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MTA USES

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“Give acknowledgment to the supervisor(s) who assisted the student in the preparation of his graduation project “

Table of Contents

Subjects	Page No.
Acknowledgement	I
List of Contents	II
List of Figures	III
List of Abbreviations	IV
Introduction	1
Aim of the study	2
Chapter One : Literature review	3
1.1 Historical Perspective	4
1.2 Composition	5
1.3 Manipulation and setting reaction	6
1.4 Properties	8
1.5 Types of MTA	10
1.6 Mechanism of action	11
1.7 Reaction with other dental materials	12
1.8 Advantages of MTA	13
1.9 Disadvantages of MTA	14
1.10 Clinical Applications of MTA	15
1.10.1 Pulp Capping	16
1.10.2 Vital Pulp Therapy (Pulpotomy and Apexogenesis)	17
1.10.3 Apexification	18
1.10.4 Regeneration	19
1.10.5 Root-End Filling	20
1.10.6 Root Perforation	22
Chapter Two : Conclusion	23
2.1 Conclusion	24
References	25

List of Figures

Figure No.	Figure Title	Page No.
Figure 1	MTA product	4
Figure 2	Apexification	18
Figure 3	Regeneration	20
Figure 4	Root-End Filling	21
Figure 5	Root Perforation	22

List of Abbreviations

Abbreviation	Description
MTA	Mineral Trioxide Aggregate
FDA	Food and Drug Administration
Ca(OH) ₂	Calcium Hydroxide
Na ₂ HPO ₄	Disodium phosphate, or disodium hydrogen phosphate, or sodium phosphate dibasic
CaCl ₂	Calcium Chloride
Ca(HCO ₂) ₂	Calcium Formate
CHX	Chlorhexidine
GIC	Glass Ionomer Cement
WMTA	White Mineral Trioxide Aggregate
EBA	Ethoxy Benzoic Acid
IRM	Intermediate Restorative Material
GMTA	Gray Mineral Trioxide Aggregate
NaOCL	Sodium Hypochlorite
Feo	Ferrous Oxide
EDTA	Ethylenediaminetetraacetic Acid

Introduction

Throughout history various materials have been utilized for root canal fillings and repairs including amalgam, zinc oxide eugenol cements, composite resin and glass ionomer cements. However, none of these materials have fully met all the criteria for a substance. *(Roberts HW et al., 2008)* As a result the search, for biocompatible materials with physical, chemical and mechanical properties continues to this day. Mineral Trioxide Aggregate (MTA) is a cytotoxic material with bioactive properties that does not contain resins. It has been employed in procedures since the 1990s. MTA, which stands for Mineral Trioxide Aggregate has become increasingly popular in the field of endodontics, over the two decades. The components of MTA consist of calcium, aluminum and selenium in its trioxide aggregate. Its characteristics such, as being hydrophilic, radiopaque having good sealing properties and low solubility are well known; especially in dentistry, the biocompatibility and sealing abilities of MTA play a vital role. *(Parirokh M and Torabinejad M,2010)* Initially developed as a material for repairing roots MTA has proven successful in treatments such as pulp capping and pulpotomy in both temporary and permanent teeth affected by caries or trauma. Additionally, it has been used in apexogenesis/apexification processes. Originally composed of grey Portland cement and bismuth oxide, for radio opacity purposes MTAs introduction stemmed from the nature of Portland cement used in construction—a quality suited for wet dental environments. *(Camilleri, J.,2017)*

Aim of the study

1. Reviewing the basic information about MTA
2. knowing the practical applications of MTA in pediatric dentistry

Chapter One

Literature review

1.1 Historical Perspective

The use of Portland cement was first documented in 1878 in a research paper, by Doctor Witte from Germany, who studied its application in root canal fillings (*Witte.,1878*). A hundred years later Mahmoud Torabinejad and Dean White obtained US patents for a material called Mineral Trioxide Aggregate (MTA) based on Portland cement (*Torabinejad M, and White DJ., 1998*). Torabinejad further elaborated on the properties of MTA in 1993 (*Hungaro Duarte MA et al., 2014*). Subsequently numerous patents have been granted for materials containing Portland cement in the US and EU. In 1999 Pro Root MTA was introduced as the available MTA product in the US followed by MTA Angelus receiving FDA approval in 2011 after its launch, in Brazil. MTA Angelus has a setting time is packaged in containers that offer control during dispensing and retains the same beneficial qualities, as traditional MTA. While the original ProRoot MTA comes in single use packets the newer MTA Angelus is contained in sealed bottles that enable practitioners to dispense an amount of powder while sealing the rest for use. (*Duarte MA, et al.,2003*), (*Menezes R, et al.,2004*), (*Koulaouzidou EA, et al.,2008*), (*Lolayekar N, et al.,2009*)

The traditional ProRoot MTA typically takes 2 to 3 hours to set whereas MTA Angelus sets in 15 minutes after preparation. This reduced setting time can be advantageous for clinicians who want to ensure the material sets during placement allowing them to proceed with restorative procedures without concerns about MTA displacement. The setting time of MTA Angelus is achieved by lowering the calcium sulfate concentration, which's responsible for the longer setting time in the original formula .

