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RESEARCH ARTICLE

RETROGRADE FILLING MATERIALS AND RECENT ADVANCES: A LITERATURE REVIEW.

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Abstract

The purpose of root end filling is to establish a seal between the root canal space and periradicular tissues. Almost every available dental restorative material has been used as root end filling material. Unlike the orthograde root canal filling materials root end filling materials are placed in direct contact with the vital periapical tissues. So thus the tissue responses of these materials become important and may influence the outcome of surgical endodontic treatment. This article reviews different root-end filling materials and compare their biocompatibility, sealing ability, anti-bacterial effects and microleakage.

Introduction:-

The main objective of all endodontic procedures is to obtain a hermetic seal between the periodontium and root canal system, so that no bacteria or bacterial by products can enter or leave from the canal. Apicectomy followed by retrograde filling is a common treatment when conventional root canal treatment has failed. Throughout the dental history, a wide variety of root end filling materials have been evaluated for biocompatibility, adhesiveness, dimensional stability, solubility, leakage etc in an attempt to identify the ideal material. A thorough understanding of the available materials is very important for the success of the treatment. Many materials have been used as root-end filling materials. These include amalgam, gutta percha, zinc-oxide eugenol cements (IRM, Super-EBA), MTA, Glass ionomer cements, composite resins, compomers, diaket, Biodentine, Ceramicrete, Bioaggregate, EndoSequence, etc.

Root-end filling materials should:-

1. Adhere or bond to tooth tissue and ‘‘seal’’ the root end three dimensionally
2. Not promote, and preferably inhibit, the growth of pathogenic microorganisms
3. Be dimensionally stable and unaffected by moisture in either the set or unset state
4. Be well tolerated by periradicular tissues with no inflammatory reactions
5. Stimulate the regeneration of normal periodontium
6. Be nontoxic both locally and systemically
7. Not corrode or be electrochemically active
8. Not stain the tooth or the periradicular tissues
9. Be easily distinguishable on radiographs
10. Have a long shelf life, be easy to handle

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Amalgam:-

It is the most extensively used retrofilling material from past seven decades. Farrar (1884) first reported amalgam as a root end filling material. Later Rhein (1897), Faulhaber and Newmann (1912), Happels (1914) and Garvin (1919) supported to the use of amalgam as root end filling materials. It is easy to manipulate, has self-sealing capacity, is radio-opaque and insoluble in tissue fluids because of the formation of corrosion products. The preferred amalgam is high copper-zinc free. It remains as a standard to which other materials are compared.

Studies by Tronstad., *et al*.[4] and Abdul., *et al*. [5] have found that the apical seal is significantly improved when varnish was applied to the cavity prior to the placement of a retrograde amalgam filling. Other comparative studies showed that freshly mixed conventional amalgams are very cytotoxic due to unreacted mercury with cytotoxicity decreasing as the material hardens. Scientists show concern about the free mercury and its potential toxicity. [6] Zhu., *et a*l. [7] suggested that amalgam had higher cell toxicity to human periodontal ligament cells and human osteoblast-like cells than IRM and Super-EBA.

Electrochemical corrosion products of amalgam were reported to be responsible for failure of root-end fillings. [8] A study of tissue response to various root-end filling materials done by Chong *et al* in 1997 showed that all roots filled with amalgam showed moderate or severe inflammation. Scattering of excess amalgam particles during placement of the root-end filling can lead to corrosion of the implanted material and cause unsightly amalgam tattoos. [9] Also, it does not seal the root end three-dimensionally and does not prevent the leakage of microorganisms and their products in the peri-radicular tissues. [10,11] Many clinical studies have shown poor outcomes with amalgam root-end fillings and amalgam can no longer be considered as the ideal root-end filling material.[12] Due to these reasons in recent times, amalgam is not a favourite material for root end filling.

Gutta Percha:-

Gutta Percha was introduced by Bowman in 1867. It is the most popular and most commonly used core filling material in endodontics. It is a trans-isomer of polyisoprene, existing in alpha and beta crystalline forms. Friedman described its composition as consisting of 20% gutta-percha matrix, 60% zinc oxide filler, 11% heavy metal sulphates as radioopacifiers and 3% waxes as plasticizers.[13] Thermoplasticized gutta percha has a better sealing ability when compared to amalgam. It absorbs moisture from the periapical region and expands initially, which is later followed by contraction. This contraction leads to poor marginal adaptation and leakage. [14]

Although this nonresorbable, biocompatible material has good handling characteristics it has the following disadvantages:

1. It is moisture sensitive.
2. The apical seal depends on the structure of the gutta-percha, its degree and condensation, and the nature and amount of root canal sealer used.
3. There is a tendency for its margins to open when the canal root interface is cut, heated or burnished.

