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Intermediate Restorative Materials

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Authors' contributions

This work was carried out in collaboration between both authors. Author KJY took the lead in writing the manuscript. Author SM provided critical feedback and help shaped the manuscript. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Introduction: Intermediate restorative materials are materials that are intended to be used for temporary restoration that usually lasts up to a year. During treatment that requires multiple appointments, intermediate restorative materials can be used to cover the tooth structure to maintain occlusion, protect the pulp, seal the cavity from any external factors such as bacteria and fluid, and maintaining the periodontal relationship temporarily until treatment is finalized. Intermediate restorative materials are classified mainly according to their composition, they are zinc oxide-eugenol based, calcium sulfate-based, glass ionomer cement, and resin composite-based.
Aims: To review the composition, setting reaction, and usage of intermediate restorative materials mentioned above by accessing the Pub Med database.
Methodology: An advanced search was done in the PubMed-Medline resource database. Initially, keywords such as 'intermediate restorative material', 'temporary restorative material', and 'temporary restoration' are input into the search. After the initial search, the articles are reduced as the titles and years of the articles were screened through thoroughly to remove any irrelevant articles. On top of that, the abstract of the articles is read through thoroughly and finally, the articles with the relevant information are read in full texts to collect the articles with significant data

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for this narrative review. Other than that, articles and textbooks were also extracted from external journals.

Conclusion: It can be concluded that each materials can serve multiple purposes, their usage varies based on their advantages, although some materials may have some drawbacks such as cytotoxicity or weak strength, they could still be applied if their benefit outweighs the risks.

Keywords: Zinc oxide-eugenol cement; calcium sulfate; glass ionomer cements; composite resins; dental pulp cavity; powders; cavit; polymers.

1. INTRODUCTION

Intermediate restorative materials (IRM) are materials that are intended to be used for temporary restoration that usually lasts up to a year. During treatment that requires multiple appointments, IRM can be used to restore the tooth structure to maintain occlusion, protects the pulp, seal the cavity from any external factors such as bacteria and fluid, and maintain the periodontal relationship temporarily until treatment is completed [1]. In a situation where dental caries is treated over several appointments, IRM is used to stabilize dental caries to stop the progression [2]. As IRM is design for temporary restoration, it should allow replacement easily, but at the same time have reasonable strength, antibacterial property, radiopacity, ability to stimulate pulpal healing, abrasive resistance, and sealing ability so that the tooth can function normally before the permanent restoration is given [3,4]. IRM is majorly classified according to its composition. They are zinc oxide-eugenol (ZOE) based, calcium sulfate-based, glass ionomer cement (GIC), and composite resin-based [5]. This article will give an overview of the composition, setting reaction, and the other usage of IRM stated above besides being a temporary restorative material.

2. MATERIALS AND METHODS

An advanced search was done in the PubMed-Medline resource database. Initially, the keywords that were input into the search are 'intermediate restorative material', 'temporary restorative material', and 'temporary restoration'. After the initial search, the setting was altered so that only articles that were published from 2011 onward will appear. Next, the articles were further reduced as the titles of the articles were screened through thoroughly to remove any irrelevant articles. The abstract of the articles was read through and finally, the articles with the relevant information were read in full texts to collect the articles with significant data for this narrative review.

3. RESULTS

The initial search on PubMed with the keywords shows results of 706 articles. 346 articles are removed from the list as their publication date were before 2011. Next, 24 more articles were excluded as they did not have full-text versions. Afterwards, screening of the titles and abstracts was done, leading to the selection of 12 articles that had significant information about the topic of this review. In addition to that, 2 more articles and books that were manually selected were also added, making the total number of sources 14. From these 14 articles and textbook, further information was extracted and their sources of origin were explored, this allowed for more detailed information to be included in this review article.

