J Stoma 2015; 68, 4: 485-491
DOI: 10.5604/00114553.1177534

CASE REPORT

Application of MTA to endodontic treatment of immature permanent teeth

Zastosowanie MTA w leczeniu endodontycznym zębów stałych z niezakończonym rozwojem

Elżbieta Pels[1], Izabela Tkacz-Ciebiera[1], Jerzy Błaszczak[2], Agnieszka Skawińska[1], Maria Mielnik-Błaszczak[1]

[1] **Katedra i Zakład Stomatologii Wieku Rozwojowego, Uniwersytet Medyczny w Lublinie, Polska**
Chair and Department of Paediatric Dentistry, Medical University of Lublin, Poland
Head: prof. dr hab. *M. Mielnik-Blaszczak*

[2] **Katedra i Zakład Ortopedii Szczękowej, Uniwersytet Medyczny w Lublinie, Polska**
Chair and Department of Orthodontics, Medical University of Lublin, Poland
Head: dr n. med. *I. Dunin-Wilczyńska*

Abstract

MTA (Mineral Trioxide Aggregate) is a new dental material of many clinical applications. MTA formulation is recommended for retrograde root filling, direct pulp capping, closing perforation resulting from the process of internal or external resorption, closing iatrogenic perforation, and in the apexification process as part of the final filling of the root canal in the periapical area. The aim of the study was to present physical and chemical properties and the use of MTA in the process of apexification and in the treatment of inflammatory periapical lesions in permanent immature teeth. Clinical examination revealed extensive damage to teeth 37 and 47 as a result of dental caries in a 12-year-old patient. Very deep carious lesions in these teeth resulted in necrosis of the pulp tissue and irreversible periapical inflammation. Endodontic treatment of immature permanent teeth was performed using formulations that initiate the process of apexification. Mineral Trioxide Aggregate (MTA) was used. It was found that MTA forms a good barrier ensuring the tightness of root canal filling. The material has a good antibacterial effect and satisfactory properties of enhancing the process of healing of inflammatory periapical lesions of immature teeth. The results of effective treatment of teeth with incomplete root formation require long-term studies

KEYWORDS:
apexification, MTA, healing of periapical tissues of immature teeth

Streszczenie

MTA (Mineral Trioxide Aggregate) jest nowym materiałem stomatologicznym, który znalazł wiele zastosowań klinicznych. Preparat MTA jest zalecany do wstecznych wypełnień kanału korzeniowego, do bezpośredniego pokrycia miazgi, do zamknięcia perforacji powstałej wskutek rozwijającej się resorpcji wewnętrznej lub zewnętrznej, zamknięcia perforacji jatrogennej oraz w procesie apeksyfikacji jako element ostatecznego wypełnienia kanału korzeniowego w okolicy okołowierzchołkowej. Celem pracy było przedstawienie właściwości fizycznych i chemicznych oraz zastosowania materiału MTA (ang. Mineral Trioxide Aggregate) w procesie apeksyfikacji i w leczeniu zapalnych zmian okołowierzchołkowych w zębach stałych z niezakończonym rozwojem korzenia. Badaniem klinicznym stwierdzono znaczne zniszczenie zębów 37,47 u 12-letniego pacjenta wskutek procesu próchnicowego. W wyniku bardzo głębokiej próchnicy w tych zębach doszło do martwicy tkanki miazgowej i nieodwracalnych zapaleń tkanek okołowierzchołkowych. Podjęto leczenie endodontyczne niedojrzałych zębów stałych z zastosowaniem preparatów inicjujących proces apeksyfikacji. Wykorzystanie mineralnego agregatu trójtlenkowego – MTA. MTA tworzy dobrą barierę zapewniającą szczelność wypełnienia kanału.

HASŁA INDEKSOWE:
apeksyfikacja, MTA, gojenie tkanek okołowierzchołkowych zębów niedojrzałych

for the objective assessment. MTA is a formulation with favourable properties and may seem a material of the future.