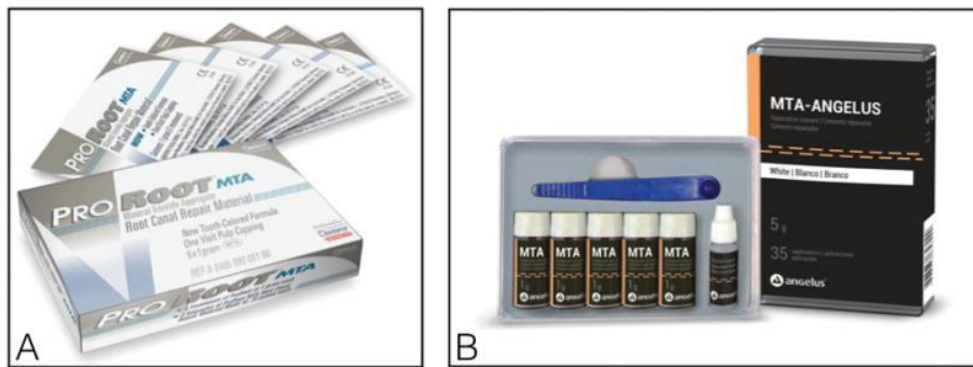


Fig 1: MTA product

A. ProRoot MTA. B. MTA-Angelus.

1.2 Composition

MTA, a mineral aggregate consists of tricalcium silicate, tricalcium aluminate, tricalcium oxide silicate oxide and bismuth oxide. This material comprises calcium oxide (50–75%, by weight) and silicon dioxide (15–25%) which when combined produce compounds like tricalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite. Upon adding water the cement undergoes hydration to form a hydrate gel that eventually solidifies into a structure. This hydration process creates calcium $\text{Ca}(\text{OH})_2$ as a byproduct. Leads to the release of calcium ions causing an increase in pH levels. Studies have shown that after mixing MTA its pH value is initially 10.2 and rises to 12.5 after 3 hours. The high pH microenvironment contributes to the materials properties. (*Lee SJ, et al., 1993*), (*Schwartz RS, et al., 1990*),

MTA shares similarities with Portland cement in composition. Includes bismuth oxide for radiopacity purposes.

Accelerators such, as sodium phosphate dibasic (Na_2HPO_4) calcium format

($\text{Ca}(\text{HCO}_2)_2$) and calcium chloride (CaCl_2) are added to speed up the setting process. (*Srinivasan V, et al., 2009*)

Several research studies have looked into the makeup of MTA. These studies often found differences based on the type of MTA the tools used to analyze its composition or the liquid combined with the MTA powder.

1.3 Manipulation and setting reaction

To prepare MTA mix its powder with water in a 3;1 ratio (powder, to liquid). It has been observed that using either doxycycline or chlorhexidine (CHX) of water does not impact MTAs sealing ability. A metal or plastic spatula can be utilized to mix it on a glass slab or paper pad until it reaches the consistency of a putty paste. Initially mixing the material produces a colloidal gel that eventually solidifies into a structure. To deliver the MTA mix to the intended location tools such as a paper point, plugger, ultrasonic condensation or carriers with designs and messing guns can be employed. (*Sluyk SR, et al.,1998*)

The average setting time for MTA is 165 ± 5 minutes. Moisture from tissues or from a moistened cotton pellet aids in the setting reaction. However excessive moisture may result in a "mixture. The use of accelerators such as CaCl_2 , $\text{Ca}(\text{HCO}_2)_2$ and Na_2HPO_4 was discovered to reduce MTAs setting time but also significantly decrease its strength. Conversely employing a 2% lidocaine solution and saline extends the setting time without impacting compressive strength. (*Asgary S, et al.,2005*)

The mixing duration, for MTA is critical; excessive mixing can lead to dehydration of the mixture. It is recommended to keep the mixing time under 4 minutes.

Its recommended to use the mixture after blending to prevent it from becoming dry and sandy. For placing MTA in a spot you can use hand tools or ultrasonic techniques. According to Parashos et al. using methods can enhance the compaction and flow of MTA. Excessive usage may have negative effects, on its properties. Research suggests that two seconds of ultrasonication per increment is optimal for achieving microhardness, sealing and avoiding voids. A recent study indicated that the ultrasonic approach reduced the setting time of MTA.

