▶ Review article ◀

Retreatment Challenges and Removal Strategies for Hydraulic Calcium Silicate–Based Root Canal Sealers: A Review

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Abstract

Hydraulic calcium silicate sealers (HCSs) are increasingly used in endodontics for their bioactivity, alkaline pH, calcium release, dentin bonding, and biocompatibility. While beneficial in primary treatment, these properties complicate nonsurgical retreatment, where effective removal of filling materials is essential for disinfection and healing. HCSs become progressively harder, strongly bonded to dentin, and lack predictable solvents for dissolution. Nickel–titanium (NiTi) rotary and reciprocating instruments improve efficiency but consistently leave remnants, particularly in the apical third. Solvents such as chloroform, formic acid, hydrochloric acid, and citric acid show inconsistent effectiveness and may affect dentin integrity. Adjunctive activation methods including ultrasonic or sonic irrigation, shape-memory files, and laser-assisted photoacoustic techniques enhance removal but still cannot achieve complete cleanliness. Although complete elimination of HCSs remains unachievable, combining mechanical instrumentation with solvents and supplemental activation offers the greatest improvement in reducing remnants and supporting successful disinfection and periapical healing.

Keywords: hydraulic calcium silicate sealers, NiTi instruments, retreatment, solvents, supplemental irrigation

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Introduction

Root canal treatment is primarily focused on preserving natural teeth and ensuring the maintenance of long-term periapical health. Although primary treatment typically produces reliable results, persistent or recurrent apical periodontitis sometimes requires non-surgical root canal retreatment (1). This procedure involves the comprehensive elimination of intra-radicular microbial populations, which are recognized as the principal cause of treatment failure, along with the complete removal of pre-existing root canal filling materials. The complete removal of previous materials enables effective chemo-mechanical disinfection and enhances periapical healing (2). Complete elimination of residual filling material is crucial, as any remaining debris may harbor bacteria and compromise the success of subsequent disinfection and obturation efforts (3).

The use of hydraulic calcium silicate sealers (HCSs) has increased rapidly and is now common in endodontic practice (4,5). These materials, widely identified as bioceramic sealers, have gained considerable popularity, particularly when integrated with sealer-based obturation techniques (6,7). Reported properties include lack of shrinkage, alkaline pH, calcium ion release, hydroxyapatite formation, strong bond strength, antimicrobial activity, sealability, and biocompatibility (8–12). However, the same characteristics that make HCSs effective in primary treatment can also present challenges during subsequent retreatment processes. HCSs are difficult to remove due to their strong adhesion to dentin, their ability to mineralize, high hardness, and relative insolubility (8,13). These characteristics frequently lead to incomplete removal and residual material persisting within the canal. Additionally, there are no clinically established solvents for these materials, and available evidence regarding solvent efficacy is either limited or inconsistent. Furthermore, re-establishing apical patency can be difficult (14).

This literature review aims to comprehensively examine the complexities involved in the retreatment of HCSs. It assesses the intrinsic material characteristics that influence the difficulty of their removal, evaluates the comparative effectiveness of retreatment approaches for HCSs versus conventional sealers, and discusses the impact of adjunctive techniques on enhancing material elimination and maintaining canal cleanliness. Furthermore, this review will discuss the clinical considerations for HCS removal.

Hydraulic Calcium Silicate Sealers

HCSs are a class of endodontic materials used for root canal obturation (15). These materials are defined by their hydraulic nature, meaning they require the presence of water or moisture to initiate and complete their setting reaction. This characteristic allows for effective performance when in contact with surrounding biological tissues and fluids. HCSs are available in various forms, including premixed, injectable pastes in syringes that are ready for immediate use.

While all HCSs contain calcium and silicate, their specific compositions can vary significantly between different commercial products. For example, EndoSequence BC Sealer and TotalFill BC Sealer are composed of calcium silicates, calcium phosphate monobasic, calcium hydroxide, zirconium oxide (as a radiopacifier), and filler/thickening agents. Similarly, Ceraseal contains tricalcium silicate, dicalcium silicate, tricalcium aluminate, and 45-50% zirconium oxide.