Materiał wykazuje dobre działanie antybakteryjne oraz satysfakcjonujace właściwości stymulacji gojenia zmian zapalnych tkanek okołowierzchołkowych zębów niedojrzałych. Wyniki zastosowania skutecznego leczenia zębów z niezakończonym rozwojem korzeni wymagają wieloletnich obserwacji dla obiektywnej oceny. MTA jest preparatem, który posiada pozytywne właściwości i może wydawać się materiałem przyszłości.

Introduction

MTA (Mineral Trioxide Aggregate) is a new dental material of many clinical applications. The product was developed and described for the first time in 1993 by *Torabinejad* et al. from the Loma Linda University in the USA.[1,2] The material is hydrophilic powder consisting of tricalcium silicate ($3CaOSiO_2$), bismuth oxide (Bi_2O_3), dicalcium silicate ($2CaOSiO_2$), tricalcium aluminate ($3CaO$-Al_2O_3), tetracalcium aluminoferrite ($4\ CaO$-Al_2O_3-Fe_2O_3), and hydrated calcium sulphate ($CaSO_4$-$2H_2O$). It may contain up to 0.6% of insoluble crystalline silica and trace amounts of free magnesium oxide (MgO), potassium oxide (K_2O) and sodium sulphate (Na_2SO_4).[1] The powder is mixed with distilled water at a ratio of 3:1; when mixed with water, it should be used immediately.[3] It has highly alkaline properties; when bound, its pH value is 10.2, rising to approximately 12.5 after a few hours. It has a consistency of colloidal gel which hardens and forms a barrier which is liquid impermeable.[1,2] As a result, a conglomerate of trioxides of metals effectively inhibits the growth of microorganisms and inflammatory processes in the vial pulp, and stimulates mineralization.[4] Mineral Trioxide Aggregate is characterised by good adhesive properties, small micro-leakage, high biocompatibility and low cytotoxicity. The content of bismuth favours a good absorption of X-rays by the material, while the addition of lithium salts and sodium chloride has a beneficial effect on the formation of calcium complexes in the reaction of material binding and in the mechanism of dentine bridge formation. Moreover, the formulation has good mechanical resistance as well as antibacterial and antifungal properties, lack of resorption and tissue biocompatibility; it is not toxic to pulp cells and has excellent odontotrophic properties.[2-6]

MTA powder is mixed with sterile water to achieve the consistency of wet sand. The material should be slightly condensed with a moist, sterile cotton ball, avoiding pressure. Prior to application, a scaffolding of $CaSO_4$ (Capset) or hemostatic sponge (e.g. Biocol, Antema or Spongostan) can be prepared. The scaffolding enables formation of a box-like space that allows for correct condensation. Because of its consistency and low viscosity, MTA creates some problems during application. It is applied using special devices, for example, a block for MTA portioning or an applicator. It is also possible to use S-condensers for vertical condensation of gutta-percha.[1,2,4]

Due to its hydrophilic properties, MTA solidifies in the presence of moisture, which is a very important feature because certain humidity is always present during procedures. This property enables the operation in the root canal in the presence of exudate which appears during the treatment of teeth with necrotic pulp or apical periodontitis.[3]

In view of these properties, attempts of clinical use of Mineral Trioxide Aggregate in dentistry have been initiated. The first step was retrograde root canal filling and apicoectomy. Over time, positive results were achieved for closing perforations and root canals as well as filling bone defects in the alveolar process and root cementum loss resulting from pathological resorption. The properties of MTA have led to attempts to use this cementum for root canal filling in teeth with both complete and incomplete apical development. Over the past few years, attempts have also been made to use MTA in the biological treatment of deciduous and permanent teeth, and thus in methods of direct capping and pulpotomy. [1,2,4,6,7]

The aim of the study was to present own clinical experience in the use of ProRoot MTA (Mineral Trioxide Aggregate) during the treatment of permanent teeth with incomplete development in the process of apexification, and basing on the review of literature, to demonstrate physicochemical properties and opportunities for the clinical use of MTA.

Material and methods

A 12-year-old patient accompanied by his parent came to the Department of Paedodontics complaining of toothache of teeth 37 and 47. Clinical examination revealed very deep caries penetrating into the area of the pulp in teeth 37 and 47 which resulted in pulp necrosis and irreversible periapical inflammation.