When it comes to condensation pressure its advised not to apply pressure when compacting MTA. Increased condensation pressure could lead to decreased

surface hardness of MTA as it may reduce water ingress spaces for cement hydration. (*Sluyk SR, et al.,1998*)

In a study applying glass ionomer cement (GIC) over WMTA after 45 minutes during one visit perforation repair didn't affect calcium salts formation at their interface or WMTA setting. Additionally GIC setting wasn't disrupted by the presence of WMTA.

To enhance the setting time and handling properties of MTA adding GIC powder, to the MTA mixture has been proposed.

One research study indicated that while there were improvements, in setting times the strength and pH levels were lower when compared to using MTA powder. In another study the impact of adding GIC to the MTA mix to enhance setting time on the amount of calcium released from the mixture was examined. This calcium release is crucial for the functions of MTA. The study revealed that combining MTA and GIC in a 2;1 volume ratio did not significantly alter the calcium release, from the mixture. However additional clinical assessment was recommended for evaluation. (*Sluyk SR, et al.,1998*), (*Torabinejad M, et al.,1998*)

1.4 Properties

1. When it comes to the properties of these materials they offer a working time of about 5 minutes but their setting time is quite long ranging from 3 to 4 hours. To speed up the setting process of MTA accelerators, like CaCl_2 , $\text{Ca}(\text{HCO}_2)_2$ and Na_2HPO_4 are used, although they do decrease its strength significantly. Conversely using a 2% lidocaine solution and saline can extend the setting time without impacting the strength. The mixing time for MTA is critical. Should ideally be than 4 minutes. It is also recommended to use the mixture after mixing to prevent it from dehydrating and turning into a texture.
2. In terms of strength MTA typically reaches around 40 MPa after 24 hours. Increases to about 67.3 MPa after 21 days. Studies have shown that grey MTA tends to have strength compared to white MTA.
3. Regarding radioopacity *Torabinejad M (1995)* noted that the average radioopacity of MTA is 7.17 mm, to the thickness of aluminum and sufficient, for radiographic visualization. According to a study, by Shah PMN in 1996 it was discovered that MTA exhibits a radiodensity to Zinc Oxide Eugenol.
4. The solubility of MTA increases when it is mixed with water. *Buding (2008)* observed the release of $\text{Ca}(\text{OH})_2$ when set MTA comes into contact with water. This release of $\text{Ca}(\text{OH})_2$ contributes to its property of inducing cementogenesis
5. The initial pH of Ph MTA is 10.2 which then rises to 12.5 three hours after mixing.
6. *Al Hazaimi et al. (2006)* mentioned the effects of MTA against enterococcus faecalis and streptococcus sanguis. No significant antimicrobial activity was noted against anaerobes
7. *Sumer et al. (2006)* highlighted the biocompatibility of MTA. *Arens and Torobinejad (1996)* used MTA for treating perforations and osseous repair.

Koh et al. Demonstrated that MTA can trigger interleukins production making it a conducive environment for bone cell regeneration. In a comparison by *Kettering and Torabinejad (1995)* it was found that MTA is non mutagenic and less cytotoxic, than Super EBA and IRM

8. Marginal adaptation and sealing capability of MTA are highlighted by its sealing properties as it expands during the setting process. It is recommended to place a cotton pellet in contact, with MTA before applying the restoration for improved sealing. *Valois et al. (2004)* determined that a thickness of 4 mm of MTA is sufficient for ensuring sealing.
9. Regarding mineralization *Holland et al. (1999)* suggested that the tricalcium oxide component in MTA reacts with tissue fluids to produce Ca(OH)_2 leading to the formation of tissue to Ca(OH)_2 . *Faraco et al. (2001)* observed that the dentin bridge formed with MTA shows development and superior structural integrity compared to Ca(OH)_2 . Studies, by *Dominguez et al. (2003)* and *Tziafas (2002)* indicate that MTA promotes dentin formation while preserving pulp integrity.

1.5 Types of MTA

There are two types of MTA distinguished by their colors; gray (GMTA) and white (WMTA). Initially gray Pro root MTA was introduced, Due, to concerns about discoloration white MTA was developed in 2002 (*Parirokh M and Torabinejad M 2010*), (*Kratchman SI 2004*). The key difference between them is that WMTA contains levels of iron, aluminum and magnesium oxides compared to GMTA. As gray and colleagues suggested that the lighter shade of WMTA is likely due to reduced oxide (FeO) content. Additionally, GMTA has crystal sizes compared to WMTA. GMTA also exhibits longer setting times, lower radiopacity, higher solubility and different pH values than WMTA. In terms of strength there are conflicting findings; one study shows strength for GMTA while two others indicate higher strength for WMTA. Moreover, GMTA demonstrates effects, at lower concentrations compared to WMTA against certain microorganisms.

