Pulpotomy: A journey through the products available over time

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ABSTRACT
The objective of this chapter is to present two preventive techniques of pulp therapy, with a view to avoiding pulpectomy, and to explain the medications used in such procedures.

Keywords: Pulpotomy, Therapy, Medications.

1 INTRODUCTION

The objective of this chapter is to present two preventive techniques of pulp therapy, with a view to avoiding pulpectomy, and to explain the medications used in such procedures.

Therefore, at the end of the above, the reader should be able to define direct pulp capping and pulpotomy, in addition to being familiar with the drugs available on the market to date for the execution of the procedures in question and, finally, with the process of pulp tissue revascularization.

Mind Map

		Drugs
		Formocresol
	Direct pulp capping	Calcium hydroxide
Defiinir		Mineral Trioxide Aggregate
	Pulpotomy	Bioceramics
		Bone morphogenetic proteins
		Fibrin-rich plasma

The advancement of biotechnology has provided significant changes in the field of tissue engineering and, as a result, regenerative therapies such as pulp revascularization have been gaining ground in endodontics, especially in the treatment of immature permanent teeth.

Direct pulp capping and pulpotomy are techniques that aim to preserve the tooth in the arch by maintaining pulp vitality, which has been compromised by decayed tissue or some fracture of the dental crown.

Despite the usefulness of both techniques and their wide possibility of use for treatments in young primary and permanent teeth, there are a large number of dentists who are not familiar with their particularities, including difficulties in the management of these techniques, as well as the available medications.

It should also be added that today, the growing number of products intended for this procedure has gained new and unprecedented options. However, the diversity of materials is not a quantity directly proportional to the knowledge of the technique and use, of the material options, in clinical practice, therefore, the results may vary negatively, mainly, as written in the previous paragraph, due to mastery of the technique.

It is worth mentioning that to date, a chemical compound considered ideal for performing direct pulp capping and pulpotomies has not been achieved. However, the success of the treatment is high when the diagnosis is accurate and the technique is used assertively.

Among the oldest products we have some worthy of note, such as formocresol, tricresol formalin, calcium hydroxide, mineral trioxide (MTA) and bioceramic compounds. The use of laser therapy (FERNANDES, 2012), ferric sulfate (COSTA, 2011; PENG, 2007) and host defense peptides (PDHs) that may act alone or in combination with other biomolecules (MARTINS, 2019) are more recent. Currently, fibrin-rich plasma (PRF) is used (Wu *et al.*, 2023) with satisfactory results, according to the authors' publications.

However, when indicated and possible, a technique known as direct pulp capping prior to pulpotomy may be performed. And, consequently, if there is direct capping, there is also indirect capping, however, here we will address direct capping, since pulpotomy follows in sequence and indirect capping does not require such an arsenal of medications.

1.1 DIRECT PULP CAPPING

Pulp capping is an important measure and widely used in the daily practice of dentistry, including with a preventive view in children and adolescents, when performed consciously, based on a good diagnosis of the pulp condition at the time of exposure, it can prevent the tooth from undergoing an invasive endodontic intervention. In addition to calcium hydroxide, other materials have been tested for their action in promoting pulp repair by the formation of dentin bridges after direct pulp capping. One of the viable material alternatives for pulp capping are ceramics based on calcium phosphates, especially hydroxyapatite (HAp) and tricalcium phosphate (β-TCP). These materials do not promote

the formation of necrotic areas, which is characteristic of the use of calcium hydroxide, they are biocompatible and favor the repair of pulp tissue.

The difference between the direct pulp capping technique and pulpotomy is linked only to the preservation of the remaining tooth structure, where the former removes the decayed tissue and accidentally reaches the pulp tissue, the roof of the pulp chamber, exposing the pulp tissue in reduced dimensions, usually 1 mm2; The pulpotomy technique, on the other hand, necessarily includes the removal of the roof of the pulp chamber, i.e., the same technique as the coronary opening in pulpectomies, but without invading the root canals, whether in the cervical or middle third.

1.2 PULPOTOMY TECHNIQUE

The first steps are anamnesis, clinical examination and radiographic analysis. The dental crown must have enough dental remnant to receive the restorative material without the need for an intraradicular core or pin, otherwise pulpotomy is ruled out, moving on to pulpectomy.

