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Changes of endodontic reciprocating files after retreatment of Neo Sealer Flo bioceramic

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Abstract
Endodontic retreatment is essential when infection persists or recurs in previously treated teeth. Contemporary progress in calcium silicate-based bioceramic sealers have undergone substantial improvements treatment outcomes attributable to their superior biocompatibility, antimicrobial properties, and capability to form a hermetic seal. Their penetration into dentinal tubules, chemical bonding with tooth structure, and alkaline environment help eliminate residual microorganisms and enhance long-term prognosis. Moreover, the single cone (SC) obturation technique, once regarded as inadequate, has regained acceptance when combined with these sealers, achieving high success rates, while the WVC technique continues to offer superior adaptation but with technique-dependent limitations on certain sealers. On the mechanical side, advances in instrumentation, particularly the introduction of oscillating motion systems and heat-treated NiTi files, have improved clinical safety by reducing the risk of instrument fracture and increasing fatigue tolerance. Although studies present mixed findings on their efficiency compared to continuous or adaptive motion systems, the integration of innovative sealing materials with modern instrumentation provides a more predictable, biologically favorable, and efficient approach to retreatment. Nevertheless, further longitudinal clinical investigations are warranted to definitively determine their long-term durability, sealing performance, and clinical advantages of these evolving materials and techniques.

Keywords: Reciprocating files, Neo Sealer Flo bioceramic, calcium silicate-based sealers, NiTi

Introduction
Endodontic retreatment is indicated for a tooth that has undergone prior treatment presents with recurrent infection. The outcome of such secondary treatment largely relies on the complete extraction of root canal obturation materials and the effective elimination of the bacterial pathogens responsible for the initial treatment failure [1].

Recently, the clinical utilization of contemporary preformulated calcium silicate-based sealers (CSBSs) has expanded considerably, owing to their user-friendly handling, favorable physicochemical properties, and associated clinical benefits [2].

Bioceramic sealers possess several critical characteristics that contribute to their efficacy in endodontic practice. Their outstanding biocompatibility is attributed to their chemical resemblance to biological hydroxyapatite, a principal constituent of natural bone. [3]. Bioceramic sealers establish a highly effective hermetic seal, thus inhibiting the infiltration of bacteria and fluids into the root canal system [4]. These sealers are capable of developing a chemical interaction with the tooth substrate and demonstrate antibacterial activity, attributable to their alkaline pH and the in situ precipitation that occurs upon setting. This mechanism entraps bacteria, thereby diminishing the bacterial load within the root canal system and reducing the probability of reinfection [5].

The capacity of the sealer to infiltrate dentinal tubules contributes to an enhanced seal, effectively blocking the flow of fluids and microorganisms from the root canal and the periodontium. Furthermore, bioceramic sealers with superior penetration capabilities can demonstrate antimicrobial activity, thereby reducing the probability of recurrence of infection. Adequate penetration also facilitates optimal adaptation of the sealer to the anatomical anomalies in the dentinal tubule structure, promoting the formation of a hermetic seal [6].

Reciprocating files operate through a repetitive back-and-forth or up-and-down motion. These instrument systems utilize a centric oscillating motion, initially rotating counterclockwise (e.g., Reciproc 150°, WaveOne 170°) to cut dentin, followed by a clockwise rotation (e.g., Reciproc 30°, WaveOne 50°) to remove the debris. This alternating motion minimizes the screw-in effect commonly observed using continuous rotary instrumentation. The angles of rotation are deliberately maintained below the stress threshold necessary to cause instrument fracture if binding occurs within the dentin; specifically, the counterclockwise alternating angle remains within the elastic limit of the material used in each system, thereby enhancing procedural safety [7].

Bioceramics

They are ceramic materials engineered particularly for medical and dental application. This category encompasses alumina, zirconia, bioactive glass, glass-ceramics, hydroxyapatite, and various calcium phosphate compounds [8].

These materials have numerous applications within the medical field, including their use as replacements for hips, knees, teeth, tendons, and ligaments. They are additionally utilized in reconstruction of the maxillofacial region, jawbone enhancement and stabilization, spinal fusion procedures, as bone fillers after tumor resection, and in the manufacturing of prosthetic heart valves [9].

Bioceramic-based sealers can be categorized based on their reactivity with surrounding tissues into bioinert, bioactive, and biodegradable types. Of these, only the bioactive and biodegradable sealers are relevant for endodontic applications [10].

