MINERAL TRIOXIDE AGGREGATE USE IN CHILDREN'S PRIMARY AND PERMANENT TEETH

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Abstract

Mineral trioxide aggregate (MTA) is a bioactive, non-cytotoxic cement originally introduced as a material for filling root canals and repairing root perforations. Over the years, its use has expanded to include versatile applications in endodontics, general dentistry, dental traumatology and pediatric dentistry as well. The aim of this article was to carry out an updated scientific review on the mineral trioxide aggregate applications in pediatric dental practice.

Keywords: *Mineral Trioxide Aggregate, pediatric dentistry, primary teeth, permanent teeth*.

1. INTRODUCTION

Historically, a various number of materials has been used as root canal filling or as root perforations repair materials, such as: amalgam, zinc-oxide-eugenol cements, composite resin and glass-ionomer cements. Unfortunately, none of them met all requirements of an ideal material [1], so that the search for biocompatible dental materials presenting good physical, chemical and mechanical properties still continues nowadays. Mineral Trioxide Aggregate (MTA) is a bioactive, non-cytotoxic material that contains no resins and that has been used for endodontic applications since early 1990's. Originally introduced as a root repair material, it has been used successfully in many procedures, including direct pulp-capping and pulpotomy in temporary and permanent (young and mature) teeth affected by simple/complicated carious lesions or by dental trauma, as well as in the process of apexogenesis/apexification.

MTA was initially composed of grey Portland cement and bismuth oxide as a radio-opacity agent. Portland cement used in the construction industry is hydraulic. Since most dental procedures are performed in a wet environment, Portland cement was introduced as an endodontic material [2], the first reported use of Portland cement in the specialty literature dating back to 1878, when Doctor Witte of Germany published a case study on the use of Portland cement for root canal fillings [3]. A century later, Mahmoud Torabinejad from Loma Linda University, and co-inventor Dean White, obtained two United States patents [4-5] for an endodontic material based on Portland cement, which became known as the Mineral Trioxide Aggregate. In 1993, Torabinejad described the physical and chemical properties of MTA [6].

Since then, more than 20 new patents have been issued in the United States and the European Union for materials that include Portland cement for dentistry. MTA is made primarily of three oxides (calcium oxide, silicon dioxide and aluminum trioxide), secondary from minerals and tertiary from bismuth oxide as a radiopaque powder (aggregate). As to its composition, MTA basically resembles the Portland cement, with the exception of bismuth oxide which was added to MTA for radio-opacity [6] and is currently commercialized, and used in pediatric dentistry in two different forms: green MTA (GMTA) and white MTA (WMTA).

In order to use MTA in an optimum, effective and successful manner, it is of a real importance to know which are the action mechanism and the correct way of employing it. Mineral Trioxide Aggregate action mechanism is similar to that of calcium hydroxide ($Ca(OH)_2$). As a consequence of MTA hydration, $Ca(OH)_2$ is produced as a by-product, that will dissociate into Ca^{2+} and OH^- ions. The Ca^{2+} ions will lead to the formation of calcium carbonate, which will serve as the core of calcification. The alkalinity of the environment, together with the calcium carbonate, will stimulate the formation of type I collagen which, alongwith calcium, will induce mineralization [7].

2. MTA PROPERTIES

- biocompatibility;
- sealing ability higher than that of amalgam or of the super Ethoxybenzoic Acid (EBA) (reinforced zinc oxide eugenol cement);
- initial pH is approximately 10.2 and the outlet pH is 12.5 (after a 3 hour immersion in solution);
- socket time: 4 hours;
- compressive strength: 70 MPa, comparable to that of IRM (Dentsply Caulk, Milford, Delaware, USA);
- low cytotoxicity;
- it induces minimal inflammation if it exceeds the apex;
- excellent bioactive properties;
- it induces dentine bridge formation (with odontoblastic layer formation);
- tissue regeneration by activation of cementoblasts;
- antibacterial effect on some facultative bacteria (*S. mitis, S. mutans, S. Salivarius, Lactobacillus, S. epidermidis*) against *Enterococcus faecalis* and *Streptococcus sanguis in vivo*, and no effect on any of the strictly anaerobic bacteria;
- it stimulates the release of cytokines from pulp fibroblasts, which in turn stimulate hard tissue formation and promote rapid cell growth [6,8-11].

