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Review

Ability of new obturation materials to improve the seal of the root canal system: A review

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ABSTRACT

New obturation biomaterials have been introduced over the past decade to improve the seal of the root canal system. However, it is not clear whether they have really produced a three-dimensional impervious seal that is important for reducing diseases associated with root canal treatment. A review of the literature was performed to identify models that have been employed for evaluating the seal of the root canal system. In vitro and in vivo models are not totally adept at quantifying the seal of root canals obturated with classic materials. Thus, one has to resort to clinical outcomes to examine whether there are real benefits associated with the use of recently introduced materials for obturating root canals. However, there is no simple answer because endodontic treatment outcomes are influenced by a host of other predictors that are more likely to take precedence over the influence of obturation materials. From the perspective of clinical performance, classic root filling materials have stood the test of time. Because many of the recently introduced materials are so new, there is not enough evidence yet to support their ability to improve clinical performance. This emphasizes the need to translate anecdotal information into clinically relevant research data on new biomaterials.

1. Introduction

There is increasing need for the medical and dental professions to base their clinical judgement on evidence-based knowledge [1,2]. The requirement for integrating biologically based knowledge with the advent of new biomaterials designed to improve root canal treatment was widely acknowledged even before endodontics became a specialty [3]. Because diseases of the dental pulp are predominantly infectious in nature [4], the development of new root filling materials should be targeted at improving the ability and efficacy for endodontists to eliminate infections and prevent recontamination [5,6]. As early as 1925, Dr. Walter Hess and his student Dr. Ernst Zürcher showed that root canal systems have exceedingly complex morphologies that may not be amenable to complete shaping and cleaning [7]. Contemporary non-destructive imaging, such as microcomputed tomography, further reinforced this notion from a three-dimensional (3-D) perspective [8,9]. Since then, knowledge of root canal infections has also improved. Apical periodontitis, as it is now known, is not caused by fluid stagnation within unfilled canal spaces [10]. Rather, it is an inflammatory reaction of the periapical tissues and an immunological response of the host defense system to microbes that have infected the root canal system [11,12]. Successful root canal treatment therefore depends critically on controlling pulp space infection [13–15]. Root canal infection, like many other infections, is predominantly a biofilm-induced disease [16–18]. The association between bacterial biofilms and apical periodontitis has been confirmed by more recent histobacteriological studies [19,20].

Success in root canal treatment was founded upon the triad of thorough canal debridement, effective disinfection and obturation of the canal space [21]. Historically, a significant share of this triad had been allocated to obturation of the canal space. Obturation of the canal space to the working length [22] has been depicted as the

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most critical component of root canal treatment for sealing and isolating the canal space from irritants that remain after appropriate shaping and cleaning, and for eliminating subsequent leakage from the periradicular tissues or oral cavity into the filled canal space [23,24]. Results from these early works are supported by recent studies that highlight the contribution of root filling quality to the success of primary and secondary root canal treatment [25–28]. Nevertheless, contemporary research attests that shaping and cleaning are strategically more significant than obturation of the canal space for eliminating root canal infections [29]. Apical periodontitis has been shown to heal in teeth with unfilled canals following meticulous shaping and cleaning, and placement of a coronal seal [30]. It is indubitable that a high-quality coronal seal is important for endodontic success [31]. However, insisting that healing reliably occurs in the presence of a defective root filling creates a very narrow view [32] of the important roles played by canal obturation in preserving the environment created by shaping and cleaning and preventing microbial reinfection of the canal space [33], both of which are essential for securing long-term periradicular heath.

New obturation materials have been introduced into the endodontic market over the last decade. Some of these are modifications of materials developed for restorative dentistry. Others may be considered as new breeds, embracing radically new concepts that have not been employed before in the field of endodontics. These seemingly unrelated new developments share a bona fide feature: their promotions are accompanied by impressive case reports. It is beyond doubt that those clinical cases are performed by outstanding clinicians who, in every way, have demonstrated their "conscientious adherence to high (professional) ideals" [34]. Those cases are demonstrations of the results of excellent shaping and cleaning, and perhaps of sound obturation techniques. On further reflection, do they really demonstrate the superiority of one particular new filling material? The present review highlights and analyzes how the quality of seal is determined for the classic root canal obturation materials. This will provide the background for clinicians to determine, based on the best available evidence to date, whether the recently introduced root canal obturation materials have improved the seal of the root canal system. Search of the literature on the seal of the root canal system was accomplished via the MEDINE (Ovid) database on in vitro and in vivo studies published between 1981 and 2013, using key words "root filling" OR "obturation" OR "leakage" OR "seal". Four journals (*Journal of Endodontics*, *International Endodontic Journal*, *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology* and *Endodontics and Dental Traumatology*) and the bibliography of all relevant articles and review articles were also searched manually.