Other examples include EndoSeal MTA, which is composed of calcium silicate, calcium aluminate, calcium sulfate, and a radiopaque material (4).

The setting reaction of HCSs is a key feature that distinguishes them from other types of sealers. As hydraulic materials, they are set by reacting with water, which can be absorbed from the surrounding dentinal tubules. This hydration process involves the reaction of tricalcium and dicalcium silicates, which results in the formation of a calcium silicate hydrate gel and calcium hydroxide as a primary byproduct (16). The released calcium hydroxide elevates the local pH, contributing to the material's antimicrobial properties. A secondary reaction takes place when the released calcium ions interact with tissue fluids containing phosphate, resulting in the development of an interfacial layer of hydroxyapatite or apatite-like crystals at the junction between the sealer and the dentinal walls. This process contributes to the material's bioactivity and ability to form a chemical bond with the tooth structure, enhancing the seal of the root canal system.

Properties of HCSs Associated with Challenges Retreatability

The complete removal of filling materials remains largely unachievable in most cases, irrespective of the sealer type or retreatment method used. The presence of residual filling material can harbor necrotic tissue or bacteria, contributing to persistent periapical inflammation or pain post-retreatment. The retreatability of root canal sealers, particularly HCSs, is influenced by several inherent material properties and clinical factors.

Hardness and compressive strength: HCSs become gradually harder during setting, and several studies have reported that fully set HCSs can reach hardness values comparable to, or even greater than, those of AH Plus (17), contributing to their well-recognized retreatment resistance. EndoSequence BC Sealer shows low initial compressive strength (13 MPa) and increases by 28 days to 19–22 MPa (18). For iRoot SP, a compressive-strength value of 8.6 MPa has been reported. This increase is due to continuing hydration and crystallization processes that continue for several weeks. High microhardness, and compressive strength can make the removal considerably more challenging compared to other sealer types (19). The strength of the HCSs set is a critical factor determining its retrieval. Different brands of HCSs exhibit varying degrees of retrievability due to their diverse chemical compositions.

Bond to dentin: A key characteristic of HCSs is their bioactivity, which leads to the formation of hydroxyapatite upon contact with dentinal fluid. This reaction promotes a strong chemical bond with the dentin, often forming a tag-like structure or a mineral infiltration zone. Study on the push-out bond strength of HCSs to dentin show variable results, with some HCSs having bond strengths comparable to or lower than epoxy resin-based sealers like AH Plus, while others show higher resistance (20).

Lack of solvents: A major concern regarding HCSs retreatability is the absence of clinically established solvents for these materials. While various solutions like formic acid, citric acid, acetic acid, carbonated water, chloroform, and hydrochloric acid have been tested, a definitive solvent for calcium silicate-based sealers has not yet been identified. Evidence is limited and often conflicting regarding the efficacy (21).

Effect of Obturation Technique on Retreatment of HCSs

The obturation technique plays a significant role in the retreatability of (HCSs), primarily because different techniques influence sealer distribution, apical density, and the extent of sealer–dentin interlocking. Studies have shown that single-cone techniques, which rely on a substantial volume of HCSs, generally result in greater difficulty during retreatment because the sealer forms a continuous apical plug and penetrates dentinal tubules extensively (14). This bulk presence of HCSs is strongly associated with reduced ability to regain patency, especially when the gutta-percha cone is placed short of the working length.

Conversely, warm vertical compaction techniques distribute gutta-percha more densely and reduce the relative volume of sealers, potentially improving retreatability by limiting the thickness of HCSs layers that must be removed. Warm techniques also tend to create fewer voids, but they allow more gutta-percha to occupy the canal space, which is more responsive to heat and solvents during retreatment (22).

A recent study showed that retreatment efficiency did not differ between canals obturated with a HCSs using either the single-cone or continuous-wave condensation technique. This similarity can be attributed to the fact that both techniques produced comparable filling volumes and comparable distribution of the HCSs. As reported in their micro-CT analysis, both groups exhibited similar amounts of remaining filling material across all canal thirds, indicating that once the same bioceramic sealer is used, the obturation technique does not substantially change the resistance of the set material to mechanical removal (23).

