# Pulpotomy Medicaments: Continued Search for New Alternatives- A Review

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## Abstract

Pulpotomy therapy is the treatment of choice for cariously exposed vital primary molars. Controversies surrounding formocresol which enjoys good clinical success as a pulpotomy medicament has triggered the search for better alternatives. The objective of this narrative review is to provide an overview of the materials that have been studied as alternatives to formocresol to aid clinicians in making an informed choice of medicament for pulpotomy.

*Key Words: Dental pulp, Pulpotomy, Medicament*

## Introduction

A pulpotomy is performed in a primary tooth with extensive caries without evidence of radicular pathology when caries removal results in a carious or mechanical pulp exposure [1]. If caries removal process leads to pulp exposure, a pulpotomy is undertaken since direct pulp capping in cariously exposed primary teeth has been shown to have poor success [1]. Formocresol has been a popular pulpotomy medicament in the primary dentition [2]. Concerns have been raised over the use of formocresol in humans, mainly as a result of its toxicity and potential carcinogenicity [2]. Despite these concerns, pulpotomy with Formo Cresol (FC) is still a universally preferred technique. A survey conducted in the US reported that majority of dentists used FC as pulpotomy medicament and they were not concerned about adverse effects [3] while a survey conducted in the UK showed that 66.5%of pediatric dentists used FC for pulpotomy, 54.2% were concerned regarding their preferred medicament and were considering change of their chosen technique [3]. In view of the controversies surrounding formocresol, various alternative medicaments have been studied. The aim of this narrative review is to provide an overview of these alternatives. The Europeans were the first to introduce pulpotomy procedure [4]. *Table 1* summarizes the history and chronology of various pulpotomy medicaments. Don M. Ranly classified pulpotomy based on treatment objectives into devitalization, (Mummification, Cauterization), preservation (minimal devitalization, noninductive) and regeneration (inductive, reparative). Non chemical methods of pulpotomy include use of electro surgery and lasers [4].

**Devitalisation pulpotomy**

The first approach to pulpotomy treatment of primary teeth was devitalisation. Pulpotomy using formocresol was introduced by Buckley in 1904. Since then various modifications have been tried and advocated regarding the techniques of FC pulpotomy and the concentrations [4]. Buckley's formula of formocresol includes formaldehyde 19%, Cresol 35%, glycrerine 15%, and water with an approximate pH of 5.1. Currently 1:5 dilution of Buckley's formocresol is commonly used. A diluent consisting of 3 parts of glycerine (90 ml) added to 1 part distilled water (30 ml) is prepared. Later 4 parts of diluent (120 ml) is mixed with 1 part of Buckley's FC (30 ml) [5,6]. Commercially available products vary in concentrations of their ingredients, for example Sultan formocresol available in India consists of 48.5% formaldehyde, 48.5% cresol and 3% glycerine.

Formocresol prevents tissue autolysis by binding to peptide group of side chain of amino acid. It is a reversible process without changing of basic structure of protein molecules [7]. The multi-visit formocresol technique was advocated by Sweet in 1930 [8]. Sweet reported clinical success of 97% and stated that when completely fixed radicular pulp was theoretically

***Table 1**. History and chronology of various pulpotomy medicaments.*

| | |
|---|---|
| 1885 | Leptowski: Introduced formalin as fixative and mummifying agent [5]. |
| 1886 | Gold foil was used to cover the exposed vital pulp [5] |
| 1898 | Gysi: Introduced paraformaldehyde as a pulpotomy medicament [5]. |
| 1904 | Buckley: Introduced formocresol for pulpotomy [5]. |
| 1930 | Hermann: Introduced calcium hydroxide as calxyl, which was used for pulp capping, was also tried for pulpotomy [5] |
| 1975 | S'Gravenmade: used gluteraldehyde and stated that glutaraldehyde is potential to replace formocresol [4]. |
| 1980 | Nevins AJ: reported the use of collagen-calcium phosphate gel in pulpotomy [6]. |
| 1981 | Bimstein E: used enriched collagen solution [7] |
| 1983 | Ruemping et al.: demonstrated the use of electrosurgery for pulpotomy [4]. |
| 1985 | Shoji: used carbon dioxide laser in pulpotomy [5]. |
| 1991 | Fei et al. used Ferrric sulfate in pulpotomy [4]. |
| 1991 | Nakashima used bone morphogenic protein [4]. |
| 1993 | Kim SW : Tetrandrine, a bisbenzylisoquinoline alkaloid was tested as a pulpotomy medicament [8]. |
| 1993 | Torabinejad: MTA was introduced for perforation repair. MTA has been tried for various vital pulp therapy procedures including pulpotomy [2]. |
| 2002 | Hafez AA and Cox CF reported the use of sodium hypochlorite to control bleeding and its use in pulpotomy [58]. |