Mineral Trioxide Aggregate applications in temporary and permanent teeth of children and adolescents are various, from pulp capping to internal or external root resorption repair (Figs.1, 2).

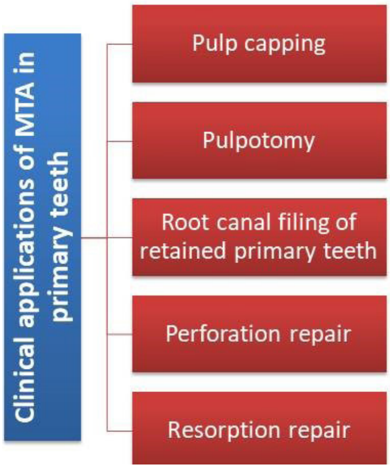

Fig.1. MTA use in temporary teeth

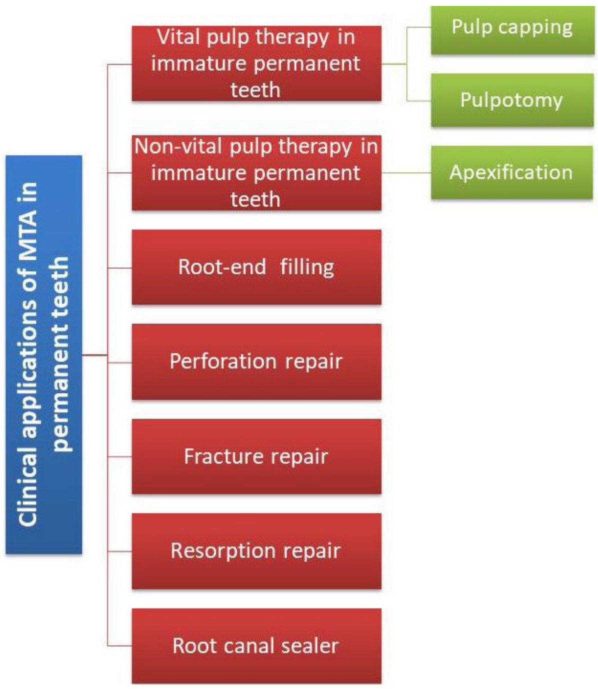

Fig.2. MTA use in permanent teeth

2.1. Direct/indirect pulp capping in primary teeth

MTA has been proposed for pulp capping in primary dentition due to its excellent biocompatibility. The studies carried out in this area of interest concluded that pulp tissue heals faster with the mineral trioxide aggregate [12]. The American Academy of Pediatric Dentistry (AAPD) recommended the use of MTA as a direct pulp capping material to be placed on pinpoint mechanical or traumatic pulp exposures in primary teeth with normal pulps, under optimal conditions for a favorable response [13].

MTA induces the formation of a dentin reactional bridge, better than that determined by the application of calcium hydroxide, it is more homogeneous and continues with the initial dentin, while simultaneously causing less hyperemia and less pulp necrosis - as compared to calcium hydroxide [8].

2.2. Direct pulp capping in young permanent teeth

Pulp capping represents an appropriate procedure in immature permanent teeth with pulp exposure and with no signs of irreversible pulpitis. In such cases, MTA is preferred to calcium hydroxide, since data from the specialty literature indicates that pulp tissue heels faster, with no pulp necrosis, in cases in which MTA was applied. MTA stimulates the formation of dentinal bridge in contact with dental pulp tissue. The dentin formation effect of MTA may be a consequence of its sealing properties, of its biocompatibility and alkalinity [14]. Bogen *et al*. [15] reported a success rate of 97.6% based on thermal test (cold testing), clinical examination, radiographic assessment and follow up for 9 years, in a study that used MTA as a pulp capping agent for cariously exposed young permanent teeth with reversible pulpitis.

According to Hilton T.J. [16], on the basis of recent literature, it would appear that the MTA success rate is due to the fact that it serves as a reservoir of calcium hydroxide and/or to its capacity of providing a seal at the site of pulp exposure.

2.3. Pulpotomy in primary teeth

MTA seems to have specific characteristics, which recommend it as an appropriate material for pulpotomy in deciduous teeth, namely: its biocompatibility, its ability to harden in a humid environment and its sealing properties [17]. The AAPD recommended the use of MTA for pulpotomy of primary teeth with normal pulp tissue or with reversible pulpitis, when caries removal results in pulp exposure, or after a traumatic pulp exposure [18].