Retreatment Techniques

Mechanical Instruments

When performing retreatment of root canals previously filled with HCSs, clinicians face unique challenges due to the specific properties of these materials. Retrieval using both Nickel–titanium (NiTi) rotary files and reciprocating files has been evaluated, but complete removal of filling materials, especially from complex anatomies such as C-shaped or severely curved canals, and particularly from the apical third, remains challenging (23-26).

Continuous rotation files

Rotary instruments in continuous rotation are widely used for the removal of root canal filling materials, and their design and metallurgical characteristics have evolved substantially from traditional multi-file sequences to heat-treated and adaptive single-file systems (27). These developments aimed to improve flexibility, fatigue resistance, and cutting efficiency, particularly when negotiating challenging obturation materials such as HCSs. Heat-treated alloys and adaptive metallurgy—such as the phase-transformation behavior of HyFlex CM or the serpentine motion of XP-endo instruments—improve canal wall adaptation and facilitate penetration into recesses and oval extensions that stiffer, conventional rotary instruments often leave untouched. These heat-modified single-file systems also demonstrate higher apical patency rates and shorter patency recovery times, thereby reducing solvent use and lowering clinical workload (28,29).

However, the mechanics of continuous rotation impose unique limitations. Constant circumferential engagement increases the likelihood of taper lock, torsional overload, and debris compaction, especially when instruments encounter the high microhardness or strong dentin–bioceramic bonding interface characteristic of HCSs. Microstructural analyses show that conventional rotary files develop microcracks, tip fractures, and machining defects after use, raising concerns regarding durability and safety in retreatment (30). Although heat treatment has improved flexibility and reduced fatigue, certain systems continue to show evidence of structural compromise, with some instruments exhibiting minor unwinding, surface distortion (28). The performance of rotary files depends not only on clinical technique but also on the interaction between alloy treatment, cross-sectional geometry, taper configuration, and the mechanical properties of bioceramic sealers.

Reciprocating files

Reciprocating systems, operating with alternating clockwise and counter-clockwise motions (CW/CCW), were developed to reduce torsional stress, improve centralization, and minimize canal deformation during retreatment (31). These systems have been studied in HCSs, revealing both significant benefits and persistent challenges.

Reciproc and Reciproc Blue have demonstrated reliable performance in retreatment, achieving material removal rates comparable across HCSs and epoxy resin sealers, even in severely curved canals (32). Several studies indicate that reciprocating instruments are more effective in removing HCSs than rotary systems, particularly in terms of overall cleanliness and reduced apical debris extrusion (33,34). However, this advantage is accompanied by reduced efficiency, as reciprocating systems typically necessitate longer operating times, particularly when used with HCSs such as EndoSequence BC.

WaveOne Gold has shown similarly strong retreatment outcomes, particularly in oval canals. It achieved high percentages of material removal (approximately 87–90%) for both TotalFill BC and AH Plus sealers. Interestingly, retreatment of TotalFill BC was associated with lower apical load and faster times than AH Plus, and WaveOne Gold successfully regained patency in all HCS-filled canals. However, HCSs removal generally required more strokes with reciprocating files than with conventional sealers, indicating that this material is more resistant to mechanical disruption (35).

R-Motion is a recently introduced reciprocating system characterized by a smoother cutting edge and a more conservative cross-sectional profile than Reciproc Blue and WaveOne Gold. Its design philosophy emphasizes minimally aggressive dentin engagement to enhance safety and reduce taper lock (36). However, these conservative geometric features also reduce cutting aggressiveness and decrease the active contact area, which may limit its efficiency when disrupting the dense HCS–dentin interface. Correspondingly, early studies report that R-Motion removes filling materials less effectively than Reciproc Blue and WaveOne Gold, an outcome likely attributable to its less prominent cutting edges and limited flute engagement. In addition, R-Motion generally requires longer operating times than most rotary systems, reinforcing the characteristic trade-off of reciprocating instruments—greater thoroughness at the expense of speed (33).

The mechanical performance of reciprocating instruments is influenced by their metallurgical properties. Reciproc Blue, manufactured from thermomechanical treated alloy, provides greater flexibility and resistance to fracture compared to earlier designs. However, like other NiTi instruments, reciprocating files can display reverse windings and flute deformation after repeated use, particularly in challenging retreatments (28).

