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The Use of Mineral Trioxide Aggregate and Biodentine in Furcal Perforations Sealing – A Review Article

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Abstract
Pulp cavity perforation is defined as pathological connection between root canal system and external surface of the tooth. This iatrogenic pulp chamber injury may have serious implications on the success of root canal treatment. The sealing of perforation is crucial for good prognosis of the treated tooth. The ideal material for sealing perforations in the pulp cavity should be characterized by a good adhesion, lack of sensitivity to tissue fluids, volume stability, radiopacity on radiographs and excellent bioactivity and biocompatibility. To date the most well-known bioceramic material to is mineral trioxide aggregate. Due to over thirty years of its application in endodontics, it is called the „gold standard" for perforation repair. Recently, many new bioceramic materials have been developed and introduced to dentistry and endodontics, showing promising clinical results. One of the materials successfully used for pulp chamber floor perforation repair is Biodentine. According to the manufacturers, Biodentine has a much shorter setting time compared to other bioceramic cements, and also has better mechanical properties and is easier to use. The aim of the article is to analyse the available research and compare the properties of those bioceramic materials in a perforation sealing procedure. Based on the analysis of the current literature, it can be concluded that mineral trioxide aggregate is still the most proven and tested material among bioceramic materials, but Biodentine is a good alternative as it is relatively easy to manipulate but also has predictable clinical results.

Key words: *bioceramic, MTA, Biodentine, pulp chamber, perforation.*

Introduction

Perforation of the tooth cavity may be pathological, related to the resorptive or carious process or iatrogenic, being a complication during or after root canal treatment (RCT). Due to the increasing frequency of performance of endodontic treatment procedures by general dentists [1, 2], the number of iatrogenic complications may increase. Perforations within the root canal system are associated with worsening treatment prognosis, especially when a bacterial infection develops [3–5]. According to the dictionary of endodontic terms of the American Association of Endodontists, perforation is defined as a pathological connection of the root canal system with the external surface of the tooth [6]. The frequency of this complication ranges from 0.6% to 17.6% [3, 4]. Epidemiological studies have shown that perforation most often occurs during prosthetic treatment – preparation for a crown-root post, and less frequently during endodontic procedures [3, 4, 7, 8]. In 1996, Fuss and Trope [3] proposed a classification of root perforation. The researchers found that the prognosis of the tooth is influenced by factors such as the size of the perforation, its location and the time elapsed from the injury to its repair, which was in agreement with other reports [3, 5, 7]. Based on the factors earlier mentioned, the ideal treatment strategy can be determined. According to the cited researchers, the most favourable healing conditions occurred when the injury was immediately sealed, while large perforations or their location in the cervical region of the tooth (connection with the gingival sulcus or alveolar bone) reduced the chance for effective repair treatment [3]. Currently, due to the use of bioceramic materials in endodontics, the size of the perforation is rather a controversial issue. Before the widespread use of bioceramic materials, various dental materials were used for root perforation repair, such as amalgam [9], zinc oxide eugenol cement [9], or resin-modified glass ionomer cements [10] and resin materials [11]. Perforation treatment became possible thanks to the introduction in 1993 of the mineral trioxide aggregate (MTA) into dentistry [12]. Initially, this natural bioceramic material was used for retrograde filling of root canals. According to data from the literature, bioceramics are used in clinical conditions in: vital pulp therapy, orthograde and retrograde root canal filling, apexification, perforation repair and root defect repair [13, 14]. Bioceramics available on the market have similar biological properties, but they have certain chemical differences that affect their contrast in radiographs, the degree of difficulty in handling and the setting time [14–16]. One of these successfully used for pulp chamber floor perforation repair materials is Biodentine (BD). The aim of this study is to analyse the available recently published research and compare the properties of MTA and BD in the cases of treatment of pulp cavity furcal injury. The author of this study searched digital databases (PubMed, Google Scholar) in September 2023. The search has been conducted to evaluate the chemical composition and setting time of MTA and BD and their clinical features, like: sealing ability with or without a matrix barrier under the bioceramic, leakage resistance, immune response and bone formation after sealing the furcal perforations in in vivo animal studies, cytotoxicity, push-out bond strength, the impact of rinsing agents used during endodontic procedures on the bioceramics, washout resistance, discoloration of tooth tissues after placing the bioceramics in the pulp cavity, and to see if the size of the perforation reduces the success of the treatment. The search has been conducted using these keywords: calcium silicate-based cements, MTA, Biodentine, physicochemical properties, perforation, matrix barrier, leakage resistance, sealing ability, washout resistance, cytotoxicity and discoloration.