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sterilized and devitalized, obviating infection and internal resorption [9]. Doyle in 1962 advocated 2 visit pulpotomy [10]. Spedding and Redig suggested 5 minute single visit pulpotomy that brought about partial devitalization [11,12]. Redig reported good success rate with 5 minutes single visit pulpotomy in humans, after which the 5 minute treatment with formocresol became and has remained, the standard against which all new modalities are compared. However, the original advantage of complete mummification, sterilization and metabolic suppression was lost. Instead, the short treatment leaves the pulp only partially devitalized. Commonly, the pulp remains half dead, half vital, and chronically inflamed [12].

Garcia Godoy in 1991 advocated 1 minute single visit pulpotomy [13]. Zahra et.al in 2011 used 1 minute formocresol pulpotomy and reported success rates comparable to techniques that use the 5-minute diluted or full-strength solutions reported in the literature [14]. Clinical success ranges from 55% to 98% [15,16]. Despite the high success rates, concerns are raised regarding the toxicity of formocresol. Formocresol is believed to cause mutagenicity, cytotoxicity and carcinogenicity [17]. Eugenia reported dentigerous cyst associated with a formocresol pulpotomized deciduous molar [18]. IARC (June 2004) classified formocresol as carcinogen that has potency to cause leukemia and nasopharyngeal carcinoma. However, Ranly calculated the formocresol concentration following pulpotomy and reported that 3000 pulpotomies will have to be performed in same individual to reach toxic levels [19]. In two stage devitalizing pulpotomy entire coronal and radicular pulp tissue is fixed. It is used when shorter appointments are required and for better patient management. Miyamato advocated two visit pulpotomy for effective management of uncooperative children [20]. During the first visit the material containing formalin or paraformaldehyde is placed in contact with the pulp, left for 5-7 days and pulpotomy is completed under local anesthesia in the second visit. Materials used are Gysi Triopaste (Tricresol 10 ml, cresol 20 ml, glycerine 4ml, paraformaldehyde 20 ml, zinc oxide eugenol 60 g), Easlick's Paraformaldehyde paste (paraformaldehyde 1 g, Procaine base 0.03 g, Powdered asbestos 0.05 g, Petrolleum gelly 125 g, Carimine to color) and Paraform devitalizing paste (Paraformaldehyde 1g, Lignocaine 0.06g, Propylene glycol 0.5g, Carbowax 1.3g, Carmine to color).

**Preservative pulpotomy**

Materials used in preservative pulpotomy technique produce minimal insult to orifice tissue, thereby maintaining vitality and normal histological appearance of radicular pulp. The materials included in this category are ZOE, glutaraldehyde, ferric sulfate [4].

**a)** Zinc Oxide Eugenol (ZOE) was the first agent to be used for preservation. Earlier studies have shown that teeth treated with a pulpotomy using ZOE base demonstrated internal resorption and inflammation at the pulpotomy amputation site [21-23]. ZOE acted as obtundent but apparently failed to suppress the metabolism adequately [23]. Hansen HP placed corticosteroid dressing prior to application of ZOE to overcome the internal resorption. However the degree of improvement and success were not remarkable [24]. It has been assumed that internal resorption is associated with eugenol. When ZOE is used as a sub-base following pulpotomy, eugenol directly contacts with the vital tissue and causes moderate to severe inflammatory response [24]. Products such as IRM and ZOE B&T are reinforced ZOE materials with improved mechanical properties. Reinforced ZOE contains polymethyl methacrylate, zinc oxide, acetic acid, and eugenol [25]. Fuks et al. found that 73% of pulpotomized primary teeth of baboons treated with IRM presented with mild or no inflammation [26].

