REVIEW

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Materials used in pulpotomy: an overview

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ABSTRACT

A pulpotomy is a dental method that can be used on both children and adults. Tooth decay can lead to an infection wherein the pulp inside the tooth gets affected. In such cases, a pulpotomy is performed, wherein the pulp present in the crown (the visible part of the tooth) is extracted while the pulp in the root canal is retained. Devitalization, preservation, and regeneration have been the three main directions that pulpotomy therapy for primary teeth has taken. Formocresol and electrocautery are examples of devitalization (mummification, cauterization), which is when vital tissue is intended to be destroyed. Treatment with glutaraldehyde and ferric sulphate is an example of preservation (minimum devitalization, noninductive), which is the retention of the most vital tissue without inducing reparative dentin. Calcium hydroxide has long been linked to regeneration (inductive, reparative), the activation of a dent in bridge. In the upcoming years, regeneration is anticipated to grow the fastest of the three categories.

Keywords: MTA, pulpotomy, formocresol, devitalization, preservation

Abbreviations:

ABS	– Ankaferd Blood Stopper	MSDS	– Material safety data sheet
Ca(OH)	– Calcium hydroxide	MTA	– Mineral trioxide aggregate
FDA	– Food and drug administration	NS	– Nigella sativa
IL	– Interleukin		

INTRODUCTION

When a permanent tooth has large caries but no sign of radicular infection, a procedure known as a pulpotomy is used to remove the caries and part of the coronal pulp tissue. The pulpotomy procedure removes the coronal pulp and puts a pulp-capping biocompatible substance material to promote healing or an agent and restores the remaining pulp tissue [1]. The medication widely used for pulpotomy was formocresol, according to the literature [2]. Despite the success rate, there are still many unknowns around the usage of formocresol, including its potential for mutagenic, carcinogenic, and allergic effects [3]. Between the ages of 2 and 11, 42% of children develop cavities in their baby teeth. Severe decay can cause inflammation of the pulp, known as pulpitis. A pulpotomy may be performed on primary or permanent teeth if it has already reached the critical stage and the decay has reached the pulp. It has been stated that there are limited signs for both reversible and irreversible pulpitis. Reversible pulpitis hurts when handled, but the soreness goes away and is treated with over-the-counter painkillers. Unexplained tooth pain, abnormal tooth mobility, and soft tissue irritation unrelated to gum disease are examples of irreversible conditions. Pulpotomy is typically utilized on primary teeth in young children because it preserves the tooth's roots, leaving them open to development. Primary teeth must be left intact because they maintain the space between developing permanent teeth. Empirical evidence has demonstrated that endodontic therapy can be efficaciously administered to both adult and pediatric patients, provided that an adequate amount of healthy pulp tissue is present with-

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in the tooth to ensure its vitality and operational capacity.

The pulpotomy procedure is suggested when caries removal exposes the pulp of a primary tooth with a normal pulp or reversible pulpitis. It is also recommended when the pulp becomes uncomfortable or exposed to pulp, even if there is no pathologic resorption or radiographic evidence of inflammation [4]. After removing the coronal tissue, it's important to ensure that the remaining radicular tissue is healthy and free of pus, necrosis, or continuous bleeding that cannot be controlled with a cotton pellet after several minutes [1].

In the absence of any negative health indicators or symptoms like sensitivity, irritation or edema, the root pulp should remain asymptomatic. After surgery, there may be no radiographic evidence of external root resorption. Internal root resorption is likely to be stable and self-limiting [5-8].