As gray and Kamran (*Asgary S, Kamrani FA 2008*) also found that both types of MTA have properties. Another approach involves blending resin into the MTA mixture, for use as a root canal sealant. This adjustment aims to enhance material flow dentine bonding setting time and minimize micro leakage. For instance, MTA Fillapex (Angelus, Londrina, Brazil) (*Camilleri J, 2014*) is a product of this resin incorporation. However it was observed that adding resin to the materials may decrease the presence of essential Ca(OH)_2 needed for root development in immature permanent teeth. (*Camilleri J., 2014,2015*)

On the contrary NeoMTA (NuSmile, Houston, USA) is a form of MTA without any resin content. It is promoted as a cost MTA specifically designed for pulp therapy. The powder comes in a vial that can be resealed to allow usage according to treatment requirements for better cost efficiency. The mixing liquid is in gel form, for blending and application. Moreover, it features a staining formula and quick setting time. All beneficial attributes when treating young patients. (*Xu Z., 2016*)

A similar product to consider is the Neo MTA. By Avalon Biomed Inc. In Bradenton, Florida. It features a powder gel composition. Is recommended for pulpotomies due, to its ability to avoid staining the tooth structure. This is achieved by substituting tantalum oxide, for bismuth oxide to provide opacity. *(Camilleri J., 2015)*

1.6 Mechanism of action

The MTA powder, made up of particles is mixed with water to kickstart a hydration reaction that releases heat. This process involves the dissolution and precipitation of substances. As the inorganic particles dissolve in water calcium silicate hydrate forms, through a nucleation growth process and calcium hydroxide precipitates boosting the hydration rate of MTA. This hydrated cement leads to the formation of a calcium silicate hydrate based colloidal gel that solidifies into a barrier with alkalinity. As calcium precipitates the ratio of calcium silicate decreases. According to research by Koh et al. MTA enhances the production of interleukins IL 1 α , IL 1 β , IL 6 and IL 8. These interleukins activate osteoclasts stimulating bone matrix production. IL 6 and IL 8 encourage bone resorption. Support the growth of blood vessels. Consequently MTA shows promise, in regenerating ligament and bone tissue. *(Camilleri J, 2005,2006)*

1.7 Reaction with other dental materials

MTA does not. Interfere with materials according to studies. When glass ionomer cements or composite resins are used as materials, over MTA they do not impact the setting of MTA (*Nandini S, et al., 2007*). Some interactions may arise when MTA is combined with materials during treatment, such as;

- Chlorhexidine (CHX); Could lead to challenges, in proper setting.
- Sodium hypochlorite (NaOCl); May result in a shorter setting time.
- Saline (NaCl); Might extend the setting time.
- Lignocaine; Could also prolong the setting time.

1.8 Advantages of MTA

Advantages of MTA (Srinivasan V, et al., 2009), (Steinig TH, et al., 2003)

- Compatible, with the tissues surrounding the root.
- Not harmful, to cells.
- Shows properties.
- Does not get absorbed by the body.
- Provides sealing.
- Has a pH level when combined with water.
- Helps in the regrowth of ligament.

