preparation technique, operator experience, curvature angle, radius and position, and instrument geometry, motion, and alloy.

1.7. Supplementary Approaches

These procedures are recommended for use after instrumentation with the main purpose of maximizing cleaning and disinfection before placing an intracanal medication or the final obturation. Supplementary approaches include mechanical, sonic, ultrasonic and laser means [56].

Mechanical effects are usually represented by the agitation of the irrigant in the canal by manually pumping instruments or gutta-percha points or by engine-driven instruments operated at low speed (e.g., lentulo spirals, plastic instruments, or NiTi finishing instruments). Finishing instruments have received a great deal of attention over the last years and studies have demonstrated that they can significantly improve disinfection after instrumentation [53,106]. One of the most commonly used is the XP-endo Finisher R instrument (FKG Dentaire, LaChaux-deFonds, Switzerland), which was specially designed for retreatment. This finishing instrument is a variant of the XP-endo Finisher (FKG Dentaire), with a larger core diameter (ISO 30). It exhibits a zero taper and, at the body temperature, undergoes morphological changes to acquire a spoon-like shape that expands its reach in the canal system. Both the XP-endo Finisher and the XP-endo Finisher R have been demonstrated to be highly effective in removing the residual filling material during retreatment [21,25,26,107–109]. The additional reduction in residual material provided by these finishing instruments may reach a mean of 40% to 69%, including the isthmus area [42,75]. A study showed that XP-endo Finisher R was more effective than sonic and ultrasonic devices in removing the previous filling material in oval canals [110]. A systematic review concluded that the supplementary approach with XP-Endo Finisher or XP-Endo Finisher R is effective in enhancing the removal of root canal filling materials during root canal retreatment [111].

The Self Adjusting File (SAF) (ReDent-Nova, Ra'anana, Israel) is a non-conventional hollow and flexible instrument for root canal preparation, which was devised to adapt itself to the canal morphology in cross-section. Because the instrument surface is lightly abrasive and can scrape dentin, there is a good potential for cleaning the canals free of residual filling material during or after preparation [112,113]. When used for canal preparation during retreatment, the amount of residual material after using SAF was not significantly different from conventional instruments [25,114]. Nonetheless, favorable results have been reported for the SAF instrument when used as an adjunctive step after the preparation of oval [113] or curved canals [115].

A commonly used approach to supplement disinfection after preparation is the agitation of sodium hypochlorite by sonic or ultrasonic devices. Sonic frequencies range from 20 Hz to 20 kHz. The EndoActivator is a sonic handpiece that operates at 167 Hz or 10,000 cpm and uses non-cutting polymer tips to agitate the irrigant in the canal [116]. Studies have evaluated its effects on filling material removal. Some showed that EndoActivator might increase the removal of filling material [117], even though it was significantly less effective than ultrasonics [117] and XP-endo Finisher [110,118]. However, another study observed no significant improvement in filling material removal [94].

Ultrasonic frequencies are greater than 20 kHz. Ultrasonic units for endodontic use usually oscillate at frequencies ranging from 25 to 30 kHz [119,120]. Ultrasonic activation of irrigant solutions is another widely used supplementary approach. The main effects of ultrasonics result from the phenomena of cavitation and acoustic streaming and possibly warming of the irrigant [119,121–123]. Ultrasonic effects can affect and disorganize bacterial biofilms and wash away detached bacterial cells from the canals [120,124,125]. Moreover, cavitation may weaken the bacterial membranes and potentiate the antimicrobial effectiveness of NaOCl [120,126]. The phenomena of acoustic streaming and cavitation are dependent on the free displacement of the ultrasonically activated instrument [122,123,127]. Many studies have addressed the effects of ultrasonics in improving disinfection by NaOCl after preparation, and the results are conflicting [128–131]. Ultrasonics have also been used to enhance the removal of the filling material during retreatment and studies have shown significant improvement [50,132,133]. For instance, a study revealed that passive ultrasonic irrigation reduced, on average, 43% of the volume of the remaining filling material [50]. However, other studies showed no significant improvement [89,94,134,135].

Laser has also been proposed for a supplementary step of irrigant activation during canal treatment and retreatment, to improve disinfection and also to enhance filling material removal. A study used the Er:YAG laser, Er:YAG laser-based photon-induced photoacoustic streaming (PIPS), and Nd:YAG laser and reported a significant improvement in material removal; a comparison between them showed better results for the Er:YAG laser [136]. PIPS was significantly better than sonic and ultrasonic approaches in removing filling remnants from oval canals [137]. The additional cleaning effects of PIPS seem not to be significantly affected by the type of filling material [138]. However, a study reported that the PIPS method did not have a significant effect on the removal of filling remnants in comparison with conventional needle irrigation [139]. When the Er:YAG laser-initiated shockwave-enhanced emission of photoacoustic streaming (SWEEPS) was used in curved canals, it improved the removal of filling remnants and performed better than PUI when no solvent was used [140]. The superior cleaning effects of SWEEPS over PUI were confirmed by another study [141]. A study compared PUI and super short pulse (SSP) and SWEEPS modes of Er:YAG laser-activated irrigation (LAI) with two different laser tips for removing filling materials in curved canals and concluded that all of them were significantly effective; the LAI/SSP showed better results than the others [142].

2. Conclusions

It is salient to point out that, regardless of the method used for the removal of filling remnants, using or not a supplementary step, virtually all studies demonstrated that the canals are rarely, if ever, completely cleaned after these procedures. In the large majority of studies, the previous obturation was adequate in terms of apical length and homogeneity, which arguably increases the difficulties for full removal. This is not the rule in the clinical setting, as most cases presenting with post-treatment AP show inadequate root canal fillings [4,7,143]. Filling removal in these cases may not be so challenging and this helps explain the better outcomes for teeth with post-treatment disease that have inadequate fillings when compared to the ones with previous adequate fillings [15].

Virtually all studies on the subject of filling removal had an ex vivo nature (extracted teeth). Most studies were based on recently placed fillings; therefore, their results cannot be extrapolated to aged fillings, which are the most common in the clinical scenario. Despite the limitations of ex vivo studies, there is currently no effective and reliable means to evaluate filling material removal in the in vivo situation.

The impact of filling material removal on the success of endodontic retreatment still needs to be confirmed by long-term outcome studies. However, given the difficulties in performing such evaluation in the clinical setting, this question may long remain to be answered. Logical thinking indicates that complete removal may improve disinfection of the canal system by permitting the antimicrobial irrigants and medications to reach residual bacteria that are the cause of post-treatment disease. Taking into account the performance of the current retreatment techniques, in which no one predictably promotes complete filling removal, supplementary procedures should be considered indispensable in non-surgical retreatment. Further research is also encouraged to develop and evaluate techniques and strategies that can successfully clean root canals during retreatment.

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