Overall, reciprocating files have both advantages and limitations in the retreatment of HCSs. They offer superior thoroughness of filling material removal but often at the expense of longer retreatment times and occasional difficulty regaining patency. While newer systems like WaveOne Gold have advanced the balance toward efficiency and reliability, the resistance of HCSs remains a significant obstacle, demanding more strokes and greater mechanical effort than with traditional sealers (Table 1).

Solvents

Unlike gutta-percha, which can be dissolved by various organic solvents, HCSs are generally more resistant to chemical dissolution, and currently, no ideal solvent exists for predictable retrieval. Studies on the effectiveness of solvents for HCSs have yielded inconsistent results, with some even reporting disadvantages. Several solvents have been assessed for their effectiveness in retrieving HCSs.

Table 1 Comparison of Continuous Rotation and Reciprocating Systems in the Retreatment of HCSs

Feature	Continuous Rotation Systems	Reciprocating Systems
Motion Pattern	Continuous 360° rotation	Alternating CW/CCW motion
Torsional Stress	Higher; increased risk of taper lock and torsional failure	Lower; reduced risk of torsional failure
Debris Extrusion	Generally higher; more apical compaction	Typically, lower apical extrusion
Cutting Efficiency	More aggressive and faster cutting	Variable; often less aggressive, depending on cross-section and flute design
Patency	More predictable patency regain; shorter time	Good in certain systems (e.g., WaveOne Gold), but less consistent overall
Effectiveness in HCSs Removal	Good, but often inferior to reciprocating in total cleanliness	Frequently more thorough removal and lower debris extrusion
Operating Time	Generally faster retreatment time	Longer operating time; more strokes required for HCSs removal
Common Limitations	Taper lock, debris compaction, file distortion	Reduced efficiency; slower material removal, especially with conservative designs

Organic Solvents

The use of organic solvents like chloroform for dissolving gutta-percha is well-established, but they are often ineffective on sealers alone. In one study evaluating patency in canals filled with EndoSequence BC Sealer, chloroform achieved patency in 93% of cases (37). However, its efficacy has been inconsistent across studies. For example, Hess et al. found chloroform to be ineffective in some samples when re-establishing patency with BC sealer (14). Conversely, one systematic review noted that among two studies using chloroform, only one reported improved removal of endodontic filling material (38). The use of chloroform is also controversial due to its toxicity if ingested or inhaled in sufficient quantities, leading to a need for safer protocols.

There is very limited information on the effectiveness of xylol (xylene) and eucalyptol specifically for the retrieval of HCSs. They are considered less effective alternatives to chloroform for dissolving gutta-percha. However, their efficacy does not extend to the sealer component, which often makes up the bulk of the remaining material after retreatment (39).

Acids as Solvents

Acids are being investigated for their potential to chemically deteriorate HCSs, which are susceptible to dissolution at low pH.

Formic acid (FA)

10% formic acid shows promise, as it has been demonstrated to dissolve Portland cement, which shares chemical similarities with HCSs. One study found that 10% formic acid, when used in conjunction with mechanical instrumentation for 5 minutes, was highly efficient, achieving over 95% removal of obturation material (gutta-percha and HCSs) without damaging the dentin (40). It effectively altered the structural integrity of the sealer. Another study found that although 10% of FA and chloroform can achieve patency, they do so more slowly than 20% HCl. Scanning electron microscopy (SEM) showed 10% FA left dentinal tubules open and clear with minimal debris, without causing significant erosion (21). However, there are conflicting reports, with some literature stating that FA could not successfully dislodge or dissolve HCSs. 20% formic acid was found to be too aggressive, causing corrosion and reducing the microhardness of dentin (40,41).

Hydrochloric acid (HCl)

20% hydrochloric acid was found to be superior to 10% formic acid and chloroform in achieving patency in teeth obturated with EndoSequence BC Sealer, with a significantly faster time. While it helped clear dentinal tubules, SEM analysis showed it caused more evident superficial erosion of dentinal tubules compared to other irrigants, though this erosion might be limited (21). Its safety in endodontic procedures needs further research.

