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The endodontic materials – A narrative review

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Abstract

Current endodontic materials include those that have been thoroughly tested by scientific investigation, clinical usage, and time, as well as others that are the result of new knowledge in the field of dental materials. Article sections are devoted to obturation materials, sealers, irrigation materials, root-end filling materials, perforation repair materials and intracanal medicaments. Knowing the particular qualities of materials can aid the clinician in choosing those that are appropriate for a given situation. Properties, components, and rationale for the materials' use are presented to aid the clinician in choosing materials for a particular need.

When treating endodontic cases, clinicians need access to a variety of materials. There are different materials for each step of the treatment process, from cleaning a canal, to obturating a canal to sealing a canal once the procedure is complete. Selecting the right materials will help ensure a pleasant experience for the patient as well as a more predictable, successful outcome. Core build-up materials, for example, build up the core of the unhealthy tooth to allow for better crown retention, reduced sensitivity and increased strength. Endodontic intracanal lubricants help remove calcifications and the smear layer as well as lubricate the canal to facilitate canal shaping for obturation. Post systems enable clinicians to place restorations that wouldn't have been possible otherwise because of inadequate tooth structure.

There is a need to review recent advancements in the field of endodontic materials. This review article describes the advancement in endodontic materials.

Keywords: endodontic materials, calcium hydroxide, MTA, EDTA, bioceramic sealer

Introduction

Choosing the ideal dental product for a certain clinical use might be difficult. While highlighting the drawbacks of competing products, many dental materials are marketed as being new and improved. However, in situations where there are numerous options, the history and demonstrated clinical success of the originating products in any material category can occasionally serve as the deciding factor in selection in endodontics.

There are a variety of endodontic materials available today, some of which have undergone extensive testing through research, clinical application, and time, while others are the outcome of recent advancements in the field of dental materials. There are sections of the article devoted to root-end filling materials, sealers, irrigation materials, smear layer removal, and intracanal medications. Knowing the specific characteristics of various materials might help the doctor select those that are suited for a certain setting. To assist the physician in selecting materials for a specific requirement, properties, components, and the rationale for their usage are described [1].

Table 1: Summery of endodontic materials

Endodontic uses	Materials
Materials used in vital pulp therapy	1. $Ca(OH)_2$ 2. Zinc oxide eugenol cement 3. Corticosteroids and antibiotics 4. Polycarboxylate cement 5. Inert materials (Isobutyl cyanoacrylate and Tri calcium phosphate ceramic) Collagen 6. Bonding agents 4-META-MMA-TBB adhesives and hybridizing dentin bonding agents 7. Calcium phosphate 8. Hydroxyapatite 9. Lasers CO2 Nd: YAG

	10. Glass ionomer/ Resin modified glass ionomer. 11. Mineral trioxide aggregate 12. Bone sialoprotein 13. Biodentine ENZYMES Heme-Oxygenase-1 Simvastatin 14. Propolis 15. Novel endodontic cement 16. Emdogain
Materials used as root canal irrigants	1. Sodium hypochlorite 2. Ethylenediamine tetra-acetic acid 3. Chlorhexidine 4. Citric acid 5. MTAD 6. Tetraclean 7. Hydrogen peroxide 8. Iodine potassium iodide 9. 1-Hydroxyethylidene-1,1-bisphosphonate 10. QMiX
Intracanal medicaments	1. Calcium hydroxide 2. Chlorhexidine 3. Ledermix 4. Triple antibiotic paste 5. Bioactive glass
Root canal obturation materials	1. Core obturation materials 2. Root canal sealers (cementing medium)
Root-end filling materials	1. Amalgam 2. Zinc oxide eugenol cements 3. Composite resins (Retroplast) 4. Glass ionomer cements 5. Diaket (3M/ESPE, Seefeld, Germany) 6. Resin ionomer suspension and compomer 7. Other types of cement
Perforation repair materials	1. Indium foil 2. Amalgam 3. Zinc Oxide Eugenol 4. Super EBA 5. IRM (Intermediate Restorative Material) 6. Gutta Percha 7. Cavit 8. Glass Ionomer Cement 9. Metal-Modified Glass Ionomer Cement 10. Composite 11. Dentin chips 12. Decalcified Freezed Dried Bone 13. Calcium Phosphate Cement 14. Tricalcium Phosphate Cement 15. Hydroxyapatite 16. Calcium hydroxide

Materials used in vital pulp therapy

Phillip Pfaffhistorically carried out the first pulp capping surgery in 1756, packing a little piece of gold over an exposed critical pulp to aid in healing. However, the conditions under which the pulp capping procedure is carried out have a significant impact on its success, and the prognosis is affected by the age, type, site, and size of pulp exposure. The pulp capping material should also have the following desired qualities, for example.