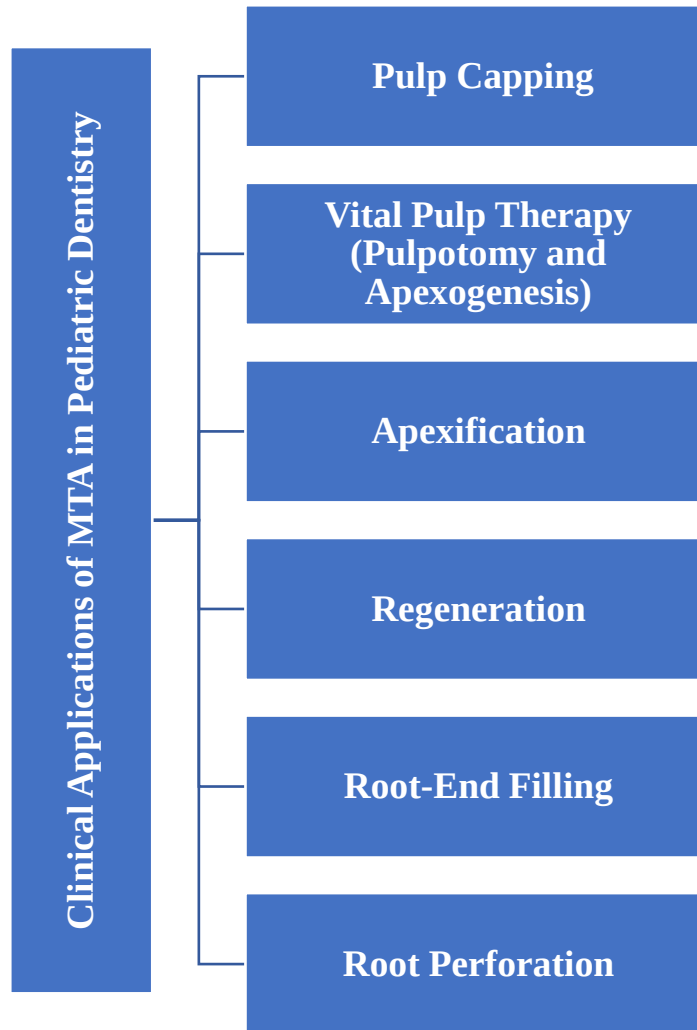
1.9 Disadvantages of MTA

Disadvantages of MTA (Srinivasan V, et al., 2009), (Steinig TH, et al., 2003)

- When using MTA, it's important that the area being treated is free, from infection to allow the MTA to set properly as acidity can hinder this process.
- This procedure requires skill and knowledge from the operator.
- Handling MTA as a pulp capping material can be challenging due, to its grainy texture, lower durability and initial lack of firmness.
- Unfortunately using MTA for pulpotomies in molars filling pulp chambers of teeth and as a barrier has led to crown discoloration. A study comparing the color stability of MTA Plus with Neo MTA Plus and Biodentine during pulpotomies, on teeth using sodium hypochlorite solution revealed that MTA Plus exhibited discoloration while Neo MTA Plus and Biodentine did not display any discoloration.
- Additionally, it is costly.
- Its insoluble nature and the presence of FeO, in its composition contribute to minimizing arsenic release into tissues.

1.10 Clinical Applications of MTA

Clinical Applications of MTA in Pediatric Dentistry Includes :



1.10.1 Pulp Capping

Sometimes dental procedures can lead to exposure of the pulp of the teeth. While some dentists may be cautious, about performing pulp capping due to its nature as a treatment, MTA (Mineral Trioxide Aggregate) shows promise in improving the effectiveness of this procedure in the future (*Farsi N, et al.,2006*), (*Bogen G, et al.,2008*). Unlike calcium hydroxide MTA has the advantage of being more resistant to dissolution (*Faraco IM, Jr, Holland R.,2001*). It forms a seal by expanding as it sets effectively preventing bacteria from entering the pulp area. Studies suggest that using MTA for pulp capping in cases without symptoms or limited infection (pulpitis) can be beneficial. Research also indicates that compared to calcium MTA leads to inflammation and increased formation of new dentin. With MTA Angelus setting within 15 minutes during pulp capping the final filling can be promptly placed directly in contact, with the MTA material.

1.10.2 Vital Pulp Therapy (Pulpotomy and Apexogenesis)

When facing pulp inflammation due, to invasion a dentist may opt for a pulpotomy in the pulp chamber (*Camp JH.,2008*), (*Barrieshi-Nusair KM and Qudeimat MA.,2006*). This procedure, also referred to as apexogenesis aims to support the growth of the root tip and structure. It is usually carried out on teeth with developing roots that still have pulp. The part of the pulp near the root, which's relatively free from inflammation is preserved during this treatment. By encouraging odontoblasts to mature and assisting in formation as root development progresses smoothly. This results in root walls (reducing risks) and eventual closure at the tip (apexogenesis) forming a narrowing at the base that facilitates future root canal procedures.

During this process dentists should use a diamond bur in the pulp chamber to seal tissue and control bleeding. Subsequently disinfection using agents like sodium hypochlorite or chlorhexidine should be performed before rinsing with saline solution. Stopping bleeding can be achieved by applying pressure with a cotton pellet, for minutes before filling the area with MTA.

1.10.3 Apexification

Treating the pulp inside a tooth's root has always posed challenges, for dentists due to the absence of a barrier at the root tip. Traditionally this issue has been addressed through prolonged use of calcium hydroxide which could span over years involve visits and potentially increase the risk of root fractures (*Andreasen JO, et al.,2002*). However a recent development in care is Mineral Trioxide Aggregate (MTA) which offers a one visit solution by creating a protective barrier. (*Witherspoon DE and Ham K.,2001*), (*Witherspoon DE, et al.,2008*)

Clinical procedure

In the procedure when there is bone loss at the apex of the tooth a collagen/gelatin sponge similar to Gelfoam® can be placed apically to facilitate the application of MTA to the depth. To accomplish this a small piece (2×2mm) of Gelfoam® is gently guided down and through the root apex using a file. Following this step MTA is meticulously packed into the canal using a cone. The dentist may use a rubber stopper on the gutta percha cone to determine how much MTA needs to be placed in the part. (see Figure 2B). 3–5mm of MTA has sealed off the third the remaining space, in the coronal canal can be filled using a warm gutta percha technique (see Figure 2C).

