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Review Article

Pulpotomy: Modern concepts and materials

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ABSTRACT

Pulpotomy is one of the most common treatment modalities in pediatric dentistry where amputation of only coronal pulp is done. Radicular pulp remain untouched and treated with long term clinically successful medicaments such as formocresol, glutaraldehyde, ferric sulphate etc. The success of pulpotomy depends on assessment of the pulp and the technique. Due to the availability of newer material nowadays pulp regeneration can also be done.

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1. Introduction

The pulp Therapy has many controversy than any other treatment in pediatric dentistry specially pulpotomy. This review article presented in the context of rationals that have guided development of new and very divergent treatment modalities while no reviews presented a framework for the systemic analysis of past development or future trends.¹

According to the AAPD a pulpotomy is performed in a primary tooth with extensive caries but without evidence of radicular pathology when caries removal results in a carious or mechanical pulp exposure. The coronal pulp is amputated and the remaining vital radicular pulp tissue is treated with a long term clinically successful medicament such as Buckley's solution of formocresol or ferric sulphate.²

According to Finn (1995), pulpotomy is defined as the complete removal of coronal portion of the dental pulp, followed by the placement of the suitable dressing or medicament that will promote healing and preserve the vitality of the tooth.

1.1. Indications of pulpotomy

1. Pulp exposure during removal of caries in primary teeth
2. Pulp exposure due to trauma
3. No history of spontaneous pain
4. Hemorrhage from exposure site is easily controllable
5. Hemorrhage from the exposure site is bright red in colour
6. No intraradicular bone loss
7. No intraradicular radiolucency
8. Absence of abscess or fistula
9. In young permanent tooth with vital exposed pulp and incompletely formed root
10. History of spontaneous pain

Pulpotomy can be performed using different techniques including non pharmacotherapeutic treatments such as electrosurgery and lasers or pharmacotherapeutic approaches by dressing pulp tissue with different medicaments or biological materials such as formocresol, glutaraldehyde, ferric sulphate, freeze dried bone, bone morphogenic protein (BMP), osteogenic protein, sodium hyochloride, calcium enriched mixture (CEM), enriched collagen solutions and fully synthetic nano crystalline

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hydroxyapatite paste.

1.2. Classification of pulpotomy

Pulpotomy can be classified according to treatment objectives (Don M Ranly 1994).¹

1.3. Depending on the size of exposure

1. Partial pulpotomy (shallow, low level or Cvek's Pulpotomy.
2. Cervical pulpotomy (deep, high level, total or conventional pulpotomy.

1.4. Classification depending upon the number of visits

1. Single visit pulpotomy
2. Multivisit pulpotomy

2. Formocresol Pulpotomy/ Single Visit Pulpotomy

Pulpotomy using formocresol was first introduced by Buckley in 1904³

Buckley's formula consisted of

1. Formaldehyde – 19%
2. Cresol – 35%
3. Glycerine – 15%
4. And water

The Ph of Buckley's solution is 5.1

Currently 1:5 dilution of Buckley's Formocresol is commonly used. A diluent consisting of 3 part of glycerine (90 ml) added to 1 part distilled water (30ml) is prepared. Later 4 parts of diluent (120 ml) is mixed with 1 part of buckley's formocresol (30 ml).

Sweet (1930) proposed the multivisit technique.

Doyle (1962) proposed the two visit pulpotomy.

Spedding (1965) gave a five minute protocol (partial devitalization).

Redig gave five minutes single visit pulpotomy

Garcia Godoy (1991) advocated 1 min. single visit pulpotomy.

Current pulpotomy procedure uses 4 minutes of application time.

2.1. Steps of single visit pulpotomy

1. Anaesthetize the tooth and tissue
2. Isolate the tooth with rubber dam
3. Remove caries with a high speed straight bur without entering the pulp chamber
4. Remove the roof of pulp chamber with a slow speed round bur
5. Remove coronal pulp with a large excavator or a large round bur

6. Apply formocresol with a pledget of cotton and apply it on the amputated pulp for 4 minutes.
7. Remove formocresol pledget after 4 minutes and check that hemorrhage stopped
8. Filled the pulp chamber with Zinc Oxide Eugenol cement
9. Restore the tooth with stainless crown.

