Study of the Compatibility of New Biomaterials in Vital Pulp Therapy in Pediatric Dentistry

CARMEN TODEA[1], ANDREEA IGNA[1]*, EMILIA OGODESCU[1]*, IRINA ZETU[2], ALEXANDRU OGODESCU[1]

[1]Victor Babes University of Medicine and Pharmacy, Faculty of Dentistry, 2 Eftimie Murgu Sq., 300041 Timisoara, Romania

[2] Grigore T. Popa University of Medicine and Pharmacy of Iasi, 16 Universitatii Str., 700115 Iasi, Romania

Vital pulp therapy is an expanding concept in pediatric dentistry today thanks to the potential exhibited by new biomaterials to stimulate regeneration of the pulp cells. Biocompatibility, bioactivity and dentin-like physical properties, as well as good handling, fast setting and the possibility to fill large cavities with a single material are some of the ideal properties of materials aimed to heal traumatized and inflamed dental pulps, given by a good balance of their chemical components.

Keywords: biodentine, mineral trioxide aggregate, vital pulp therapy, primary teeth, immature permanent teeth

Biomaterials, according to the European Society for Biomaterials (ESB), are defined as *materials intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body*. They aim is not only to integrate and be tolerated by the body, but also to influence biological processes toward the goal of tissue regeneration [1-4]. Preserving vitality of the dental pulp is a major concern today in pediatric dentistry, in both primary and young, immature permanent teeth. As it has been revealed that the inflamed pulp has the potential to heal, procedures like stepwise excavation, indirect/direct pulp capping, and pulpotomy are gaining popularity [5-7]. Furthermore, the survival rate of teeth that received a root canal treatment compared to vital teeth, especially molars, is significantly lower [8]. Non-vital teeth lose their ability to sense environmental changes, making the progression of caries unnoticeable by patients. Another advantage of maintained dental pulp vitality is to maintain the capacity for limited dentin regeneration. Reparative dentin formation is particularly important for immature permanent teeth, because of their incomplete apical and dentinal wall development. A successful vital pulp treatment requires maintenance of tooth vitality by obtaining a good seal against bacteria, no severe inflammatory reactions, and stable hemodynamic within the pulp and also implies stimulation of the pulp-dentin complex towards the formation of a continuous dentin bridge at the pulp-dentin border, as part of the healing process [9-14].

Experimental part

Materials and methods

We elaborated a comprehensive general review, integrating data from relevant studies on the chosen topic. A search of Medline/PubMed and Google Scholar electronic resources was performed, centered on *biomaterials* and *vital pulp therapy* key words. Several books, reviews of literature on the topic and manufacturer's brochures were also included in the documentation. The data were also correlated to our clinical experience with new biomaterials.

Results and discussions

Developed in the 1920s by Hermann [15], calcium hydroxide, $Ca(OH)_2$, has been the gold standard in vital pulp therapy for decades. Its use as a pulp dressing material in capping or pulpotomies has shown over time both advantages and disadvantages. It has been demonstrated that calcium hydroxide has the ability to stimulate dentinogenesis and lead to formation of tertiary/reactionary dentin [16, 17]. On the other hand, it is a resorbable material and lacks the ability to provide an appropriate seal for the exposed pulp. This is a major disadvantage that causes unpleasant side effects like bacterial contamination, inflammation or necrosis of the pulp [18]. More, there are studies that add internal root resorption or necrosis of alveolar mucosa to the list of defects caused by calcium hydroxide [19, 20]. As a consequence, researchers began investigations on new materials to be used in vital pulp therapy that can overcome the drawbacks of calcium hydroxide.

Calcium silicate-based materials have drawn attention in recent years due to their biocompatibility and clinical advantages, as revealed by numerous studies in the field of dentistry [21-28]. A recent comparative study investigating the chemical composition and porosity characteristics of various calcium silicate-based cements concluded that, among them, Biodentine and Mineral Trioxide Aggregate (MTA) showed superior physico-chemical properties [29].

