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# COMPARATIVE OVERVIEW OF TRADITIONAL AND EMERGING PULPOTOMY AGENTS IN PRIMARY TEETH

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## Abstract

Pulpotomy procedure involves amputation of coronal pulp tissue and saving the radicular pulp as the pulp exposure is minimal and thus the pulp will heal itself. This literature review includes variety of medicaments that are available for pulpotomy procedure. To make a choice of medicament according to the patient's need is very comprehensive task therefore, it is imperative that the clinician using these therapeutic procedures has the necessary knowledge about the technique and the type of medicaments used.

## *INTRODUCTION:*

Pulpotomy is an essential dental surgery used to preserve the structure and function of primary teeth damaged or severely decayed. It is a procedure in

which the coronal pulp is removed, followed by the application of medicaments to promote healing and prevent infection. This technique is primarily employed in pediatric dentistry, where preserving primary teeth until their natural exfoliation is paramount for proper development and function of the erupting permanent dentition.

The objectives of pulpotomy include pain relief, tooth structure preservation, prevention of infection, and encouragement of pulp healing through preserving the health and functionality of the residual radicular pulp. Two major reasons that necessitate a pulpotomy is caries and traumatic injuries resulting in pulp exposure. Accidental pulpal exposure during dental procedures and developmental defects may also at times require pulpotomy procedure.

Based on techniques, pulpotomy agents can be categorized into three types: pulp devitalizing agents, preservative agents and regenerative agents as listed in table 1. To select one pulpotomy agent from the extensive list of options becomes quite challenging so instead of looking for newer materials based on scientific data, the majority of practitioners base their decisions on the cost of the material. This article's goal is to summarize the information on currently accessible and more promising materials without delving deeply into treatment recommendations and clinical practices.

Table:1 Various agents used for pulpotomy

| Vital pulpotomy | | | |
|---|---|---|---|
| Type | Purpose/ Feature | Examples | |
| DEVITALIZATION | Intended to mummify the vital tissue | Single sitting:<br>Formacresol<br>Electrosurgery<br>LASER | Two sitting:<br>Gysi triopaste<br>Earslick<br>formaldehyde |
| PRESERVATION | Maintain vital tissue with no induction of reparative dentine | Zinc oxide eugenol<br>Glutaraldehyde<br>Ferric sulphate | |
| REGENERATION | Formation of dentine bridge | Calcium hydroxide<br>Mineral trioxide aggregate<br>Biodentine<br>Enamel matrix derivative<br>Bone morphogenic protein<br>Enriched collagen<br>Freeze dried bone<br>Platelet rich fibrin | |

| | | |
|---|---|---|
| | | Platelet rich plasma |
| Non vital pulpotomy | | |
| MORTAL PULPOTOMY | Done in teeth with non negotiable canals | Beechwood cresol<br>Formacresol |

## *MATERIAL METHODOLOGY:*

A comprehensive electronic literature search was conducted in PubMed, Google Scholar, Scopus, Embase, Web of Science, and the Cochrane Library using combinations of keywords and Boolean operators such as "pulpotomy" AND "primary molars" AND "primary teeth," "endodontics" AND "vital pulp," and terms like "formocresol," "calcium hydroxide," "ferric sulphate" OR "ferric sulfate," "MTA" OR "mineral trioxide aggregate," and "Biodentine" OR "calcium silicate". Additional phrases including "laser pulpotomy," "electrosurgical pulpotomy," "platelet rich fibrin," "Emdogain," "Chitosan" "herbal pulpotomy," and "zinc oxide eugenol" were also searched. Titles and abstracts were screened, full texts of relevant articles were obtained, and the reference lists of selected papers were checked manually to identify further studies. Only studies on pulpotomy in primary teeth available in English were included in this review.

## DIFFERENT TYPES OF MATERIALS USED IN PULPOTOMY PROCEDURE

### ELECTROSURGERY

Electrosurgery is a hemostatic procedure that uses high frequency radio waves to cut and coagulate tissues as an alternative to pharmacological processes. Electrosurgical pulpotomies are fast, efficient, self-limiting, exhibits good hemostasis, provides good field visibility, posing no systemic effects and ensures sterilization at the application site throughout the procedure. Conversely, electrosurgical pulpotomy appears to necessitate a more precise diagnosis. Another consideration is the production of lateral heat, because of which there is requirement of a 10-to 15-second cooling period to assimilate this accumulated heat. Studies revealed that although radiographic and clinical success with electrosurgical pulpotomy varied from 84% to 96.8% and 87.5% to 100% respectively.[1]