**b)** Glutaraldehyde for pulp fixation was proposed by s-Gravenmade in 1975. This di-aldehyde has a limited shelf life and a cross-linking ability superior to that of formocresol. In recent years, glutaraldehyde has been proposed as an alternative to formocresol based on its superior fixative properties, self-limiting penetration, low antigenticity, low toxicity and elimination of cresol [10,27]. Glutaraldehyde produces rapid surface fixation. Narrow zone of eosinophillic stained and compressed fixed tissue is found beneath the area of application which blends with underlying normal pulp [27,28]. Hill reported minimal antimicrobial concentration of glutaraldehyde as 3.125% [29].. Ranly, Garcia Godoy in 1987 noted that increasing the concentration and longer time improves fixation and suggested the use of 4% Glutaraldehyde for 4 minutes or 8% Glutaraldehyde for 2 minutes [27]. Sandra Maria et al. suggested the use of 2 % for 5 minutes [29,30]. Presently, 2 % glutaraldehyde for 5 minutes is used for pulpotomy. Various studies report improved success rates (*Table 2*). Garcia-godoy reported that despite of high success rates the drawbacks in using glutaraldehyde includes the cost and inadequate fixation that leaves a deficient barrier susceptible for sub base irritation resulting in internal resorption [31].

**c)** Ferric Sulfate (FS) a non-aldehyde chemical has received attention recently as a pulpotomy agent. This haemostatic compound was proposed on the theory that it prevents the problem in clot formation thereby minimizing chances of inflammation and internal resorption. 15.5% FS has been investigated widely [32]. Casas et al. used 16% FS compared with primary teeth pulpectomy and reported RCT-treated molars demonstrated significantly greater survival than FS treated molars after 3 years treatment. When ferric sulfate comes in contact with pulp tissue forms ferric ion-protein complex that mechanically occludes capillaries on amputation site forming barrier for irritants of sub-base [33]. Equal outcomes for ferric sulfate and formocresol were reported after 6 weeks use in baboon teeth by Fuks [26]. Cotes

***Table 2**. Clinical and radiographic success of glutaraldehyde pulpotomy.*

| Author | Sample size | Clinical success (%) | Radiographic success (%) | Follow-up (Months) |
|---|---|---|---|---|
| Garcia-Godoy [25] | 49 | 100 | 98 | 42 |
| Prakash et al. [30] | 30 | 100 | 100 | 6 |
| Fuks et al. [31] | 53 | 96 | 82 | 25 |
| Shumayrikh and Adenubi [82] | 57 | 92.9 | 73.6 | 12 |
| Raghavendra et al. [83] | 30 | 100% | 83.3% | 12 |

et al. reported more reparative dentine and fibrosis with ferric sulphate [34]. Several studies compared the clinical success of ferric sulfate with formocresol (*Table 3*).

**Regenerative pulpotomy**

It is also called as inductive pulpotomy or reparative pulpotomy. This mechanism encourages the radicular pulp to heal and form a dentin bridge/hard tissue barrier. Ranly stated that "Ideal pulpotomy treatment should leave the radicular pulp vital and healthy and completely enclosed within an odontoblast-lined dentin chamber." In this situation, the tissue would be isolated from noxious restorative materials in the chamber, thereby diminishing the chances of internal resorption. Additionally, the odontoclasts of an uninflamed pulp could enter into the exfoliative process at the appropriate time and sustain it in a physiologic manner. Unlike the other two categories i.e devitalization and preservation, the rationale for developing regeneration is based on sound biologic principle [4]. Materials used in regenerative pulpotomy are Calcium hydroxide, mineral trioxide aggregate, bone morphogenic protein (BMP 2, 3, 4, 5, 6, 7 and OP-2), Collagen.