4. DISCUSSION

4.1 Zinc Oxide-eugenol Based Materials

4.1.1 Composition

ZOE-based material is made up of two components, powder and liquid. The powder is composed of zinc oxide, rosin, and zinc acetate while the liquid is composed of eugenol and acetic acid. The rosin, which is another name for abietic acid, plays a role in reducing the fracture, increasing the strength and working time of the materials. On the other hand, zinc acetate and acetic acid are present to act as a catalyst to increase the rate of the reaction [6,7]. Modifications have been done to improve the mechanical properties of ZOE-based material, such as the addition of polymethyl methacrylate (PMM), alumina, and ethoxy benzoic acid (EBA) [8,9].

4.1.2 Setting reaction

The reaction between zinc oxide and eugenol occurs in the presence of water and is separated into two phases. First, zinc oxide reacts with water to form zinc hydroxide, which dissociates to form Zn2+ and OH-. Second, Zn2+ reacts with eugenolate to form zinc eugenolate chelation while OH- reacts with H+ to form water. This mixture takes four to ten minutes to set. The set cement form is consisting of an unstructured zinc eugenolate matrix enclosing the zinc oxide particles [6].

First

$$ZnO + H2O \rightarrow Zn(OH)2$$

Second

$$Zn(OH)2 + 2HE \rightarrow ZnE2 + H2O$$

4.1.3 Usage

ZOE is multifunctional, due to its properties such as antibacterial action, and good marginal sealing, it can be used as a temporary filling material, luting agent, base, and liner [10]. A luting agent is a material that can bond indirect restorative materials such as a crown, bridges, and orthodontic brackets onto teeth while a base is an insulating cement placed near the pulp to protect it from thermal and chemical injury [11]. ZOE is biocompatible given that it has a neutral pH and anodyne effect on hyperemic pulpal tissue, the eugenol that is released from the matrix has a sedative effect, making it suitable to be applied as pulp chamber filling materials after pulp treatment in primary teeth [6,7]. Despite that, ZOE has relatively low compressive strength and is considered the weakest luting agent for permanent cementation, though PMM and EBA had been added to increase the compressive strength, they are at risk of causing cytotoxicity such as skin, eye, and respiratory irritation [12,13]. Finally, ZOE-based materials should be avoided when restoration uses resin-based composite as the radical scavenging molecules in eugenol will inhibit polymerization of the monomer in resin-based composite [14].

4.2 Calcium Sulfate Based Materials

4.2.1 Composition

The main calcium sulfate-based material being used is Cavit, it contains zinc oxide, calcium sulfate, zinc sulfate, glycol acetate, polyvinyl acetate resins, polyvinyl chloride acetate, triethanolamine, and premixed pigments [15]. Other than that, there are other varieties such as Cavit-W and Cavit-G which have different resin content that subsequently affects their outcome of hardness and setting [16].

4.2.2 Setting reaction

The setting reaction of cavit occurs by water reacting with calcium sulfate and with zinc oxide which gives rise to zinc sulfate as the set material [17].

4.2.3 Usage

Cavit is mainly used as an IRM because it has an excellent sealing ability cause by high linear expansion from water absorption, it is also not affected by thermal cycling, a factor that leads to microleakage [17,18]. Other than that, it can be easily molded and removed from the cavity [19]. When it was evaluated based on its properties such as solubility, water absorption, and sealing ability to serve as an IRM for endodontic therapy, Cavit was observed to be better than the other IRM [20]. However, Cavit cannot be used as a base nor cementing material for a temporary crown due to its slow setting time, film thickness, and high hygroscopic expansion [17].

4.3 Glass Ionomer Cement

4.3.1 Composition

GIC is classified into two types, the conventional GIC and resin-modified GIC (RMGIC). A GIC is composed of three components, polymeric acid, basic glass, and water [21]. The polymeric acid is polyalkenoic acid namely homopolymer poly[acrylic] acid and the 2:1 copolymer of acrylic acid and maleic acid. The basic glass used is alumina-silicate that is calcium-based, to add radiopacity, calcium is sometimes substituted with strontium or lanthanum [6]. Fluoride is also part of the basic glass, it is added to lower the melting point of the material, and GIC is observed to release fluoride after they have set [22].