DISCUSSION

Formocresol

For 80 years, dental professionals have utilized formocresol for the deciduous pulpotomy of teeth. The formocresol pulpotomy devitalization strategy is the molecular, reparative method for primary pulp treatment. In 1904, Buckley introduced formocresol for primary teeth treatment in the USA. In the primary dentition, formocresol was a popular pulpotomy medication [2]. Because of formocresol's toxicity and potential for cancer, there are now questions about its usage in humans [2]. Despite these problems, pulpotomy using formocresol has become a widely accepted treatment. In the UK, a study found that 66.5% of pediatric dentists use formocresol for pulpectomy. However, 54.2% of those dentists are concerned about their choice of drug and are considering changing their technique. In the US, a survey found that most dentists use formocresol as a pulpotomy drug, and they are not worried about any adverse effects. The pulpotomy protocol was first developed by Europeans [9]. Sweet created the formocresol pulpotomy system in 1930. As a result, formocresol is now a widely used pulpotomy medication for primary teeth. The operation was initially included in five trips. Sweet has lowered the number of appointments over time due to concerns with behavior change and the economy [10]. Doyle et al. compared the effects of formocresol and calcium hydroxide Ca(OH) using a two-visit procedure [11]. Spedding and Redig advocated a single pulpotomy visit lasting 5 minutes with a partial devitalization as the end result [12]. The five-minute formocresol therapy has been the benchmark for evaluating all new treatment methods, ever since Redig's successful single visit pulpotomy in humans. However, the original purpose of complete mummification, sterilization, and metabolic suppression has been overlooked. Instead, the fast treatment only weakly devitalizes the pulp. The pulp typically remains chronically inflammatory, half-dead, and half-vital [12]. Garcia Godoy proposed the one-minute pulpotomy visit in 1991 [13]. In 2011, Zahra et al. used the diluted or full-strength solutions for five minutes and observed that a one-minute formocresol pulpotomy resulted in performance rates comparable to those reported in the literature [14]. The clinical outcomes of this approach vary between 55% and 98% [5,15]. Although formocresol has shown high success rates, its toxicity has been subject to scrutiny. Formocresol is thought to be carcinogenic, mutagenic, and poisonous to cells [16]. Eugenia has discovered dentigerous cysts connected to formocresol pulpotomies deciduous molars, [17]. IARC (June 2004) classified formocresol as a carcinogen with the potential to lead to leukemia and nasopharyngeal cancer. However, Ranly assessed the level of formocresol after pulpotomy and calculated that the same organism would need to have 3000 pulpotomies in order to reach hazardous levels [18]. The entire coronal and radicular pulp tissue is repaired throughout the course of two phases of pulpotomy devitalization. It is utilized when shorter sessions are necessary and to improve patient outcomes. Miyamato advised a pulpotomy visit for the effective handling of uncooperative children [19].

Formocresol is a solution that is used to prevent the breakdown of tissues by attaching to the peptide group of an amino acid side chain. It is a reversible process and doesn't alter the basic structure of protein molecules [2]. Due to the controversies surrounding the use of formocresol, several alternatives have been researched. This narrative analysis aims to provide a summary of these alternatives.

Calcium hydroxide

The first material that was used in pulpotomy and was capable of dentine regeneration was Ca(OH). This material triggers a stimulation that is delicately balanced between resorption and repair. The main disadvantage of this alternate method is internal resorption.

Zander reported a 70% success rate using a thick Ca(OH) paste and water [20]. The creation of dentine bridges and full healing of pulp stumps was noted by Doyle et al., while some patients experienced treatment failure, which was manifested as internal resorption [21]. Cvek pulpotomy outcomes with Ca(OH) were less noteworthy [22].

Ferric sulphate

A 15.5% acidic solution of ferric sulphate, a hemostatic chemical, developed without the use of aldehyde [23]. Ferric sulphate can be easily adjusted

and produces the same effect as formocresol when administered for 15 seconds without having any hazardous side effects [24].

The mechanism of action in which ferric sulphate works is not yet fully understood. It was previously believed that the reaction of blood to ferric sulphate ions caused blood proteins to cluster together and form a metal protein complex that might block capillaries and lead to hemostasis. As a result, there will be less concern about uncontrolled bleeding, which will lower the dangers of infection and internal resorption. Reduced working and manipulation times are the main advantages of ferric sulphate over formocresol [24]. Ferric sulphate, in contrast, is less strong and easily accessible, making it simple for children to use. Ferric sulphate has antibacterial properties as well [23]. Ferric sulphate performed similarly to formocresol in certain trials while outperforming it in others [23].

Nigella sativa oil

An indigenous herbaceous plant called Nigella sativa (NS) is widely utilized in herbal therapy throughout the world. NS, also known as black cumin and black seed, has been shown to have numerous medicinal benefits. It acts as a bronchodilator, hypotensive, analgesic, antibacterial, anti-inflammatory, and immune-potentiating agent, among other things [25]. NS has the ability to speed up the healing of burn wounds since it contains proteins that can cause human keratocytes to release fibronectin into the dermal fibroblast [25]. NS can be also used as a preventative addition to conventional chemotherapy to treat oral mucositis in rats [26].