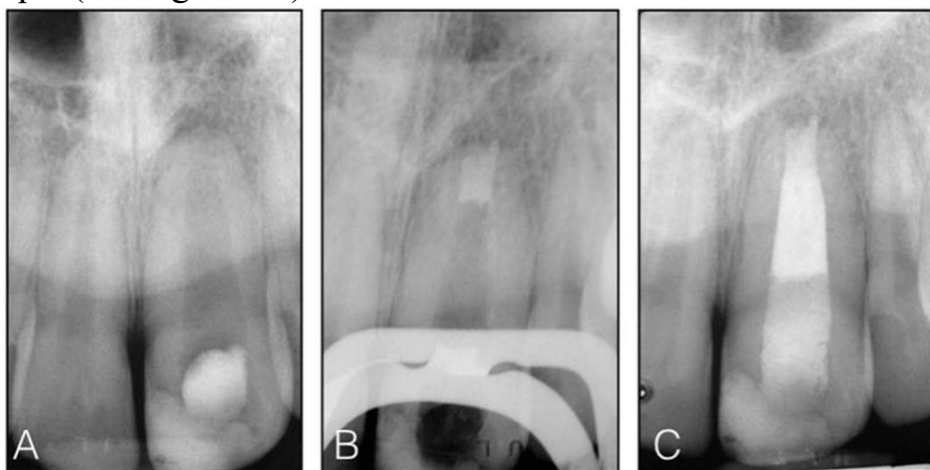


Fig 2 : Apexification

Fig 2A. Pre-operative radiograph. **Fig 2B.** MTA-Angelus placed in the apical third. **Fig 2C.** Postoperative radiograph.

1.10.4 Regeneration

Regeneration (Banchs F, Trope M.,2004), (Miller EK, et al.,2012)

Treating a pulp, inside a root with walls can be quite challenging as it raises the risk of root fractures. A modern approach involves revitalizing the dentin pulp complex by cleansing the root canal with a paste followed by tissue repair and regeneration. This method promotes the thickening of walls by creating tissue to dentin. However further research is needed to grasp how this formed hard tissue boosts the strength of the original thin root structure.

Clinical procedure

In practice regenerating the pulp space in endodontics is advised for cases where the dentinal wall are extremely thin and there is an apex larger than 1mm in diameter on radiographs (as illustrated in Figure 3A). The root canal system undergoes disinfection using sodium hypochlorite irrigation followed by applying a paste dressing that remains in place for a week. During treatment EDTA is utilized to condition the dentin walls triggering the release of growth factors. Bleeding is induced in tissues housing stem cells to encourage filling of the pulp space with a blood clot serving as a scaffold. MTA is then carefully positioned at the canal entrance touching the clot to prevent any leakage, from above (as shown in Figure 3C) .Over time the blood clot will gradually be substituted by tissue, with compositions as the root walls keep getting thicker because of the deposition of dentin material, on the existing root dentin.