2.2. Mechanism of action of formocresol

Formocresol prevents tissue autolysis by binding the peptide group of side chain of amino acid. It is a reversible process without changing of basic structure of protein molecules.

2.3. Controversy between 1 minute formocresol pulpotomy vs 5 minutes formocresol pulpotomy

Zohra et al (2011) used 1 minute formocresol pulpotomy and reported success rates comparable to techniques that used the 5 minute diluted or full strength solutions reported in the literature.

2.4. Histological changes

Massler and Mansukhani (1959) reported that between 7 to 14 days three zones appeared.

1. A broad acidophilic zone (fixation)
2. A broad pale – staining zone (atrophy)
3. A broad zone of inflammatory cells

After 60 days only strand of eosinophilic fibrous tissue remained at the exposure site.

2.5. Concerns of formocresol

1. Formocresol is believed to cause mutagenicity, cytogenecity and carcinogenicity.
2. IARC (June 2004) classified formaldehyde as a carcinogen that has potency to cause leukemia and nasopharyngeal carcinoma. However Ranly calculated the formocresol concentration following pulpotomy and reported that 3000 pulpotomies have to be performed in the same individual to reach toxic level.
3. Systemic distribution – Myers (1978) while using radioisotope labelled formaldehyde to perform pulpotomies in animals found its presence in PDL, dentine, bone and urine.
4. Antigenecity – Thoden Valzen found immunogenic potential of formaldehyde in rabbits, dogs, and guinea pigs.
5. Mutagenecity and cytogenecity – According to studies done formaldehyde dentaures nuclic acids by forming methylol derivaties that renders genetic machinery inoperable. It may also affect biosynthesis and cell reproduction by interacting with DNA and RNA.

Table 1:

Types	Other name	Vital pulpotomy	
		Features	Examples
Devitalization	Mummification Cauterization	Intended to mummify the vital tissue	Single sitting Formocresol Electrosurgery LASER Two sittings Gysi triopaste Easlick's formaldehyde Paraform devitalizing paste Zinc oxide eugenol
Preservation	Minimum devitalization, non inductive	Maintains vital tissue with no induction of reparative dentine	Glutaraldehyde Ferric sulphate Ca(OH) ₂ Bone morphogenic protein
Regeneration	Inductive, reparative	Causes formation of dentin bridge	Mineral trioxide aggregate Enriched collagen Freezed dried bone Osteogenic protein
		Non vital pulpotomy	
Mortal pulpotomy		It is done inn teeth with nonnegotiable root canals	Beechwood cresol Formocresol

2.6. Two visit devitalization pulpotomy

2.6.1. Indications

1. Evidence of sluggish or profuse bleeding at the amputation site
2. Hemorrhage difficult to control
3. Slight purulence in the pulp chamber but not at the amputation site
4. Thickening of the periodontal ligament
5. A history of spontaneous pain without other contraindications

2.7. Contraindications

1. Non restorable tooth
2. Soon to be exfoliated tooth
3. Necrotic pulp

It is a two stage procedure involving the use of paraformaldehyde. The medicament has a devitalizing, mummifying and bactericidal action.

2.7.1. Technique of two visit pulpotomy

1. First appointment

- (a) Same as formocresol pulpotomy but paraformaldehyde paste in cotton pellet is placed over the exposure and the tooth is sealed for 1 to 2 weeks.
- (b) Formaldehyde gas liberates from the paraformaldehyde paste and permeates through the coronal and radicular pulp fixing the tissues.

2. Second appointment

- (a) Pulpotomy is carried out with the help of LA and pulp chamber is filled with antiseptic paste and the tooth is restored with stainless steel crown.

2.7.2. Materials used in two visit pulpotomy

1. Gysi triopaste consist of tricresol, cresol, glyserine, paraformaldehyde, zinc oxide eugenol
2. Easlick's paraformaldehyde paste consist of paraformaldehyde, procaine base, powdered asbestos, petroleum jelly
3. Paraform devitalizing paste consist of paraformaldehyde, lignocaine, propylene glycol, carbowax, carmine for colour.