Citric acid

Recent preliminary research indicates that 10% and 20% of citric acid solutions have a significant dissolving capability on various HCSs (e.g., AH Plus Bioceramic Sealer, Bio-C Sealer, BioRoot RCS, TotalFill BC Sealer). It causes intense gas release and visible bubbling, leading to pore and crack formation in the sealer material. Crucially, these concentrations were found to have minimal or no negative impact on root dentin structure, even after prolonged exposure in simulated retreatment protocols. This finding suggests citric acid as a promising solvent for HCSs sealers. The low pH of citric acid (typically below 2) is thought to contribute to its superior dissolving properties, as HCSs hydration products become unstable below a pH of 8.8 (42).

Acetic acid

5% acetic acid was tested in one study and resulted in decreased success rates for obtaining apical patency for HCSs when compared to using no solution. While it could theoretically increase HCSs solubility by facilitating calcium ion leach-out, its practical efficacy in retreatment has been shown to be limited (41) (Table 2).

Chelating Agents and Other Solutions

Ethylene diamine tetra-acetic acid (EDTA)

Primarily functions as a calcium chelator and is widely used for smear layer removal (43). One study found that 17% EDTA (applied for 5 minutes) affected the structural integrity of TotalFill BC sealer without damaging dentin, but it was less effective in material removal than 10% formic acid (40). Another study noted that EDTA caused less structural damage to sealers compared to citric acid (42). Some studies suggest EDTA has very minimal solubility on HCSs materials and no evident potential to be used as a solvent (39).

Sodium hypochlorite (NaOCl)

2.5% NaOCl is routinely used for disinfection during retreatment and as an irrigant, but it is not primarily a solvent for sealers. 6% NaOCl was found to decrease the success rates of obtaining apical patency for HCSs when compared to using no solution in one study (41).

Table 2 Factors Contributing to the Retreatment Difficulty of HCSs Sealers

Factor	Concise Explanation
High Microhardness and Compressive Strength	HCSs continue hydrating and crystallizing for weeks, increasing hardness and resistance to mechanical removal
Strong Chemical Bonding to Dentin	Formation of hydroxyapatite, mineral infiltration zones, and tag-like structures leads to strong adhesion to dentin walls
Complex Canal Anatomy	Curvatures, isthmuses, lateral canals, and C-shaped configurations trap HCSs residues and hinder file access
Apical Sealer-Only Region	In many cases, gutta-percha does not reach the apex, leaving only HCSs in the apical 1–2 mm, making patency difficult to regain
Lack of Effective Solvents	No predictable solvent exists; agents like chloroform, xylene, EDTA, acetic acid, HCl, and FA show limited or inconsistent softening effects and may damage dentin

Carbonated water

Carbonated water (containing dissolved carbon dioxide) decreased the success rates for apical patency when compared to using no solution for HCSs. The carbonation reaction theoretically weakens HCSs by forming calcium carbonate (41).

In summary, the literature presents conflicting results, with some studies showing efficacy for certain solvents and others demonstrating decreased patency rates or no significant dissolving effect. One study reported that apical patency was obtained in almost all samples when no solution was used, and that the use of 6% NaOCl, 5% acetic acid, or carbonated water decreased the success rates for obtaining apical patency. This was attributed to liquids potentially dampening the energy of the retrieving motion when absorbed into the sealer's pores. The ideal solvent should dissolve the filling material without adversely affecting dentin microstructure. Whereas 20% HCl and 20% FA can erode dentin, 10% FA and 10–20% citric acid show promise with minimal dentin effects under experimental conditions. Despite the use of various mechanical and chemical techniques, complete removal of HCSs from the root canal system remains unachievable. Persistent challenges include regaining patency and removing material from inaccessible areas. The integration of mechanical and chemical removal techniques is considered to yield promising outcomes, especially when the chemical agents specifically target the sealer's chemistry. Further standardized research is necessary to fully understand the effects of various solvents on HCSs and root dentin, and to establish clear clinical protocols for their use in retreatment.

Supplemental Irrigation Techniques

Supplemental irrigation techniques, including various activation methods, are essential because mechanical removal alone is often insufficient, and residual material can harbor microorganisms. These methods enhance irrigant contact with canal walls, aiding debris and smear layer removal.