A radiograph was taken (Fig 1, Fig 2), showing an incomplete process of formation of the root apex and thinning of the bone structure in the periapical area. It was decided to perform endodontic treatment of immature permanent teeth using formulations that initiate the process of apexification.

After inducing anaesthesia and isolating teeth 37 and 47 with a rubber dam, the extensive carious tissue was removed. Next, using a microscope, a good access to the pulp chamber was assured; the remnants of necrotic pulp were removed from the chamber and root canals. Wide canals, divergent in the apical area, were prepared using endodontic instruments, and irrigated with 2.25% sodium hypochlorite and 0.5% metronidazole. Then, sodium hypochlorite was heated ultrasonically for 10-15 minutes in order to thoroughly disinfect the root canals. Due to the presence of exudate, the formulation based on calcium hydroxide and iodoform (Calciplast + J) was placed in the canals (Fig 3, Fig 4).

During the second visit after one week, the calcium hydroxide paste was removed from the canals by means of copious irrigation with

Fig. 1. Tooth 37 with incomplete root formation, thinning of the bone structure in the periapical area.

Fig. 2. Tooth 47 with incomplete root formation, thinning of the bone structure in the periapical area.

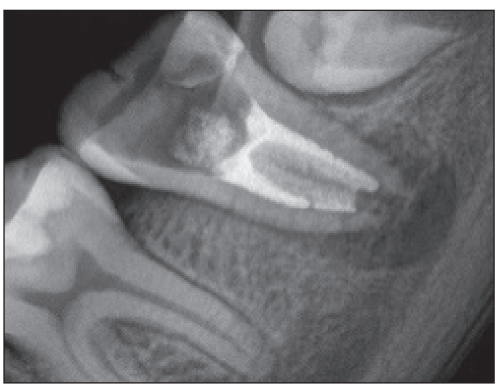

Fig. 3. Tooth 37 with $Ca(OH)_2$ +J

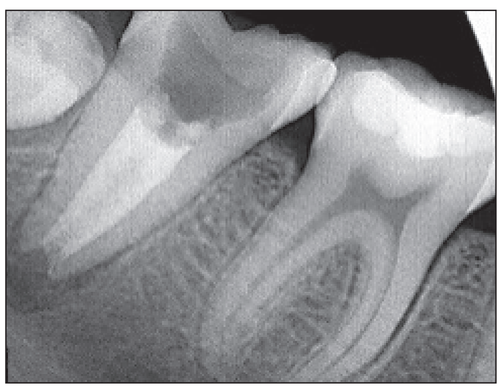

Fig. 4. Tooth 47 with $Ca(OH)_2$ +J

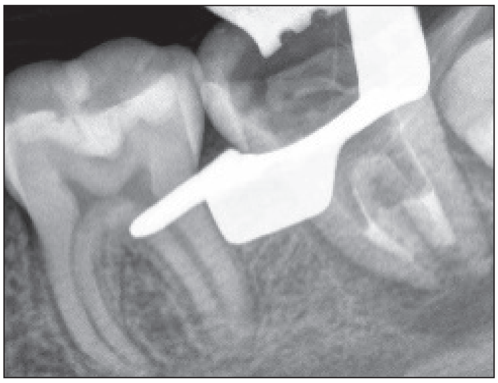

Fig. 5. *Tooth 37 with ProRoot™ MTA 3-5 mm in the apical area.*

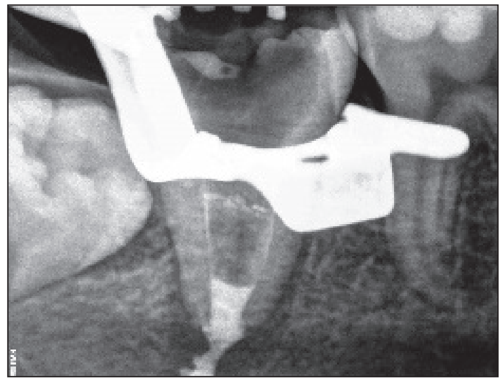

Fig. 6. *Tooth 47 with ProRoot™ MTA.*

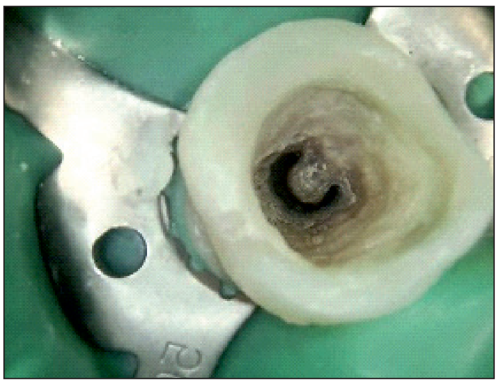

Fig. 7. *Tooth 37 with final canal obturation.*

Fig. 8. *Tooth 47 with final canal obturation.*

preheated sodium hypochlorite solution. The canals were then dried with paper points, and the formulation based on $Ca(OH)_2$ was applied for a period of 2-3 weeks. A sterile cotton swab was placed in the chamber, and the cavity was closed using a tight temporary filling with glass-ionomer cement.