2. The classics (traditional gutta-percha and sealer)

Historically, gutta-percha, the trans-isomer of polyisoprene, has been the material of choice as a solid, inert core filling material for root canal obturation, beginning with Bowman's introduction of the material into endodontics in 1867 [35]. Contemporary gutta-percha-based root filling materials utilize $\sim$20% of the raw polymer, with the remaining composition consisting of zinc oxide, wax/resin and metal sulphates [36,37]. Different gutta-percha obturation techniques have been employed, including single-cone technique, solvent softening techniques, cold or warm lateral compaction, warm vertical compaction, continuous wave compaction, thermoplastic injection techniques and thermomechanical compaction techniques, as well as core-carrier techniques [38,39]. Of notable mention is that the single-cone obturation technique, developed in the 1980s for standardization of endodontic instruments and filling points [40], has been revived with the introduction of some contemporary filling techniques [41].

Although gutta-percha is not the ideal filling material for root canals, it satisfies most of the criteria for such a material. In particular, gutta-percha exhibits minimal toxicity, allergenicity and tissue irritability when it is retained within the canal space [42]. Gutta-percha is predominantly non-resorbable and is well tolerated in cases of inadvertent overextension into the periradicular tissues [43], when the overextended material is present in bulk instead of fine particles [44]. Gutta-percha is degradable by bacteria species associated with the *Nocardia* genus [45]. However, such species have not been identified as endodontic pathogens, despite the vast diversity of microbial flora reported in untreated teeth and root-filled teeth with apical periodontitis [46–49]. Although gutta-percha retrieved from retreatment cases had been reported to degrade chemically over time via a slow oxidative process [50], there was no associated loss of texture or disappearance of the material from the obturated canal space. Moreover, those root fillings are defective by default as the internal milieu of the canal space should be predominantly anaerobic if the latter is appropriately sealed.

A shortcoming of gutta-percha-based root filling materials is their lack of adhesiveness to canal wall dentin. Because of this limitation, a sealer or cement has to be used with gutta-percha to attain a fluid-tight seal, and to fill the space between the canal wall dentin and the obturating material interface. Sealers also fill voids and irregularities in the root canal, lateral and accessory canals and spaces between gutta-percha points used in lateral condensation techniques. Different types of sealers are currently available, including zinc oxide eugenol and noneugenol sealers, calcium hydroxide sealers, glass ionomer sealers, epoxy-resin-based sealers, silicone sealers, medicated sealers and the more recently introduced methacrylate resin-based sealers and calcium silicate-based sealers. Penetration of sealers and even gutta-percha into dentinal tubules has been demonstrated when the canal wall smear layer is removed [51–53]. The extent of penetration of root canal sealers into dentinal tubules [54–56] has often been used to demonstrate the improvement of sealability to root canals during the launch of new root filling materials and techniques. However, studies have shown that there is no correlation between sealer penetration into dentinal tubules and sealability in non-bonded [57] or bonded [58] root fillings. Along the same line of thought, a small puff of sealer extending through the apical ramifications [22] or lateral canals [59–61] has been considered by some clinicians to be indicative of an optimally obturated canal space with a well-sealed apical constriction or lateral portal of exit. The need to force filling materials into these regions to enhance treatment outcome is not supported by a recent histopathological study [62]. In that study, pulp tissues within those ramifications were not removed by contemporary chemomechanical preparation techniques. Forcing materials into those ramifications in teeth with vital pulps resulted in tissue damage and inflammation. The radiographic appearance of filling materials within those ramifications, while visibly appealing, could not guarantee optimal sealing or disinfection. In large ramifications of necrotic pulps where microbes could reach sufficient quantity to cause or maintain disease, the authors opined that alternative strategies that enable thorough disinfection of those regions should be sought to enhance treatment outcome.

Over the last couple of decades, endodontics has benefited from groundbreaking advancements in imaging capabilities, better magnification, more accurate working length determination technology, more efficient canal shaping armamentarium, more advanced canal irrigation solutions, and radical changes in tissue dissolution and disinfectant delivery techniques. All of these improvements have contributed to enhanced obturation of the