Pulpotomy is recommended in a single session, immediate technique, or in two sessions, mediate technique.

In the mediate technique, after removing the coronary pulp and obtaining hemostasis, usually with the aid of saline solution and sterile cotton ball irrigations in the pulp chamber, soaked in a drug association of corticosteroids and antibiotics, the bleeding condition is controlled, then a new sterile cotton ball is placed, which will remain for 48/72 hours. finishing the protection with temporary restorative material. After this period, the recommendation is to remove the temporary restoration and cotton ball, without anesthesia, and proceed to the procedures of the immediate technique (HOLLAND & SOUZA, 1970; HOLLAND *et al*., 1979; HOLLAND & SOUZA, 1984; HOLLAND *et al*., 1991)

In the immediate technique, after removal of the coronary pulp, bleeding is controlled with a sterile cotton ball soaked in a combination of corticosteroids and antibiotics for 5 minutes, followed by coating with calcium hydroxide PA and final tooth restoration. In this technique, the definitive restoration of the tooth will be performed in the same session, avoiding displacement or fracture of the temporary restoration, and there may be bacterial infiltration before the formation of the dentin bridge (ASSED, 2005). The use of an anti-inflammatory solution before calcium hydroxide has therapeutic properties that help with pulp healing (NETO *et al*., 2015).

It is worth remembering that absolute isolation is a mandatory condition in both techniques. After the removal of the decayed tissue with the aid of ball drills, diameter compatible with the cavity, mounted at low speed, the pulp roof is eliminated through "Endo Z" type cutters mounted at high speed and constant irrigation, and at the end, if there is a pulp remnant in the chamber, it must be removed with sharp curettes and irrigation with saline solution.

Regarding the two techniques, the choice for immediate or mediate is exactly in the environment in question, in cases of public care in basic health units (UBS) and dental specialty centers (DSC) the indication is the immediate technique, in clinics and private offices you can opt for the mediate.

2 MATERIALS USED IN PULPOTOMIES

2.1 PULPOTOMY WITH FORMOCRESOL

Formocresol is an ancient chemical commonly used in the pulpotomy technique due to its clinical and radiographic success with favorable results, its use is currently questioned due to histological analysis.

After its application on the pulp, four layers are observed:

First layer: fixed fabric;

Second layer: with reduced number of cells and fibers (atrophied);

Third layer: with a concentration of inflammatory cells;

Fourth layer: normal fabric.

However, histological analyses showed mild to severe inflammation, reaching total degeneration and pulp necrosis (CORRÊA, 2005). ANTONIO *et al*. (2002) investigated the effects of formocresol through a literature review and observed coagulation necrosis, chronic inflammatory reaction and dentin resorption in some cases. Therefore, among many other works, the questioning of the use of such a substance began.

In order to obtain data on the use of formocresol, COHEN & HARGREAVES (2008) analyzed that at the end of the eighties, North American dental schools recommended this substance in pediatric dentistry departments. Subsequently, observations by KRAMER *et al*. (2008) reported that this substance is also the most taught in most Brazilian dental schools.

2.2 CALCIUM HYDROXIDE PULPOTOMY

In 1929, HESS described for the first time the technique of pulpotomy with calcium hydroxide, however, due to the low success rates obtained in the 50's and 60's, it led to doubts as to its efficacy for such a procedure.

Among the traditional substances in use by the Unified Health System (SUS), formocresol and calcium hydroxide stand out over the other substances, for three reasons, which are quite clear and practical, namely:

1st- Low value,

2º- Access and ease of use,

3rd - Positive results.

Calcium hydroxide in its pure form is a white powder, with an approximate pH of 12.4, giving it properties such as mineralization stimulants and antimicrobial agent.

This material tends to be the component of pastes, irrigation solutions, cements and liners of cavities and obturators of root canals (CONSOLARO *et al.*1997). The alkalinity produced by calcium hydroxide causes coagulation necrosis, stimulating the formation of a hard tissue directly adjacent to the interface of the material and the exposure. When calcium hydroxide is applied directly to the pulp tissue, there is a caustic effect causing a layer of superficial necrosis. Granulation zones composed of mineral organic matter, precursors of the mineralized bridge, appear and may be irregularly shaped, evidencing chronic inflammation of the pulp tissue (SOARES, 1992).