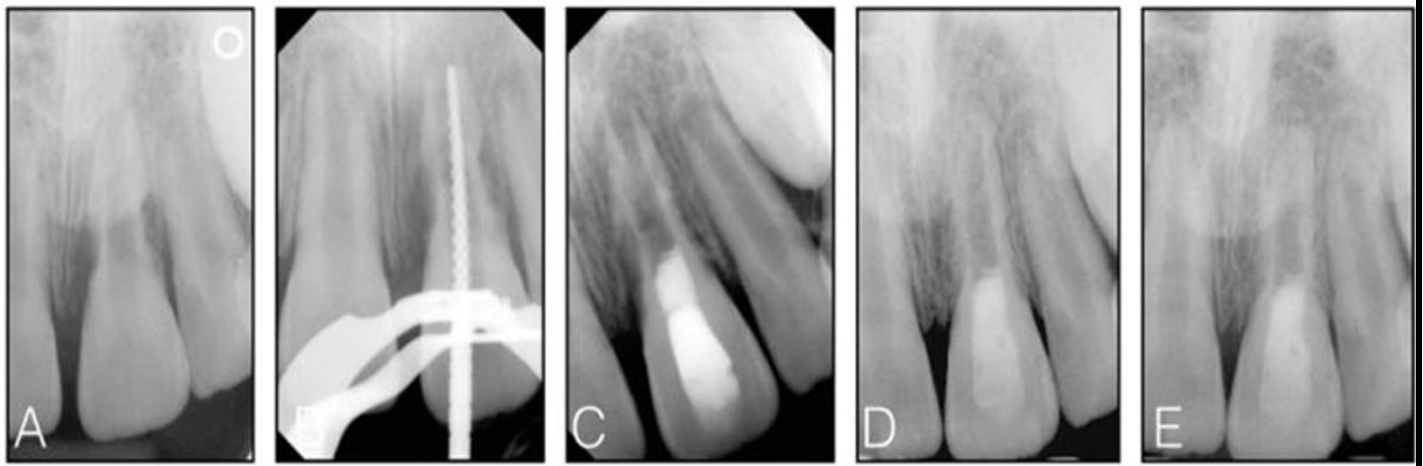


Fig 3 : Regeneration

Fig 3A. Pre-operative radiograph showing the aggressive external root resorption and the thin dentinal walls. **Fig 3B.** Working length confirmation. **Fig 3C.** Post-operative radiograph. **Fig 3D.** one year follow up showing a healthy lamina dura and root development. **Fig 3E.** Three years follow up showing the continued root development.

1.10.5 Root-End Filling

Root-End Filling (Chong BS.,2004), (Kim S. and Kratchman S.,2006)

A retro filling procedure, also known as root end filling is performed in endodontics when a microsurgical approach, beyond the root is needed to address treatment related issues. Surgical interventions are often necessary for cases that cannot be effectively treated using root canal methods due to canal structures or complications from treatments. MTA exhibits physical sealing properties. Promotes the formation of a biological seal through cell growth directly on the cementum, during the healing process.

Clinical Procedure

Following the trimming of 3mm of the root (as depicted in Figure 4B) the canal is meticulously cleaned using tools to prepare for the retro filling process (as shown in Figure 4C). Once this step is completed MTA is. Carefully packed into place to finalize the retro filling procedure (illustrated in Figure 4D).

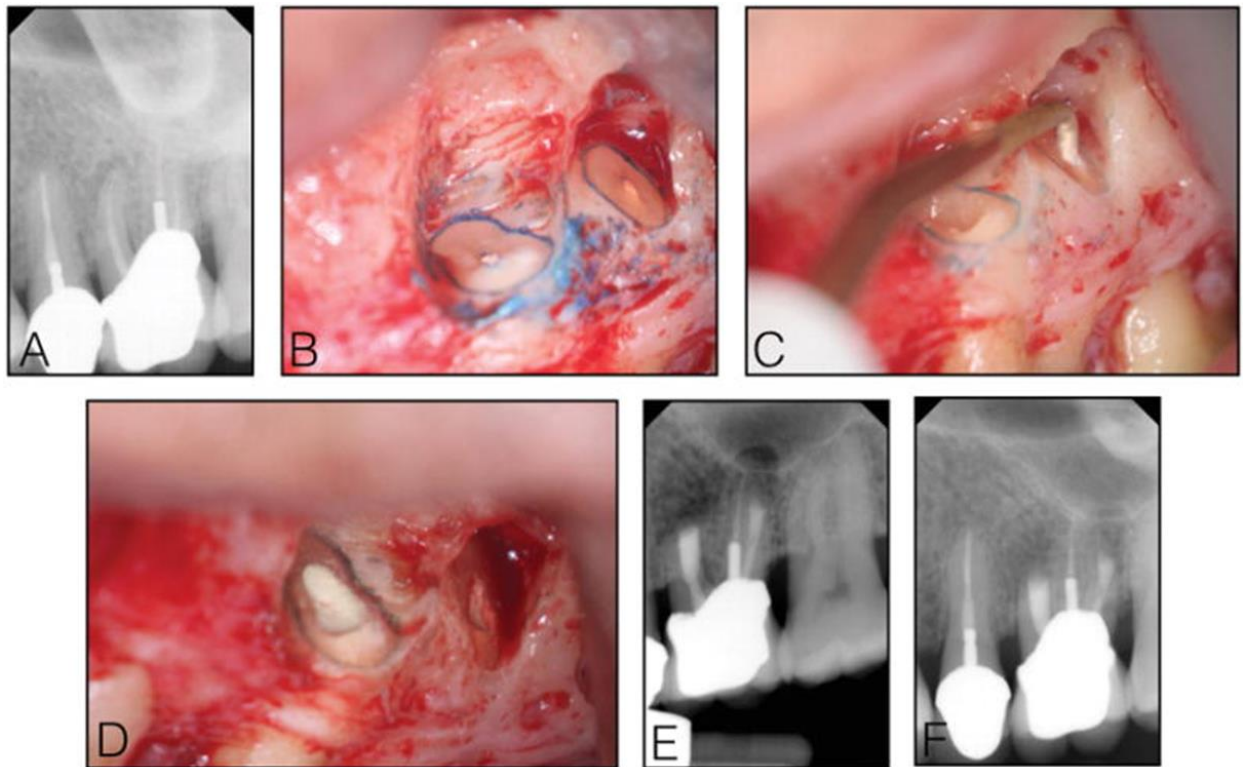


Fig 4 : Root-End Filling

Fig 4A. Pre-operative radiograph. **Fig 4B.** 3mm root resection with methylene blue staining. **Fig 4C.** Retro-preparation with ultrasonic tip. **Fig 4D.** MTA-Angelus placed as a retro-filling. **Fig 4E.** Post-operative radiograph. **Fig 4F.** Six month follow-up.