Bioinert: These materials exhibit chemical stability *in vivo* and demonstrate outstanding tolerance to corrosion, wear, and mechanical stress [11]. They are biologically inert and do not interact with living tissues. This category includes materials such as alumina and zirconia, which are frequently employed in orthopedic and dental applications—for example, femoral heads and dental implants—but are not utilized in endodontics [12].

Bioactive: This indicates that the material engages with the biological environment. In endodontics, bioactive ceramic sealers have the potential to promote tissue regeneration, healing, and effective sealing. Materials in this category include calcium silicate sealers, bioactive glass, bioactive glass-ceramics, and hydroxyapatite [13].

Biodegradable: Biodegradable bioceramics constitute a class of ceramic materials capable of degrading over time under physiological conditions. They are engineered to be gradually resorbed by the body or integrated into surrounding tissues. The most commonly used materials in this category are calcium phosphates and bioactive glasses [14].

NeoSEALER Flo (Avalon Biomed, Houston, TX, USA) represents a newly developed preformatted, bioactive, resin-free sealer based on calcium silicate. Its composition includes tricalcium silicate, dicalcium silicate, calcium aluminate, calcium aluminum oxide (grossite), tricalcium aluminate, tantalite as a radiopacifier, and trace amounts of calcium sulfate [15].

CSBSs are increasingly favored as root canal sealers owing to their antimicrobial activity, favorable tolerance, alkaline pH, and bioactive properties [16].

The single cone (SC) obturation techniques in combination with conventional sealers was previously deemed inappropriate. Recently, the SC technique has been reconsidered with the use of CSBSs, given that these materials do not shrink upon setting. The use of the SC technique with CSBSs has shown a high success rate (approximately 90%) in both initial treatment and retreatment cases. SC obturation in combination with CSBSs has resulted in significantly less porosity, particularly in the coronal third, compared with teeth filled using the lateral compaction technique [17].

Root canal sealers are required to exhibit sufficient radiopacity to allow clear differentiation from surrounding anatomical structures, thereby enabling accurate evaluation of the root filling quality via radiographic imaging. Based on ISO 6876:2001, the least required radiopacity for a root canal sealer corresponds to 3.00 mm of aluminum [8].

The antimicrobial properties of a root canal sealer improve the efficacy of endodontic treatment by eradicating residual intraradicular microorganisms that may persist following treatment or infiltrate the canal subsequently via microleakage. Literature indicates that the principal antimicrobial activity of root canal sealers are attributed to their alkalinity and the liberation of calcium ions, which promote tissue restoration via the formation of mineralized deposits. Two primary procedures are employed to assess the antibacterial efficacy of CSBSs: the agar diffusion assay and direct contact test. *Enterococcus faecalis* is the most commonly isolated intraradicular microorganism in cases of periapical periodontitis and is consequently frequently employed to evaluate the antibacterial properties of root canal sealers. Additionally, other microorganisms—including *Micrococcus luteus, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans, and Streptococcus mutans* have been utilized to assess the antimicrobial activity of CSBSs [8].

A correlation was also noted between pH levels and the concentration of released Ca^{2+} ions. The liberation of calcium and hydroxyl ions from calcium silicate-based materials can lead to the generation of an apatite layer when exposed to phosphate-containing fluids over a period of approximately two months. This interfacial layer promotes the establishment of a chemical bond among the calcium silicate-based material and the dentinal walls. Accordingly, EndoSequence BC Sealer, which is formulated from a calcium silicate composition, is anticipated to establish a chemical bond with dentin, thereby minimizing marginal leakage and gap formation [18].

The attachment of root canal sealers refers to the material's capacity to attach to root canal dentin and improve the bonding of gutta-percha cones to both the dentin and to one another. In this context, the term "bonding" is often more accurate than "adhesion," as the interaction primarily involves physical interlocking rather than chemical affinity. There is no standardized method for quantifying bonding of the sealer to root dentin; consequently, the adhesive ability of root filling materials is typically assessed via microleakage and bond strength tests. The sealing efficacy of a sealer is influenced by its dissolvability as well as its capacity to bond with dentin and root canal filling cones. Various *in vitro* research has assessed the sealing efficacy of various CSBSs. Despite variations in methodology, these studies have consistently reported satisfactory sealing performance, comparable to that of alternative readily marketed sealers.

However, until recently, evidence with regard to the long-term sealing performance and clinical outcomes related to CSBSs has been limited [8].