### LASER

Laser application to dental tissues shows increased healing, controlled hemorrhage, stimulate dentinogenesis and preserve the vitality of dental pulp.[2] Laser- assisted pulpotomies also ensure high cooperation in pediatric patients as there is less chair side time and the procedure is entirely painless. Studies revealed that radiographic and clinical success was in a range of 85.71% to 100% and 67% to

94.1% following a laser pulpotomy.[1]

## MINERAL TRIOXIDE AGGREGATE (MTA)

MTA was approved by the FDA in 1998 after being initially mentioned in dental publications in 1993. This powder is based on tricalcium silicate, dicalcium silicate, bismuth oxide, tetracalcium aluminate, tetracalcium aluminate ferrate, and dehydrated calcium sulfate with pH range from 10-12 of set product. MTA promotes the production of dentin bridges while preserving the normal histology of the pulp. MTA is a technique- sensitive polymer that takes about 4 hours to set when exposed to damp. More contemporary materials, such as rapid setting MTA which requires just 10 minutes to set, are also available under the brand name of ENDOCEM MTA. MTA has high degree of biocompatibility and sealing ability, which inturn prevents bacterial penetration. Tooth discoloration is a drawback commonly seen with slow setting grey MTA. The success rates of MTA as a pulpotomy material ranges from 75% to 100% [3,4] and can sometimes exceed 90% [5-10]

## BIODENTINE (BD)

Biodentine is a calcium silicate-based material recommended for use in a number of clinical applications, including pulp capping, root perforations, apexification, resorptions, and dentine replacement. Septodont (2009) was created especially as a "dentine replacement" substance because it offers sufficient compressive strength values to survive external masticatory impacts.

BD needs about 9-12 minutes to set hence being a weak restorative substance in its early setup phase, according to Hashem et al.[11] In order to give BD enough time to mature and become strong enough to survive the contraction pressures of the resin composite, it is advisable to postpone installation of the overlaying resin composite as definitive restoration for atleast 2 weeks. In BD, zirconium oxide serves as a radiopacifier. A study by Tanalp et al.[12] found that the radiopacity of Biodentine was significantly lower than the 3 mm Al baseline value set by ISO. Grech et al.[13] evaluated the materials' physical characteristics and showed negative solubility values for material. Biodentine changed the dentine tissue's strength and stiffness after aging in 100% humidity.[14]

Biodentine does not require special preparation of the dentin walls thus explaining the material's good marginal integrity. The capacity of calcium silicate materials to generate hydroxyapatite crystals improves the material's capacity to seal, particularly when they develop at the material-dentinal wall interface. BD shows color stability therefore the scientists hypothesized its use as a substitute beneath light-cured restorative materials in aesthetically sensitive locations. The clinical and radiographic success rates of BD as pulpotomy material ranges from 80% to 95%.[15]

## EMDOGAIN (EMD)

Porcine teeth provide the enamel matrix (EMD) extract, of which 90% consists of amelogenins that stimulate periodontium adhesion during tooth creation. The US-FDA approved it in 1996 for the treatment of soft tissue recessions and periodontium abnormalities.

By upregulating Osterix and Runx2 transcription factors, EMD plays a major role in odontogenesis. In human pulp capped with EMD as opposed to CH, Fransson et al. found increased expression levels of dentine sialoprotein (DSP) and collagen I, biomarkers suggestive of odontoblast proliferation and dentine development.[16] A 6 month follow up research demonstrated that EMD produces noticeably superior outcomes than FC but in another similar study of two years follow-up, author didn’t find any conclusive evidence of a significant advantage of EMD over FC and MTA; which thereby imply that

while EMD may result in better outcomes during the first few months of implantation, its effectiveness gradually wanes with time.(6,17) This phenomenon may be related to the inflammatory effects of EMD as it's a matter of fact that elements like resin particles and dentine debris causes irritation and bacterial contamination, which in turn might hinder the development of dentin bridges.[18] Further more in vitro and in vivo studies are required for EMD material to be studied as pulpotomy agent.

**PLATELET RICH FIBRIN (PRF)**

Researchers have been concentrating on finding a biological pulpotomy agent that reduces inflammation and encourages regeneration for some time. It has been suggested that platelet-rich fibrin (PRF) is a promising agent for this use. Placing it directly over the severed pulp should cause little to no inflammation because it is entirely autologous, which should make it more biocompatible and kinder to the pulp. By reducing pulpal inflammation through the release of healing cytokines like interleukin (IL)-4 and preventing IL-1b from stimulating matrix metalloproteinase-1 (MMP-1) and 3, PRF has the potential to aid in pulpal healing.