- Stimulate reparative dentin formation
- Maintain pulpal vitality
- Release fluoride to prevent secondary caries
- Bactericidal or bacteriostatic
- Adhere to dentin
- Adhere to restorative material
- Resist forces during restoration placement and during the life of restoration.
- Sterile
- Radiopaque
- Provide bacterial seal [2]

Table 2: Summary of advantages and disadvantages of various pulp capping agents [3]

Pulp capping agent	Advantages	Disadvantages
Ca (OH)2 (1960's)	▪ Gold standard of direct pulp capping materials ▪ Excellent antibacterial properties ▪ Induction of mineralization ▪ Low cytotoxicity	▪ Highly soluble in oral fluids ▪ Subject to dissolution over time ▪ Extensive dentinformation obliterating the pulp chamber. ▪ Lack of adhesion ▪ Degradation after acid etching ▪ Presence of tunnels in reparative dentin

Zinc oxide eugenol cement (1960-70's)	▪ Reduces inflammation	▪ Lack of calcific bridge formation ▪ Releases eugenol in high concentration which is cytotoxic. ▪ Demonstrate interfacial leakage
Corticosteroids and antibiotics (1970's)	▪ Reduces pulp inflammation. ▪ Vancomycin + Ca (OH)2 • stimulated a more regular reparative dentin bridge.	▪ Should not be used in patients at risk from bacteremia.
Polycarboxylate cement (1970's)	▪ Chemically bond to the tooth structure	▪ Lack of antibacterial effect Fail to stimulate calcific bridge formation
Inert materials (1970's) (Isobutyl cyanoacrylate and Tri calcium phosphate ceramic)	▪ Reduces pulp inflammation Stimulate dentin bridge formation	▪ None of these materials have been promoted to the dental profession as a viable technique
Collagen (1980)	▪ Less irritating than Ca (OH)2 and promotes mineralization	▪ Does not help in thick dentin bridge formation
Bonding agents (1995) 4-META-MMA-TBB adhesives and hybridizing dentin bonding agents	▪ Superior adhesion to hard tissues Effective seal against microleakage.	▪ Absence of calcific bridge formation *In vivo* studies have demonstrated that the application of an adhesive resin directly onto a site of pulp exposure, or to a thin layer of dentin (less than 0.5 mm), causes dilatation and congestion of blood vessels as well as chronic inflammatory pulpal response
Calcium phosphate (1900's)	▪ Helps in bridge formation with no superficial tissue necrosis. ▪ Significant absence of pulp inflammation compared to Ca (OH)2 ▪ Good physical properties	▪ Clinical trials are necessary to evaluate this material
Hydroxyapatite (1995)	▪ Biocompatible ▪ Act as scaffold for the newly formed mineralized tissue	▪ Mild inflammation with superficial necrosis of pulp
Glass ionomer/ Resin modified glass ionomer (1995)	▪ Excellent bacterial seal ▪ Fluoride release, coefficient of thermal expansion and modulus of elasticity similar to dentin Bond to both enamel and dentin ▪ Good biocompatibility	▪ Causes chronic inflammation. ▪ Lack of dentin bridge formation ▪ Cytotoxic when in direct cell contact ▪ Poor physical properties, high solubility and slow setting rate RMGIC is more cytotoxic than conventional GIC, so it should not be applied directly to the pulp tissue
Mineral trioxide aggregate (1996-2008)	▪ Good biocompatibility ▪ Less pulpal inflammation ▪ More predictable hard tissue barrier formation in comparison to calcium hydroxide ▪ Antibacterial property ▪ Radiopacity ▪ Releases bioactive dentin matrix proteins	▪ More expensive ▪ Poor handling characteristics ▪ Long setting time ▪ Grey MTA causes tooth discoloration ▪ Two step procedure ▪ High solubility
Biodentine (2000)	▪ Biocompatible ▪ Good antimicrobial activity. ▪ Stimulate tertiary dentinformation. ▪ Stronger mechanically, less soluble and produces tighter seals compared to Ca (OH)2 ▪ Less setting time, good handling characteristics than MTA	▪ More long term clinical studies areneeded for a definitive evaluation of Biodentine
Propolis (2005-2010)	▪ Antioxidantantibacterial, antifungal, antiviral and anti-inflammatory properties ▪ Superior bridge formation compared to Dycal, similar results to MTA. ▪ Forms dental pulp collagen, reduces both pulp inflammation and degeneration. ▪ Stimulate reparative dentin formation	▪ Showed mild/moderate inflammation after 2,4 weeks with partial dentinal bridge formation.
Endo sequence root repair material (2010-11)	▪ Antibacterial property ▪ Less cytotoxic than MTA, Dycal and light cure Ca (OH)2	▪ Bioactivity of the cells as well as ALP activity were decreased gradually when exposed to ERRM