The WVC technique was introduced by Schilder in the 1967s with the aim of enhancing root canal wall adaptation [19]. The WVC technique includes heating the GP until it softens and alters its phase, thereby achieving intimate conformity to the walls of the prepared root canal. In this technique, less sealer and more heated GP are used. The WVC technique is associated with better adaptation to the canal wall [20, 21]. However, this technique is time-consuming, responsible for the sealer's apical extrusion, leading to post-operative pain [22, 23]. With practice, GP control has improved, reducing operating time and benefiting from the heated GP approach. Generally, the WVC technique needs a lower proportion of sealer than the cold filling technique [23].

While WVC remains a widely employed practices among clinicians and endodontists, [24, 25] the heat produced during WVC can adversely impact the physicochemical characteristics of specific root canal sealers [26]. Because CSBSs rely on moisture for setting and exhibit subsequent setting expansion, exposure to heat can adversely influence their physical and chemical properties [26, 27]. Conversely, manufacturers recommend using CSBSs with the single-cone technique (SCT) rather than WVC [24, 25]. EndoSequence BC (Brasseler USA, Savannah, GA) appears to tolerate elevated temperatures well. Although heat exposure induces minor alterations in its setting behavior and chemical properties, the sealer remains stable exhibiting minimal weight loss. In contrast, BioRoot RCS (Septodont, Louisville, USA) exhibits substantial weight loss, raised viscosity, and decreased flowability when subjected to heat. Consequently, BioRoot RCS is better suited for use with the single-cone (SC) obturation procedure rather than WVC [28].

Most studies suggest that oscillating motion, in contrast to continuous rotation, enhances the endurance against cyclic fatigue of endodontic instruments, independent of factors such as rotational speed, the curvature angle of simulated canals, instrument design, or the surface properties of NiTi instruments [29].

Differences have been observed in the effectiveness and efficiency of removing root canal fillings from curved canals via rotary files with various motion patterns. Continuous rotation entails a consistent clockwise rotation of the rotary file, while oscillating motion involves alternating clockwise and counterclockwise rotations, completing a full 360° cycle over three alternating cycles. Adaptive motion functions as a continuous clockwise rotation under stress-free conditions, transitioning to oscillating motion when the instrument experiences stress [30].

Research comparing various file motions has reported inconsistent findings. Some investigations have observed comparable effectiveness and efficiency of continuous rotation versus oscillating motions for removing root canal fillings in curved canals [31, 32]. However, other investigations have reported indicating that oscillating motion can remove approximately twice as much root canal filling material as continuous rotation [33]. Moreover, an additional study demonstrated demonstrating that continuous rotation was more effective and faster in clearing root canal obturation material than oscillating motion [34]. Furthermore, research has indicated that adaptive motion can remove 6-10% more root canal filling material compared to continuous rotation [35].

WaveOne Gold (Dentsply, Maillefer, Ballaigues, Switzerland) is produced using a gold heat treatment process and features an off-centered parallelogram cross-section with two cutting edges. Unlike the pre-applied heat treatment utilized in M-Wire technology, the gold heat treatment is manually performed by heating the file and subsequently allowing it to cool gradually, resulting in the formation of Ti_3Ni_4 precipitates distributed across the surface. This novel heat treatment enhances both the file's flexibility and its tolerance to cyclic fatigue [36, 37].

EdgeOne and EdgeFile X7 (EdgeEndo, Albuquerque, NM, USA) are recently introduced instruments manufactured made from heat-treated FireWire NiTi, which is reported to offer enhanced tolerance to cyclic fatigue. EdgeOne is a single-file oscillating system featuring a parallelogram cross-section, whereas EdgeFile X7 is a multi-file rotary system featuring a parabolic cross-section. As stated by the manufacturer, both cross-sectional designs improve cutting performance and instrument strength, thereby increasing tolerance to fracture [38].

Introducing different kinematic motions have raised nowadays a new perception of the efficiency of the instruments. It has been claimed that reciprocation motion helps increase the CFR and life of NiTi instruments. The idea of rotating in counterclockwise and clockwise movements aids in relieving the stress on the instrument and decreasing the impact of screwing in [39].

Most studies suggest that oscillating motion, relative to continuous rotation, enhances the cyclic fatigue tolerance of endodontic instruments, irrespective of factors such as rotational speed, canal curvature angle or radius, instrument geometry and taper, as well as the surface properties of NiTi instruments [29].

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