DIRECT PULP CAPPING MATERIALS- A REVIEW

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WHAT IS PULP CAPPING?
Pulp protection is the term coined by AAPD which recommends the placement of a protective base or a liner on the pulpal and axial walls of the cavity preparation to act as a protective barrier between the restorative material and the tooth.\[1\]

Pulp treatment modality can be classified to 2 categories.\[2\]

A- conservative Treatment-Which aims at maintaining pulp vitality, include
1. Protective base.
2. Indirect pulp treatment.
3. Direct pulp capping.
4. Pulpotomy.

B-Radical treatment-consisting of pulpectomy and root filling

INDIRECT PULP CAPPING
It is defined by Ingle as a procedure where in small amount of carious dentin is retained in deep areas of cavity to avoid exposure of pulp, followed by placement of a suitable medicament and restorative material that seals off the carious dentin and encourages pulp recovery.

A radiopaque base is placed over the remaining affected dentin to stimulate healing and repair. The tooth is then restored with a material that seals the involved dentin from the oral environment.\[3\]
Direct Pulp Capping
The procedure in which the small exposure of the pulp, encountered during cavity preparation or following a traumatic injury or due to caries, with a sound surrounding dentin, is dressed with an appropriate biocompatible radio-opaque base in contact with the exposed pulp tissue prior to placing a restoration is termed as a direct pulp capping. [4]

Ideal Requirements of Pulp Capping Material (As Suggested By Cohen And Combe)
The materials should be radiopaque and have good bacterial seal. They should maintain pulp vitality and should also induce Reparative dentin formation. They should induce Fluoride release and adhere to dentin. They should adhere to restorative materials and should resist forces. They should be bacteriostatic and bactericidal.

Various Materials Used For Direct Pulp Capping
1. Gold Foil
The first method of capping exposed pulps, using gold foils, was described by Pfaff in 1756. Until the end of the 19th century, most materials were used empirically with the idea that the pulp tissue must be irritated by etching or cauterization to heal. Later, more attention was drawn to disinfecting agents, because it became obvious that microorganisms were the reason for pulp inflammation - but these agents were cytotoxic. [5,6,7]

2. Zinc Oxide Eugenol
Since insufficient or inappropriate diagnoses were made before treatment, even necrotic pulps were capped. The first scientific clinical study to compare different capping materials was made by Dätwyler in 1921, whereupon zinc oxide-eugenol showed the best results. One year later, Rebel performed the first animal experiments with disastrous results, so he regarded the exposed pulp as a doomed organ. [8]

3. Corticosteroids and antibiotics
Corticosteroids like hydrocortisone, Cleocin, cortisone, Ledermix, penicillin, neomycin and along with calcium hydroxide was used for pulp capping with the thought of reducing or preventing pulp inflammation. Gardner, et al., found that vancomycin, in combination with calcium hydroxide was somewhat more effective than calcium hydroxide used alone and stimulated a more regular reparative dentin bridge. [9]
Watts and Paterson cautioned that anti-inflammatory compounds should not be used in patients at risk from bacteremia Qureshi.

4. Polycarboxylate cement
They chemically bond to tooth structure. There is lack of antibacterial effect. Fails to stimulate calcific bridge formation. McWalter, G et al., found that it lacks an antibacterial effect and calcific brid. Fluocinolone acetonide

5. Isobutyl Cyanoacrylate
Cyanoacrylate is an adhesive that results from the chemical reaction between formaldehyde and the esters of cyanoacetate.\textsuperscript{[10,11]} It is an excellent pulp capping agent because of its haemostatic and bacteriostatic properties; at the same time it causes less inflammation than calcium hydroxide. But it can not be regarded as an adequate therapeutic alternative to calcium hydroxide since it does not produce a continuous barrier of a reparative dentin following application of the exposed pulp tissue. Bhaskar SH et al., and Heys DR et al., investigated isobutyl cyanoacrylate and tricalcium phosphate ceramic as direct pulp capping materials. Although pulpal response in the form of reduced inflammation and unpredictable dentin bridging were found, but none of these materials have been promoted to the dental profession as a viable technique.\textsuperscript{[13,14]}