4.3.2 Setting reaction

GIC is commonly available in powder-liquid form, with glass being the powder and the acid being the solution, it can also exist as paste-paste, GIC is either mixed using hand or using auto-mixer if they are placed in a capsule. Hand mixing GIC and capsulated GIC are formulated differently, capsulated GIC would have to be deactivated slightly as the vibrating action is far more efficient than hand-mixing [22]. GIC sets by an acid-base reaction. First, when the acid comes into contact with the basic glass, H+ from the acid attack the basic surface of the glass particles, liberating F- and Ca2+ (or Sr2+), followed by Al3+. This process usually take two to three minutes. A rigid framework is then formed as the ions crosslink with the acid. Water is absorbed into the cement in the process. After the ionic cross-linking process which causes instant hardening, the cement undergoes a maturation phase where it continues to harden and become more translucent [23].

4.3.3 Usage

GIC is indicated for restorations in pediatric dentistry when the patient is uncooperative, it is easy to manipulate and save time under this condition as it bond to the tooth structure chemically without etching and priming, here, GIC plays a role as the fluoride-releasing material to stop caries progression while partial caries removal is carried out [24]. GIC can be used for other different purposes if their powder to liquid ratio is adjusted differently. If the mixture has a low powder to liquid ratio (1.5:2 to 3.8:1), it will set fast and have moderate strength, this mixture can be used for luting and bonding for prosthodontic and orthodontic appliances. If GIC has a high powder to liquid ratio (3:1 To 6.8:1), its color matches with the teeth and thus is suitable to be used for anterior teeth restorations, in pediatric cases if the ratio is 3:1 to 4:1, the appearance will be poorer so it will only be applied to the posterior restorations. Nonetheless, GIC is only ideal for class I restorations and not class II as they are observed to fail more often than other restorative materials [25].

Other than that, GIC can also be used as lining or base cement, fissure sealant, and as a restorative material in atraumatic restorative treatment (ART) [23,26]. ART is a type of caries management technique when there are limited facilities, as compared to drills and burs that are driven by electricity, this technique only uses hand instruments such as chisels and excavators to remove caries, GIC is then used to restore the cavity. Another reason why it was chosen is due to its adhesive properties which allow restorations to stay on tooth surfaces with minimal preparation [11]. When used as restorative material or luting agent, fluoride is released from GIC, fluoride could buffer acid in active caries and facilitate mineralization of teeth, forming fluorapatite crystals [27,28].

4.4 Resin Modified Glass Ionomer Cement

4.4.1 Composition

RMGIC contained all the components mentioned above, polymeric acid, basic glass, and water. The basic glass has a similar composition as those found in GIC, meanwhile, the polymeric acid may undergo modification such as the addition of monomer 2-hydroxyethyl (HEMA), pendant methacrylate group, and initiator (camphorquinone) for light-cured polymerization [29,30].

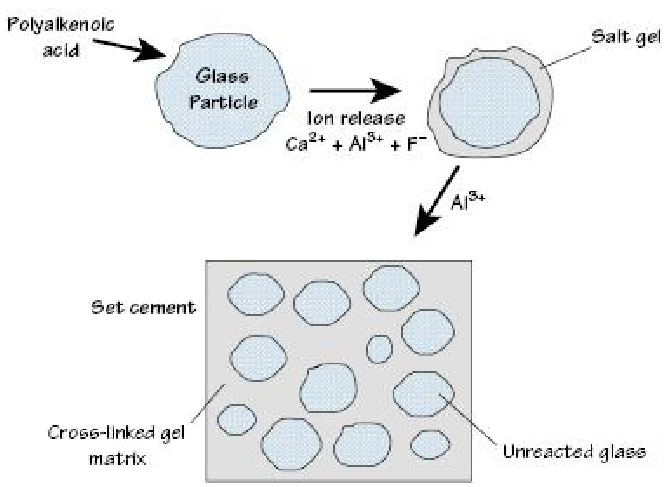

Fig. 1. Setting reaction of GIC

4.4.2 Setting reaction

RMGIC exists in many forms including powder-liquid, paste-paste, and capsules. The setting reaction of RMGIC is divided into two-part, first, RMGIC undergoes a light cure or self-cure radical polymerization of the extra components, HEMA, and pendant methacrylate group [31]. Secondly, RMGIC went through the same acid-base neutralization reaction as in GIC. As RMGIC has lower water content than GIC, the rate of this acid-base reaction is slower [6].