Passive ultrasonic irrigation (PUI)

PUI creates acoustic microstreaming and cavitation effects that help remove debris, organic tissue, and even root canal sealers from inaccessible areas (44). One study found that PUI resulted in a significantly higher percentage of cleaned walls compared to syringe irrigation due to energy transfer, acoustic streaming, cavitation, tip vibration, and potential gutta-percha plasticization and sealer debonding. However, compared to XP-Endo Finisher and XP-Endo Finisher R, PUI had a significantly lower mean percentage of cleaned area in all root sections after retreatment of TotalFill HiFlow BC sealer, with the lowest percentage in the apical third (46). Some studies indicate that PUI does not provide additional effectiveness in removing residual material in certain contexts or compared to other advanced methods (46-48).

EDDY sonic activation

EDDY is a sonic device that uses high-frequency vibration (~6,000 Hz) and a polyamide tip to create cavitation and sonic flow, enhancing irrigation activation through three-dimensional movement. In canals filled with MTA Fillapex, EDDY activation was significantly more effective than conventional needle irrigation (CNI) in removing residual filling material across all coronal, middle, and apical sections.

Its superior performance in the apical area may be due to its greater tip flexibility. The superior efficiency of EDDY over CNI in removing residual filling material is attributed to its acoustic conduction and cavitation effects (49).

Ultra-X

Ultra-X is a wireless ultrasonic device (45 kHz) that utilizes acoustic microflow, agitation, and cavitation. When retreating canals filled with HCS (BioSerra), Ultra-X was statistically superior to CNI in the coronal region, and significantly superior to both EDDY and CNI in the middle and apical regions. The differences in efficacy between Ultra-X and EDDY for different sealers (MTA Fillapex vs. BioSerra) may be due to the physical and chemical qualities of the sealers and the removal efficiency of the activation devices (49).

XP-endo Finisher (XPF) and XP-endo Finisher R (XPR)

These are shape-memory NiTi alloy instruments that, are straight in the martensitic phase (cooled) and transform to a serpentine austenitic phase at body temperature, allowing them to contact and clean inaccessible areas. XPR has a stiffer core (ISO No.30, taper: 0%) than XPF (ISO No.25, taper: 0%), potentially making it more efficient (51). Used as supplementary techniques after initial retreatment of HCSs, XPR and XPF showed better cleaning ability compared with PUI in all thirds of each root canal. XPR achieved 86.49% cleaned surface area, and XPF achieved 85.97%. The mechanical action of XPR was found to be more effective than activating irrigating solutions using PUI in dislodging root filling material (45). One study indicated that ultrasonic tips were more effective than XPF in reducing the percentage of residual filling material; notably, the ultrasonic tip utilized in this research featured a flat, equilateral triangular shape and was operated with pendulum movements (51). Another study found that XPF, when used after initial retreatment with WOG files, significantly enhanced the removal of filling material, resulting in higher percentages of removed filling volume for AH Plus Bioceramic (AHB) and Ceraseal (CER) compared to AH Plus Jet (AHJ). AHB and CER groups showed higher mean percentages of removed filling volume at 94.8% and 92.5%, respectively, compared to 87.1% for the AHJ group (52). However, one study found that XPF significantly reduced remaining material in the AH Plus group but did not significantly reduce the volume of HCSs fillings (53).

Laser-assisted photoacoustic streaming

These methods involve placing a laser fiber in the pulp chamber to create effective vibrations, elevate temperature, and induce acoustic transmission, cavitation bubbles, and hydrodynamic shear stresses, which improve the retrievability of filling material.