Mineral Trioxide Aggregate (MTA**)** was introduced by Mahmoud Torabinejad in 1993 and approved for endodontic use by the U.S. Food and Drug Administration in 1998. Since then, it has been used in a wide range of endodontic procedures. Its chemical composition consists of calcium oxide (CaO), silicon dioxide (SiO_2) and bismuth trioxide (Bi_2O_3) - the main components, and various amounts of aluminum, magnesium and ferrous oxides, which make the difference between the two types of MTA: grey and white [30, 31]. Clinical studies proved that MTA has the potential to be used successfully as a pulp-capping or pulpotomy material during vital pulp therapy [32, 33], but the years of clinical experience have also revealed some disadvantages that occur in practice, such as a long setting time and potential of discoloration [34].

Released in 2009 by Septodont, Biodentine™ is a tricalcium silicate cement designed as a *dentine replacement* material, highly biocompatible, and biologically active [35]. Apart from these features, Biodentine attracted attention in the field of dentistry also due to its fast setting time, high compressive strength, excellent sealing ability, and ease of handling, as well as its versatile usage in both endodontic repair and restorative procedures, without causing any staining of the treated teeth [36]. It overcomes the drawbacks of calcium

* email; andreeaigna@gmail.com; eogodescu@gmail.com

hydroxide and MTA and has a great potential to revolutionize the different treatment modalities in pediatric dentistry, especially after traumatic injuries, which are frequent occurrences in young patients, thus giving hope to preserving tooth vitality [37-41].

Biodentine is available in form of a capsule containing two separate components: a powder and a liquid. According to the producer, the powder consists of tricalcium silicate ($3CaO\ SiO_2$), dicalcium silicate ($2CaOSiO_2$), calcium carbonate ($CaCO_3$) and oxide (CaO) filler, iron oxide (Fe_2O_3) shade, and zirconium oxide (ZrO_2) radioopacifier. The liquid, on the other hand, contains calcium chloride ($CaCl_2$) as an accelerator and a hydrosoluble polymer that serves as a water reducing agent and water [35]. The exact concentration of its components has not been provided by the manufacturer. A study performed by Camilleri J. et al. [23] has revealed the components' concentration of Biodentine. They suggest the absence of dicalcium silicate component, which implies that the increased amount of tricalcium silicate from Biodentine, compared to other cements, leads to a faster reaction rate and a less porous microstructure. Moreover, Biodentine includes calcium carbonate which together with the additives in the mixing liquid results in a material with enhanced chemical properties. After mixing the two components in the triturator for 30 s [24], the initial setting time takes about 12 min, as indicated by the producer. The reduced setting times, as well as the good marginal seal that is ensured are granted by the $CaCl_2$ in the liquid agent. From a clinical point of view, this eliminates the need of using a provisional material on top of Biodentine, which means that large cavities can be filled exclusively with Biodentine as a long-term therapeutic filling, in both primary (fig. 1) and permanent teeth (fig. 2).

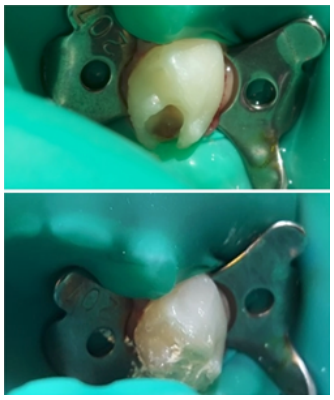

Fig. 1. Distal carious lesion on a primary upper molar in a 5-year old patient, filled with Biodentine

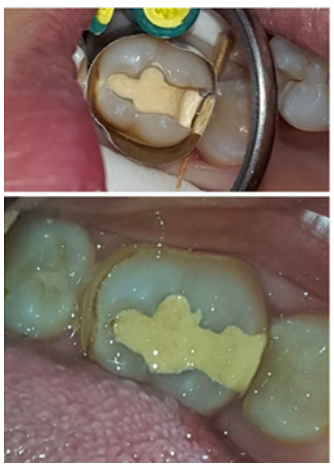

Fig. 2. Deep carious lesion on a first permanent molar in a 15-year old patient, filled with Biodentine