3. Glutaraldehyde Pulpotomy

Glutaraldehyde for pulp fixation was proposed by Gravenmade (1975), In recent years glutaraldehyde has been proposed as an alternative to formocresol based on its superior fixative properties, self limiting penetration, low antigenicity, low toxicity and elimination of cresol. Glutaraldehyde has a cross linking property superior to that of formocresol.³

3.1. Histology

Narrow zone of eosinophilic stained and compressed fix tissue is found beneath the area of application which blends with underlying normal pulp.

Concentration and application time of glutaraldehyde

Garcia Godoy (1987) found that increase in concentration and longer time improves fixation and suggested the use of 4% glutaraldehyde for 4 minutes or 8% glutaraldehyde for 2 minutes.

3.2. Disadvantages

1. It is costly
2. Inadequate fixation that leaves a deficient barrier susceptible for sub-base irritation resulting in internal resorption.

4. Ferric Sulphate Pulpotomy

It is a non aldehyde chemical which is used as a pulpotomy material. Ferric sulphate is a coagulative and hemostatic agent this compound was proposed as a pulpotomy agent that it prevents the problem in clot formation thereby minimizing chances of inflammation and internal resorption.⁴

4.1. Mechanism of action of ferric sulphate

When ferric sulphate comes in contact with pulp tissue it forms ferric ion protein complex that mechanically occludes capillaries in the amputation site forming barrier for irritants of sub base.

4.2. Advantages

1. Minimizes clot formation at the amputation site
2. Cheap

4.3. Disadvantages

1. Some studies reported fibrosis.

5. Calcium Hydroxide Pulpotomy

Calcium hydroxide was introduced to dentistry in 1938 by Nygren. In 1930 Herman showed that calcium hydroxide stimulated the formation of new dentine when placed in contact with human pulp tissue.⁵

Calcium hydroxide was used as a medicament for indirect pulp capping, direct pulp capping and pulpotomy in permanent and primary teeth because of its bactericidal effect and ability to form reparative dentine bridge however, there are a controversies regarding the use of calcium hydroxide in primary teeth pulpotomy, because it results in the development of chronic pulpal inflammation and internal resorption.

In case of deciduous teeth even before the actual time for exfoliation there is an inherent predeliction for the formation of odontoclasts. The preexisting propensity for transformation could be influenced and hastened by placement of calcium hydroxide, probly through its high alkaline ph. It is very likely that high alkaline ph of

calcium hydroxide could trigger existing pre- odontoclasts (stromal undifferentiated mesenchymal cells) to transform into odontoclasts which causes internal resorption. Hence, calcium hydroxide is not recommended as a pulpotomy agent in case of primary teeth.

6. Newer Concepts in Pulpotomy

6.1. MTA pulpotomy

As a member of hydroxycilic calcium silicate cement MTA was introduced by Lee et al and patented by Torabinejad and White in 1995.⁶

MTA consist of tricalcium silicate, bismuth oxide, tetracalcium alumina, ferrite, calcium sulphate dehydrate.

6.2. Mechanism of action

When MTA is mixed with water a colloidal gel with a ph 12.5 similar to that of calcium hydroxide is formed. MTA in contact with pulp tissue promotes dentin bridge formation.

6.3. Advantages

1. Biocompatibility
2. Bactericidal
3. Induction of cementogenesis, osteogenesis, dentogenesis
4. Good sealing ability
5. Is duperior to formocreo; which is considered the gold standard in pulpotomy

6.4. Disadvantages

1. Expensive
2. Fast Setting time

7. Calcium Enriched Mixture Cement (CEM)

CEM cement was introduced as a endodontic filling material. The major componenets of the cement are calcium oxide, sulphur trioxide, phosphorus peroxide and silver dioxide.⁷

7.1. Advantages

1. Biocompatible
2. The physical properties of the cement such as flow, film thickness and setting in aquous environment are favorable.
3. Has antibacterial activity
4. Induces hydroxyappatite formation

8. Electrosurgery

It is a non – pharmacological hemostatic technique which has been suggested for the pulpotomy procedure.⁸

8.1. Mechanism of action

Electrosurgery involves cutting and coagulating soft tissues by means of high frequency electric current passing through the cells. These technique carbonizes and heat denatures the pulp and bacterial contamination.