According to Huang et al., dental pulp stem cells were not cytotoxically affected by PRF, and each cell retained its natural shape. By releasing growth factors like PDGF and TGF- Beta, which are crucial for the proliferation and differentiation of stem cells, PRF also actively contributes to pulpal repair. Its disadvantage includes the pre-procedural blood sampling and processing PRF, as most of the children have needle-phobia and intense laboratory setup for same.[19]

**HERBAL AGENTS**

Alcohol-free propolis has demonstrated a clinically acceptable success rate as pulpotomy medicament both in short term and long term.[20] Other Herbal medicinal products such as Aloe vera, Elaeagnus angustifolia, Ankaferd BloodStopper, turmeric, and Copaifera langsdorffii oil are also used as a pulpotomy medicament because of their low cytotoxicity compared to standard synthetic materials.[21]

**8. FORMACRESOL (FC)**

Buckley first presented FC in 1904 but Sweet (1936) created a specific treatment method

with excellent clinical results for use on exposed primary teeth, thus popularizing FC. The recommendation is to deliver FC at a dilution of either 1:5 or 1:25. Formacresol produces formaldehyde vapors, which function as a germicidal agent and reversibly inhibit various enzymes involved in the inflammatory process.[22] It also fixes the pulp tissue and stops more enzymatic degradation. Multiple researches have demonstrated that formaldehyde is quickly transformed into formic acid and carbon dioxide following application, with a half-life of 1-2 minutes. Although widely used, its use as a pulpotomy agent is said to be controversial due to its potential for sensitization, toxicity, mutagenic, or carcinogenic effects.[23,24] Thus formacresol application in dentistry is still up for debate. It has become the baseline due to substantial study on its efficacy and clinical success rates ranging from 70% to 100%.[25]

**9. CALCIUM HYDROXIDE (CH)**

In 1930, Hermann invented CH as a material for pulp capping under the name of CALXYL. CH has two ways to help the mineralization process. Fistly, it provides a source of calcium ions for

mineralization and secondly, it enhances the activity of calcium-dependent pyrophosphatase, which reduces the concentration of pyrophosphate ions that limit mineralization in the tissues. Though CH is biocompatible and has potential to cause tissue mineralization, it has shown to have internal resorption and chronic pulpal inflammation in primary teeth. Huth et al. (2005) used CH in pulpotomy to treat cases of essential pulp exposure and success rates reported varied from 50-60%.[26]

**10. FERRIC SULPHATE (FS)**

FS is a non-aldehyde substance that is frequently applied as astringent. Ferric sulfate was
initially utilized by Landau and Johnsen (1988) to limit pulpal hemorrhage. FS is sold under the trade name ASTRINGEDENT in a 15.5% solution. No mummification was seen in any of the pulpotomized tissue since ferric sulfate is not a fixative agent. Blood from the pulpal tissue coming in contact with FS leads to formation of ferric ion complex, and the membrane of this complex mechanically closes blood vessels to cause hemostasis.[26] Thirty second application time of ferric sulfate is also quite advantageous, particularly for pediatric patients. The internal root resorption observed with FS is comparable to that with formacresol and FS has radiographic and clinical success ranging from 19–100% and 53.8–100% respectively.[27]

**11. ZINC OXIDE−EUGENOL (ZOE)**

ZOE is one of the compounds that dentists utilize most commonly while treating pulpal pain because of the palliative properties of the material. In pediatric dentistry ZOE is used only as a primary pulp canal obturating paste and thermal insulating base in restorative procedures. It is reported that when ZOE is used as a capping base in pulpotomised teeth, the pulp tissue hydrolyzes it to form zinc hydroxide and release eugenol. This excess eugenol act as an irritant to tissues thereby eliciting a chronic inflammatory response and suppressing the immune system defense; eventually causing internal root resorption. Compared to other experimental agents, ZOE was deemed a less-than-ideal material for pulpotomy in approximately 55% of investigations.[28,29] Authors speculated that the addition of polymethil methacrylate to the reinforced zinc oxide-eugenol may lessen the irritant effects of eugenol on the pulp tissue.[30] In another study Hui-Derksen et al. reported a very high global success rate of 94% in primary molars followed for an average of 4 years. Therefore ZOE still remains a doubtful material for pulpotomy.[31,32]

**12. CHITOSAN (CH)**

Chitosan is a biocompatible, biodegradable, and antibacterial polysaccharide that shows strong hemostatic, anti-inflammatory, and wound-healing properties, making it a promising biomaterial for dental and pulpal applications. It promotes odontogenic differentiation of dental pulp stem cells and supports reparative dentin formation, indicating suitability for pulpotomy procedures. Animal studies have reported pulpal healing and dentin bridge formation rates of approximately 85–100%, comparable to established agents like calcium hydroxide and mineral trioxide aggregate (MTA). Human clinical studies have

shown clinical and radiographic success rates ranging from 80–95%, with outcomes similar to or slightly lower than MTA but superior to formocresol in terms of biocompatibility.[33] Overall, comparative studies suggest chitosan is a viable and biologically favorable alternative pulpotomy medicament, though long-term human trials remain limited.