The NS extracts demonstrated analgesic, anti-inflammatory, and antibacterial action has led to its usage as a pulpotomy agent. In order to categorize the pulpal response to sodium hypochlorite and formocresol, the histopathology of the pulp tissues of dogs was examined [27].

According to their claims, NS has anti-inflammatory properties, and when used to treat pulp, the pulp's potency is maintained. Then it was suggested to use the chemical as a pulpotomy drug for primary teeth [27]. Additionally, NS is used in dentistry to prevent dental caries and treat oral ulcers, oral mucositis, gum, and periodontal infections [25,28,29].

Aloe Vera

Aloe vera, an African native that is frequently referred to as a “medicinal herb”, has a number of properties, including antifungal, antibacterial, immunomodulatory, anti-inflammatory, antiviral, and defensive against a variety of pathogens [30]. It is used as a therapeutic agent in the treatment of lichen planus, chronic oral conditions, extraction sockets, and aphthous ulcers in dentistry [31]. Steroids' ability to reduce inflammation is well-developed in A. Vera gel, which causes low amounts of prostaglandin to grow [32]. They concluded that freshly extracted gel can be used as a pulpotomy agent successfully [33].

Aloe vera, when applied directly to exposed rat pulpal tissue, demonstrates good biocompatibility and promotes the formation of tertiary dentin bridges [34]. This result was caused by various bioactive components, such as beta-sitosterol, glycoproteins, and polysaccharides. These components promote cell proliferation, angiogenesis, and wound healing [34].

Honey

Honey has a solid reputation among natural goods in the literature due to its medicinal properties. It is antibacterial and promotes the healing of wounds [35]. Polyphenols found in honey have protective effects against periodontal disease, oral cancer, and dental caries [36]. It can be used to create dental caries prevention products like toothpaste and mouthwash [37].

This natural product was chosen by Kumari et al. as a pulpotomy agent, with similar results on both the clinical and radiological fronts [38]. Another important aspect of honey's effectiveness as a pulpotomy agent is the higher rate of anti-inflammatory and healing qualities brought on by its acidic existence.

As honey acidity lowers the pH of the wound and increases the amount of oxygen accessible in the blood from hemoglobin, it tries to supply oxygen to healing tissue. Honey has been shown to significantly increase the release of certain cytokines from monocytes, including tumor necrosis factor-alpha, interleukin (IL)-1, and IL-6, which have been found to be crucial for tissue repair and healing. Ankaferd Blood Stopper (ABS) is an herbal extract that was created from five different plants: *Thymus vulgaris, Glycyrrhiza glabra, Vitis vinifera, Alpinia officinarum,* and *Urtica dioica* [39]. These plants have various effects on the endothelium, blood cells, angiogenesis, cell proliferation, vascular dynamics, and act as cell mediators. In a study conducted by Goker et al., the possible mechanisms of ABS are described in detail [39].

As soon as ABS is applied, a protein network that is enclosed forms, providing focal areas for crucial erythrocyte aggregation. The primary and secondary hemostatic systems are covered by the ABS-induced blood cell protein network growth, specifically in erythrocytes, without any disruption of the specific coagulation components [40].

ABS pulpotomy tests have shown a progress rate between 89 and 100 percent [41]. But in this case, further research is required.

Mineral trioxide aggregate

Mineral trioxide aggregate (MTA) introduced by Mohammed Taorabinejad in 1993 at Loma Linda University in California, USA. At 1998 this material gets the approval by U.S food and drug administration (FDA). ProRoot MTA, the first commercially available MTA product, was introduced by Dentsply Tulsa Dental Specialties in 1999. Since that there were different companies introduced multiple MTA products in the market. This product was used in There are a number of dental procedures which involve the treatment of pulp. These procedures include pulp capping, pulpotomy, apexogenesis, apexification, regeneration, repair of perforations, and root end filling [42-47]. According to the material safety data sheet (MSDS), Pro Root MTA (White) is composed of powder made up of tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide, calcium sulfate dihydrate, bismuth oxide, aluminum oxide, and sulfur oxide. Mixing of powder and water is essential to apply MTA, however, there is a definite water to powder ratio specified by each manufacture. After mixing of MTA powder with liquid and application of the material for the specific purpose, final setting time of three hours need to be go before placing a root filling material or final restorative material [48]. When compared to other restorative materials, MTA showed the least cytotoxicity to human gingival fibroblasts and L-929. It also resulted in complete dentinal bridge formation with minimal or no pulp response and minimal or no inflammation [49,50]. Addition of dentin powder to MTA helps to accelerate the process of killing bacteria [51].