1.10.6 Root Perforation

Root Perforation (Mente J, et al.,2014), (Main C, et al.,2004)

Perforations often occur due, to damage, which can lead to a connection between the canal of a tooth and the surrounding tissues. They may also occur when the root experiences resorption affecting the thickness of the root. MTA, renowned for its sealing properties and compatibility with the body is commonly used to repair these perforations with results.

Clinical procedure

During a procedure it is crucial to assess the size of any hole that appears. If there is a gap in the bone it should be filled with a substance that promotes bone growth. Options such, as bone grafts, calcium sulfate or collagen/gelatin sponge can be utilized for this purpose (refer to Figure 5A). Subsequently repair the damaged part of the tooth using MTA (refer to Figure 5B).

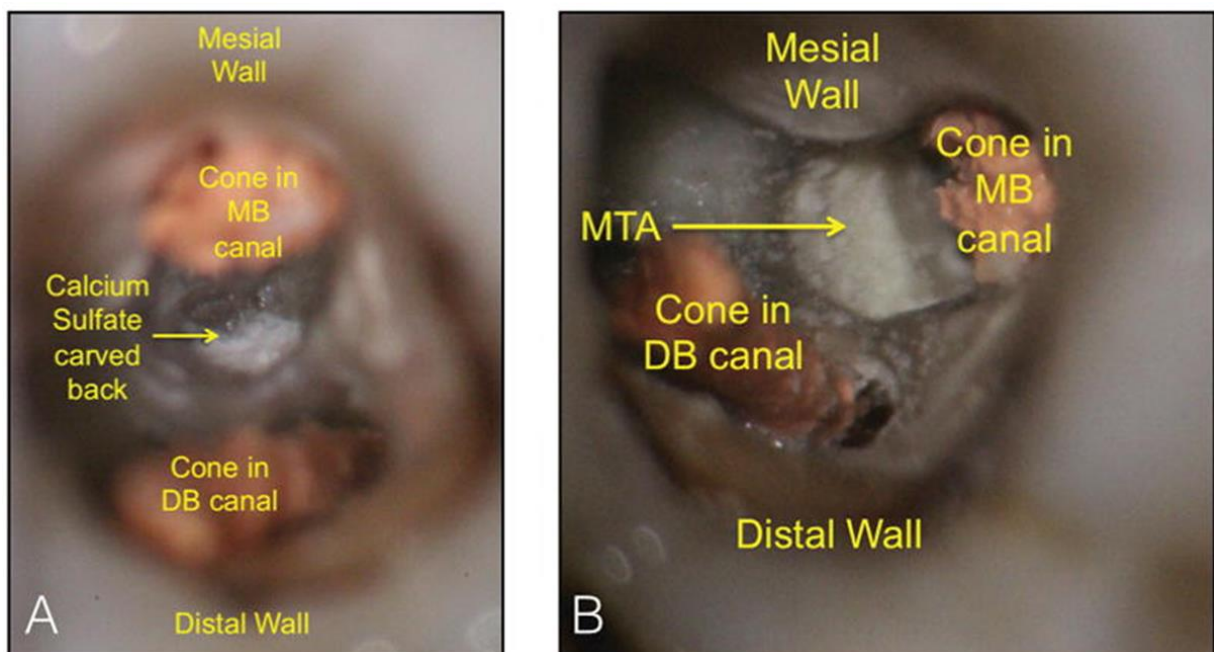


Fig 5 : Root Perforation

Fig 5A. Calcium sulfate placed in the bony portion of the perforation. **Fig 5B.** MTA-Angelus placed in the dentinal portion of the perforation.

Chapter Two

Conclusion

2.1 Conclusion

MTA is a material, with benefits. Pediatric dentists have successfully utilized it in scenarios. While MTA offers advantages, its drawbacks, such as cost, potential for discoloration handling challenges and long setting time cannot be ignored. With the introduction of silicate materials like Biodentine that address MTAs limitations there is competition to become the preferred alternative for dental applications where MTA is commonly used. Nonetheless with the arrival of enhanced MTA products it is likely that MTA based materials will continue to play a role, in quality dental care for years to come.

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