4.4.3 Usage

RMGIC has similar properties as the conventional GIC but they are more translucent and last longer than GIC in class II restorations [25]. RMGIC can be used for the same clinical applications as GIC. However, their biocompatibility is compromised as HEMA will leach out from the RMGIC in the first 24 hours of application [32]. This HEMA is cytotoxic to the pulp, causing inflammatory responses from mild to severe and it can be inhaled as vapor, therefore, RMGIC should be used in a well-ventilated area to prevent any health risks [33,34]. To add to the cytotoxic effect of HEMA, HEMA is found to be released in the cement more if the material is under cured, therefore, it is recommended that adequate mixing or light curing should be carried out to optimize the polymerization process [6]. Furthermore, the requirement of electronic lamps for curing makes it an unsuitable material to be used for ART [23].

4.5 Composite Resin Based Material

4.5.1 Composition

In dentistry, the word 'composite' is applied to materials with polymeric matrix and inert filler that is set by free radical addition polymerization [35]. Composite resin is a mixture of organic and inorganic components, the organic components are comprised of resin, initiator system, and a silane coupling agent while the inorganic component is the reinforcing fillers [36].

The resin is made up of dimethacrylate monomers, 2,2-bis[4-(2-hydroxy-3-methacrylyloxypropoxy)phenyl] propane (BisGMA) is generally used as the main monomer, however, its high viscosity makes it harder to manipulate, thus, low viscosity monomer such as triethylene glycol dimethacrylate (TEDGMA), and urethane dimethacrylate (UDMA) is usually added as a diluent to lower the viscosity of the monomer [38].

The initiator system used in modern composite resin is a photoinitiator that is sensitive to blue light [39]. Camphorquinone is the typical choice of photoinitiator being used, other choices may include 1-phenyl-1,2-propanedione (PPD) [40], monoacylphosphine oxide (Lucirin TPO), and bis-acylphosphine oxide [41]. PPD and bis-acylphosphine oxide appear less yellow than camphorquinone in visible light, thus they are chosen from the aesthetic point of view [36].

The last organic component in composite resin is the coupling agent, most often, silicon-based substances namely γ-methacryloxy-propyl tri-methoxysilane is used [30]. It enhances mechanical strength by promoting bonding of the filler particles and the resin matrix, it also prevents the entrance of water at the interface [42].

Finally, the last component to be introduced is the filler particles. Modern filler particles are produced from barium silicate or radio-opaque silicate glass. They are classified according to their sizes as shown in Fig. 2 below.

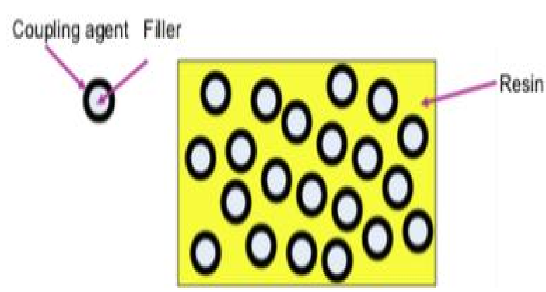

Fig. 2. Components of a composite resin [37]