Materials used as root canal irrigants

The removal of pulpal tissue, bacteria, and shavings of dentine from the canal comes after a straight-line access cavity has been created. Mechanical preparation and chemical irrigation are used to accomplish this. The success of the therapy depends on the effectiveness of root canal irrigation, which is crucial for the cleaning of the root canal system [4]

Ideal properties of root canal Irrigants

- Broad antimicrobial spectrum
- High efficacy against anaerobic and facultative microorganisms organized in biofilms.

- Able to dissolve necrotic pulp tissue remnants.
- Able to inactivate endotoxins.
- Able to prevent the formation of a smear layer during instrumentation or to dissolve it once formed.
- Systemically, nontoxic, non-antigenic, and non-cariogenic if it comes in contact with vital tissues.
- Non caustic to periodontal tissues
- Little potential to cause an anaphylactic reaction.
- Has low surface tension.
- Does not stain tooth structure
- Has no adverse effects on the sealing ability of filling material
- Relatively inexpensive [5]

Table 3: Properties and effects of different irrigants used during root canal treatment.

Irrigant	Antibacterial effect	Dissolution of tissues	Smear layer removal	Concentration (%)
NaOCl	Effective antibacterial agent bybreaking down proteins into aminoacids	▪ Dissolves necrotic tissue at low concentration ▪ At high concentration, it dissolves both vital and necrotic tissues	Removes the organic part of smear layer (Goldman *et al*., 1976)	0.5-6.25
EDTA	Limited antibacterial effect	Limited antibacterial effect	Removes the inorganic part of smear layer	17
CHX	Effective antibacterial agent against Gram negative, Gram, Gram positive, and yeasts	No dissolution capacity	No smear layer removal	2
MTAD	Antibacterial effect due to doxycycline	No dissolution capacity	Removes smear layer through doxycycline and citric acid	
Citric acid	No antibacterial effect	No dissolution capacity	Removes smear layer	10-50
QMiX	Antibacterial effect	No dissolution capacity	Removes smear layer	

Intracanal medicaments

In order to prevent bacterial growth between appointments as a result of surviving microorganisms and leaky temporary restorations, intracanal medications are essential adjuncts. There are many compounds that can be employed as intracanal medications to increase the antibacterial efficacy of our cleaning techniques.

Calcium hydroxide

Calcium hydroxide has a particular importance in dentistry. It has been extensively used as an intracanal medicament since Hermann introduced it in 1920. It is a slurry of Ca $(OH)_2$ in a water base but can be mixed with either water or saline and should have a thick consistency in order to carry as many Ca $(OH)_2$ particles as possible. Chemically, calcium hydroxide is classified as a strong base with a high pH (approximately 12.5-12.8) that kills bacteria by direct contact [6]

Ledermix

Paste Ledermix was created in 1960 by Schroeder and Triadan and released for sale in 1962 by Lederle Pharmaceuticals. Ledermix paste contains an antibiotic demeclocycline - HCl (3.2%) and a corticosteroid, triamcinolone acetonide (1%), in a polyethylene glycol base The paste utilizes corticosteroids to control pain and inflammation related with pulp and periapical diseases [7]. Triamcinolone and demeclocycline are both capable of diffusing through dentinal tubules and cementum to reach the periradicular and periapical tissues, therefore antibiotic is added to Ledermix to make up for the apparent corticoid-induced reduction in the host immunological response [8].

The efficacy of Ledermix as an intracanal medication has been supported by numerous investigations [9–11]. Ledermix is water soluble, readily washed out, and does not have any systemic negative effects when used intravenously, making it ideal for use in endodontic therapy and in between appointments [12].