Comparative assessment of all pulpotomy agents used till date are enlisted in table 2 for better understanding. Radiographic depiction of pulpotomy done with newer material like MTA, Biodentine and Emdogain in depicted in Figure 1

## Table 2: Comparative evaluation of different pulpotomy agents

| Material | Success rate | Mode of action | Advantage | Disadvantage |
|---|---|---|---|---|
| 1. Formacresol | 70-80% | Fix the pulp tisue | Easy application and fast working time (1-2 min) | Carcinogenic and mutagenic potential Internal root resorption |
| 2. Calcium hydroxide | 50-60% | Tissue mineralization-calcium dependent pyrophosphate | Biocompatible, | Poor cohesive strength, greater solubility, and marginal leakage |
| 3. Ferric sulphate | 54-100% | Ferric ion complex-Mechanical closure of blood vessels | Shorter application time (30sec) | Tissue irritation, postoperative sensitivity and tissue discoloration |
| 4. Zinc oxide eugenol | 15-94% | Preservation of pulp tissue without induction of reparative dentine | Astringent properties-eugenol | Destructive properties on direct application on pulp |

| | | | | |
|---|---|---|---|---|
| 5. Electrosurgery | 84-97% | Hemostasis-electrocoagulation | Precise, good field visibility, sterilization, fast technique | Lateral heat generation-15 sec cooling period; Burnt smell |
| 6. Laser | 67-95% | Hemostasis-stimulate dentinogenesis | Less chairside time, | Require precision with equipment handling |
| 7. Mineral trioxide aggregate | 75-100% | Dentin bridge production | Biocompatibility Sealing ability | Tooth discoloration; High solubility; material cost |
| 8. Biodentine | 80-95% | Dentin bridge production | Good marginal integrity Color stability | Setting time; material cost |
| 9. Emdogain | -- | Regeneration | Regenerative potential | Postoperative inflammation – allergic reactions |
| 10. Platelet rich fibrin | -- | Growth factors released | Biocompatibility | Pre-procedural blood sampling-needle phobia |

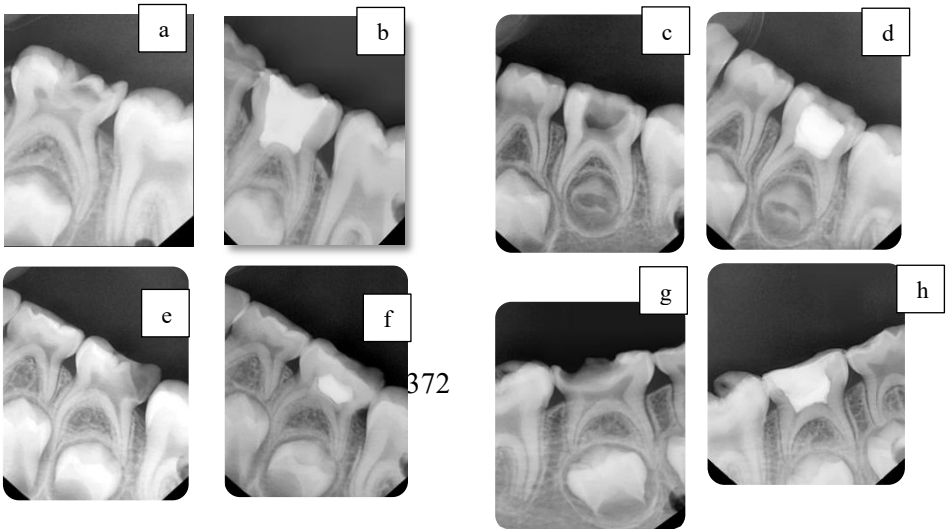

Figure 1 : Preoperative and post operative radiograph for Laser pulpotomy (a, b); MTA pulpotomy (c, d); Biodentin pulpotomy (e, f) and Emdogain pulpotomy (g, h) respectively.

## *CONCLUSION*

At the conclusion of this review, it should be clear that choice of newer pulpotomy agent/materials is in the hands of dentist. Formocresol is a standard material for fixing the pulp. Biodentine, MTA and Emdogain are newer materials that may have role in direct pulp capping and pulpotomy. Pulpotomy technique has shown paradigm shift to MTA, Biodentine and hence should be encouraged more. More in vivo studies with long term follow up are needed for enamel matrix derivative (Emdogain) as animal studies aren't sufficient to draw conclusion. None of the materials showed toxic symptoms and hence are biofriendly in all patients.

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