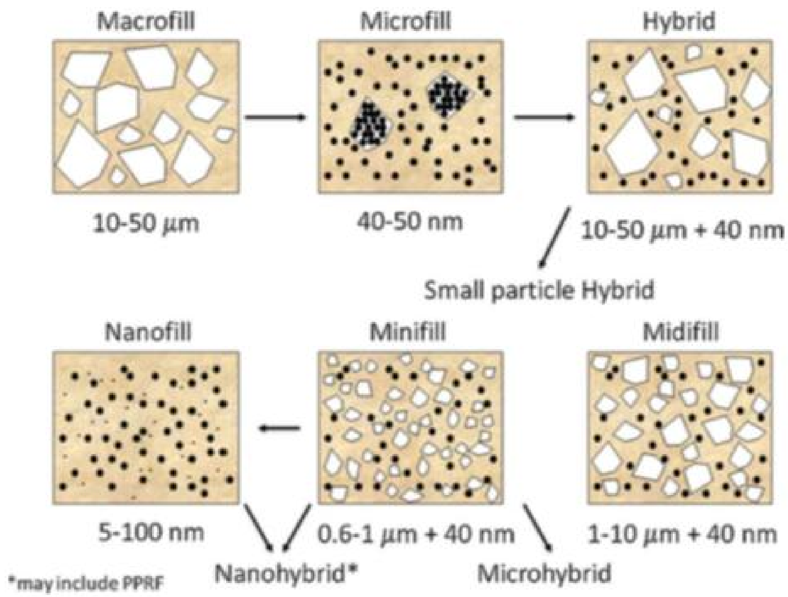

Fig. 3. Filler particles based on sizes [36]

4.5.2 Setting reaction

In general, composite resin is set by free radical polymerization that involves three steps. First is initiation, the initiator system is activated and free radicals are released, these free radicals react readily with the monomers to form a larger molecule. The second step is propagation, this defines the continuous addition of monomer molecule, forming a longer polymer chain [43]. Last is termination, this process means the polymerization process is completed. Free radical polymerization can be initiated by three processes, light curing, cold curing, and dual curing. For direct restorations and adhesive systems, the light-curing method is mostly employed [44,45]. Light curing happens when the photoinitiator absorbs the visible light and sets off the polymerization as mentioned above [37]. Cold curing initiated the process by a redox reaction that happens after mixing camphorquinone and dimethylamino ethyl methacrylate. Dual curing employ mechanism from both light- and cold-curing, it is mostly used in bulk -fill restorations, the redox reaction in the cold-curing mechanism will help to cure area that is unreachable by visible light [46].

4.5.3 Usage

Composite resin is commonly used as direct restorative material, however, its usage is not limited to this only, it can also serve other purposes as cavity liners, pit and fissure sealants, indirect restorations, cementing prosthodontic and orthodontic appliances, and sealers for endodontic treatment [36]. There are a few notes to be taken on the properties of composite resin, first, the pulp may be irritated by the heat produced from the polymerization process as it is exothermic in nature, thus, appropriate insulating material should be placed on to prevent sensitivity or damage.

Second, composite resin undergoes polymerization shrinkage, the extent to which they shrink depends on the number of addition polymerization that takes place, this is determined by the types of monomer used as shrinkage mainly occur in the resin part, composite resin will also have less shrinkage if their inert filler loadings are high. Polymerization shrinkage is to be taken note of because it will compromise the marginal seal and break the adhesive bond between tooth and restorations [30]. To avoid shrinkage in light-activated composite resin as much as possible, layering technique is used. The layering technique is applied to the composite restoration of a cavity that exceeds 2mm, this will ensure the composite resin is exposed to an adequate amount of lighting and the volume of contracting material is reduced to decrease polymerization shrinkage stresses [36]. Another determining factor of polymerization shrinkage is configuration factor (C factor), C factor stand for the ratio of internal surface to external surface. The shape of the cavity, angles of the wall, and the number of walls all will determine the C factor which in turn determine the behavior of polymerization shrinkage. To reduce shrinkage, the value of the C-factor should be small [47].

5. CONCLUSION

In conclusion, intermediate restorative materials are classified according to their composition, namely ZOE-based materials, calcium sulfate-based materials, GIC, and composite resin-based. Each material has different properties and is not only used as an IRM alone, their usage varies based on the advantages that they have, some may be applied as cement or liner. Although some materials may have some drawbacks such as cytotoxicity or weak strength, they will still be used if their benefit outweighs the risks.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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