**a)** Calcium hydroxide was the first agent used in pulpotomies that demonstrated any capacity to induce regeneration of dentin [35]. The rationale that prompted its use by Zander was fundamentally erroneous, he attributed the action of calcium hydroxide to a modification of the solubility product of Calcium, phosphate and a precipitation of salt into an organic matrix [35]. Ignored was the origin of this matrix and how odontoblast processes became included in it. More likely than not, the high pH of calcium hydroxide wounds the pulp in a manner that permits the intrinsic reparative cascade to begin. Unfortunately, the stimulus evoked by this compound is delicately balanced between one of repair and one of resorption. The main draw-back of this alternative intervention is internal resorption. 70% success rate was reported by Zander with the use of thick paste of Ca(OH) and water [35]. Schroder et al. and Doyle et al. reported dentine bridge formation and complete healing of the pulp stumps but some cases showed treatment failure in form of internal resorption [14,36]. Magnusson obtained less impressive results with use of calcium hydroxide for pulpotomy [37].

**b)** Mineral Trioxide Aggregate (MTA*)* has shown good success rates as pulpotomy agent. MTA was introduced by Torabinejad [2]. Studies on MTA reveal that it not only exhibits good sealing ability, excellent long term prognosis and good biocompatibility but favors tissue regeneration as well. MTA has a pH of 10.2 immediately after mixing and increases to 12.5 after 3 hours of setting. MTA in contact with pulp tissue encourages dentin bridge formation. Dominguez et al. following histological evaluation reported that MTA caused minimal pulpal inflammation [38]. *Table 4* shows the success rates comparing MTA versus FC. However drawback of most studies were short follow up period and dropouts in follow up. Recent reviews and meta-analysis done by Simancas-pallares et al. [39], Po-Yen Lin et al. [40], Shirvani and Agasy [41], reported high success rates of pulpotomy with MTA. In contrast Anthonappa et al. [42] reported no evidence that MTA was better than present materials and techniques as pulpotomy medicament**.**

**c)** Bone Morphogenic Proteins (BMP) is thought to induce reparative dentin with recombinant dentinogenic proteins similar to the native proteins of the body. This exciting era was based on two classic observations made many years ago. Huggins reported urinary tract epithelia implanted into the abdominal wall of dogs evoked bone formation [43]. Urist observed that demineralized bone matrix, stimulated new bone formation when implanted in ectopic sites such as muscle.

***Table 3****. Success rate comparison of ferric sulfate with formocresol.*

| Author | Sample size | | Clinical success (%) | | Radiographic success (%) | | Follow up (months) |
|---|---|---|---|---|---|---|---|
| | FC | FS | FC | FS | FC | FS | |
| Fei et al. [33] | 27 | 29 | 96 | 100 | 81 | 97 | 12 |
| Fuks et al. [24] | 37 | 55 | 84 | 93 | 80 | 93 | 35 |
| Aktoren and Gencay [34] | 24 | 24 | 88 | 88 | 80 | 84 | 24 |
| Papagiannoulis [84] | 60 | 73 | 97 | 90 | 78 | 74 | 36 |
| Ibrevic and Al-Jame [85] | 80 | 84 | 97 | 96 | 94 | 92 | 42-48 |
| Markovic et al. [86] | 33 | 37 | 91 | 89 | 85 | 82 | 18 |
| Huth et al. [14] | 48 | 49 | 96 | 100 | 90 | 86 | 24 |
| Sonmez [87] | 13 | 15 | 76.9 | 73.3 | 77 | 74 | 24 |
| Elham [88] | 24 | 28 | 100 | 96.4 | 87.5 | 85.7 | 9 |
| Raghavendra et al. [83] | 30 | 30 | 86.7 | 96.7 | 56.7 | 63.3 | 12 |

