“Bioactive Dental Composites And Bonding Agents”

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Abstract
Existing dental restorative materials are largely inert and used to restore lost tooth components. In this article, we will look back at the progress that has been made on a new class of bioactive materials that can not only restore the loss of tooth structure but also serve as therapeutic agents. Replacement of lost minerals, inhibition of recurrent caries, neutralization of acids, repulsion of proteins, suppression of biofilms and acid production, demonstration of low cytotoxicity similar to current resins, protection of dental pulp, and promotion of tertiary dentin formation are all possible with remineralizing and antibacterial composites and bonding agents. The ability to ion release and prevent caries is a promising use for this emerging class of bioactive materials.

Keywords: Remineralization; nanoparticles of calcium phosphate and silver; bioactive composites; monomers that inhibit the growth of bacteria;

Introduction:

Composites are widely used to repair teeth that have been affected by dental caries [1, 2]. This trend is expected to continue as the disease is widespread and patients place greater value on cosmetics. Longer clinical lifespans are the result of vastly enhanced composite compositions and characteristics [8–14]. In spite of this, recurrent caries along the tooth-composite interfaces continues to be a leading cause of restoration failure and subsequent replacement [3]. When compared to alternative restoration materials, composites are more likely to collect biofilms [4].

Because of the increased biofilm formation on composites, composite resins may alter the composition of the bacteria in dental plaque biofilm [5]. This is because, in the resin composites they inherently stimulate bacterial growth. “The weakest aspect of the restoration is the composite-tooth connection point, which can develop microgaps and microleakage over time and serve as an entry route for microorganisms that might induce recurrent caries [6]. These problems have prompted the development of a new category of bioactive dental materials that incorporate remineralizing and antibacterial additives. Commonly, calcium phosphate (CP) materials take the inorganic form of amorphous calcium phosphate (ACP), HA (Ca10(PO4)6(OH)2), tetracalcium phosphate [TTCP, (Ca4(PO4)2O)], monocalcium phosphate monohydrate [MCPM, (Ca(H2PO4)2.H2O)], β-tricalcium phosphate [β-TCP, (β-Ca3(PO4)2)], α-tricalcium phosphate [α-TCP, (α-Ca3(PO4)2)] and octacalcium phosphate [OCP, (Ca8H2(PO4)6.5H2O)4].” After its invention in 1969 by Professor Hench, bioactive glass (BAG) has received a considerable interest. Silicon, calcium, salt, phosphorus, and oxygen are the building blocks of this material [7]. This means there is a high need for resin-based composites that incorporate bioactive remineralizing agents.
Bioactivity in dental materials is preferable since it improves mechanical characteristics and bonding strength through particle disintegration at the surface and a microstructure morphology that aids in the advancement of crack deflection and toughening mechanisms.

Their essential cosmetics have not changed much since the 1950s [8], despite breakthroughs in dental composite technology. Many modern composites simply consist of glass or fired particles suspended in a methacrylate resin manufactured using bifunctional monomers. The composite's relieving properties come from the coupling agents often silane, which artificially links the glass/fired particles with the methacrylate network.

Whisker reinforced CaP composite (ART composite), which has been recommended for use in atraumatic beneficial therapies, has shown ability to remineralize dentin with caries and artificial caries-like lesions [9]. The flexural strength and elastic modulus of a composite made of amorphous calcium phosphate (ACP) were increased by the addition of a barium-glass filler without affecting the material's ion release characteristics. Using a spray drying techniques, researchers have recently developed and implanted CaP nanoparticles with a size of roughly 100 nm into dental composites [10,11]. While the CaP nanocomposite has superior mechanical properties to those of standard CaP-containing composites [10,11], it nevertheless exhibits ion release rates that are lesser than other.

Review of Literature:

If you take care of oral biofilms by feeding them sucrose many times a day to stimulate acid production, using a nanoparticles of amorphous calcium phosphate (NACP) composites can significantly reduce the amount of time that caries takes to develop under the biofilms in situ. Compared to the area around the control composite, the finish mineral loss was 33% lower around the NACP composite [12].

Other than composites, NACP has also been included into dental adhesives. Adding 40% NACP by mass did not reduce the bonding strength to dentin. Due to its tiny dimensions, it might flow into dentinal tubules with the cement while bonding, especially after acid etching the dentin. Examination with a scanning electron microscope (SEM) revealed a few resin labels containing various NACP penetrated into the dentinal tubules. CaP-containing dental composites and adhesives are effective in the fight against recurrent caries [13], since they have the potential to remineralize tooth structure.