During the next visit, the calcium hydroxide formulation was removed from the canals using the preheated sodium hypochlorite solution, and the canals were irrigated with saline and dried with paper points. All procedures were performed with rubber dam isolation, using a microscope.

The next step was to prepare ProRoot MTA in accordance with the attached instructions. Using an MTA applicator, the material was placed in the periapical area and then packed by means of pluggers and paper points.

A barrier filling the canal was formed over the length of 3 to 5 mm. The location of ProRoot™ MTA was confirmed radiographically (Fig 5, Fig 6). A wet sterile cotton swab was placed and the cavity was filled with a temporary material for 24 hours.

After 48 hours, the temporary filling and paper point were removed, and the remaining part of the root canal was filled with thermal gutta-percha using vertical condensation. An X-ray was taken in order to verify the accuracy of root canal filling (Fig 7, Fig 8).

During the same visit, final filling with a composite was made. The next step was clinical and radiographic follow-up after three and six months, when a hard tissue barrier was formed in the periapical area. After one year of treatment there were no signs of inflammation, and regression of lesions in the periapical area was observed (Fig 9, Fig 10).

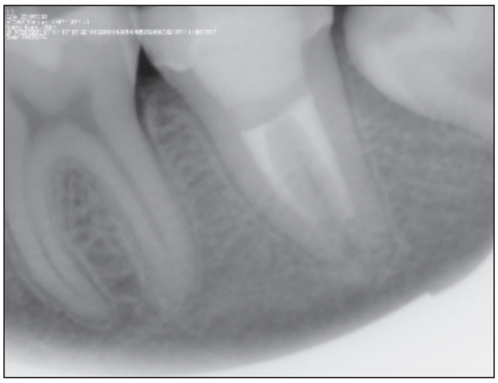

Fig. 9. *Tooth 37 – one year after the procedure.*

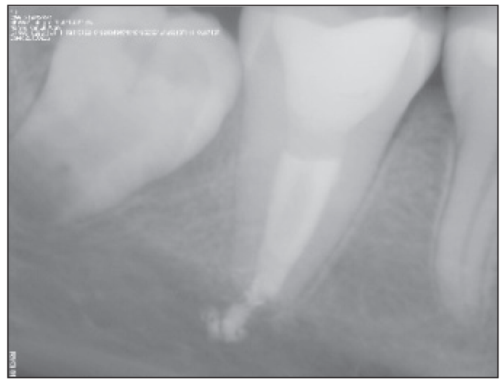

Fig. 10. *Tooth 47 – one year after the procedure.*

Discussion

The appearance of the tooth crown in the mouth is not an indicator of its development. The process of permanent tooth root formation takes on average the next three years. Treatment of lesions and diseases of tooth pulp in this period is a major challenge for clinicians. In immature teeth, root canals are very broad throughout their course, often wider in the vicinity of the apex than in the chamber, resembling an inverted cone. The lumen of the periapical apertures is very wide, and the walls of the canals are very thin. These features make it difficult, or even impossible, to prepare and fill the root canals correctly. Therefore, a precondition for endodontic treatment of immature teeth is the use of methods that ensure continued healthy growth of the root apex.[8,9]