***Table 4****. Success rate comparison of MTA with formocresol.*

| Author | Sample size | | Clinical success (%) | | Radiographic success (%) | | Follow up (months) |
|---|---|---|---|---|---|---|---|
| | FC | MTA | FC | MTA | FC | MTA | |
| Cuisia et al. [37] | 30 | 30 | 93 | 97 | 77 | 93 | 6 |
| Agamy et al. [38] | 20 | 19 | 90 | 100 | 90 | 100 | 12 |
| Jabbarifar et al. [89] | 32 | 32 | 91 | 94 | 91 | 94 | 12 |
| Farsi et al. [90] | 36 | 38 | 97 | 100 | 86 | 100 | 24 |
| Holan et al. [91] | 29 | 33 | 83 | 97 | 83 | 97 | ≤ 74 |
| Naik and Hedge [92] | 23 | 24 | 100 | 100 | 100 | 100 | 6 |
| Sonmez et al. [87] | 13 | 15 | 79.9 | 66.6 | 79.9 | 66.6 | 24 |
| Subramaniam et al. [93] | 20 | 20 | 95 | 95 | 95 | 95 | 24 |
| Hugar and Deshpande [94] | 30 | 30 | 96 | 100 | 96 | 100 | 36 |
| Godhi et al. [95] | 25 | 25 | 96 | 96 | 96 | 96 | 12 |
| Srinivasan & Jayanthi [96] | 46 | 47 | 78 | 96 | 78 | 96 | 12 |

Urist concluded that bone matrix contains a factor capable of autoinduction and he named this factor bone morphogenetic protein [44]. Since that time, countless labs have attempted to purify the factors. However due to its existence in such minute quantities and high affinity for the bone matrix, progress has been slow. Only very recently, with techniques of molecular biology significant progress has been made. If BMP can induce dentin as well as bone, dentists might at last have a true biological pulp-capping and pulpotomy agent. Although tightly associated with collagen of matrix, BMPs are classified as noncollagenous proteins. Rutherford studied pulp response in monkey teeth and stated recombinant human BMP-2 and BMP-4 induce differentiation of adult pulp cells into odontoblasts. Silva et al. reported that rhBMP7 did not show favorable results and there was failure to form dentin bridge [46]. Loren K et al. elicited the role RhBMP-2 in pulpal healing of experimental subjects [47]. Currently animal studies using recombinant human BMP's are being tested, however no suitable product for human use is available yet.

**Newer materials**

Various studies have been carried out in search of ideal pulpotomy material. Some of the materials which proved effective are lyophilized freeze dried platelet, enamel matrix derivative, propolis, sodium hypochlorite, bioactive glass and ankaferd blood stopper.

**a)** Lyophilized freeze dried platelet acts as signaling proteins that get involved in regulation of cell proliferation, migration and extracellular matrix production. It contains transforming growth factor, platelet derived growth factor, bone morphogenic proteins and insulin growth factor. These regulate key cellular processes like differentiation, mitogenesis and chemotaxis [48]. Kalaskar and Damle compared the efficacy of lyophilized freeze dried platelet derived preparation with calcium hydroxide as pulpotomy agents in primary molars and reported that the success rate of lyophilized freeze-dried platelet derived preparation was better than calcium hydroxide [49].

**b)** Enamel Matrix Derivative (EMD) is obtained from embryonic enamel as amelogenin. *In vitro* experiments on EMD have shown that, it stimulates PDL cell proliferation and is widely used in periodontology. The ability of EMD to facilitate the regenerative process is well established, this process mimic normal dontogenesis and it is believed that reciprocal ectodermal signaling controls and patterns the same [50]. Currently, emdogain gel (starutmann, Switzerland) has been successfully employed for pulpotomy procedures. Nakamara et al. noted that emdogain induced repair of exposed pulp by fibrodentin matrix formation and subsequent dentinogenesis [51]. Ishizaki et al. noted abundant tertiary dentin formation after 8 weeks of EMD pulpotomy [52]. Similarly, Jumana reported location of dentin bridge that is formed at the interface between the wounded and unharmed pulp tissue below the amputation site [53]. Jumana and Ahmed reported the clinical success of 93% using emdogain for pulpotomy [54].