In comparison of MTA with zinc oxide eugenol cements, MTA has generally shown better sealing ability as a root-end filling material and discovered to promote the formation of thicker dentin bridge [52,53].

Clinical reports have also shown highly successful outcomes such as preservation of pulp vitality and continued root formation using MTA [54].

Pulpotomy procedures have seen a rise in the usage of MTA as a common material in recent years of permanent teeth showing symptoms of curable and non-curable pulpitis and in complex coronal fractures of immature and mature teeth [55].

By contrast, the high solubility, high price, and color-changing effect of both the gray and white forms are among the drawbacks of MTA as a pulpotomy agent [56].

MTA contains of calcium sulphate dehydrate, tetracalcium alumina, bismuth oxide, ferrite, and tricalcium silicate. After mixing, MTA has a pH of 10.2. After three hours of setting, the pH rises to 12.5. When MTA comes into touch with pulp tissue, dentin bridge development is promoted.

Most trials had the drawback of having a short follow-up duration and follow-up absences. Recent meta-analyses and reviews by Simancas-Pallares et al. [21], Po-Yen Lin et al. [57], Shirvani and Agasy [58], and others have found that pulpotomy with MTA has a high success rate. On the other hand, Anthonappa et al. found no proof that MTA was more effective than modern tools and materials as a pulpotomy medication [59].

Biodentine

Biodentine is a calcium silicate-based material designed to replace the dentine and be dentine substitute. This material became commercially available in 2009-2010 [60,61]. According to MSDS, Biodentine is a dental material that consists of a combination of powder and liquid components. The powder is composed of calcium carbonate, zirconium dioxide, and calcium oxide, while the liquid contains calcium chloride dihydrate. Together, these components create a material that has various dental applications, such as in pulp therapy and root canal treatment. To start using the Biodentine in any procedure five drops of the liquid need to be placed inside the capsule which contains the powder before placing it in the mixing device for 30 seconds with 4200 vibration per minute. When biocompatibility was assessed, no mutagenic effect nor DNA damage or break was observed in vitro [62]. Furthermore, when the material was directly applied to the pulp tissue can help in the healing process by improving the migration and proliferation of stem cells and induce the mineralization process [63,64].

It is popular to use for multiple procedure such as perforation repair, apexification, retrograde filling and more even though that it can cause death of the pulpal cells under the material [65]. In 2013 Biodentine was used for the first time in pulpotomy of permanent teeth by Villat, Grosgogeat [66] which was successful with 6 months follow-up.

BMP (Bone Morhogenic Protein)

BMP is a substance that promotes the growth of reparative dentin by using recombinant dentin proteins similar to the body's natural proteins. The most extensively researched proteins in pulp tissue are BMP-2, BMP-4, and BMP-7 (OP-1).

Fibroblast-like cells from the lower pulp migrate to the amputation area, which is free of contamination. They then proliferate and transport the tissues. Either the inactive matrix is formed, or the same scaffolds are used to adhere the age-undifferentiated stem and mesenchymal cells [67].

Glutaraldehyde Pulpotomy

Gravenmade proposed using glutaraldehyde for pulpotomy. Recently, it has been suggested as an al-

ternative to formocresol due to its superior fixative properties. Glutaraldehyde has the advantage of eliminating cresol, being less toxic, having a low antidote and self-limiting penetration. In comparison, formocresol has weaker crosslinking properties than glutaraldehyde [67].

CONCLUSION

The success of pulpotomy procedures depends on various critical variables, including case evaluation, clinical and diagnosis, and the material used for the procedure. The two most commonly used pulpotomy agents are formocresol and MTA. While formocresol still has good clinical and radiological success rates and remains a popular choice, MTA has gained popularity due to its biocompatibility, excellent sealing ability, and promotion of dentine bridge formation. However, there is still not enough evidence to determine conclusively which pulpotomy treatment is superior. Ultimately, the choice of pulpotomy agent should be based on individual case assessment and the clinician's expertise.

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