A 2018 three-year literature review found controversies regarding the initial setting time, with values ranging from 6.5 ± 1.7 to 30 ± 0 min [37]. Saliva and blood contamination increase the setting time of Biodentine, but do not affect its compressive strength [42-44]. However, there is accordance within data regarding the short setting time of Biodentine compared to other similar materials. As part of its chemical setting reaction, $Ca(OH)_2$ is also formed. This reaction is associated with the presence of an extremely alkaline environment with a *p*H of about 12.5 which stimulates the pulp tissue to form reactive dentine. Due to this alkaline *p*H, Biodentine exhibits antimicrobial properties. Antibacterial activity of different pulp capping materials evaluated by agar diffusion test revealed inhibition of Streptoccocus sanguis and Streptoccocus salivarius species by Biodentine, but no activity against Streptoccocus mutans species [45].

Histologically, the bioactive tricalcium silicate demonstrated the ability to induce odontoblast differentiation from pulp progenitor cells [46]. Pulp capping studies illustrated formation of complete dentinal bridges with normal pulp histology and, when compared to MTA, the thickness of the bridges was significantly higher with Biodentine [47-49]. It is interesting to know that Biodentine shows biomimetic remineralization and causes deposition of calcium phosphate on the surface, which suggests a high rate of calcium release with fast formation of apatite and makes Biodentine a scaffold for clinical healing [50, 51]. Furthermore, data imply that Biodentine is a bioactive and biocompatible material capable of enhancing human dental pulp stem cells proliferation, migration, differentiation and adhesion abilities [51-54]. This makes Biodentine a great capping material, in both direct and indirect techniques (fig. 3).

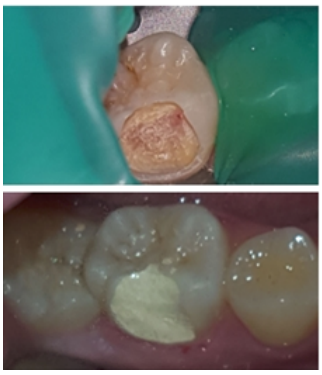

Fig. 3. Direct pulp capping with Biodentine in a first lower permanent molar in a 13-year old patient. Pulp vitality was preserved

Regarding solubility over time, Biodentine exhibited higher solubility in comparison with MTA and other test cements, but Singh et al. [55] suggest that the solubility of Biodentine may actually be working in favor of the material rather than against it, given the remineralization process and formation of an interfacial layer with the dentin. However, this solubility seems to occur only at the surface and causes negligible dimensional change. Wet or dry hardening clinical conditions do not affect the final surface hardness of the material [56]. Acidic *p*H of 6.4 and lower affects the microstructure of Biodentine, negatively influencing the surface hardness, compressive strength, and bond strength. Compared to white MTA though, Biodentine is more suitable to be used in acidic environments [57], due to the $CaCl_2$ from its composition, which seems to significantly increase surface hardness and strength to environmental *p*H [58].

Values of elastic modulus, compressive strength and microhardness are higher than MTA, and very similar to values of natural dentine [44, 59]. Regarding color stability, Biodentine shows no signs of discoloration at 6 months evaluation, but a discrete delayed tooth discoloration may be evident at 1-year evaluation or in the presence of endodontic irrigants and blood. Still, the possible coloration induced by Biodentine is significantly less evident compared with MTA. Clinical studies (randomized controlled trials and case control studies) showed Biodentine to be a suitable alternative to MTA, with a wide range of clinical indications [40].

Conclusions

Progress in the field of biomaterials gives hope to minimally invasive treatment options in young patients and to preserving tooth vitality in cases of traumatized teeth with pulpal involvement, trauma/caries-affected young immature teeth, accidental pulpal exposure and pulpotomized primary or young permanent teeth. At present, Biodentine represents the biomaterial of choice in such cases. With optimal physical and chemical properties and a bioactive behavior towards stimulation of tissue regeneration, Biodentine has brought a valuable contribution to dental therapeutic procedures with regard to pulp vitality.

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