8.2. Advantages

1. The self limiting pulp penetration is only a few cell layers deep.
2. Good visualization
3. Hemostasis without chemical coagulation
4. Less chair time

9. Laser Pulpotomy

Lasers have been introduced to medicine and dentistry since the early 1960s. Different lasers are used in pediatric dentistry. These lasers include diagnosis of caries development (diode 655 nm), argon lasers for composite curing, Co2 lasers with wavelength of 10600 nm for soft tissue surgeries, Nd: YAG lasers with wavelength of 1064 nm as well as diode laser with wavelength of 810-980 nm for soft tissue cutting, the Erbium laser family including Er: YAG (2940 nm) and Er; Cr: YSGG (2780 nm) which were used in hard tissues, cavity preparation and in soft tissue surgery and also low power lasers which are used in stimulatory and inhibitory biologic process. Several studies have revealed that laser have proper effects in pulpotomy of primary teeth with results similar or even better than formocresol pulpotomy. The advantages of laser compared to conventional pulpotomy, are hemostasis, preservation of vital tissues near the tooth apex, absence of vibration and odor.⁹

Hz, Co2 laser and 632/980 nm diode lasers can be used for pulpotomy of primary teeth. Liu et al. in a clinical study compared the effects of Nd: YAG laser pulpotomy with FC on human primary teeth. They concluded that the success rates of the Nd: YAG laser was significantly higher than the FC pulpotomy.

10. Naocl Pulpotomy

Sodium hypochlorite has been used as an irrigant in dentistry for decades. Hafez and others demonstrated that the application of sodium hypochlorite selectively dissolves the superficial necrotic pulp tissue while leaving the deeper healthy pulp tissue unharmed.¹⁰

10.1. Advantages

1. It is biocompatible
2. It is non irritating to the pulp tissue
3. It is an effective hemostatic agent

Various studies have shown good success rate of sodium hypochlorite pulpotomy.

11. BMP (Bone Morphogenic Protein)

BMP is thought to induce reparative dentin with recombinant dentinogenic proteins similar to the native proteins of the body. This was based on two classic observations.¹¹

1. Huggins reported urinary tract epithelia implanted into the abdominal wall of dogs evoked bone formation
2. Urist also noted that demineralized bone matrix stimulated new bone formation when implanted in ectopic sites such as muscles. Urist concluded that bone matrix contains a factor capable of autoinduction and named it BMP.

The proteins most studied in pulp tissue have been BMP- 2, BMP-4 and BMP- 7 (OP-1).

Studies on BMP-7 has been done by Rutherford, Jepson and sin. Whereis studies on BMP 2 and 4 has been done by Nakashima and Ren.

11.1. Mechanism of action of BMP

Cells similar to fibroblasts migrate from the lower pulp tissue to the amputation zone (free from contamination) where they proliferate following this, there is formation of inactive matrix or utilization of the scaffolds itself, for the stem and undifferentiated mesenchymal cells to adhere tooth.

BMP – 2, 4 and 7 induce the differentiation of the adhered cells into odontoblasts that, inturn take part in the production and mineralization of the dentin matrix.

In a study done by Bengtson et al (2008) they found the success rate of BMP-2 on human deciduous teeth to be 100%.

These suggests that rh BMP -2 is a material with inductive properties that should be further investigated for use as an alternative to pulpotomy treatment.

12. Enamel Matrix Derivative (EMD)

Enamel matrix derivative (emdogain) is an extract derived from porcine foetal tooth material and mainly consists of amelogenins, a class of protein known to induce the proliferation of periodontal ligamental cells.¹²

The ability of EMD to facilitate the regenerative process is well established. This process mimics normal odontogenesis and it is believed that reciprocates ectodermal signaling controls and patterns.

Currently emdogain gel (Straumann, Switzerland) has been successfully employed for pulpotomy procedures. EMD by means of amelogenin and ameline rich fraction has the potential to induce a process that seems to immitate

normal dentinogenesis. It influences the odontoblasts and endothelial cells of the pulpal capillary vessels to create a calcified barrier over the pulp amputation site.