6. Adhesive liners
They provide a complete marginal seal and prevents bacterial intrusion. Allows pulp repair, characterized by a new odontoblast cell layer underlying the dentin bridge formation. Many studies have indicated that composite & resin-modified glass-ionomer are compatible with pulp tissue. According to Miyakoshi et al., 4-META adhesives and hybridizing dentin bonding agents provide superior adhesion to peripheral hard tissues and effective seal against micro leakage. But they have poor outcome due to its cytotoxic effect and absence of calcific bridge formation. However Hebling et al. (1999), reported in their study that the (all bond 2) adhesive system did not appear to allow any pulp repair and does not appear to be indicated for pulp capping of human teeth. Costa et al. (2003), evaluated the response of pulps of rats capped with resinmodified glass-ionomer cement or self-etching adhesive system. Despite some inflammatory pulpal response, both experimental pulp-capping agents allowed pulpal healing characterized by cell-rich fibro dentin and tertiary dentin deposition.\textsuperscript{[15,16,17]}
7. Calcium Hydroxide
In 1920 Hermann, introduced calcium hydroxide for root canal fillings. Between 1928 and 1930 he studied the reaction of vital pulp tissue to calcium hydroxide to prove that it was a biocompatible material.\cite{18,19}

Since then, calcium hydroxide has been recommended by several authors for direct pulp capping, but it took until the middle of 20th century until it was regarded as the standard of care. However, several disadvantages have been listed with the use of calcium hydroxide material. Presence of tunnels in dentin barrier, extensive dentin formation obliterating the pulp chamber, high solubility in oral fluids, and lack of adhesion and degradation after acid etching are some of the limitations reported. When calcium hydroxide is applied directly to pulp tissue, there is necrosis of the adjacent pulp tissue and inflammation of the contiguous tissue. However, It has excellent antibacterial properties and low cytotoxicity.

**Advantages**
- Initially bactericidal then bacteriostatic
- Promotes healing and repair
- High pH stimulates fibroblasts
- Neutralizes low pH of acids
- Stops internal resorption
- Particles may obturate open tubules

**Disadvantages**
- Does not exclusively stimulate dentinogenesis
- Does not exclusively stimulate reparative dentin
- Associated with primary tooth resorption
- May dissolve after one year with cavosurface dissolution
- May degrade acid etching
- Degrades upon tooth flexure
- Marginal failure with amalgam condensation
- Does not adhere to the dentin or resin restoration

8. Glass Ionomer (GI) / Resin-Modified Glass Ionomer (RMGI)
While not as cytotoxic as ZOE, GI/RMGI is also cytotoxic when in direct cell contact. Glass ionomer also provides an excellent bacterial seal and shows good biocompatibility when used
in close approximation but not in direct contact with the pulp fluoride release, coefficient of thermal expansion and modulus of elasticity similar to dentin. Although there is, lack of dentin bridge formation, high solubility and slow setting rate. RMGIC as direct pulp capping agent exhibited chronic inflammation and lack of dentin bridge formation; whereas the calcium hydroxide control groups showed significantly better pulpal healing.\cite{20}

9. Calcium phosphate Compounds

Alpha-tricalcium phosphate & Tetracalcium phosphate (4CP) set & convert to hydroxyapatite. Calcium phosphate cement was suggested as viable alternative because of its good biocompatibility, superior compressive strength and its transformation into hydroxyapatite over time. Yoshimine et al., demonstrated that in contrast to calcium hydroxide, tetracalcium phosphate cement induced bridge formation with no superficial tissue necrosis and significant absence of pulp inflammation.\cite{21}

10. Hydroxyapatite

It is biocompatible and can act as a scaffold for the newly formed mineralized tissue. Mild inflammation may be induced with superficial necrosis of pulp. It is the most thermodynamically stable of the synthetic calcium phospha Modified Bioglass Formula (MBF) Stanly et al. (2001) reported that MBF#68 used as direct pulp capping agent showed 1- no evidence of mummification 2- high incidence of properly positioned dentine bridge. At 2 weeks, inflammatory changes in the pulp. 4 weeks, some samples showed normal pulp histology, with evidence of vasodilation.\cite{22}