**c)** Propolis is a wax - cum - resin substance that is produced by bees. It is shown to have antibacterial, antiviral, antifungal, immunostimulation hypotensive and cytostatic activity mainly due to the presence of lavonoids (2-phenyl-1,4-benzopyrone), aromatic acids, and esters. As an anti-inflammatory agent, it inhibits prostaglandin synthesis. Carmen et al. compared the effectiveness of 10% propolis tincture and formocresol pulpotomy in primary molars and showed that 10% propolis tincture was as effective as FC [55]. Lima et al. following histological analysis concluded that the inflammatory response was less severe, the area of pulp necrosis was smaller, and more frequent formation of a mineralized tissue barrier was evident [56]. Ozorio et al. in their histologic study noted the complete calcific bridge formation in propolis group [57].

**d)** Sodium hypochlorite (NaOCl) has been successfully used for decades in endodontic therapy as an irrigant. Since the 1950s, studies have verified that NaOCl is biocompatible, nonirritating to exposed pulpal tissue and an effective hemostatic agent. Hafez and others demonstrated that the application of NaOCl selectively dissolves the superficial necrotic pulp tissue while leaving the deeper healthy pulp tissue unharmed [58]. Cox et al reported that hemostasis is best achieved with NaOCl. Chompu-Inwai et al. reported similar success rate of NaOCl/RMGIC when compared to FC/ZOE in their 3 month evaluation [59]. Vargas et al. showed promising results from a pilot study using 5% NaOCl as a primary molar pulpotomy agent [60]. Various studies have shown a good success rate with NaOCl as pulpotomy agent ranging from 82 to 100% [61,62]. Histologically Roza et al. noted mild inflammation and also dentin bridge formation after 2 months following NaOCl pulpotomy [63].

**e)** Bioactive glass has been studied more than 30 years as a bone substitute. It reacts with aqueous solution and form a carbonate apatite layer. Originally BAGs were considered as osteoconductive. Recent evidence suggests that they are osteoinductive. BAGs are biocompatible, antibacterial and stimulate osteoblasts [64]. Some authors state odontoblast stimulation and subsequent reparative dentin formation; however studies are ongoing to prove exact mechanism of bridge formation. Animal study by Salako et al., reported that BAG showed localized areas of inflammation in the pulp especially in the mid root portion and 4 week old samples showed comparative better results where the inflammation was resolved and odontoblastic layer was evident [64].

**f)** Ankaferd Blood Stopper (ABS) is a herbal extract obtained from 5 different plants: Thymus vulgaris, Glycyrrhiza glabra, Vitis vinifera, Alpinia officinarum, and Urtica dioica. Each of these plants has some effect on the endothelium, blood cells, angiogenesis, cellular proliferation, vascular dynamics and also as cell mediators. The possible mechanism is explained by Goker et al. Following application of ABS, it forms an encapsulated protein network that provides focal points for vital erythrocyte aggregation. ABS- induced protein network formation with blood cells particularly erythrocytes covers the primary and secondary haemostatic system without disturbing individual coagulation factors [65]. It is suggested that ABS may be used to control pulpal haemorrhage following the mechanical exposure of pulps. The levels of coagulation factors II, V, VIII, IX, X, XI, and XII were not affected by ABS, therefore ABS might be used in patients with deficient primary or/and secondary hemostasis, including patients with disseminated intravascular coagulation [66]. Studies on pulpotomy with ABS have shown success rate ranging

from 89% to 100%. [66,67]. However, long term studies are required in this regard.

**g)** Nano Hydroxy Apatite has been introduced for augmentation procedures in osseous defects and is attracting increasing interest in medicine and dentistry. NHA is biocompatible and non-irritating to pulp tissue. Shayegan et al. following histological evaluation reported that there was a significant difference between NHA and FC in terms of pulp response. The results of the study show that NHA appears to be more biocompatible and provokes only mild inflammatory reaction in pulp tissue in both pulpotomy and direct pulp capping treatments [68].