Triple antibiotics pastes

This medication contains the antibiotics metronidazole, ciprofloxacin, and minocycline in the form of a paste. This paste has also been used in regenerative endodontics and has the potential to be effective in eliminating bacteria [13]. Even though there was a periapical radiolucency and a drainingbuccal sinus tract present, it was clinically demonstrated that it stimulated root formation in young permanent teeth with an open apex [14]

Root canal obturation materials

Requirements for an ideal root filling materials. (Grossman)

- It should be easily introduced into the canal.
- It should seal the canal laterally as well as apically.
- It should not shrink after being inserted.
- It should be impervious to moisture.
- It should be bacteriostatic or at least not encourage bacterial growth.
- It should be radiopaque.
- It should not stain tooth structure.
- It should not irritate periapical tissue.
- It should be sterile, or quickly and easily sterilized before insertion.
- It should be easily removed from the root canal if necessary.

Gutta-percha

Gutta-percha crystals can form in either the α or β phase. The two only differ slightly in terms of physical and chemical characteristics. The b-phase, which predominates in the products used in endodontics, arises after refining and occurs in nature when the material is in the α phase. Supposedly more fluid and softening at a lower temperature, gutta-percha. Some complex statements depict a β core beneath an α gutta-percha surface. There is little, if any, evidence that this distinction is significant [15].

Gutta-percha points are made up of up to 80% zinc oxide and just 20% gutta-percha in their final form. Metal salts and a dye are included for color and radiographic contrast. Some producers include antimicrobials such calcium hydroxide as an example [16].

Resilon

A polyurethane thermoplastic root canal filling material is called Resilon. It is used with some sealants, including Resinate, RealSeal, and Epiphany. The goal of using this material was to create a "monoblock" in which the resilon sealer (epiphany) attaches to both the etched canal wall and the resilon cone. However, it is still debatable whether this goal can be successfully accomplished [17].

Root canal sealers

When performing an obturation, sealers are applied as a thin, tacky paste that acts as a lubricant and luting agent. This allows the core obturation material, such as gutta-percha points or other rigid materials, to slide in and become fixed in the canal [18, 19] Sealers can fill voids, [20] lateral canals, [21] and accessory canals where core obturation materials cannot infiltrate [22, 23]

Bioceramic-based sealers

Due to the development of these sealers from MTA and the intensive research and technological efforts aimed at enhancing the use of Bioceramic in endodontics, they are currently enjoying widespread appeal. Tricalcium Silicate is the primary component of MTA and MTA-like materials, which are valued for their outstanding sealing capabilities, hydrophilic characteristics, and bioactivity [25]

Table 4: Bioceramic-based sealers [24]

Bioceramic-based sealer	Description	Composition
MTA Fillapex (Angelus Industria de Produtos Odontologicos Ltda; Londrina, Parana, Brazil)	A resin MTA-based root canal sealer ▪ Available as a dual paste that are combined in a mixing tip	▪ Natural resin, salicylate resin, diluting resin, bismuth trioxide, nanoparticulated silica, MTA, and pigments
iRoot SP (Innovative BioCeramix Inc., Vancouver, BC, Canada) aka Endosequence BC sealer (Brasseler USA, Savannah, GA)	▪ A bioactive alkaline calcium silicate sealer ▪ Premixed readyto-use single paste	▪ Zirconium oxide, calcium silicates, calcium phosphate monobasic ▪ CH and filling and thickening agents
Endo CPM Sealer (EGEO SRL, Buenos Aires, Argentina)	▪ An MTA-based root canal sealer ▪ Powder/gel	▪ MTA in addition to calcium chloride, calcium carbonate, sodium citrate, propylene glycol alginate, and propylene glycol
MTA Plus (Avalon Biomed, Bradenton, FL) and (Prevest Denpro, Jammu City, India	▪ A calcium silicate sealer ▪ Powder/gel	▪ MTA powder with a finer particle size ▪ Two formulations are available either mixed with water or a hydrosoluble gel for decreasing washout property
Generex B ProRoot Endo Sealer (Dentsply Tulsa Dental Specialties, Tulsa, OK, United States)	▪ A calcium silicate sealer ▪ Mixed with a liquid-to-powder ratio of 1:2	▪ The powder is composed of tricalcium silicate, dicalcium silicate, calcium sulfate (as a setting retardant), bismuth oxide (as a radiopacifier), and a small amount of tricalcium aluminate ▪ The liquid is composed of water and a viscous watersoluble polymer
Mineral Trioxide Aggregate Sealer (MTAS)	▪ Powder-to-liquid ratio of 5:3 by weight	▪ Two formulas are available: ▪ The first one was introduced by Camilleri and associates consist of a mixture of 80% white Portland cement and 20% bismuth oxide ▪ The second one was introduced from Brazil and is composed of Portland cement, zirconium oxide (radiopacifier), calcium chloride, and a resinous vehicle