Chemical composition and setting time

For the first time, MTA was introduced in 1993 as a material for retrograde root canal filling [12]. It is available in the form of a powder with a composition similar to Portland cement, it is a conglomerate of tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium aluminoferrate, and additionally contains bismuth oxide (X-ray contrast) and gypsum. When mixed with distilled water, it has the consistency of wet sand, which sets within a few hours. BD was launched on the dental market in 2011. It is a two-component material. The powder contains tricalcium silicate, dicalcium silicate, calcium oxide, calcium carbonate, zirconium dioxide (contrast agent) and iron oxide (gives colour). The liquid consists of calcium chloride (setting accelerator), water-soluble polymer and water. According to the manufacturer's instructions, after combining the powder with the liquid in a shaker (30 seconds; 4000–4200 rpm) and placing the BD on the site of damage, its setting time is 12 minutes. RCT should be performed at the next visit in accordance with current recommendations. These data were confirmed in a study published by Buła et al., where, after mixing the material, the initial setting stage lasted 15 minutes, and the second stage, denominated by the cited authors as „maturing", lasted 120 minutes; therefore, it is reasonable to divide RCT with

BD into two separate visits [17]. Interestingly, in in vitro and in vivo studies published in 2023, the authors concluded that the distribution of BD nanoparticles is crucial for the osteogenic potential at an earlier stage of binding compared to MTA [18].

The size of perforation

With the introduction of bioceramic materials into endodontics, discrepancies have emerged in studies regarding the prognosis of perforated teeth [19–21]. According to Alves de Mente et al., the size of the perforation does not reduce the success of the treatment [22], what is in contrast to other reports [23, 24]. Due to advantages related to physicochemical and biological properties similar to dentin and high compressive strength [14, 21, 25], the bioceramics have high sealing abilities and biocompatibility [8, 26]. According to the literature, the healing rate after perforation repair ranges from 69.8% to 93% [22, 24], and the follow-up period was two years or more [22–24, 27, 28]. In a study with a 14-year follow-up to 8 years, a very low initial failure rate was observed, but after this follow-up period a significant increase in failure rates was observed [24].

Matrix barrier

For a long time, the issue of using a matrix barrier has been a topic of debate. There is still no agreement on the use of a matrix barrier under the bioceramic in injury repair. Researchers reported that different barriers have been proposed, among others, calcium sulphate [29], collagen [30], platelet--rich fibrin matrix (PRF) [27, 31] or concentrated growth factors (CGF) [31]. The scientists have examined whether there are any differences of healing outcomes between mending procedures with or without a barrier [29, 31, 32]. Aladimi et al. [29] concluded that calcium sulphate under MTA provided the best results in the repair of accidental perforation of the furcation region. The cited authors also found that MTA with or without calcium sulphate showed greater bone and cement apposition, less bone resorption, epithelial proliferation and inflammation compared to nano-modified glass ionomer filled with resin [29]. According to another study, in order to prevent BD extrusion during the treatment of open apex, furcation perforation and horizontal root fracture, platelet-rich fibrin was used as the external matrix [27]. In the mentioned clinical research, the patients were followed for 2–3 years, and the treated teeth showed significant healing. Similarly, recently data were presented where MTA with PRF or CGF demonstrated more bone formation, and fewer inflammatory cell counts than MTA alone, which was statistically significant [31]. Interestingly, others reported that only in the cases of large perforations, a resorbable matrix such as collagen or calcium sulphate was used [32]. However, authors of publication from 2022 stated that extrusion of the bioceramics into periodontal tissues may worsen the results of the perforation treatment [7].

Sealing ability

The leakage resistance and sealing ability of bioceramic materials used in perforation repair are important factors influencing the outcome of RCT. The results of recently published studies conducted on samples of extracted mandibular molars with dye penetration assessment indicated better sealing properties of BD compared to MTA [33–36], which may be related to the difference in particle size (BD has smaller particles) [37] and the method of preparing the material for use (MTA – hand mixing; BD – mechanical mixing), which results in lower porosity of BD than MTA. Other researchers have also assessed the sealing ability of MTA and BD to repair furcation perforations [30, 34]. In an in vitro study published by Das et al., the sealing ability of the bioceramics was assessed [34]. The researchers concluded that BD demonstrated better sealing ability than MTA-Angelus. The authors mentioned above concluded that BD can be considered as a repair agent for furcation perforation. The results of the in vitro studies presented above are in contradiction with clinical studies, where scientists concluded that MTA effectively seals root perforations and can improve the prognosis of perforated teeth [22, 24, 38].