11. TheraCal LC

Is a light cured, resin modified calcium silicate filled liner designed for use in direct and indirect pulp capping, as a protective base/liner under composites, amalgams, cements, and other base materials. TheraCal LC performs as an insulator/barrier and protectant of the dental pulpal complex. The proprietary formulation of TheraCal LC consists of tricalcium silicate particles in a hydrophilic monomer that provides significant calcium release making it a uniquely stable and durable material as a liner or base. Calcium release stimulates hydroxy apatite and secondary dentin bridge formation.\cite{23}

12. Mineral Trioxide Aggregate (MTA)

In recent years a new cement (mineral trioxide aggregate [MTA]), developed in the 1990s by Torabinejad and his coworkers at Loma Linda University (California), has become available
as a root canal repair material and for direct pulp capping. During the setting process, MTA has an initial pH of 10.2, which increases to up to 12.5 during the first few hours. Comp strength: 26.4 Mpa -24 hrs & 30.4 Mpa – 21 days. It prevents microleakage over the vital pulp and is biocompatible. It Promotes regeneration of the original tissues when it is placed in contact with the dental pulp or periradicular tissues.[24]

MTA has the ability to stimulate cytokine release from bone cells promotes hard tissue formation. Pitt Ford et al. were the first to evaluate the performance of MTA for pulp capping in monkey’s teeth, and they demonstrated superior performance of MTA compared with calcium hydroxideStudies on pulp capping of carious-exposed permanent teeth with MTA have reported high success rates, which ranged from 93%–98%.

13. Biodentine
Biodentine® (Septodont, Saint-Maur-des-Fosses, France) is a new generation material based on calcium silicate synthesized by bioactive technology Biodentine stimulates release of TGF-β from pulpal cells, stimulating reparative dentin formation in a very short period of time. Particular growth factors from the TGF-β family have the ability to initiate odontoblast differentiation and hence produce tertiary dentine by cell signalling Once mixed, biodentine™ sets in approximately 10-12 minutes. The consistency of biodentine is similar to that of phosphate cement.[24,25]

Another study of indirect pulp capping on rat molars concluded that Biodentine™ was able to stimulate (thick and dense) reactionary dentine formation, which stopped after about three months when a sufficient dentine barrier was formed. Studies conducted to test Biodentine™ for application as a direct pulp capping agent and for pulpotomy showed that it was well tolerated even when in direct contact with the pulp. It was even suggested that the quality of dentine bridges formed were better than those formed by calcium hydroxide alone.

Used for pulp capping, the material offers certain advantages over calcium hydroxide: It is stronger mechanically, less soluble and produces tighter seals.

14. Denaturated albumin
This protein has calcium binding properties. If a pulp exposure is capped with a protein, the protein may become a matrix for calcification, thereby increasing the chances of biologic obliteration.[18]
15. Laser

To overcome the histological deficits of electrosurgery, Laser was introduced. CO2 Laser, Argon Laser, Diode Laser, Erbium:Yttrium-Aluminum Garnet (Er.YAG) are widely used.

Laser radiation has been proposed for pulp treatment based on its haemostatic, coagulative and sterilizing effects. Yasuda Y, et al., did a study to examine the effect of CO2 laser irradiation on mineralization in dental pulp cells in rats and the results suggested that CO2 laser irradiation stimulated mineralization in dental pulp cells.\(^{[16,19]}\)

**Advantages**

- Better clinical, radiographic, and histological results after using of laser for pulpotomy in primary teeth.
- Patient did not present any pain or discomfort and no analgesic was needed in Diode laser pulpotomies.

**Disadvantages**

- The high cost.