Resin based sealers

The popularity of resin sealers is attributed to their good adhesive qualities and absence of eugenol. These sealants are either urethane methacrylate resin sealants (such as Endo REZ and Epiphany) or epoxy-resin sealants (such as AH-26 and AH-plus). Hexamethylenetetramine (methenamine) is used for polymerization in the bisphenol epoxy resin sealer known as AH-26 (Dentsply International Maillefer). AH-26 exhibits improved radiopacity, low solubility, low polymerization shrinkage, and tissue compatibility in addition to its adhesive qualities. However, the main drawback of using this sealer is that the methenamine releases some formaldehyde as it sets [26].

Additionally, tooth discoloration and a longer workday are drawbacks. A variant of AH-26 called AH-plus (Dentsply International) has comparable sealing abilities without releasing formaldehyde [27]. The AH-plus sealer has a shorter working time (24 hours) and setting time than AH-26, as well as reduced solubility and higher radiopacity [28].

Root-end filling materials

A satisfactory outcome of periradicular surgery depends on how the resected root end is managed [29]. The part of the root apex that cannot be cleaned, shaped, or filled due to instrumentation limitations or that is linked to an extra radicular infection that is resistant to non-surgical treatment is excised. A "physical seal" is created by adding a filler substance to a prepared root-end cavity to stop the spread of germs or their byproducts into the surrounding periradicular tissues. One of the crucial procedures in managing the root end is placing a root-end filler [30].

After periradicular surgery, re-establishing an apical attachment apparatus and osseous repair is the ideal healing response [31, 32].

The requirements of an ideal root-end filling material [28, 30, 33]

- Root-end filling materials should:
- Adhere or bond to tooth tissue and ‘‘seal’’ the root end three dimensionally.
- Not promote, and preferably inhibit, the growth of pathogenic microorganisms

- Be dimensionally stable and unaffected by moisture in either the set or unset state.
- Be well tolerated by periradicular tissues with no inflammatory reactions.
- Stimulate the regeneration of normal periodontium.
- Be nontoxic both locally and systemically.
- Not corrode or be electrochemically active
- Not stain the tooth or the periradicular tissues.
- Be easily distinguishable on radiographs.
- Have a long shelf life, be easy to handle.

Perforation repair materials

Root perforations can develop iatrogenically during root canal therapy or pathologically as a result of resorption and caries. If not corrected, such perforations could negatively affect the course of treatment and continue to be a serious problem. Perforation may occur while preparing access cavities or the post-operative area, or it may happen as a result of internal resorption spreading into the periradicular tissues [34].

Ideal requirements of Root Repair Material [35]

- It should provide adequate seal.
- It should be biocompatible.
- It should have ability to produce osteogenesis and cementogenesis.
- It should be bacteriostatic, and radiopaque.
- It should also be beneficial to use a resorbable matrix in which a sealing material can be condensed.
- It should be relatively inexpensive.
- It should be non-toxic, non-cariogenic and easy to place.

No material offers all of these properties. In search for the ideal material, numerous sealing materials and techniques have been tested over the years with varying success.

- Indium foil
- Amalgam
- Plaster of Paris
- Zinc Oxide Eugenol
- Super EBA
- IRM (Intermediate Restorative Material)
- Gutta Percha
- Cavit
- Glass Ionomer Cement
- Metal-Modified Glass Ionomer Cement
- Composite
- Dentin chips
- Decalcified Freezed Dried Bone
- Calcium Phosphate Cement
- Tricalcium Phosphate Cement
- Hydroxyapatite
- Calcium hydroxide
- Portland Cement
- MTA
- Biodentine
- Endosequence
- Bio aggregate

Conclusion

The fundamentals of endodontic instruments and therapy are well known. An environment that supports periradicular healing is created by thoroughly cleaning the canal system to remove as much pulpal tissue, germs, and byproducts as feasible, followed by full obturation to avoid apical or coronal leaking. As a necessity for current root canal sealers, the philosophy of achieving a hermetic closure of the root apex has been replaced with the development of a fluid-tight antibacterial seal. The continuous development of new materials for endodontic therapy will be fueled by research and development of tools and materials.

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