Review Article

EFFECT OF NANO-FILLED GLASS IONOMER CEMENT ON THE REMINERALIZATION OF CARIES LESION: A LITERATURE REVIEW

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ABSTRACT

In dentistry, glass ionomer cement, or GICs, is used for a wide range of purposes. To improve upon glass ionomers' poor mechanical performance, many tweaks to traditional GICs have been implemented. The system, modification, or material size in the region of 1-100 nm is often used in nanotechnology. Reducing the size of the glass particles and adding nano-sized bioceramics to the glass powder are two ways to nano-modify traditional GICs and resin-modified glass ionomer cement (RMGICs). Searches of PubMed were conducted to learn more about the antibacterial characteristics of various restorative materials. To evaluate the antibacterial qualities of common filler materials, certain keywords were selected. Also discussed were techniques for incorporating antibacterial agents into restorative materials and methods for measuring their efficacy. According to research, the mechanical and bonding capabilities of commercially available nano-filled RMGIC are not noticeably better than those of standard RMGIC. Stopping the development of caries lesions by histological remineralization is a huge advantage. In this article, we examine the research on the antibacterial characteristics of dental filling materials.

Key words: Nano-filled, GIC, Remineralization, Caries

Introduction

The incidence of dental caries after restorative therapy is said to be high, with some authors stating rates as high as 50-60% [1]. Secondary caries is frequently cited as the primary cause of composite resin or glass-ionomer cement (GIC) restorative failure. More than half of the restorations done in the United States were replacements for failed restorations, with composite restorations exhibiting greater failure rates and more recurring decay as compared to amalgam, which may be related to amalgam's better antibacterial capabilities. Composites have been stated to accumulate more plaque than other materials, which may potentially explain the higher rates of recurrent degradation seen with this material [2].

Secondary deterioration most usually occurs at the contact between the restoration and the prepared cavity [3]. When fermentable carbohydrates are available, the tooth structure is demineralized because of the invasion of acid-generating bacteria such as Streptococcus mutants. As a result, an efficient antibacterial/bactericidal restorative material would be an excellent place to avoid secondary decay, particularly because cariogenic bacteria, primarily S. mutans, have been found to bind to restorative materials. The use of synthetic biomaterials to restore lost or injured tissue is not a novel notion [4]. Plaster of Paris, for example, was developed as a bone substitute at the end of the nineteenth century. Dental silver amalgams are restorative materials that have been around for almost 150 years. Glass ionomer cement (GIC), for example, is a new dental material that has changed restorative techniques, notably in minimally invasive dentistry [5]. The stimulation of cellular growth, proliferation, and tissue development by a biomaterial is referred to as bioactivity. Furthermore, bioactivity denotes a material's anti-bacterial function in preventing or curing illness in the tissues. Because of the presence of silicates and fluorides, alumina-fluorosilicate glasses in GICs have intrinsic bioactive characteristics. Each alteration with a significant consequence was evaluated in terms of its impact on the final qualities of GICs. Furthermore, the existing state and prospects of nano-modified glass ionomers have been evaluated [6]. Wilson and Kent created GICs, a dental material group, and it was innovative at the time. GIC has many major advantages, including the capacity to chemically bond with tooth structures through the chelation of the carboxyl group of acid polymeric chains and calcium ions (Ca^{2+}) in the apatite of enamel and dentine [6]. Furthermore, GICs have adequate translucency and color, and they may have an anti-carious action owing to the emission of fluoride (F) ions. Since the creation of GIC, considerable research has been conducted to enhance its qualities.

GICs were traditionally made up of two primary components: a powder of fluoro-aluminosilicate glass and an aqueous solution containing polyalkenoic acids [7]. The aqueous component's major element is polyacrylic acid. Less viscous polyacids, such as maleic and itaconic acids, may be included in the solution to facilitate manipulation. To increase radiopacity, further additives such as Ba- and Sr-salts might be added to the powder. Tartaric acid is often added to the liquid component to improve handling qualities and extend the working duration. The first setting process is a gelation reaction between the components, followed by the binding of the unreacted glass particles that function as fillers in the silica (SiO_2) gel matrix in conventional glass ionomer cement. The cross-linking of the polymeric chains of the polyacid component (cross-linked acrylate matrix) with calcium and aluminum ions contained in the powder component causes the hardening of the resulting composite. GICs harden in 2-3 minutes, although the chemical reaction for full hardening may take up to 48 hours [8]. Sodium and fluoride ions, in general, do not react chemically and stay unreacted inside the matrix. The ultimate "maturation" of the cement may take many months as the aluminum ions are progressively released and water is bound by the acid and glass.

