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Dislodgment Resistance, Adhesive Pattern, and Dentinal Tubule Penetration of a Novel Experimental Algin Biopolymer-Incorporated Bioceramic-Based Root Canal Sealer

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Abstract: The currently available bioceramic-based sealers still demonstrate low bond strength with a poor seal in root canal despite desirable biological properties. Hence, the present study aimed to determine the dislodgment resistance, adhesive pattern, and dentinal tubule penetration of a novel experimental algin-incorporated bioactive glass 58S calcium silicate-based (Bio-G) sealer and compared it with commercialised bioceramic-based sealers. A total of 112 lower premolars were instrumented to size 30. Four groups ($n = 16$) were assigned for the dislodgment resistance test: control, gutta-percha + Bio-G, gutta-percha + BioRoot RCS, and gutta-percha + iRoot SP, with exclusion of the control group in adhesive pattern and dentinal tubule penetration tests. Obturation was done, and teeth were placed in an incubator to allow sealer setting. For the dentinal tubule penetration test, sealers were mixed with 0.1% of rhodamine B dye. Subsequently, teeth were cut into a 1 mm-thick cross section at 5 mm and 10 mm levels from the root apex, respectively. Push-out bond strength, adhesive pattern, and dentinal tubule penetration tests were performed. Bio-G showed the highest mean push-out bond strength ($p < 0.05$), while iRoot SP showed the greatest sealer penetration ($p < 0.05$). Bio-G demonstrated more favourable adhesive patterns. No significant association was noted between dislodgment resistance and dentinal tubule penetration ($p > 0.05$).

Keywords: alginate; biomaterials; biopolymer; bond strength; dentistry; endodontics; hydrogel

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1. Introduction

A proper three-dimensional seal of the prepared root canal system is necessary for successful endodontic treatment to prevent bacterial reinvasion via microleakage [1]. Although gutta-percha is still the most commonly used core filling material in such a treatment, root canal sealers are needed, as the lack of bonding and adhesion between gutta-percha and the root dentinal walls poses a challenge in forming a hermetic seal in the root canal system [2]. Hence, a root canal sealer is employed in this situation to provide a fluid-tight seal at the gutta-percha core-sealer and dentin-sealer interfaces [3]. It is worth noting that a fluid-tight seal is crucial for enhancing the sealer materials' bond strength and preventing dislodgment under high occlusal stresses [1]. In addition, root canal sealers fill the anatomical irregularities within the complex root canal system, provide a certain degree of dentinal tubule penetration, and minimise microleakage [4].

A variety of root canal sealers have been introduced into the market, including epoxy resin-based, methacrylate resin-based, calcium hydroxide-based, glass ionomer cement-based, silicon-based, zinc oxide eugenol-based, and bioceramic-based (which includes mineral trioxide aggregate and pure calcium silicate) sealers [5]. Bioceramic-based root canal sealers have gained popularity among clinicians, and a systematic review has shown that root canal obturated with bioceramic-based sealer was associated with significantly lower short-term postoperative pain accompanied with lower analgesic intake and flare-up incidence, as compared to root canal-treated teeth obturated with other sealers [6]. Bioceramic materials based on mineral trioxide aggregate (MTA) were initially developed at Loma Linda University in the 1990s, and later they were modified into root canal sealers to offset the shortcomings of resin-based sealers [7]. Nevertheless, MTA exhibits poor flowability with the presence of heavy metals, leading to the development of new-generation bioceramic sealers based on pure calcium silicate cement [8,9].

iRoot SP (BioCeramix Inc. in Vancouver, BC, Canada) is an injectable calcium silicate-based root canal sealer consisting of calcium silicate, calcium phosphate, calcium hydroxide, zirconium oxide as a radiopacifier, filler, and thickening agents [9]. Unlike other calcium silicate sealers, IRoot SP contains monobasic calcium phosphate, which has been claimed to facilitate the reaction with calcium hydroxide and form hydroxyapatite during its hydration [10]. In 2016, a new root canal sealer based on tricalcium silicate, BioRoot RCS (Septodont, Saint-Maur-des-Fossés Cedex, Paris, France), was released [11]. The liquid portion consists of calcium chloride and polycarboxylate, while the powder is made up of tricalcium silicate, calcium phosphate, povidone, and zirconium dioxide [3]. It has been reported that BioRoot RCS displayed exceptional push-out bond and excellent sealing ability, making it an excellent bioceramic sealer of choice [1]. Furthermore, BioRoot RCS has a lower concentration of heavy metals such as lead, chromium, and arsenic as compared to other MTA products [12]. This is crucial for achieving a highly predictable outcome when employing biomaterials for root canal treatment. In 2022, a new experimental bioceramic-based sealer was invented by incorporating alginate biopolymer into bioactive glass 58S and calcium silicate [13].

Algin, also known as alginic acid, is a hydrophilic polymer derived from seaweed that forms a viscous gel-like structure when hydrated [14,15]. When combined with sodium or calcium, it can undergo gelation and produce salts known as alginates. Alginate gelation occurs when divalent cations, such as calcium ion, Ca^{2+}, bind to alginate and create an insoluble diamond-shaped hole with a hydrophilic cavity that binds the Ca^{2+} by multi-coordinating the oxygen atoms from the carboxyl groups [14]. Furthermore, alginate is a nontoxic, commonly accessible, biocompatible, and nonimmunogenic marine biopolymer [16]. Alginates have several free hydroxyl and carboxyl groups scattered throughout their backbone, making them very reactive and prone to strong cross-linking with other particles. Alginate is frequently employed in medical applications including wound healing, medication administration, and tissue engineering due to its unique features [17]. Moreover, regardless of temperature, algin can form strong intermolecular cross-linking with a shorter setting time, which is of primary interest in current clinical practise, as this will further enhance the intermolecular cohesiveness, preventing material dislodgment from the root canal walls and making it operator-friendly due to its fast setting [14]. However, the use of alginate hydrogel in endodontics, particularly for root canal sealers, is still considered new, and there is little evidence available in the literature. Therefore, it is possible to speculate that this compact gel-like framework will enable adequate root canal system sealing.

Push-out bond strength tests are typically used to assess resistance of sealers being forced out of the root dentine wall [1,3,9]. These are mechanical tests in which the gutta-percha and sealer are pushed out or dislodged by applying a longitudinal tensile load to the long axis of the root sample. As fracturing occurs parallel to the dentine-bonding interface and the push-out bond strength test is repeatable, it can be used to evaluate parallel-sided samples even when the bond strength is low [18]. Another significant consideration when assessing root canal sealers is their capacity to penetrate the dentinal tubule and create a