12.1. Mechanism of action of EMD

It has been reported that enamel matrix proteins participate in the differentiation and maturation of odontoblastic cells and when the pulp is exposed to EMD, a substantial amount of reparative dentin-like tissue is formed in a process much resembling classic wound healing which subsequent neogenesis of normal pulp tissue. These formations of new dentin start from within the pulp at some distance from the exposure site.

Jumana and Ahmed reported the clinical success of 93% using Emdogain for pulpotomy.

13. Propolis

Propolis is a wax cum resin substance that is produced by bees.¹³

1. It is shown to have antibacterial property
2. Antiviral property
3. Antifungal property
4. Hypotensive property
5. Cytostatic activity due to the presence of flavonoids (2 phenyl 1,4 – benzopyryne, aromatic acids and esters)

Histological studies have shown that the inflammatory response when propolis was applied to the amputated pulp was less severe, the area of pulp necrosis was smaller and there was more frequent formation of calcific barrier.

14. Ankaferd Blood Stopper (ABS)

It is a herbal extract obtained from 5 different plants¹⁴

1. Thymus vulgaris
2. Glycyrrhiza glabra
3. Vitis vinifera
4. Alpinia officinarum
5. Urtica dioica

All of these plants has some effect on the endothelium, blood cells, angiogenesis cellular proliferation vascular dynamics and also as cell mediator.

14.1. Mechanism of action of ABS

Following application of ABS, it forms an encapsulated protein network that provides focal points for vital erythrocytes aggregation. ABS induce protein network formation with blood cells particularly erythrocytes covering the primary and secondary hemostatic system without disturbing individual coagulation factors.

It is suggested that ABS may be used to control pulpal hemorrhage following the mechanical exposure of

the pulp. The levels of coagulation factors II, V, VIII, IX, X, XI and XII were not affected by ABS, therefore ABS can be used in patients with primary or /and secondary hemostasis including patients with disseminated intravascular coagulation.

Studies show the success rate of ABS in pulpotomy between the range of 89 -100%.

14.2. Bioactive Glass (BAG)

Bioactive glass has been studied for more than 30 years as a bone substitute. They react with aqueous solutions and produce a carbonated apatite layer. BAG is biocompatible and has osteogenic potential. Many researchers claim that it has odontogenic potential and can form reparative dentin.¹⁵ Animal studies by Salako et al reported that BAG showed localized area of inflammation in the pulp and four weeks all samples showed comparatively better results where the inflammation was resolved and an odontogenic layer was evident.

15. Nanohydroxy Apatite (NHA)

Hydroxyapatite has already been used in bone grafts in orthopedic and in dental applications due to its structural similarity with bone and teeth. Despite each biocompatibility, one of the problems related to hydroxyapatite is the release of crystals or agglomerates that could impair cell activity and hinder the regeneration process. As natural bone has nanoscale features, it is believed that nanostructured hydroxyapatite could improve the properties of synthetic bone.¹⁶

Recently a fully synthetic nanocrystalline hydroxyapatite (NHA) paste containing approximately 65% water and 35% apatite particles was introduced.

The advantages of this material are

1. Its close contact with surrounding tissue
2. Its rapid resorption capacities
3. High number of molecules on its surface

The biocompatibility of NHA combined with its structural similarity to teeth allows NHA to stimulate odontoblasts thus promoting the formation of dentine bridges.

Shayegan (2010) in his study found NHA to be biocompatible and observed that it provoked mild inflammatory reaction in pulp tissue after pulpotomy.

16. Platelet Rich Plasma (PRP)

It was first introduced by Marx in 1998 for reconstruction of mandibular defects. PRP gel is an autologous modification of fibrin glue obtained from autologous blood used to deliver growth factors in high concentrations. It is an autologous concentration of human platelets in a small volume of plasma. It mimics the coagulation cascade leading to

formation of fibrin clot which consolidates and adheres to application site.¹⁷

It is biocompatible, biodegradable and promotes healing. PRP has been found to work in 3 ways

1. Increase in cell division
2. Inhibition of excess inflammation by decreasing early macrophase proliferation and
3. Degranulation of the granules in platelets, which contain the synthesized and prepackaged growth factors

Studies have reported could clinical success rates of pulpotomy using PRP

17. PULPOTEC

Pulpotec is a radio-opaque, non resorbable paste that is used in pulpotomy. Its powder consists of polyoxymethelene, iodoform and liquid consist of dexamethasone acetate, formaldehyde, phenol and guaiacol.¹⁸

17.1. Mechanism of action

The mode of action is by cycatrization of the pulp stump at the chamber – canal interface, while maintaining the structure of the underlying pulp.