Materials and Methods

A systematic literature review from 2015 to 2022 was performed using PubMed, Medline, and ScienceDirect databases. The keywords used were “remineralization,” “glass ionomer” “and “nano-filled” **(Table 1)**. In addition, the PRISMA flowchart was used to describe the selection process of searched articles.

Table 1. Inclusion and exclusion criteria for the literature review.

No	Inclusion criteria	Exclusion criteria
1	Literature review	Narrative review
2	Publishes between 2015-2022	Out of the time range
3	nano-filled Glass ionomer cement	Other types of composites
4	English language of publication	Publications other than the English language
5	In Vivo and In Vitro study	-

Results and Discussion

Hydroxyapatite and fluor hydroxyapatite are employed in many areas of dentistry, including implant dentistry and caries prevention since their chemical composition is comparable to that of mineralized bone and tooth tissues [9]. For instance, nano-hydroxyapatite (nap) crystals might encourage the remineralization of enamel. Recently, resin composites modified by the inclusion of nap have been reported to exhibit greater mechanical characteristics than unmodified resin composites. In a similar vein, traditional GIC's compressive, tensile, and flexural strengths are improved by the addition of nap or nano-fluorapatite (nFAp) to the powder component after 7 days of storage in distilled water [10].

Chlorhexidine acetate, chlorhexidine diacetate, chlorhexidine gluconate, and chlorhexidine hydrochloride have all been tried as additives in resins, GICs, RMGICs, and bonding agents. Chlorhexidine, in all its forms, has been shown to boost antibacterial activity against cariogenic bacteria, however, it has also been shown to lower bond strength and increase setting time; both changes are undesirable. A claim was made that the presence or absence of chlorhexidine in a substance had no impact on its antimicrobial properties. Increases in chlorhexidine concentration led to longer-lasting benefits but also increased material degradation. Chlorhexidine Digluconate or diacetate added to Chemiflux Superior GIC, as claimed by Turkan, has long-lasting antibacterial activities against S. mutans and L. acidophilus without negatively impacting the material's physical qualities. Adding 1% chlorhexidine diacetate improved the material's antimicrobial, physicochemical, and bonding capabilities. Due to their typically lower mechanical qualities, these materials have been largely advised for the ART technique. The mechanical qualities of dental materials containing chlorhexidine have been improved in recent years. Silica and silicon carbide nanoparticles enhanced the material's physical qualities. Since it has been known for over a century that silver compounds have anti-cariogenic effects, the introduction of resins leaching silver in situ or incorporating silver compounds into dental material is not surprising. The high surface-to-volume ratio of nano-particulate silver ions has been proven to inhibit enzyme activity and DNA replication in bacteria. In bacteria, the nanoparticles alter the cell's structure and permeability after attaching to the outer membrane. In vitro bacterial inhibition tests using 0.2 and 0.5% silver benzoate (Abs) in chemical cure resin against S. mutants revealed 52.4% and 97.4%, respectively. This action is achieved without giving rise to resistant bacterial strains. When curing with light, you can only use up to 0.15 percent Abs before you start to see a reduction in hardness. At the same concentration of silver benzoate, the light-cured resins are noticeably darker. The higher nanoparticle sizes seen with the light-cured variety may explain this. Since the chemical curing process is slower, more nucleation sites for silver nanoparticles may occur, leading to a larger number of particles that are both smaller and more evenly distributed throughout the material. More research into the resin's mechanical characteristics and optimization of the initiator system is recommended to create a commercially viable product with applications in dentistry and medicine [11].

Unlike traditional GICs, which are made up of glass powder and a polyacid solution, resin-modified GICs additionally have a polymer resin component, which typically sets through a self-activated (chemically cured) or light-activated polymerization process. Combining the strength of a resin composite with the cavity-fighting power of GICs, these "hybrid" materials have been produced. It has been shown that RMGICs not only release fluoride but also have reduced solubility and greater flexural strength compared to traditional GICs. After 24 hours in situ, early RMGICs grew by 3.4% to 11.3% owing to water sorption. However, this issue is no longer present with more recent formulations. Despite recent advancements, traditional RMGICs still lack the strength and durability of resin composites and have a less appealing appearance. Furthermore, RMGICs have lower fluoride release and increased creep compared to traditional powder-based ionomers [12].