NACP and sol-gel handled bioactive glasses (BAGs) that release calcium and phosphate particles are two examples of dental beneficial materials. Another study looked at how the addition of BAG to a composite altered the behavior of microbial biofilms that attacked the gaps between in vitro dental filling models that were subjected to cyclic mechanical pressure. In contrast, the results showed that the BAG group had a substantially thinner layer of normally occurring bacteria in the gap between the two surfaces. As a result, dental composites containing BAG may be useful in preventing the onset and progression of recurrent caries at the bonding sites of tooth restorations [14].

Some calcium silicate cements that bridge the gap between composites and enamel are economically viable for use in either direct or indirect pulp caping treatment. Biodentine (Septodont, Lancaster, Dad) is a multipurpose material that may be used to mask stains, restore dentin, and replace lost enamel. Calcium carbonate, dicalcium silicate, and tricalcium silicate are used as fillers; polycarboxylate is used to reduce the amount of water absorbed by the filler; and calcium chloride is used to control the release of gas. Biodentine is a fast-setting cement and has a setting time of 9-12 minutes after mixing. Crystals that micromechanically interlock in dentin tubules also provide an effective seal. Like other calcium silicate cements, biodentine has been shown to increase the local pH and release calcium particles. Biodentine can stimulate the formation of dentin and the repair of pulpal tissue. Calcium-silicate cements are widely used because of their particle delivery, fixing, and dentin-fixing capabilities; however, this approach can be improved upon by combining them with light-curing resin system.
Calcium silicate, blasted silica, and photopolymerizable methacrylate resin mixture TheraCal (BISCO Dental Items, Schaumburg, IL) is used for both direct and indirect pulp caping as well as a liner under other supporting materials. Due to its light-curing capabilities, TheraCal is an effective resin sealant that dries rapidly. Importantly, unlike conventional calcium silicate cement, this one sets quickly, preventing the uncured material from disintegrating too soon. The commercial product ACTIVA (Pulpdent, Watertown, Mama) has been utilized as a base/liner, mass fill, post, and core. ACTIVA combines a modified glass ionomer with a protected bioactive ionic resin to create a photopolymerizable rubberized resin.

BIOACTIVE COMPOSITES BASED ON AMORPHOUS CALCIUM PHOSPHATE

It is possible that Ca and P molecule release might help preventing demineralization of enamel and dentin for an extended period of time. The ability of the CaP composite to store and reliably release Ca and P particles would greatly aid in long-term caries prevention efforts. In the past, it was common practice for dental medications to include BisGMA and TEGDMA. As acidic paste monomers, PMGDM and BisMEP may chelate with Ca and P particles during the charging process, allowing for recharging to take place.

A light cured CaP resin cement was developed [15] to further reduce recurrent caries at the CEJ. The cement’s molecular release of calcium and phosphorus remained constant regardless the number of recharge and reload cycles used. Ca and phosphate molecule release was predicted to continue for another half a month on very little further charge [15]. A weekly follow up was once thought to be sufficient to ensure the regular re-release of molecules for a period of around seven days. These results demonstrated the possibility for long-term caries-prevention using a NACP nanocomposite and NACP because to the sustained Ca and P molecule release that they were able to achieve.

Many different calcium phosphates can be used as fillers in test composites to facilitate the travel of molecules [16]. Monocalcium phosphate, dicalcium phosphate, tricalcium phosphate, hydroxyapatite (HA), and a few others are examples of calcium phosphates. In particular, hydroxyapatite (HA), a naturally occurring mineral that plays a role in the mineralization of teeth and bones during development, is the direct replica of Amorphous Calcium Phosphate (ACP), which always has our interest. ACP is unstable from a thermodynamic perspective due to its cross-linked design; it breaks down in water to release HA and calcium and phosphate particles, all at once [17]. This component is essential for the bioactivity of ACP and can be used to make remineralizing composite materials.

ACP conversion and ion release

ACP is converted into HA by dissection and reformation. Since the calcium and phosphate particles can become solvent when the basic ACP particles break down, then ready transformed into crystalline hydroxyapatite phases that is stable, this suggests the HA may be able to speed up mineralization. As the cycle continues, the ACP particles are wrapped in a layer of HA support [18].

Adding zirconia to the ACP particles creates a hybrid compound that lowers down the process and strengthens the bioactive impact. Zirconia prevents ACP arrangement because it limits the available sites for HA nucleation and development. We were pleasantly surprised to find that zirconia’s transition to ACP enhanced its mechanical characteristics. Therefore, it is hypothesized that ACP-containing composites may be able to remineralize tooth hard tissues [19], since they can approach calcium/phosphate mixes that are supersaturated with HA.