Photon-Initiated Photoacoustic Streaming (PIPS) utilizes a low-energy Er:YAG laser with ultra-short pulses to activate irrigants. The resulting photoacoustic shock waves and cavitation effects generate rapid fluid motion capable of penetrating complex canal morphologies (54). PIPS has emerged as a highly effective adjunctive technique in the retreatment of root canals filled with HCSs. When compared to other irrigation methods, PIPS demonstrates superior efficacy in removing HCSs. micro-CT studies have shown that PIPS achieves significantly greater volumetric removal of materials such as iRoot SP and gutta-percha compared to both PUI and CSI (55). Complementary evidence indicated that incorporating PIPS into retreatment protocols could raise removal rates for EndoSequence BC sealer to as high as 96.43%. These results underscore the ability of PIPS to achieve enhanced debridement beyond that provided by mechanical instrumentation alone. The superiority of PIPS also extends to canal wall cleanliness. Scanning electron microscopy analyses have revealed that PIPS-treated canals exhibit significantly cleaner surfaces, especially in the middle and apical thirds. Lower cleanliness scores and greater exposure of dentinal tubules indicate more effective removal of debris, sealer remnants, and smear layer compared to PUI and CSI (56).

PIPS technology has evolved into newer modalities like shock wave-enhanced emission photoacoustic streaming (SWEEPS), which aims to further intensify the photoacoustic effect (57). SWEEPS combined with reciprocating instrumentation provided more satisfying results than reciprocating instrumentation combined with PUI in one study comparing retreatment of HCSs (58). Another study found that after mechanical retreatment and SWEEPS irrigation, there was a significant reduction in root canal filling material in all groups, but no complete removal (59). One study showed that the diode laser was the most effective modality for eliminating root canal filling materials in the least amount of time and led to statistically significant canal cleanliness (60) (Table 3).

Table 3 Overview of Equipment for HCS Sealer Removal

Category	Equipment/Solution	Key Advantages / Limitations
Mechanical Removal	Continuous rotation files	• Faster preparation • May leave apical remnants • Risk of microcracks or flute distortion when cutting through hard-set HCSs
	Reciprocating NiTi Files	• More effective in curved canals • More predictable patency regains • Better removal of HCSs compared with rotary files • Requires longer working time
	XP-endo Finisher / Finisher R	• Excellent supplementary cleaning • Reaches recesses and canal irregularities • Improves removal after initial instrumentation
Solvents	10% Formic Acid	• Softens HCSs with minimal dentin erosion • Effectiveness varies depending on sealer type
	10–20% Citric Acid	• Strong dissolving effect • Produces bubbling and surface breakdown • Minimal effect on dentin structure

Table 3 Overview of Equipment for HCS Sealer Removal (continued)

Category	Equipment/Solution	Key Advantages / Limitations
	20% Hydrochloric Acid	• Fastest softening performance • Facilitates patency regain • Risk of dentin erosion; not recommended clinically
	5% Acetic Acid	• Limited softening ability • Reduces patency success • Not recommended for dissolving HCSs
	Organic Solvents (Chloroform, Xylene)	• Useful for dissolving gutta-percha • Minimal effect on HCSs material
Supplemental Irrigation Techniques	Passive Ultrasonic Irrigation (PUI)	• Acoustic streaming and cavitation • Helps dislodge residual HCSs
	EDDY Sonic Activation	• High-frequency sonic agitation • Flexible polyamide tip enhances apical cleaning
	Ultra-X Ultrasonic Activation	• High-power ultrasonic agitation • Significantly improves removal in middle and apical thirds
	Laser Activation (PIPS / SWEEPS)	• Produces strong photoacoustic shock waves • Highest efficiency for HCSs sealer removal • Cannot achieve complete removal

Clinical Consideration and Procedure for HCSs retreatment

Initial Access and Coronal Gutta-Percha Removal

Access cavity preparation begins with establishing adequate entry into the root canal system to ensure visibility and straight-line access. Once access is achieved, removal of the coronal portion of gutta-percha is initiated, typically involving the first 3–4 mm. This can be accomplished using Gates-Glidden drills in sequential sizes 2, 3, and 4, or alternatively by applying a heat plugger at 160-200°C up to five seconds to thermo-soften the coronal gutta-percha (61).

Root Canal Filling Material Removal

Selection of main retreatment files plays a central role in effective removal of HCSs. Reciprocating systems, such as Reciproc Blue and WaveOne Gold, are generally more effective than rotary systems, owing to their alternating motion that helps dislodge hard-set sealers and their superior centering ability, making them particularly suitable for severely curved canals (32,33). Rotary instruments, including ProTaper Universal Retreatment and ProFile, can also be used, although systems like ProTaper Gold and Endo ReStart have shown a tendency to develop microcracks and fractured tips, while alternatives such as XP-3D Shaper and HyFlex Remover avoided these complications (28,55). Initiation of retreatment typically begins with the selected system, such as 25/.08 or 30/.10 files, applied with light apical pressure.