Depending on the vitality of the pulp in teeth with incomplete root formation, a decision is made to carry out apexogenesis or apexification. The term 'apexogenesis' refers to procedures aimed at providing physiological root development and formation of the apex, while maintaining the viable pulp in the root canal. The term 'apexification' means the formation of a periapical barrier in the form of hard, calcified tissue in the teeth without vital pulp. In the case of apexogenesis both the root and the root canal usually achieve the proper shape and size, while apexification is often accompanied by complications such as shortening of the physiological root length, delayed apex formation, or even complete inhibition of this process.[8-10]

In the process apexification, closing the apex by a mineralized barrier is often observed, while the canal remains very wide, its walls are thin and there is no natural narrowing in the form a physiological aperture.[8,9]

In the case of loss of dental pulp viability in immature teeth, the process of apexification should be initiated. The method of apexification is based on iatrogenic stimulation of the mixed pulp and periodontal tissue to initiate restorative processes within the root, stimulated with biological materials. In the vicinity of the canal apex, a barrier made of hard tissue is formed, or further root growth continues.[4]

In the case of permanent teeth with incomplete root apex formation, apexification is necessary; after removing the pulp and preparing the root canals, drugs are applied to stimulate the formation of a calcification barrier; when the barrier is formed, the canals are filled. The treatment requires several visits.[3]

Estrela et al. in their studies on MTA, Portland cement, calcium hydroxide, Sealapex and Dycal demonstrated that calcium hydroxide had the strongest antibacterial effect among the tested materials.[3,11] In endodontic treatment, when MTA is used, abandoning chlorhexidine gluconate should be considered because it interferes with MTA binding.[4]

Nandini et al. studied *in vitro* effects of the agents used for irrigation of the root canals on the properties of metal trioxide conglomerate demonstrating that chlorhexidine gluconate significantly reduced hardness and increased porosity of the material, dissolving its surface, particularly on the first day of use. At the same time, they confirmed the absence of adverse effects of sodium hypochlorite on the physical and chemical properties of MTA.[12]

MTA has low solubility in tissue fluids, so it is not resorbed in the vicinity of the apical foramen.[3]

Drugs stimulating the formation of the root apex should have antiseptic and odontotropic properties. The currently used formulations are: calcium hydroxide, dentine freeze-dried implants, tricalcium phosphate, hydroxyapatite and the recently introduced – ProoRoot MTA.[3]

Shabahang et al. also demonstrated that MTA reacted with tissue fluids to form a hard apical barrier. The resulting hard tissues have a higher density than tissues formed under the influence of osteogenic protein-1 and $Ca(OH)_2$.[3,13]

Torabinejad et al. pointed out that MTA also induces the formation of root cementum and leads to the cementum deposition on this material.[14]

Due to good marginal adhesion and good sealing properties, better than vertically condensed gutta-percha with a sealer, MTA forms a suitable protective barrier against invading microorganisms. Mineral Trioxide Aggregate has antibacterial (including anaerobes and *Enterococcus faecalis*) and antifungal properties.[4]

Al-Kahtani et al. evaluated the relationship between the thickness of the layer of Mineral Trioxide Aggregate and bacterial leakage. Their experience shows that only the MTA layer equal to, or greater than 5 mm, ensures 100% tightness against *Actinomyces viscosus* and *Staphylococcus* sp. Infection.[4,15]

MTA forms a good barrier ensuring the tightness of the root canal filling. Formulations based on calcium hydroxide are not recommended in such cases, because when the canal contains residual vital pulp, a direct contact with the hydroxide paste may result in the formation of a mineralized tissue layer, which occupies the space inside the canal and prevents pulp regeneration in this area. In addition, calcium hydroxide can damage Hertwig's sheath cells and lead to loss of the ability to stimulate the adjacent undifferentiated cells to transform into odontoblasts.[8,9,16]

Conclusions

Based on our clinical experience, we demonstrated beneficial effects of MTA (Mineral Trioxide Aggregate) in endodontic treatment of immature permanent teeth.