Given the safety concerns surrounding formocresol (tissue irritation, cytotoxic effect, mutagenic effect), MTA has been studied extensively as an alternative pulpotomy agent for primary teeth. Some of the most recent systematic studies found out that MTA is superior to formocresol, concluding that "the greater success rate of MTA can be attributed to its biocompatibility and sealing ability when compared to formocresol" [18-19]. The studies conducted by Martell *et al*. and Torabinejad *et al*. concluded that the presence of blood has little impact on the setting or degree of leakage when, during pulpotomy, a 2 mm thick layer of MTA is placed over the remaining pulp tissue [20-21]. When compared with ferric sulfate, MTA also demonstrated better long-term treatment outcomes in primary molars pulpotomy [22].

2.4. Pulpotomy in immature permanent teeth

The use of MTA as a pulpotomy dressing material in permanent teeth has been widely investigated. In a histological study conducted by Holland *et al*. [23] on dog teeth, a better dentin bridge formation occurred if pulpotomy was done using MTA as a dressing material, comparatively with calcium hydroxide. Other authors, like Bariersshi-Nusair *et al.*, Bortoluzzi *et al.*, Menezes *et al.*, Pitt Ford *et al.*, concluded that pulpotomy with MTA is efficient [7], as the repair process occurs on the remaining radicular pulp tissue through the formation of a mineralized tissue.

2.5. Apexogenesis

MTA represents the elective material in the therapy of young/immature permanent teeth with no complete root formation. This procedure is performed with the goal of preserving pulp vitality and, thus, of allowing physiologic growth and closure of the root apex. MTA seems to be one of the materials which contribute to such a process. The sealing characteristics of MTA make it preferable to conventional materials in apexogenesis technique [24]. According to the studies done by Mente *et al*. in 2009 and 2013, a success rate of 90% was observed in cases in which a MTA apical plug was placed *via* the root canal [25-26].

2.6. Apexification

The objective of apexification is to induce root end closure in an incompletely formed non-vital permanent tooth. El-Meligy and

Avery compared apexification with either $Ca(OH)_2$ or MTA, and their clinical and radiographic follow-ups of the teeth treated with MTA showed the absence of clinical symptoms and the formation of a new hard tissue in the apical area. Therefore, MTA is a successful material that can be used to induce root-end closure in necrotic immature permanent teeth and a as suitable replacement for calcium hydroxide in apexification procedures [27].

2.7. Other applications

A. In primary teeth

MTA was also reported to be used as a root canal filling of the retained primary teeth, in furcation perforation repair and resorption repair of primary teeth [28-29]. In cases in which a primary tooth does not have its succedaneous tooth and should be kept as long as possible in the oral cavity, MTA can be placed as a root canal filling material. MTA is not recommended in areas open to the oral environment (due to its solubility in bacteria, food and beverages) and as a coronal filling material, due to its low compressive strength [8].

Despite their clinically good results, MTA applications in primary teeth are still not yet widely used in daily clinical practice, due to the high cost, compared to commonly used materials [30-31].

B. In permanent teeth

Root-end filling. MTA is an effective filling material for the root canal, as it provides good sealing and leakage prevention, so that it can be used in endodontic surgery. The Kim and Kratchamn review showed that MTA was the most biocompatible root-end filling material and that it can be used in endodontic surgery with predictable outcomes [32].

Root perforation repair. A systematic review and meta-analysis conducted by Siew *et al*. in 2015, on the treatment outcome of non-surgically repaired root perforation, reported that the overall pooled success rate was 72.5%, and the success rate was enhanced to 80.9% by the use of MTA – however, the difference was not statistically significant [33].

Tooth resorption. Dental traumatic injuries, orthodontic tooth movements, pulp necrosis, etc. may induce internal or external root resorption. Classically, resorptions were treated with calcium hydroxide, but MTA proved to be a better choice in this pathology [7].

3. CONCLUSIONS

Mineral Trioxide Aggregate is a unique material, with various advantages, providing numerous possibilities for pulpal therapy. Its applications in primary and permanent teeth are widely used in daily clinical practice, and its introduction in dentistry and, implicitly, in pediatric dentistry, represented a historical milestone in the development and research of bioactive cements. Nevertheless, with the recent introduction of new improved MTA products, the MTA-based materials are likely to be used more and more in the dentistry of the child and adolescent for many years.

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