Histological studies have shown no signs of inflammation but there was a discontinuity in the odontoblastic layer lining along the dentin walls.

17.2. Nigella Sativa Oil (NS)

Nigella sativa oil is extracted from the seeds of black cummin. It is shown to have bronchodilator, immunogenic potentiating, hypotensive, analgesic, antibacterial and anti-inflammatory activity.

Omar OM et al. in his studies found that pulpotomy is done with NS showed mild to moderate vasodilation, continuous odontoblastic layer and a few samples showed scattered inflammatory cell infiltration.¹⁹

17.3. CVEK'S Pulpotomy

It is also known as partial pulpotomy or calcium hydroxide pulpotomy. It was advocated by mejare and Cvek (1978). It is a form of vital pulp therapy performed in a immature permanent tooth with an open apex that consist of the surgical amputation of 2-3 mm of damaged and inflamed coronal pulp tissue. After removal of the damaged tissue, a dressing agent is placed to stimulate healing and maintain the vitality of the remaining pulp. It has a success rate of 95% in the treatment of complicated crown fractures and 91 – 93% in cariously exposed immature asymptomatic permanent teeth.²⁰

17.4. Rationale of Cvek pulpotomy

1. To preserve the vitality of the radicular pulp and allow for normal root closure.

17.5. Indication

In young permanent immature teeth where the pulp has been exposed due to trauma or caries and the remaining radicular pulp is deemed to be vital by clinical and radiographic criteria wherein the root formation is not complete.

Procedure of cvek pulpotomy

1. Tooth is anaesthetize and isolated
2. Caries is removed with a high speed 801 – 016 ML diamond round bur with copious irrigation
3. Amputation of 2- 3 ml of the damaged coronal pulp is executed
4. The cavity is rinsed with normal saline
5. Cotton pellet moistened with saline is used with moderate pressure to attained hemostasis
6. Calcium hydroxide is then apply to the exposed pulp ensuring no clot formation takes place
7. The cavity is then sealed with temporary restorative material
8. At the 1 month follow up, the tooth should be asymptomatic and show radiographic evidence of root development and maturation
9. Then permanent restoration with amalgam is done

18. Mortal Pulpotomy

It is also known as non vital pulpotomy. Ideally speaking pulpotomy is done in the vital tooth and pulpectomy is done in case of nonvital tooth. But in some cases it is not possible to do a pulpectomy because of nonnegotiable root canals and lack of cooperation of the patients. In such cases a mortal pulpotomy is done.²¹

18.1. Procedure of Mortal Pulpotomy

18.1.1. First appointment

1. In the first appointment the necrotic pulp from the pulp chamber is removed
2. The pulp chamber is irrigated with normal saline and dried with a cotton pellet
3. The radicular pulp is then treated with a strong antiseptic solution
4. The cavity is then sealed with temporary restorative material

18.1.2. Second appointment

1. In the second appointment if the tooth is asymptomatic an antiseptic paste is put in the pulp chamber
2. The tooth is then restored with a stainless steel crown

19. Conclusion

For the maintenance of the dental arch length in children, mastication, speech and esthetics presentation of the deciduous teeth are necessary until their permanent successors erupt. Appropriate procedures such as indirect pulp capping, direct pulp capping and pulpotomy are often considered for maintaining the vitality of the deciduous teeth. The most common treatment in case of pulp exposure in symptom free primary molars is pulpotomy though deciduous molar pulpotomy has served adverse effects like internal root resorption, this is mainly due to diagnostic errors during pulp testing and technical failure while performing the procedure. Newer materials that are available as pulpotomy agents have also made regeneration of pulp tissue possible thus the only thing required while performing pulpotomy procedure is accurate diagnosis of the pulpal status and proper technique.

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None.

21. Conflict of Interest

The authors declare no conflict of interest.

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