Zinc Oxide Eugenol Cements:-

The most commonly used zinc oxide cements are Super EBA and IRM. IRM is 80% zinc oxide, 20% polymethylmethacrylate, with the liquid being 99% eugenol. Super EBA is 60% zinc oxide, 30% alumina, 6% natural resin, with the liquid being 37.5% eugenol and 62.5% ortho- ethoxybenzoic acid. These cements have excellent sealing capability and are non toxic after setting. The use of Super EBA of root-end filling material was suggested by Oynick [15] in 1978. They reported that collagen fibers grew over Super EBA root-end fillings and claimed the material to be biocompatible. Baek *et al.* [16] compared the periapical tissue responses and cementum regeneration in response to three widely used root-end filling materials, amalgam, SuperEBA, and Mineral Trioxide Aggregate (MTA) and found that Super EBA was superior to amalgam as a root-end filling material. Reports show a good healing response to super-EBA with minimal chronic inflammation at the root apex. But, super-EBA is radioluscent and technique sensitive. The eugenol content of super-EBA may be a source of irritation to the tissues. [17]

IRM is zinc oxide eugenol cement modified by addition of 20% polymethyl methacrylate by weight to the powder. The effect of IRM as a root-end filling placed in teeth prior to replantation was observed by Pitt Ford et al in 1994 and the tissue response was found to be less severe than that to amalgam. Eugenol in IRM may have an affinity for poly methyl methacrylate which reduces its release into the tissues, thereby reducing the cytotoxicity. [18] Harikaran *et al.* [19] evaluated the sealing ability of tree different materials for retrograde filling and revealed that the dye leakage scores were lowest in IRM. The sealing ability of IRM was significantly better than amalgam and glass-ionomer. Trope *et al*.[20] in a histological study confirmed the good tissue response to both EBA and IRM.

These zinc oxide cements have the following disadvantages:
1. They are moisture sensitive.
2. They cause initial tissue irritation.
3. Resorbability is questionable.

Glass Ionomer Cement:-
Glass ionomer cement was introduced as a new restorative material in the early 1970s. They are based on the reaction of ion-leachable, acid soluble calcium fluoro aluminosilicate glass particles with polyalkenoic acid. They possess adhesive properties forming a chemical bond with dentin, and have a significant fluoride releasing property. These cements are easy to handle and does not cause any adverse histological reaction in the periapical tissue.[21] Chong *et al.* [22] used light cure, resin reinforced GIC as a retro- grade filling material. It showed least microleakage due to less moisture sensitivity, less curing shrinkage and deeper penetration of polymer into dentin surface. According to MacNeil K *et al.* [23] sealing ability of GIC was adversely affected when the root end cavities were contaminated with moisture at the time of placement of cement. A study used light cure, resin reinforced GIC as a retro- grade filling material. It showed least microleakage due to less moisture sensitivity, less curing shrinkage and deeper penetration of polymer into dentin surface.[24] It is reported that newer glass ionomer cements containing glass-metal powder have less leakage and showed no pathologic signs.[25] One of the disadvantage of glass ionomers is the root preparation must be absolutely dry and seal is adversely affected by moisture and low pH.

Composite Resins:-
Composite resins are used as a retrograde filling with a bonding agent. Conventional composite resins contain a polymerizable organic matrix, inorganic fillers and a silane coupling agent. TEGDMA, Bis-GMA and UDMA have been detected in aqueous extracts [26] and formaldehyde can liberate over a long-time period. [27] These components may be the reason why the material exhibits highly anti- bacterial effects against *P. gingivalis, P. intermedia, P. endodontalis, F. Nucleatum.* [28] Rud *et al* have shown excellent long term clinical success with Retroplast composite resin root-end fill and Gluma dentin bonding agent. But, presence of a dry field during placement is important. Using composite resin for retrograde filling allows for more conservative preparation of the root- end cavity. Rud *et. al* [29] have suggested a slightly concave root-end preparations followed by bonding to the entire resected root end. Some authors have reported that some composite resins have cytotoxic effect that may persist 30 days or longer. [30]