Previous research has shown that glass ionomer cement (GIC) may both (1) release the fluoride it naturally contains and (2) release "loosely bound" fluoride it has absorbed from its environment. Caries remineralization was investigated in an in vitro investigation by situating the lesion next to a GIC. Deciduous molars were taken from 16 patients with approximal white spot lesions, and mesiodistal sections were prepared to examine the lesions. Adjacent tooth surfaces were mimicked by "linking" sections to a fake tooth repaired with a GIC. Polarized light photographs of lesions taken in water before and after exposure to artificial saliva for one and two weeks were compared. The photos were scanned, the lesion bodies were traced, and the area corresponding to the lesion bodies was calculated so that changes over time could be compared. Quantitative analysis of 62% of the sections revealed a 43% average decrease in lesion body size after the first week, with a further 14% reduction in the second week. Two out of four sections showed no change in quality, indicating that the lesion body's pore volume had shrunk in tandem with the decrease in quality [13].

The fact that glass ionomers produce fluoride is widely recognized. It has been hypothesized that fluoride, when present in sufficient quantities to inhibit the growth and attachment of bacteria on tooth surfaces and to impede the formation of a complex bacterial biofilm, can slow the rate at which demineralization occurs and speed up the rate at which remineralization occurs. Ion exchange causes the fluoride ions in the set ionomer structure to be released into the environment since they do not participate in the setting reaction. In addition, the glass ionomers may take in fluoride from the mouth and then release the ions in a way that may prevent caries from forming. Whether or whether the fluoride emitted by glass ionomer cement is adequate to prevent dental cavities has not been determined as of yet. Multiple investigations have shown that nano-RMGICs and regular RMGICs both release about as much fluoride over time as conventional GICs. In spite of this, there is still some debate about whether or not nano-RMGICs release much more fluoride than conventional RMGICs and GICs. The total fluoride released after 84 days and per specimen surface per day is equal to that of conventional RMGICs, despite a modest increase in fluoride release from nano-RMGICs at a pH of 4. Unfortunately, there are no published long-term clinical investigations evaluating secondary caries in teeth treated using nano-ionomers cement. Still, whether or not this cement outperforms traditional GICs in terms of anti-carious action in a clinical setting has to be determined [6, 14].

Conclusion

Nano-modification of traditional GICs and RMGICs may be accomplished by adding nano-sized fillers to RMGICs, shrinking glass particles, and incorporating nano-sized bioceramics into the glass powder. In terms of flexural and tensile strength, commercially available nano-filled RMGIC (Keta Nano) has no noticeable benefit over micro-filled RMGICs. The bonding characteristics of nano-filled RMGIC remain a source of concern. Recent improvements, such as the use of nano-sized apatites, have not only improved the mechanical qualities of traditional GICs but have also increased fluoride release in vitro. Apatite crystals may make the set cement more stable and increase the binding strength with tooth structure by enhancing the crystallinity of the set matrix. Increased fluoride release may aid in the reduction of secondary caries in the vicinity of restorations. However, a potential difficulty is the failure of the glass-bio ceramic interface, which might impair the mechanical qualities of the set cement. Furthermore, relatively few research on the nano-modification of GIC has focused on the impact they may have on pulpal cells. As a result, further mechanical, biological, and, finally, clinical experiments are required to determine the status of nano-modified GICs in clinical practice. Furthermore, additional research is needed to understand the influence of nano-modification of the powdered components in glass ionomers on fluoride release. Surprisingly, no research has been conducted so far to investigate this feature. Although the antimicrobial activity of restorative materials, particularly adhesive materials, is important in preventing recurrent decay and thus restoration failure, antimicrobial agents and techniques should not be introduced at the expense of or deterioration of other material properties, as this may lead to restoration failure. Bacterial adherence to restorative materials should also be evaluated, since antimicrobial products may be incapable of preventing the quick and spontaneous process of early bacterial attachment. Long-term antimicrobial activity evaluation is significant because it is clinically relevant, as is the standardization of antimicrobial testing of restorative materials since it allows appropriate comparison of antimicrobial characteristics of restorative materials.

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