**h)** Platelet Rich Plasma was introduced by Marx in 1998 for reconstruction of mandibular defects, and it represents a relatively new biotechnology that is part of the growing interest in tissue engineering and cellular therapy [69]. Gibble and Ness in 1990 introduced fibrin glue, alternatively referred to as fibrin sealant or fibrin gel, a biomaterial developed in response to the necessity for improved haemostatic agents with adhesive properties. Platelet Rich Plasma gel (PRP gel) is an autologous modification of fibrin glue obtained from autologous blood used to deliver growth factors in high concentrations [70]. It is an autologous concentration of human platelets in a small volume of plasma, mimics the coagulation cascade, leading to formation of fibrin clot, which consolidates and adheres to application site. Its biocompatible and biodegradable properties prevent tissue necrosis, extensive fibrosis and promote healing. Platelet rich plasma has been found to work via three mechanisms [70].

a) Increase in local cell division (producing more cells): According to Nathan E Carlson after the injury, platelets begin to stick to exposed collagen proteins and release granules containing adenosine diphosphate, serotonin and thromboxane, all of which contribute to the hemostatic mechanism and the clotting cascade.

b) Inhibition of excess inflammation by decreasing early macrophage proliferation.

c) Degranulation of the agranules in platelets, which contain the synthesized and prepackaged growth factors.

The active secretion of these growth factors is initiated by the clotting process of blood and begins within 10 minutes after clotting. More than 95% of the presynthesized growth factors are secreted within 1 hour [70]. PRP has been shown to remain sterile and the concentrated platelets viable for up to 8 hours once developed in the anticoagulant state [70]. PRP was found to be an ideal material for pulpotomy with low toxic effect, increased tissue regenerating properties and good clinical results [71]. Studies have reported good clinical success rates of pulpotomy using PRP [48].

**i)** Pulpotec is a newly available radiopaque, non resorbable paste that is used for pulpotomy treatment. It is available as powder liquid system (Produits Dentaires SA, Vevey. Switzerland). Powder consists of polyoxymethylene, iodoform and liquid consists of dexamethasone acetate, formaldehyde, phenol, guaiacol. Its mode of action is by cicatrization of the pulpal stump at the chamber-canal interface, while maintaining the structure of underlying pulp [72]. Previous histological studies reported no signs of inflammation, but there was a discontinuity in the odontoblastic layer lining along the dentin walls [72,73]. However more clinical trials to evaluate clinical and radiographic success are needed.

**j)** Calciumphosphate cement falls in the class of hydraulic cements, which self-harden to hydroxyapatite (HA), the bone mineral. Several formulations of CPC have been successfully designed for various orthopedic and dental applications [74,75]. CPCs possess the combination of biocompatibility, osteoconductivity and mouldability. Moreover, they are non-toxic and non-immunogenic and do not have any mutagenic or carcinogenic potential [76]. Animal studies reported the capacity of calcium phosphate to form dentin without areas of necrosis [76-78].

Chitra-CPC is a new CPC formulation with good rheological properties developed in India. Ratnakumari and Bijimole et al. used chitra-CPC and reported favourable results with mild pulpal inflammation and improved quality of dentin bridge formation [79,80].

**k)** Nigella Sativa oil (NS) extracted from black seed or black cumin is traditionally used in herbal medicine. It is shown to possess bronchodilator, immune-potentiating activity, hypotensive, analgesic, antibacterial and anti-inflammatory [81]. Omar OM et al. conducted a histopathological comparison of FC and NS pulpotomies in dogs. Specimens in NS groups showed mild to moderate vasodilatation, continuous odontoblastic layer and few samples showed scattered inflammatory cell infiltration [81].

## 5. Conclusion

Success of pulpotomy depends on various vital factors like case selection, clinical diagnosis, intraoperative diagnosis and most importantly the material used for the pulpotomy procedure. The so called "Ideal Pulpotomy material" is not yet been identified. Formocresol Pulpotomy enjoys very good clinical and radiographic success rates, and is still a popular pulpotomy material despite the concerns raised due to its toxicity, mutagenicity and carcinogenicity. Clinical studies report good success rates of Ferric sulfate 15.5% and MTA as alternatives to FC. One of the major limitations of using MTA is its high cost and its use in pediatric dentistry practice can become almost prohibitive in some circumstances. Hence, FS can still be considered a valid and inexpensive solution for pulpotomies in primary teeth.

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