Compomers:-
Compomers which are poly-acid modified composite resins were developed to combine the fluoride releasing property of glass ionomer cements with the mechanical properties of composite resins. The setting reaction is an addition polymerization which is light-initiated, similar to composite resins. The monomer contains acidic functional groups and the material sets via a free radical polymerization reaction. It does not bond to tooth structure like glass ionomer cement but need a bonding agent like composite resins. [31] Gingival tissues appear to adhere to the material, allows fibroblasts to reform around the root apex in which compomer root-end filling is placed.[32] Dyract has been shown to have good anti-bacterial effects against P.*gingivalis*, P.*intermedia*, P.*endodontalis* and F.*nucleatum*. the release of residual monomers and additives after polymerization may be the reason for the anti-bacterial effect. The results of an electrochemical study of the sealing ability of super-EBA, MTA and Dyract-flow showed that the sealing ability of Dyract-flow is equal to that of super-EBA and MTA. [33]

Diaket:-
Diaket, which is normally used as a root canal sealer has been used as a root-end filling when mixed to a thicker consistency. As a root canal sealer, it was shown to be tolerated by the tissues. Stewart in 1958 showed that Diaket is impervious to methylene blue dye and does not dissolve or absorb in the presence of periradicular tissue and fluids. As a root-end filling, diaket is shown to have superior sealing qualities when compared to amalgam. [34] Diaket also shows a good healing response characterized by bone apposition, reformation of periodontal ligament and deposition of new cementum. [35]

Mineral Trioxide Agreggate:-
It was developed by Torabinejad at Loma Linda University, CA, USA in 1993. The main molecules present in MTA are calcium and phosphorous ions, derived primarily from tricalcium silicate, tricalcium aluminate, tricalcium oxide

and silicate oxide. Its pH when set is 12.5 and its setting time is 2 hours and 45 minutes. The compressive strength of MTA is reported to be 40 MPa immediately after setting and increases to 70MPa after 21 days. [36] According to a clinical study done by Chong and Pitt ford in 2003 comparing MTA and IRM, the use of MTA showed a higher success rate. MTA has shown promising results due to its good sealing properties, bioactivity, and potential to stimulate cementogenesis. The main advantages of MTA are its biocompatibility and its osteogenic and regenerative potential [37].MTA has been demonstrated to have better anti-bacterial properties against E.*faecalis,* S.*aureus* and P.*aeruginosa* compared to other materials. Augmentation of new cementum is

necessary to make the apical barrier more resistant to penetration of micro organism biological barrier. Scanning electron microscopic analysis indicated that cementoblast could reattach and grow on MTA. In addition strong expression of osteocalcin gene was seen after application of MTA. MTA also increases the production of both proinflammatory and anti inflammatory cytokines from osteoblasts. The use of MTA has been shown to induce cementum formation and periodontal regeneration with induction of least amount of inflammation. Tissue culture experiments suggest that MTA induces cementogenesis, permitted cementoblast attachment and growth. MTA shows no toxic effects on cells and is reported to cause an increase in cell proliferation and released calcium in high amounts. [38] A disadvantage is its slow setting and less resistance against washing out during placement.

Newer Materials:-

Castor Oil Polymer:-

It is obtained from a common tropical plant Riccinus Communis, it is widely used in medicine for prostheses to replace bone because it is biocompatible, non- toxic and easy to handle. This biopolymer presents a chain of fatty acids whose molecular structures are also present in lipids of human body. It is shown to be biocompatible, non-toxic and easy to handle. [39] Martins et al [40] , in their study comparing sealing ability of MTA, COP and GIC as root end filling material have reported that the COP group showed decreased dye penetration than MTA and GIC when the depth of retropreparation was 1.5mm.

Ceramicrete:-

This material has hydroxyapatite powder and cerium oxide radioopaque fillers. This material is biocompatible and radiopaque and is also known to release calcium and phosphate ions during setting. [41] It is a self-setting phosphate ceramic that sets using an acid-base reaction to form a potassium magnesium phosphate hexahydrate ceramic matrix phase. Its mechanical properties were improved by adding calcium silicate whiskers to produce a phosphosilicate ceramic material. [42] A comparison of the root-end seal achieved using Ceramicrete, Bioaggregate and White MTA was done to study the prevention of glucose penetration. Both Bioaggregate and Ceramicrete showed similar sealing ability to MTA, with Ceramicrete showing significantly better results than Bioaggregate. [43]

An *in vitro* study was done to evaluate the ceramicrete based material as a root-end sealing material. This study used a ceramicretebased powder mixed with deionized water. This study showed that ceramicrete had a radioopacity similar to root dentin, and the sealing ability was higher compared to a SuperEBA and ProRoot MTA group. This excellent apical seal was attributed to its impervious nature and also the use of an acidic $MgH_2PO_4.H_2O$ solution as a conditioner to remove the smear layer which is believed to have improved the adaptation of ceramicrete with the dentin. On immersion of the set ceramicrete material in a Phosphate containing fluid (PCF), there was formation of Dicalcium phosphate dihydrate (DPCD) or hydroxapatite on the surface. This is due to the reaction of calcium disilicate from the ceramicrete material with the phosphate from the PCF. Thus, ceramicrete shows potential bioactivity. [44]