The results showed that the dentin bridge formed by calcium hydroxide PA was thicker and more organized in the longest time intervals and with reconstitution of the odontoblastic layer. (HOLLAND *et al*., 1979; HOLLAND & SOUZA, 1984; HOLLAND *et al*., 1991; PINTO, 1999).

The use of corticosteroids associated with antibiotics decreases inflammation, in addition to relieving intrapulp pressure, favoring the action of calcium hydroxide, including properties of stimulating the remineralization of the tissue in contact and, due to its pH, antimicrobial activity. All in all, calcium hydroxide, although ancient, is a powerful ally in pulpotomies and direct pulp capping.

2.3 PULPOTOMY WITH MINERAL TRIOXIDE AGGREGATE (MTA)

The MTA material was initially indicated for sealing dental communications with the external periodontal environment.

Some properties of MTA are noteworthy, such as high alkalinity, low solubility (AABEDI & INGLE, 1995; TORABINEJAD et al. 1995), excellent marginal sealing, antimicrobial capacity (ESTRELA *et al*, 2000), radiopacity, dimensional stability, compressive strength and high biocompatibility, with the formation of a barrier of mineralized tissue by the dental pulp in greater quantity and quality than calcium hydroxide (TORABINEJAD & CHIVIAN, 1999; HOLLAND *et al*. 2001; HOLLAND *et al.* 2001).

MTA has properties and mechanisms of action similar to the well-known calcium hydroxide, but with some superior characteristics in terms of sealing (SOUZA *et al*. 2003).

Regarding the formation of mineralized tissue, the mechanism of action between MTA and calcium hydroxide is similar. The initial effect of MTA on the surface of the exposed pulp produces a surface layer of crystalline structures with the presence of calcium oxide and calcium phosphate. Calcium oxide reacts with tissue fluids and calcium hydroxide is formed. From this stage on, the two materials act in the same way. An extracellular matrix rich in fibronectin is secreted in close contact with these crystals, forming the initial step of hard tissue formation. Columnar cells undergoing nuclear and cytoplasmic polarization begin to organize along the crystalline structures. This immediate

reaction indicates stimulation of the biosynthetic activity of pulp cells, but it is doubtful that it is a direct stimulation of the formation of reparative dentin (Pitt Ford *et al*. 1996).

The formation of an odontoblastic layer adjacent to the material is also due to the ability of the MTA material to stimulate the production of cytokines (interleukins), which are directly involved in the stimulation of mineralized tissue-forming cells, such as bone and dentin tissue. The deposition of mineralized tissue near the MTA also occurs due to its sealing capacity avoiding bacterial contamination and the low susceptibility to dissolution, biocompatibility and alkalinity (ELMAS *et al.* 2023)

In view of such properties and positive results, it did not take long for MTA to be the material of first choice in conservative procedures such as pulpotomies and direct pulp capping. However, the value of the product "is the Achilles heel" for the product in public service networks.

2.4 PULPOTOMY WITH BIOCERAMICS

Bioceramic cements are inorganic, non-metallic, and biocompatible ceramic materials used in the fields of medicine and dentistry. In general, it contains alumina, zirconia, bioactive glass, glass ceramics, calcium silicate, hydroxyapatite and calcium phosphates.

They are classified according to the interaction they present in front of the tissues, as follows:

- Bioinerts: They do not cause adverse biological reactions in the surrounding tissues (alumina and zirconia).
- Bioactives: Those that do not degrade but interact with the surrounding tissue (glass, calcium phosphate, hydroxyapatite).
- Biodegradable: These are soluble or resorbable (gypsum and tricalcium phosphates)

Bioceramic cements can be divided according to their use, and can be used for filling root canals or as restorative cements (GHONEIM *et al*. 2011).