Instrumentation sequence involves enlarging the canals at least one size beyond the previous master apical file (MAF) used in the initial treatment, in less complex canals, enlarging by two sizes beyond the previous preparation can further reduce residual sealer (62-64). The process is carried out until the predetermined working length is reached. Because retreatment of HCSs is more time-consuming compared to conventional sealers, patience and careful progression are essential to achieve optimal results.

Solvents

Targeted Acidic Solutions

10% FA is a chemical adjunct that can be applied for 5 minutes alongside mechanical instrumentation. This procedure has demonstrated over 95% removal of TotalFill BC sealer and gutta-percha without causing damage to dentin (40).

Citric acid and 20% HCl have been shown to dissolve HCSs sealers without significant impact on root dentin. Nonetheless, further research is necessary prior to clinical implementation (21,42,65).

Conventional Irrigants and Solvents

2.5% NaOCl is used for irrigation between each file insertion during mechanical removal.

17% EDTA is used for smear layer removal during final irrigation. While it can affect sealer integrity, it primarily removes the smear layer and may not effectively degrade HCSs (40,66).

Organic solvents dissolve gutta-percha, but effects on HCSs are inconsistent. The study demonstrates that the use of solvent facilitates the removal of gutta-percha from inaccessible areas more effectively than when no solvent is applied. Solvent use should be minimized and avoided beyond the apex (37).

Supplementary Irrigations

Active irrigation and supplementary mechanical methods are crucial to maximizing material removal and are considered mandatory to enhance cleaning efficacy, as mechanical removal alone is insufficient.

XPF and XPR are highly effective supplementary instruments (51). XPR is stiffer and more efficient than XPF. Their shape-memory NiTi alloy allows them to contact and clean inaccessible areas. Use after initial retreatment to enhance removal. PUI significantly improves removal of root canal filling materials by acoustic microstreaming and cavitation. Sonic Activations show greater effectiveness removal of root canal filling materials across compared to CNI.

Regain working length and apical patency

The evidence suggests that regaining apical patency is significantly more predictable and consistently achievable in anterior teeth than in posterior teeth, especially molars. This difference is primarily attributed to anatomical complexity. In anterior teeth, the straighter and simpler canal morphology allows instruments to more effectively penetrate and remove filling materials, leading to high patency rates (often 100%), even in challenging scenarios where gutta-percha is short of the apex (67). In posterior teeth, particularly molars, the presence of severe curvatures, isthmuses, and multiple canals makes it substantially more difficult to remove bioceramic sealers and regain patency. The failure to regain patency is most pronounced when the apical part of the canal is filled exclusively with a hard setting bioceramic sealer (14).

Ultimately, the most decisive factors across all tooth types are whether the apical portion of the canal is filled only with sealers or contains a gutta-percha core. Research shows that placing the gutta-percha cone short of the working length, with only HCSs in the apical 1.5–2 mm, often makes it difficult or even impossible to regain working length and apical patency, especially in bulk sealer-obturated canals. When the gutta-percha extends to the full working length, patency is much more predictable (14,68).

Conclusions

Complete removal of root canal filling materials remains impossible regardless of the instrument, technique, or solvent employed, with the apical third consistently showing the greatest amount of residual material due to anatomical complexity and bonding with dentin. Despite this limitation, retreatment of canals filled with HCSs is generally feasible, and patency can usually be regained, leading to satisfactory healing outcomes. Comparative studies of HCSs and resin-based sealers report variable outcomes; some indicate more remnants with hydraulic materials, others with resins, and several observe no significant difference. These discrepancies are likely due to differences in study design and canal morphology. Active irrigation and supplementary mechanical methods—including PUI, XPF, EDDY, lasers, and chemical solvents—significantly enhance material removal, but none achieve complete cleanliness. Thus, the clinical focus shifts from total elimination to maximizing reduction of remnants, particularly in the apical third, to facilitate canal disinfection and promote periapical healing.

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None

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