16. Growth factors

Growth factors are biological modulators that are able to promote cell proliferation and differentiation. It is considered that the biological modulators will be the promising materials that will revive the expectations for regeneration of the exposed pulp tissue, rather than, devitalization. Superior to calcium hydroxide in the mineralization inducing properties. High concentration is required. Half life is less. Appropriate dose response is required to avoid uncontrolled obliteration of pulp chamber. Osteogenic proteins, such as bone morphogenetic proteins (BMPs), which are protein bone extract containing multiple factors that stimulate bone formation. The demineralized bone matrix could stimulate new bone formation when implanted to ectopic sites such as muscles. BMP belongs to super family transforming growth factor beta (TGF-β). TGF β is a potent modulator of tissue repair in different situations.\(^{[13,15]}\)

Lianjia et al., found that BMPs are responsible for dentinogenesis, inducing non differentiated mesenchymal cells from the pulp to form odontoblast-like cells, obtaining osteodentin and tubular dentin deposition, when used as direct protectors Other osteogenically active growth factors that have been identified are PDGF (platelet-derived growth factor), IGF (insulin-like growth factor) and FGF (fibroblast growth factor).
17. Enzymes
Heme oxygenase-1 (HO) is the rate limiting enzyme in heme catabolism. Odontoblasts and oxidatively stressed dental pulp cells express HO-1, indicates that the pulp might respond to oxidative stress at the molecular level. Simvastatin improves the osteoblast function and suppresses osteoclast function, resulting in enhanced bone formation. Statin is known to induce angiogenesis and increase neuronal cells, indicating the possible effectiveness of statin in pulp regeneration along with dentin regeneration. It has an anti-inflammatory effect in various tissues, so it is considered as an ideal active ingredient in pulp capping material to accelerate reparative dentin.\(^2\)

18. Propolis
Propolis, a resinous material collected by honey bees, has been used as a traditional anti-inflammatory and anti-bacterial medicine for many centuries. Used as indirect pulp capping paste when mixed with Zno powder and this showed similar effect of Zno and eugenol as secondary dentin formation. In direct capping with this paste showed no pulp degeneration and formation of protective layer It contains flavonoids, phenolics, iron, zinc and other various aromatic compounds. Parolia A, et al., compared propolis, MTA and Dycal histologically in human dental pulp and concluded that Propolis and MTA showed similar bridge formation when compared to Dycal Study showed that direct pulp capping in rats with Non-flavonoids Propolis at 1 w showed pulp inflammation, no dentine bridge formation a long the follow up period. - Flavonoids at 1w no evidence of inflammatory response. At 2 and 4 weeks mild to moderate pulp inflammation was evident. In week 4 dentinal bridge formation was detected.\(^{17,18}\)

19. Dental pulp stem cells (DPSCs) and Stem cells from Human Exfoliated Deciduous Teeth (SHED)
Have been identified as a novel population of stem cells that have the capacity of self-renewal and multi lineage differentiation. Nakamura S et al., used mesenchymal stem cells for clinical application in tissue engineering and regenerative medicine. In this study, they compared the proliferation and stem cell marker of SHED, DSPCs and Bone Marrow Derived Mesenchymal Stem Cells (BMMSCs). In addition, gene expression profile of DSPCs and SHED were analyzed by using DNA microarray. They concluded that SHED has got significantly higher proliferation rate than that of DSPCs and BMMSCs and this could be a desirable option as a cell source for therapeutic applications.\(^{12,19}\)
20. Emdogain (EMD)

EMD is enamel matrix derivative secreted from Hertwig’s epithelial root sheath during porcine tooth development. It is an important regulator of enamel mineralization and plays an important role during periodontal tissue formation. It stimulates the regeneration of acellular cementum, periodontal ligaments, and alveolar bone. EMD contains BMP like molecules and BMP expressing cells. BMP like molecules in EMD promote odontoblast differentiation and reparative dentin formation.[25]

Nakamura Y et al., concluded that amount of hard tissue formed in EMD treated teeth was more than twice that of the calcium hydroxide treated control teeth.

21. Bioactive (Activa)

Bio active materials have been used as regenerative materials in dentistry. Activa, a new pulp regenerative material was recently introduced. It has a quick setting time of 20 seconds and biomineralisation ability for hard tissue regeneration and also high biocompatibility.[22]

REFERENCES