Within the restorative function, they are used in pulp capping of dental pulp exposures without previous pathology or symptomatology, and have demonstrated a good success rate due to their sealing capacity, low solubility and excellent mechanical properties (REYES-CARMONA *et al*., 2010)

They can be used in perforations by an endodontic procedure. The choice of bioceramic cement is determined by the area and accessibility of the drilling site, the ability to control fluids, and aesthetic factors HUANG *et al*., 2015; BILLIS, CHONG, 2019)

In particular, in front of teeth with open apexes, bioceramic cements act as an osteoconductive apical barrier because the continuous release of ions, calcium and phosphate allow the bioceramic cement to participate in the process of regeneration and remineralization of hard tissues, improving the sealing capacity by the affixing of hydroxyapatite crystals at the interface (TRAN *et al*., 2016).

Some characteristics of bioceramics used in endodontics are noteworthy, as we can mention:

1)- Ability to penetrate dentin tubules and fracture resistance (OSIRI *et al*, 2016; KHALIL *et al*., 2020);

2)- Sealing and remineralization capacity (calcium and phosphate precipitation) (JUEZ *et* al., 2019; JIMÉNEZ-SÁNCHES *et al*., 2020);

3)- Radiopacity, antimicrobial activity, biocompatibility and toxicity (ORSTAVIK, 2005; CANDEIRO *et al*., 2012; POGGIO *et al*., 2017; JIMÉNEZ-SÁNCHEZ *et al*., 2019).

All in all, it can show that bioceramic cements are biocompatible and the inflammatory response of the tissues in contact with the material is minimal and controlled, they are stable, do not suffer contraction; on the contrary, they expand and do not reabsorb. They have the ability to produce hydroxyapatite, generating a chemical bond between the dentin and the filler material.

The pH is alkaline, thus having a high antibacterial activity. They are easy to handle and handle, It is not difficult to argue that bioceramic cements have a very promising future in their application for endodontic therapy, however, once again, the indication is for clinics and private offices, since the cost of such cements is around 30 to 50% of the value of the current minimum wage, which limits their use in the public network.

2.5 PULPOTOMY WITH BONE MORPHOGENETIC PROTEINS (BMP)

Biomolecular research on bone development and repair has led to the discovery of a family of bone *morphogenetic protein* (BMP), capable of stimulating dentin regeneration. BMP can initiate bone neoformation when implanted in an extraosseous site. The tissue response to BMP implantation occurs in a similar way to embryological bone development, enabling the formation and development of repair in postnatal osteogenesis.

The BMP factor can also induce the formation of dentin, whenever applied directly to the dental pulp, and this is exactly the point that Dentistry has paid attention to.

Morphogenetic proteins are found in the organic matrix of dentin and bone, and can be synthesized by recombinant gene therapy, using a viral vector (GONÇALVES; GUIMARÃES; GARCIA, 1998).

BMPs are multifunctional growth factors, belonging to the TGF-β (Transforming Growth Factor-beta) super family (JIN et al., 2003).

BMPs are products of the metabolism of osteoblasts, odontoblasts, and various tumor cells, which are stored in concentrated form in bone, dentin, and osteosarcoma neoplastic cells. BMP-producing genes, identified by recombinant DNA techniques, have been used to synthesize recombinant BMP (rBMP) in mammalian cell cultures, producing highly active and potentially available proteins, and in even larger fractions than was previously possible.

The performance of BMPs originating from different animals was compared and implanted in rat muscles. Regardless of the animal species from which it was extracted, BMP promoted osteoinduction. GONÇALVES, GUIMARÃES AND GARCIA (1998) commented that using *in vivo* tests of ectopic bone formation, a family of nine BMPs has already been identified. In these tests, a protein sample to be tested, associated with an inert carrier, is lyophilized and implanted into the subcutaneous tissue of mice. After a certain period of time, the samples are collected and processed, evaluating the osteoinductive activity.

The analysis of the identity of BMPs allows their division into several subfamilies. The examination of the amino acid sequence of BMPs showed that BMP-2 and BMP-4 belong to the most related subgroup.

These proteins have 86% of amino acid sequences identical to each other and 33-35% identical with TGF-β.

The second subgroup, formed by BMP-5, BMP-6 (Vgr-1), BMP-7 (OP-1) and BMP-8 (OP-2), exhibits about 73-83% of amino acids similar to each other. BMP-3, also called osteogenin, being a different protein, alone forms the third subgroup, with 45% of the amino acid sequence identical to BMP-2. BMP-1 differs from other BMPs because it does not have morphogenetic activity and does not belong to the TGF-β family, and is now considered pro-collagen C proteinase.