There is only one readily available composite material designed for restoring orthodontic components that contains ACP at an affordable price. Weak mechanical qualities and bonding strength meant it was rarely manufactured. Casein phosphopeptide ACP is widely used as a powerful remineralizing agent in tooth mousse, post-whitening
remineralizing gels, and fundamentally chewing gum [20], so ACP-based composite materials are on the horizon despite the fact that they are not yet commercially available.

“BIOACTIVE COMPOSITES BASED ON BIOACTIVE GLASS (BG) BG as filler in dental composites”

Bioactive glasses "BGs" are a class of soluble glasses that primarily consist of SiO\textsubscript{2}, CaO, Na\textsubscript{2}O and P\textsubscript{2}O\textsubscript{5} differing proportions [21]. Small changes in composition can be used to adapt materials to be suited for certain applications, as the composition determines the solubility and, by extension, the bioactivity of BGs.

Due to its ability to both provide remineralizing particles and stimulate HA, BG it is a possible source for use in testing dental composites.

An array of BG reactions is triggered by the presence of water, resulting in the formation of HA. The removal of hydrogen from the arrangement in exchange for sodium and calcium particles results in the formation of silica and a silica-rich (sodium/calcium-drained) layer on the BG surface. “An increase in pH causes silica to degrade into the pursuit of the Si-O-Si bonds by the hydroxyl particles. When the HA hardens and the Si form, repolymerization of the silica-rich layer is triggered, and calcium and phosphate particles are drawn in, forming the ACP. [21].

Remineralizing effect

Similar to ACP-based composites, BG-based composites aid in the remineralization of tooth hard tissues by introducing calcium and phosphate particles. The remineralizing capacity of BG particles was shown whether they were put directly to the artificially demineralized dentin” [22] or were mixed in with a methacrylate resin like the piece of adhesive frameworks [23]. The remineralizing effect around dental veneers was shown in studies using either unmodified or polyacrylic acid altered BG applied immediately after the preparation to heal white spot lesions. Still, there is debate about whether this advantage really has any practical relevance given that the increased quantity of HA in dentin does not necessarily support its design. If HA is used to increase dentin strength, it must take place in the collagen grid intrafibrillarly, since extrabrilляр mineralization contributes no mechanical properties. Further research is needed to shed light on this matter.

Antibacterial effect

When dissolved, BG raises the pH of their surroundings which where their antibacterial effects come from. “Both pure BG and eluates derived from BG were able to inhibit bacterial growth, suggesting that the antibacterial action is not directly connected to contact toxicity but rather to the shift in pH caused by the solution.” Neutralizing the eluates proved that the antibacterial action could be traced back to the increase in pH alone. [24]. Because of this, different BGs with enhanced antibacterial characteristics may be produced by altering their composition by adding different trace components.

Marginal gap sealing

By forming HA layers at their surfaces, BG are uniquely suited to seal the marginal gap. Although experimental composites comprised of ACP and other calcium phosphates may promote HA, particle ionization is more common than precipitation, and most remineralizing particles are lost in the arrangement. However, the hydrated silica on the outer layer of BG acts as nucleation sites for HA, allowing its precipitation shortly after the breakdown process has
begun. In order to stop bacteria from entering through the marginal gap, this property can be used to build up a thick enough layer of HA on the repair surface. [25].

“Treatment of dentin hypersensitivity and postoperative sensitivity”

Since HA deposition can block dentin tubules and shut off dentinal liquid stream, it can reduce the discomfort associated with hypersensitivity. It has been shown that toothpaste is an effective means of transporting BG particles. products or cements containing BG may help reduce postoperative feeling after placing composite fillings.

While composite restorations have shown to be highly effective, there is still room for improvement in how well they bond at the dentin-restoration margins. There has been a lot of research done with the hope of increasing dentin's marginal accuracy and decreasing its removal over time, but so far this goal has proven to be farfetched [26]. “By increasing the local pH and thereby inhibiting the action of lattice metalloproteinases, and by enclosing the HA promote within the demineralized collagen organization to reduce nanoleakage and protect the hybrid layer from hydrolytic corruption, BG-containing composites have the potential to increase the durability and longevity of the hybrid layer.”

By mimicking the mineral process that normally takes place within the collagen platform, biomimetic remineralization is a novel approach to increasing the durability of the mixture layer. Polyanionic particles are used as a template for HA declaration within the collagenuous network, much like the non-collagenuous dentin proteins. For biomimetic remineralization, BG in its natural form and BG-filled resin composites or cements have been proposed as sources of calcium and phosphate particles.