MTA has clinically favourable, antibacterial properties and enhances the process of healing of inflammatory periapical lesions of teeth with incomplete development.

MTA induces apexification, and the hard tissues resulting from this process have higher density than tissues formed after the application of calcium hydroxide.

References

1. *Al-Kahtani A, Shostad S, Schifferle R, Bhambhani S:* In vitro evaluation of microleakage of an orthograde apical plug of mineral trioxide aggregate in permanent teeth with simulated immature apices. J Endod 2005; 31: 117-119.
2. *Asgary S, Parirokh M, Eghbal M, Brink F:* Chemical differences between white and gray mineral trioxide aggregate. J Endod 2005; 31: 101-103.
3. *Chueh LH, Huang GT:* Immature teeth with periradicular periodontitis or abscess undergoing apexogenesis: a paradigm shift. J Endod 2006; 32: 1205-1213.
4. *Estrela C, Bammann LL, Estrella CRA, Silva RS, Pecora JD:* Antimicrobial and chemical study of MTA, Portland cement, calcium hydroxid paste, sealapex and dycal. Braz Dent J 2000; 11: 3-9.
5. *Ferris DM, Baumgartner JC:* Perforation repair comparing two types of mineral trioxide aggregate. J Endod 2004; 30: 422-424.
6. *Fridland M, Rosado R:* Mineral trioxide aggre-

gate (MTA) solubility and porosity with different water-to-powder ratios. J Endod 2003; 29: 814-817.

7. *Hirotomi T, Yoshihara A, Ogana H, Miyazaki H:* Tooth- related risk factors for tooth loss in community – dwelling elderly people. Vommunity Dent Oral Epidemiol 2012; 40: 154-163.
8. *Kirkevang LL, Wenzel A:* Risk factors for apical periodontitis. Community Dent Oral Epidemiol 2003; 31: 59-67.
9. *Monisha R, Manish R:* MTA as A Revolution in Endodontics-A Review. IOSR J Dent Med Sci 2013; 9: 18-21.
10. *Nandini S, Natanasabapathy V, Shivanna S:* Effect of Various Chemicals as Solvents on the Dissolution of Set White Mineral Trioxide Aggregate: An In Vitro Study. J Endod 2010; 36: 135-138.
11. *Ribeiro DA, Matsumoto MA, Duarte MA, Marques ME, Salvadori DM:* Ex vivo biocompatibility tests of regular and white forms of mineral trioxide aggregate. Int Endod J 2006; 39: 26-30.
12. *Roberts HW, Toth JM, Berzins DW, Charlton DG:* Mineral trioxide aggregate material use in endodontic treatment: a review of literature. Dent Mater 2008; 24: 149-164.
13. *Shabahang S, Torabinajad M:* Apexification in immature dog teeth using Osteogenic Protein-1, Mineral Troxide Aggregate, and Calcium Hydroxide. J Endod 1999; 25, 1-5.
14. *Shah N, Logani A, Bhaskar U, Aggarwal V:* Efficacy of revascularization to induce apexification/apexogensis in infected, nonvital, immature teeth: a pilot clinical study. J Endod 2008; 34: 919-925.
15. *Thomson A, Kahler B:* Regenerative endodontics – biologically – based treatment for immature permanent teeth: a case report and review of the literature. Australian Dent Journal 2010; 55: 446-452.
16. *Thomson A, Kahler B:* Regenerative endodontics – biologically – based treatment for immature permanent teeth: a case report and review of the literature. Australian Dent Journal. 2010; 55: 446-452.
17. *Torabinejad M, Chivian N:* Clinical applications of mineral trioxide aggregate. J Endod 1999; 25: 197-205.
18. *Torabinejad M, Chivian N:* Investigation of Mineral Trioxide Aggregate for root-end filling in dogs. J Endod 1995; 21: 603-608.

Address: 20-081 Lublin, ul. Karmelicka 7
Tel.: +4881 5320619
e-mail: elzbietapels@umlub.pl

Received: 30th July 2015
Accepted: 21st September 2015