A subfamily of BMP-like proteins, important in bone formation, was called growth and differentiation factor 5 (GDF-5) or cartilage-derived morphogenetic protein 1 (CDMP-1), GDF-6 or CDMP-2, and GDF-7 or BMP-12.

These proteins are homologous to each other, and 46-57% identical to BMP-2 and even BMP-8. Although the exact function and interrelationship of each BMP are not yet fully understood, evidence indicates that it acts as part of a complex cascade of regulatory factors of cell differentiation, increasing the expression of chondroblasts and osteoblasts in injured bone sites

HU *et al*. (1998) believed that the application of growth factors as a morphogenetic signal in the irritated pulp can limit the inflammatory response, accelerate tissue regeneration and lead to the deposition of mineralized dentin of physiological quality. Thus, they mention that the advantage of this procedure is to reduce the possibility of pulp necrosis or excessive secondary calcification, due to tissue irritation induced by calcium hydroxide. Growth factors may also produce a more consistent response with fewer cases of excessive reparative dentin formation. A group of five growth factors, TGF-β1 (Transforming Growth Factor-beta1), EGF (Epidermal Growth Factor), bFGF (basic Fibroblast Growth Factor), IGF-II (insulin-like Growth Factor II), PDGF-BB (Platelet-Derived Growth Factor-BB), which function normally during wound repair and tissue regeneration were analyzed by the team. It is also indicated for use as medication in direct pulp capping.

They concluded that TGF-beta1 induced an ideal restorative dentin bridge in three weeks, and this result was not observed with conventional pulp capping medications, such as Dycal, suggesting that future pulp regimens are likely to be based on physiological strategies. Although this study did not demonstrate improved repair with PDGF-BB, bFGF, EGF, or IGF-2, these factors demonstrated clinical potential when used in combinations.

I must point out, as the person responsible for the chapter, that the product Dycal is not the best product for the study of the properties of calcium hydroxide, due to issues already addressed in the past, such as solubility and tissue diffusion.

BARTOLD *et al*. (1998) reported that many in *vivo* studies have shown that growth hormone (GH) is capable of forming hard tissues, such as: bone, dentin, enamel and cementum. In *vitro* studies have shown that GH has the ability to stimulate the proliferation of osteoblasts, including brown marrow osteoblasts, and to induce markers of bone formation such as BMPs. In view of this, the researchers hypothesized that GH and insulin growth factor (IGF-1) are able to increase the expression of BMP-4 (involved in the early stages of tooth formation) and BMP-2 (involved in the late stages of tooth formation). tooth, where BMP-2 mediates epithelial-mesenchymal interactions). The results obtained increased the possibility of BMPs mediating the local osteogenic actions of GH and IGF-1, and reinforced the view that GH could act through the mediation of factors other than IGF-1.

BENGTSON *et al*. (2004) used rhBMP-2 as a drug in the pulpotomy of human deciduous teeth in order to stimulate the formation of dentin tissue. The authors used ten primary molars with indication for pulpotomy, which was confirmed after clinical and radiographic evaluation. In five teeth, rhBMP-2 with polylactic acid/polyglycolytic scaffold was used, and in the other five patients, rhBMP-2 with collagen scaffold was used. The authors verified after ten months of direct pulp capping performed with rhBMP-2 on the pulp stumps of the deciduous teeth, and considered (at the time of observation) that there was clinical and radiographic success, since only one of the pulpotomized teeth presented mild painful symptoms on the first day, but soon there was remission of the symptom. The soft tissues did not show any alteration and in the control radiographic examination, no alteration was observed in the supporting tissues. The authors observed in some teeth the formation of a tenuous layer of hard tissue inside the chamber. However, this fact can only be confirmed with histological studies that will be performed after exfoliation of these deciduous teeth. In this study, it can be concluded, ten months after the pulpotomy was performed, that no symptoms or any clinical/radiographic signs of pathology were observed.