Antibacterial dental composites and bonding agents

The dental caries, triggered by a shift in the carbohydrate composition of the human diet, is quite common. We now know that 12-methacryloyloxydodecylpyridinium bromide (MDPB) may be co-polymerized and covalently bonded in the molecule, “immobilized to give long-term contact-restraint against oral bacteria, thanks to the extensive research conducted by Imazato et al. [27].

Clearfil Defend Bond (Kuraray Dental) with MDPB was shown to have potent antibacterial activity against S. mutans, Lactobacillus casei, and Actinomyces naeslundii,” and the potential to kill any microbes waiting inside the dentinal tubules, at a price point that most people can afford. In addition to quaternary ammonium dimethacrylate and methacryloxylethyl cetyl dimethyl ammonium chloride (DMAE-CB)-containing cements, other antimicrobial elements include antibacterial glass ionomer cements, nanocomposites, and bonding cements. Composites are essential for building the natural dental structure, but bonding cements are just as important [28].

An individual experiment produced glass ionomer materials with antimicrobial properties, the efficacy of which increased with increasing alkyl chain length [29]. A new analysis on attached plaque microorganisms shows that the durability of oral biofilms and the number of colony-forming units (CFUs) decrease significantly with increasing alkyl chain length (CL). In a similar situation, a dental composite was proven to be effective against bacteria in a biofilm mimicking tooth plaque by using human saliva.

“Original antibacterial resin cements showed no reduction in dentin bond strength after six months, likely due to the catalytic action and the concealment of framework metalloproteinases (MMPs), which effectively defended the
mixture layer through the antibacterial monomer. In this way, regardless of the potential remineralization effect of NACP, the initial antibacterial resin cements have the potential to construct a stronger and more long-lasting reinforced interface.”

At this point, most oral biofilms have formed and are flourishing. Mutans streptococci are in this group because they can colonize the mouth very quickly. It would be ideal to create a novel composite that is resistant to proteins in order to combat the issue of microbial adhesion. Silicon wafer surfaces were coated with polyethylene glycol (PEG) and two methacrylate monomers containing a pyridinium group to achieve protein-repellent activity. [30].

2-methacryloyloxyethyl phosphorylcholine (MPC) is a popular biomedical polymer because it is hydrophilic, biocompatible, and widely used [31]. It’s a methacrylate that happens to have a phospholipid further down the chain. MPC has several potential uses [31] “because to its resistance to protein adsorption and bacterial adhesion, including in prosthetic blood supply area, artificial hip joints, and microfluidic devices.” Coatings made of MPC polymers are hydrophobic, prevent protein and bacterial adhesion, and decrease the likelihood of erosion. Laboratory studies have been the main method of investigating the biocompatibility of antibacterial dental monomers.

In keeping with this line of inquiry, it would be ideal if, in addition to replacing lost tooth structure, future supporting materials were bioactive and included good therapeutic properties. While studies on novel bioactive beneficial materials with remineralizing and antimicrobial characteristics are still in their infancy, they have made significant progress. There is a need for further studies to evaluate the performance of the bioactive materials in restoratively relevant settings in in situ or in vivo human models for antibacterial and remineralization effects. This innovative class of bioactive helpful materials requires more study to completely comprehend “the remineralizing and antibacterial cycles.

To alleviate the sensitivity of the dentin, patients can use BG toothpaste, and BG also makes remineralization to occur [32]. However, there are currently no BG-based dental composites or bonding agents available to consumers.

Most of the currently available dental composites and bonding agents are biocompatible and essentially substitute the lost structure of the tooth without collaborating with oral microbes or mast cells, despite the fact that these are major causes of failures. Researchers are looking at a number of potential ways in order to explore a new era of bioactive dental composites and bonding agents with Light curing. Calcium phosphate nanoparticles added to composites and bonding agents are one approach for remineralizing damage and preventing further caries. Finally, proteins on the surface can be removed by bonding agents, making them less sticky and hence less attractive to microbes. Synergistic mixtures of several bioactive compounds are used as an alternative strategy.

These antibacterial and remineralizing characteristics exhibited cytotoxicity comparable, if not exactly, to current dental monomers and resins, as demonstrated by in vitro cell examinations and in vivo creature models; furthermore, they triggered less pulpal irritations and helped patch the dentin-pound complex. More dental decay is eliminated, lost minerals are restored, and more caries are prevented by this innovative combination of bioactive ingredients' remineralizing and antimicrobial capabilities.

References:


