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VITAL PULP THERAPY: A Literature Review Of The Material Aspect.

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ABSTRACT: There was a long-held perception that mature permanent teeth with pulp exposure has less favourable outcomes therefore root canal therapy as a treatment option has prevailed over others since the longest time. However, in the past decade we see a shift in the paradigm wherein maintaining the vitality and integrity of the pulp organ, elimination of microbes from the pulp- dentin complex and promoting regeneration of tissue has become the focus. This article throws light on materials used in vital pulp therapy procedure that helps attain protection towards the pulp - dentin complex.

Keywords: Reparative dentin, pulpotomy, pulp capping, pulp - dentin complex.

1. INTRODUCTION

There are various signs and symptoms that manifest into endodontic disease, which if left untreated leads to devastating effects. Most endodontic diseases are a result of a common etiology i.e. microbial infection. Pulpal exposures occur under three scenarios, caries, trauma and mechanical causes, with caries being the most common scenario.[1] Nearly 80% of dentists encounter pulpal exposure due to caries in their practice at least once a month.[3] Hence irrespective of the medium through which pulp exposure occurs, all the three scenarios permit bacterial insult to the pulp.

It is a common notion that pulpal exposures with a carious backdrop have an unflattering prognosis. Therefore, opting for treatment protocols like root canal treatment is more appealing, which involves the removal of the entire pulp organ. These treatment strategies got adapted in primitive times due to the inefficiency of either the treatment strategy or materials to prove a suitable environment for pulpal repair and reparative dentin bridge formation.

However, in the last decade exceptional progress was made in terms of maintaining pulp integrity and promoting pulpal repair that is broadly known as vital pulp therapy. The definition of vital pulp therapy is given to be " a treatment established to preserve and sustain the healthy state of pulp tissue that has been jeopardized by either restorative procedures, trauma or caries."[2] In recent times plenteous materials have been advocated to be incorporated in vital pulp therapy procedures which encourages pulpal repair, prevents microbial contamination and maintains pulp physiology.

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PULP CAPPING MATERIALS

Pulp capping is one of the most common and less invasive procedures in vital pulp therapy which has used a lot of materials aiming to attain clinical success like zinc oxide eugenol, glass ionomer cement or resin-modified glass ionomer cement, bonding agent, calcium hydroxide, and most latest being mineral trioxide aggregate.

Zinc oxide eugenol

Predominantly zinc oxide eugenol is used in dentistry as a temporary restorative material and cavity base.[3] Zinc oxide eugenol was introduced as a pulp capping agent as it was known to exhibit sedative and palliative effects.[4] However, over a period of time it was seen that it released eugenol which was felt to be cytotoxic towards pulp and caused ample amount of interfacial leakage leading to decreased effectiveness.[5] A study wherein, zinc oxide eugenol was used as a pulp capping agent over a period of 12 weeks showed no pulpal healing and no dentin bridge formation leading to poor clinical clinical results and chronic inflammation of pulp.

Glass ionomer cement modified with resin (RMGIC) or Glass ionomer cement (GIC).

Glass ionomer cement, due to its ability to resist bacterial invasion and prevent micro-leakage is primarily used as a base with amalgam and gold restorations and composite restorations respectively.[3-4]

As, it has the ability to bind chemically with the tooth structure that prevents the penetration of potentially toxic materials into the pulp, it is proven beneficial when used in close approximation to the pulp rather than having a direct contact with the pulp due to its cytotoxic property.[6]

Direct pulp capping with resin-modified glass ionomer cement shows to induce chronic inflammation with no reparative dentin formation, therefore giving a poor clinical outcome.

Bonding agents

In 1990's adhesives and bonding agents were brought into the picture for direct pulp capping . However, several studies showed poor pulpal healing when they were placed over exposed pulps that were infected with bacteria. Resin adhesives are basically vasodilators that cause increased bleeding thereby reducing the healing ability of the pulp.[7] The components of adhesive systems are also seen to be cytotoxic to pulpal cells specially with increased duration of contact with the pulp.[8]Unpolymerzied components were seen to be more toxic than the polymerized components.[7] Therefore, with increased bleeding due to vasodilators that causes increased moisture at the pulp capping site causes the reduction in polymerization thereby, degrading adhesion resulting in poor seal and poor clinical outcome. Therefore, it is no more suggested to use bonding agents as pulp capping agent.

Calcium hydroxide

In 1921, calcium hydroxide was introduced in dentistry as a cavity liner and after a human study in 1930 it got popularized as a pulp capping agent and has been considered as a gold standard ever since.[9]A study found 100% reduction in microorganisms that were associated with pulp infection when calcium hydroxide was in direct contact with the pulp. Due to its high alkaline pH(12.5) it causes liquefaction necrosis of the superficial layer of the pulp (approximately 1.5mm) resolving the inflamed part of the pulp. The toxicity levels of calcium hydroxide may lead to coagulative necrosis of deeper part of the pulp which causes mild inflammatory response, however, with the absence of any microbial action this inflammatory response leads to the formation of dentin barrier. It has the ability to solubilize proteins like Bone Morphogenic protein and Transforming growth factor- Beta 1, leading credence to the

release of bioactive molecules which are responsible for stimulating pulpal repair and this is the base mechanism of action. This decreases bacterial invasion and increases reparative dentin formation.[3]
Certain criticism that are associated with it are, formation of tunnel defects in the reparative dentin formed beneath the layer of calcium hydroxide.[3] However, this material shows a long term track record of clinical success (10 years) when compared to other pre-existing materials.

Mineral trioxide aggregate (MTA)
MTA is mainly used in dentistry as a cement used in root canal therapy, introduced in 1999, by Mahmoud Torabinejad. MTA substantially is calcium hydroxide that comprises of dicalcium silicates, tricalcium silicates and tricalcium aluminates amidst which bismuth oxide is incorporated as a radiopacifier.[3] MTA is predominantly available in two forms gray and white with the difference in both the forms being iron is an additive to the gray MTA.[10] MTA in several accounts resemble the potential mechanism of action of calcium hydroxide on the basis of biocompatibility, radiopacity, and with a aid to release bioactive molecules essential for reparative dentin formation and high pH. As per Li et al, MTA provides a better seal as compared to calcium hydroxide and prevents micro-leakage up to maximum degree, enhances the migration of tissue producing cells thereby, increasing tissue regeneration.[11-12]
MTA however, comes with a set of limitations some of them being, prolonged setting time, estimated to be 2 hours and 45 minutes, gray MTA causes darkening of tooth structure, due its high solubility its demonstrated a loss of 24% after 78 days of storage in water.[13] The handling characteristics of two paste formulation of MTA is different from calcium hydroxide which is easier for many operators.
MTA as a pulp capping material in certain clinical trials have shown to have comparable results to calcium hydroxide, however, certain short term studies with a clinical follow up period of two years suggested MTA to have superior clinical results than calcium hydroxide (Hilton et al, 2013).[14] Li. et al, 2015, in a systematic review and meta-analysis proved MTA to have less pulpal inflammation and better reparative dentin formation than calcium hydroxide.[11]

PULPOTOMY MATERIALS
Pulpotomy is performed on teeth with voluminous caries, wherein the infected coronal part of the pulp is amputated provided there is no evidence of radicular pathology. The remaining vital radicular pulp portion is then treated with long-term clinically successful medicaments.
Don M Ranly categorized pulpotomy based on treatment objectives into[15] :
1) Devitalization (Mummification, Cauterization)
2) Preservation (minimal devitalization, noninductive)
3) Regeneration (inductive, reparative).
Electrosurgery and lasers were included as non-chemical methods of pulpotomy.

Devitalizationpulpotomy
Formocresol as an agent in devitalizationpulpotomy was introduced by Buckley in 1904 and Sweet's brought in multiple - visit formocresol technique to mummify the pulpal tissue completely. Once the tissue is completely fixed, the radicular pulp was devitalized, thereby eliminating infection. This was considered as a highly successful technique.[15] According to Buckley's formula, formocresol included cresol 35%, formaldehyde 19%, glycerine 15% and water with an pH of 5.1. Commercially available products have varying concentrations for example sultan formocresol marketed in India comprises of 48.5% formaldehyde, 48.5% cresol and 3% glycerine. Despite researches spanning over 50 years, researchers cannot explain how two toxic materials like formaldehyde and cresol can be put to use beneficially. According to IARC (June 2004) formocresol was termed as highly carcinogenic and had the

potency to induce nasopharyngeal carcinoma and leukemia. However, Ranly differed by reporting that 3000 formocresolpulpotomies have to be carried out in the same individual to reach the toxic levels.[16]
Salako et al in 2003 carried out a study on rat molars wherein the teeth treated with formocresolpulpotomy were sectioned and after an observation period showed a zone of necrosis beyond the pulpotomy site and an atropic zone was seen beyond the pulpotomy site in 4 weeks old samples followed by fibrous tissue formation in the radicular pulp. Calcific deposits were noted in the coronal portion of the pulp, in some cases.[17]

Preservative pulpotomy
Materials used in preservative pulpotomy technique maintain the vitality and the normal histological appearance of the radicular pulp producing minimal insult to the orifice tissue.
The predominant materials use in this category are glutaraldehyde, ferric sulphate and zinc oxide eugenol.

Glutaraldehyde
To overcome the limitations formocresol posed, s'-Gravenmade in 1975 proposed glutaraldehyde which has a cross-linking ability prevailing over formocresol.[18] Due to the elimination of cresol from the composition, better fixative properties, and lower level of antigenicity, glutaraldehyde was considered as an alternative for formocresol. Gracia-Godoy reported a high success rate of glutaraldehyde along with its drawbacks which included being less cost-effective and inadequate fixation which leads to deficient barrier over the pulp becoming susceptible to irritation, resulting in internal resorption.[19] Tagger et al in 1984 carried out a study showcasing the outcome of glutaraldehyde, where, in some instances, the teeth had lost entire pulpal integrity. In some cases, macrophages infiltration was seen in the tissue at the canal orifice, in the vital part of the tissue dentin chips were seen to be embedded. The canal was narrowed at a certain distance from the orifice due to peripheral deposition of calcified tissue. Calcio-traumatic line separated this deposition of calcified tissue from pre-operative secondary dentin.[20]

Ferric sulphate
A study on 12-month clinical evaluation of ferric sulphate as a pulpotomy agent showed excellent results however, a more recent study revealed less favorable results due to heavy metal coagulation, subdues the pulp. In 2003, Salako et al conducted a study on rat molars which after treatment, and sectioning were viewed at 2 weeks and 4 weeks. A similarity was noted in terms of outcome in both the weeks, with complete pulpal destruction and some areas of acute inflammatory infiltrate. Clot formation seemed to have replaced the pulpal cells along with some calcific tissue deposition in radicular as well as coronal pulp.[17]

Zinc oxide eugenol
This material has been considered as a workhorse of early dentistry and thus it was adapted as a pulpotomy agent. Magnusson gave a comprehensive histological analysis which demonstrated internal resorption and inflammation at the amputate site,as a resultant of pulpotomies with zinc oxide eugenol due to the undesirable properties of eugenol.[21] ZOE when in direct contact with pulp causes moderate to severe inflammation therefore, reinforced ZOE was launched. This is composed of a polymethyl methacrylate, zinc oxide, acetic acid, and eugenol. Gonzales- Lara et al, conducted a study wherein, pulpotomy was carried out using ZOE with a follow-up period of 24 months, it appeared that over the remnants of pulp, a layer of dentin like tissue had formed with no stained bacteria observed in any of the samples. However, a sample

of failed pulpotomy case was taken and a layer of immature cells probably primitive dentine-like cells were seen in that case too suggestive of reparative dentin.[22]

Regenerative pulpotomy

Also called reparative pulpotomy or inductive pulpotomy. Ranly affirmed, "the radicular pulp should be left healthy and vital, and also completely encompassed within an odontoblast lined dentin chamber after an ideal pulpotomy is carried out.". Unlike the other two categories, this form of a pulpotomy is based on sound biologic principle.[15]

Certain materials known to be used in this category are calcium hydroxide, bone morphogenic protein, and mineral trioxide aggregate.

Calcium hydroxide

One of the first agents to be used in pulpotomies, it has been demonstrated to induce regenerative dentin. The rationale that prompted its use by Zander was fundamentally erroneous as he attributed the mechanism of action to be a modification of solubility product of phosphate, calcium, and precipitation of salt into an organic matrix. The mechanism of action is similar to that seen in direct pulp capping as mentioned earlier. Subramaniam P, reported a success rate of 70% when a thick paste of calcium hydroxide and water was used.[23] Schroder et al reported complete pulpal healing and dentin bridge formation with some cases showing failure due to internal resorption,however, Magnusson procured less impressive results.[24-25]

Bone Morphogenic Protein (BMP)

This material induces reparative dentin with recombinant dentinogenic proteins which are similar to native proteins of the body. Though it is very closely associated with collagen matrix, BMP'S are categorized as collagenous proteins. Rutherford studied the pulpal response in monkeys and stated that recombinant human osteogenic protein-1, BMP-7 prompted differentiation of adult pulpal cells into odontoblasts.[26]In a study by Silva et al, reported rhBMP did not show favorable results pertaining to dentin bridge formation. However, Loren K et al evoked the role of rhBMP-2 in pulpal healing in certain experimental studies.[27]

Mineral trioxide aggregate

Studies revealed MTA not only exhibited long term prognosis excellent sealing abilities and superior biocompatibility but also tissue regenerative properties. MTA has a pH of 10.2 and immediately after mixing it increases to 12.5 after 3 hours of setting and MTA when in direct contact with pulp boosts the formation of dentin bridge. In a histological study by Dominguez et al, MTA was reported to cause minimal pulpal inflammation.[28]In 2017, Taha et al assessed the outcome of pulpotomy using MTA in permanent teeth with carious exposure with a follow-up period of 3 months, 6 months, 1 year, and 3 years. It exhibited 100% clinical success and 97.5% radiographic success in the course of the first year and 92.7% success at the end of three years.[29]JafarEghbal et al in 2009, investigated MTA pulpotomy for treatment of irreversible pulpitis in human giving an outcome of histological success.[30]

Recent advances

A fair number of materials have pre-existed to make vital pulp therapy a viable treatment option however, all the above-listed materials exhibit varied limitations as well. There is a need to adapt better materials to improve the scope and better results in terms of treatment outcomes. Materials like Biodentine and Theracal have been put to use for pulpotomy and direct pulp caps in recent times. Taha et al in 2018, carried out a prospective study on pulpotomy using biodentine on cariously exposed young permanent teeth suggestive of irreversible pulpitis. With a recall period of 6 months and 1 year, an overall success rate of 95% was noted.[31]

In 2014, M Cannon et al conducted a study comparing the efficacy of Theracal LC with pure portland cement, resin-based calcium hydroxide, or glass ionomer cement as pulp capping agents in four primates. The results of which revealed at 28 days, Theracal LC and portland cement had formed significantly frequent hard tissue barrier and mild pulpal inflammation which was acceptable to be used as a pulp capping agent.[32]

When it comes to materials like calcium phosphate, Yoshimine et al, demonstrated that tetracalcium phosphate cement induced bridge formation with no superficial tissue necrosis when compared with calcium hydroxide.[33]

Hydroxyapatite is another biocompatible material with a neutral pH of 7.0. It is the most thermodynamically stable of all the synthetic calcium phosphate ceramics. It can also be used as scaffolding for newly formed mineralized tissue.[34]

Lasers - Yasuda Y et al did a study to examine the effect of CO2 laser irradiation on mineralization in dental pulp cells and the results suggested that CO2 laser irradiation stimulated mineralization in dental pulp cells.[34]

Many more materials like growth factors (recombinant insulin-like growth factor - I),simvastatin, stem cells, propolis (Russian penicillin) are also suggested to be a part of vital pulp therapy. However, more extensive research has to be carried out for them to be incorporated into clinical practice.[34]

2. CONCLUSION

Vital pulp therapy as a treatment modality is utilized to maintain the vitality of the pulp. Standard endodontic tests should reproduce symptoms and help distinguish between reversible pulpitis, irreversible pulpitis, and pulpal necrosis and this distinction is paramount since vital pulp therapy is only effective in reversible and irreversible pulpitis and not the last. Vital pulp therapy procedures like the direct pulp capping technique on mature permanent teeth are successful with a recall rate of 9 years post-operative. It is a minimally invasive, cost-effective procedure that saves time both for the patient as well as the clinician. Vital pulp therapy could have a profound effect on the quality of life of the patients especially those in underserved areas. It can have a tremendous impact on the lives of patients wherein root canal therapy is not affordable by many patients and thus extraction is elected.

DISCLOSURE

The authors had no disclosures to report.

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