GOLDBERG *et al*. (2006) said that, for many years, dentists have used a limited number of capping agents to maintain vital pulp. Of these capping agents, the one that has been shown to be the most efficient, so far, is calcium hydroxide. Lessons from biological development have provided a better understanding of the genes involved in the normal and pathological repair process. This

understanding of the reparative process has led to the addition of transcription factors, growth factors, and a series of extracellular matrix (ECM) molecules to the drug arsenal, paving the way for tissue regeneration and repair control. These bioactive molecules constitute a large family that provides tools that will modify daily practice, especially in dentistry. The biological properties of BMPs or transforming growth factors β (TGF-β) and their roles in dentin repair have led to studies (NAKASHIMA, 1990; SIX *et al*., 2002; GOLDBERG; SMITH, 2004) to determine the effects of these molecules on dentin repair where it was concluded that BMPs or TGF-β can induce the formation of reparative dentin.

All in all, it turns out that BMPs are potent agents in therapy, not only medical, but also dental. Thus, promising and powerful drugs for direct pulp capping and pulpotomies, however, the biggest obstacle of the substance remains, its cost.

2.6 FIBRIN-RICH PLASMA PULPOTOMY

Some research is investing in the use of fibrin-rich plasma (PRF) (Wu *et al*., 2023) with satisfactory results, according to the authors' publications, however, there are no publications in cases of pulpotomies, only in pulpectomies. It is a high-cost technique, requiring improvement and accreditation courses, including the need for puncture, which in psychological terms is "traumatic" for many patients, especially children.

3 REVASCULARIZATION

It is not new that the degree of tissue aggressiveness of the materials recommended and used in the techniques of direct pulp capping or pulpotomy has been analyzed in a comparative way, in the first instance, in cell culture, in subcutaneous connective tissue and in bone tissue of rats, and then directed to the evaluation in animal teeth, such as: rabbits, dogs and monkeys, used because they have a dentin-pulp complex very close to that of humans, in terms of shape and differentiated physiology (BENATTI NETO, 2000). The dentin-pulp complex has the same repair mechanisms as the supporting connective tissue, modified by a few local factors (TEN CATE, 1988).

After the direct application of a material on the exposed pulp, as previously exposed, either in direct pulp capping or in pulpotomy, it is expected that the formation of a mineralized dentin bridge will occur, and the pulp vitality will be maintained. This mineralized dentin bridge, also called dentin pons, is defined as a dentin matrix formed and deposited by a new generation of cells, such as odontoblasts, in response to a strong stimulus, after the death of the original (primary) odontoblasts, responsible for the formation of primary and physiological dentin (TURNER *et al*, 1987; Smith et al, 1995).

Although calcium hydroxide is the most widely used material for pulp capping, hard tissue deposition does not seem to be an exclusive property of this material. Although the phenomenon of pulp calcification is attributed to $Ca(OH)_2$, this material does not have the capacity to penetrate deep into the extracellular matrix. It has been reported that pulp repair may be a natural response of pulp tissue when exposed to a low-intensity irritation (HANKS *et al*, 1983).

The process of dental pulp repair, revascularization, follows a series of ordered and predictable biological events, differing little from other tissues and generally does not depend on the type of injury, being similar to what occurs in the skin after a surgical incision.

When part of the enamel is removed, stimuli reach the pulp and promote the formation of a new portion of reactive dentin, considered tertiary or repairing dentin. This same reaction mechanism is observed when the cavity preparation reaches the dentin at different depths, without causing further damage to the odontoblasts and their extensions (TEN CATE, 1988).

From the moment the injury involves the odontoblasts, the pulp response obeys a stereotyped condition. An inflammatory response involving neutrophils and macrophages, followed by proliferative and secretory phenomena, may be observed. New fibroblasts differentiate from intact pulp fibroblasts and undifferentiated perivascular cells, immediately producing a collagen matrix (BENATTI NETO, 2000). The formation of a dentin matrix and its subsequent mineralization depend on specialized secretory cells, the odontoblasts, which, according to different researchers (HANKS *et al*, 1983; TEM CATE, 1988, BENATTI NETO, 2000) would originate from undifferentiated mesenchymal cells.

The stimulus for this evolution would come with the formation of a mineralized barrier, a condition that can be satisfied with the use of special materials, such as bioceramics.