Tissue response

Previously published studies have assessed the immune response and bone formation after sealing the furcal perforations in rat teeth [39, 40] and canine molars with BD and MTA [41]. The findings of da Fonseca et al. indicate the role of BD and MTA in inducing an immunoinflammatory response, promoting the regression of the inflammatory reaction and the formation of structural elements of the periodontium, such as collagen fibres and bone matrix [39]. In the previously mentioned in vivo study, a histopathological analysis of tissue response after sealing furcation perforations in dog teeth with BD and MTA was performed [41]. The results of the cited study showed that after the use of MTA, mineralised tissue was formed in 88% of the samples, and in the case of Biodentine in 92% of the samples, but these differences were not statistically significant [41]. The evaluated materials also demonstrated the ability to partially reinsert collagen fibres. The scientists observed that only MTA induced the expression of proteins related to the formation of cement-like mineralised tissue. The cited researchers also found no bone resorption and lower number of inflammatory cells after the use of BD and MTA [41]. Tissue responses after immediate sealing of furcation perforations in rat teeth with the bioceramics have also been evaluated by others [40]. Researchers reported that BD and MTA promote appropriate periradicular tissue reactions, with a milder inflammatory reaction, less bone resorption compared to the positive control and cement repair after sealing furcal perforations [40]. Interestingly, according to a systematic review of the literature, repair of furcal perforations with BD yields better results compared to MTA [19]. In another animal study, histological response, radiographic and CT examination were compared after repair of furcation perforation with BD and MTA in canine's teeth [42]. The cited researchers obtained similar results in hard tissue resorption and repair for the bioceramics, which were radiologically evaluated, but the BD group showed significantly less inflammation, less extruded material after sealing and greater cement repair than the MTA group. The previously mentioned authors found that after repairing furcation perforation in dogs' teeth, BD is biocompatible and allows the formation of mineralised tissue with similar morphology and integrity [42]. The tissue response was also estimated on osteoblast cell cultures by Campi et al. [43]. MTA and BD presented similar bioactivity and biocompatibility. Evaluated materials were cytocompatible, capable to promote mineralised nodule deposition and alkaline pH [43].

Cytotoxicity

The issue of cytotoxicity and bioactivity of bioceramic materials was also analysed by researchers [16, 43, 44]. In the cited studies, the authors noted similar toxicity of the assessed bioceramics. MTA was the most frequently used as well as studied cement, and the systematic review of literature corroborated its reduced cytotoxicity [44].

Push-out bond strength

An interesting issue is the assessment of the push-out bond strength among the bioceramics. Research comparing MTA and BD used in the treatment of pulp chamber floor perforation in extracted mandibular molars was presented by others [30]. In the mentioned study [30], the push-out bond strength of bioceramic materials increased with the increasing setting time. The push-out bond strength of MTA and BD in blood-free samples was similar. Blood contaminated samples with BD had no effect on push-out bond strength. Different results were observed for blood contaminated samples repaired with MTA, blood contamination affected MTA samples with a setting time of 7 days. That was confirmed by a systematic review and meta-analysis of in vitro studies published in 2022 [45]. The push-out bond strength of bioceramic materials after applying a calcium hydroxide dressing was also tested [46,47]. Alsubait et al. concluded that calcium hydroxide causes a lower bond strength of MTA with root dentin [46], which was contrary to another study [47] in which researchers observed no effect on MTA's resistance to dislodgement from root canal dentin.

Rinsing agents effect

An interesting issue raised by researchers is the impact of rinsing agents on the bioceramics [46,48]. Taking into account the influence of various agents used for irrigation during endodontic treatment on the strength of the BD's and MTA's push-out bond, Guneser et al. [48] found that after exposure to solutions: 3.5% NaOCl, 2% CHX, 0.9% NaCl, BD showed significantly higher push-out bond strength than MTA [48]. This was inconsistent with later published studies, where after exposure to 2.5% NaOCl in the early setting phase, the MTA's push-out bond strength increased significantly, while BD's significantly decreased [46]. Contrasting data were presented by Afkhami et al., where CHX enhanced effectively the push-out bond strength of MTA in comparison with the control group [47].

Washout resistant

The effect of washout resistance of the bioceramics was also investigated. Falkowska et al. conducted that the assessed materials, including MTA HP and MTA Angelus White, showed good or relatively good resistance, with the exception of BD [49].

Discoloration of tooth tissues

In scientific studies, the discoloration of tooth tissues after placing various bioceramics in the pulp cavity was also assessed [13, 14, 16, 50]. According to the literature, the discoloration of MTA is related to the presence of elements like iron, manganese, copper and chromium which impart their strong colour. Interestingly, BD showed less tooth discoloration than MTA.

Conclusions

With the introduction of biocompatible perforation sealing materials, bacterial leakage prevention has become more predictable and effective. Based on the analysis of the current literature, it can be concluded that MTA is still the most proven and tested material among the bioceramics, BD is a good alternative to MTA due to its relatively easy manipulation and predictable clinical results. MTA and BD create favourable conditions for regeneration and can be successfully used in the repair of pulp cavity floor perforation.

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