Biodentine:-

It is a calcium silicate based material introduced in 2010 and is used as a material for crown and root dentin repair treatment, repair of perforations, apexifications, resorption repair and root-end fillings. [45] The main component is a highly purified tricalcium silicate powder that contains small amounts of dicalcium silicate, calcium carbonate, and a radioopaquer. The interfacial properties of dentin biodentine interface were studied under microscope and tag-like microstructures were detected. The flowable consistency of Biodentine penetrates dentinal tubules and helps in the mechanical properties of the interface. [46] Investigation of the bioactivity of Biodentine, MTA and new Tricalcium silicate cement revealed that all three cements allowed the deposition of hydroxyapatite on the surface. This shows that all three materials are bioactive. [47] An in vitro study to compare the sealing ability of MTA, Calcium phosphate cement and Biodentine MTA showed the highest seal and the least dye absorbance. Biodentine showed a seal slightly less than MTA but, higher than Calcium phosphate cement. [48]

Bioaggregate:-

Bioaggregate is a new bioceramic root repair and root-end filling material composed of a powder component consisting of tricalcium silicate, dicalcium silicate, tantalum pentoxide, calcium phosphate monobasic and amorphous silicon oxide and a liquid component of deionized water. Bioaggregate and MTA on human pulp and PDL cell growth was determined byexamining the cells grown on this cement using a phase microscope. An inhibition zone was detected in the pulp and PDL cell culture grown with MTA. Bioaggregate showed no inhibition zone around the material. Bioaggregate was found to be non-toxic to human pulp and PDL cells. [49] In a study done to compare the cytotoxicity of ProRoot MTA and DiaRoot Bioaggregate, Bioaggregate showed a significantly better inflammatory reaction and foreign body reaction than the MTA group. Bioaggregate appeared to be more biocompatible than MTA. [50] Bioaggregate has an excellent hermetic seal which can be attributed to its nano-sized particles that adhere to the dentinal wall, and its hydrophilic nature.

Endosequence:-

Endosequence is a new bioceramic material consisting of calcium silicates, monobasic calcium phosphate, and zirconium oxide. It is radioopaque, biocompatible and bioactive. Its high pH contributes to its antimicrobial activity. [51] ERRM has been shown to have negligible cytotoxicity and capability to induce cytokine expression similar to MTA. [52] The bioactivity was tested in a study by exposing the set material in phosphate-buffered saline. There was precipitation of apatite crystalline structures, which is indicative of its bioactivity. [53]

Generex A:-

Generex A is calcium silicate based cement and is similar to MTA but the handling properties are different. Instead of water the cement is mixed with a special gel. The final consistency is similar to IRM like dough and easy to manipulate. [54] It is the only new generation endodontic material which allowed osteoblast growth as compared to MTA.

Capasio:-

Capasio (Primus Consulting, Bradenton, FL, USA) is composed primarily of bismuth oxide, dental glass, and calcium alumino-silicate with a silica and polyvinyl acetate based gel. A recent study found that Capasio and MTA promote apatite deposition when exposed to synthetic tissue fluid thus had the mineralization capacity. [55] The same researchers also concluded that when used as a root-end filling material, Capasio is more likely to penetrate dentinal tubules.

Endobinder:-

EndoBinder is new cement which has calcium aluminate as the chief ingredient. It has properties similar to MTA but it does not have the disadvantages of MTA. During production, free magnesium oxide and calcium oxide are eliminated to avoid expansion of the material and ferric oxide which can cause tooth discolouration is also eliminated. Studies have shown endobinder to have good tissue response and biocompatibility. [56]

Conclusion:-

An ideal root-end filling material should meet the following characteristics which include providing a hermetic seal, to be non resorbable, non-toxic, non-carcinogenic, biocompatible and dimensionally stable. Of all the materials available, none satisfies all of the desired qualities. Based on various studies, dental amalgam should no longer be used because of its inadequate sealing, poor marginal adaptation and cytotoxic effect and of all the recent root end filling materials, MTA remains to be the material of choice and is considered the gold standard for all the future root end filling materials. Regardless of the retrograde filling material used, every effort should be made to thoroughly shape, clean and fill the root canal via orthograde approach.

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