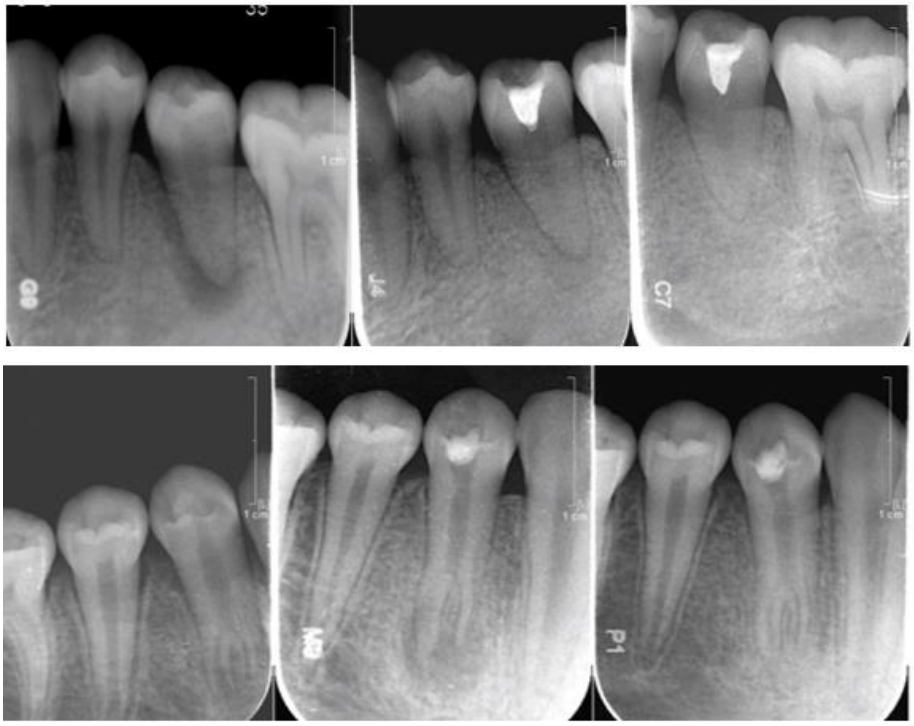
Consequently, research involving several calcium phosphate ceramics as agents used in direct pulp capping or pulpotomy has not ceased. Among them are tricalcium β-phosphate (β-TCP) and hydroxyapatite (HAp). The results already reported suggest that PAp and TCP do not harm the dental pulp, being clinically and pathologically effective in protecting the exposed human dental pulp and can be successfully used as a basic material in endodontic therapy (FUROSAWA *et al*., 1991; ENKEL *et al*., 2008. The use of these ceramics is based on the fact that dentin is the best protector of the pulp, and that the use of capping materials, whose elements are the same constituents of dentin, can result in pulp benefit.

Although calcium hydroxide stimulates the formation of new tissue, there is evidence of a necrotic area in sites immediately below the site of its application. Unlike the response when calcium phosphate-based ceramics are applied, in which case there is no apposition of other tissue adjacent to the implant and absence of necrosis, in addition, strong interfacial connections are established that confer adequate properties for the regeneration of the new tissue. Regarding calcium hydroxide,

regarding the adhesion of molecules such as fibronectin, it is suggested that the reparative dentinogenesis observed on capping with this material is caused by the production of calcite crystals from reactions with plasma or pulp fluids, which allow the adhesion of fibronectin, molecules that are a binding trigger for cell differentiation. It is known that HAp in the presence of plasma induces the formation of carbonated apatite crystals that have a high affinity with fibronectin, thus predicting a dentinogenesis process very similar to $Ca(OH)_2$ (SEUX *et al*, 1991).

4 CONCLUDING THE MATTER

At the end of the analysis and in view of the above, it can be observed that the subject is vast, as far as the point is material in question, however, in view of the cost-benefit ratio, ease of handling the material, access to the product, including in regions of the interior of the Brazilian states, it is not difficult to conclude that the material proposed for the technique of direct pulp capping and pulpotomy, immediate or mediate, is calcium hydroxide PA.



The images above represent pulpotomies treatments performed by the team of researchers WU *et al*., 2023, elucidating new trends for fibrin-rich plasma.

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