Review Article

Insights of Clinical and Medical Images

An Overview Of The Application Of Nanotechnology (Nanoparticles) In The Treatment Of Dental Caries And Control Of Oral Infections

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1. Abstract

Nanotechnology is the ability to produce new materials, tools and systems by taking control at the molecular and atomic level and using the properties that appear at those levels. With the entry of nanotechnology into the field of human knowledge and its use in the development of biological and medical sciences, dental science has not been left without this technology. In this sector, nanotechnology is used in three areas: dental materials, dental health, toothpaste and toothbrushes, and dental equipment. In short, we can mention the use of nanocomposites in the manufacture of restorative materials, nanoceramics in the manufacture of artificial teeth, nanocoatings on dental implants, nanofluorides in toothpastes, and silver nanoparticles in mouthwashes. Many species of bacteria that live in the oral cavity are opportunistic pathogens that cause systemic infections in addition to dental and periodontal diseases.

This makes oral hygiene a very serious issue, which is exacerbated by the emergence of multiple antibiotic resistance in oral bacteria. The role of nanoparticle-based materials, especially metal nanoparticles and metal oxide, as an effective and alternative/complementary antimicrobial agent is now well established. These nanoparticles can be a healthier, harmless and effective alternative to control dental biofilms and oral plankton bacteria population with less side effects or antibiotic resistance.

The antimicrobial activity of these nanoparticles against a number of oral pathogens has already been demonstrated. When these nanoparticles are added to artificial teeth materials and implants, in addition to improving the antimicrobial activity, they improve the desirable physical and chemical properties of the materials. It is hoped that the problems that have existed in various fields of dentistry will be solved by using this technology.

2. Keywords:
Nanotechnology, Tooth Decay, Dentistry, Tooth Restoration, Nano Particles

3. Introduction

The biology of dental materials is one of the basic sciences in dentistry, which as an important branch in the manufacture, design and evaluation of dental materials has a special place in most countries of the world. The materials used in dentistry include all kinds of metals and alloys, cements, plaster compounds and molding materials, polymers, composites, all kinds of resins, ceramic and porcelain, root filling materials.

These materials are often examined from two points of view, on the one hand, physical, chemical, and mechanical properties are examined and evaluated by performing detailed tests, and on the other hand, comprehensive physiological and biological studies are conducted to determine the biocompatibility and biological effects of the materials.

The increasing use of dental materials caused the standardization of dental materials to be considered in the early 19th century, and standard guidelines were prepared by the ISO International Standard Institute. If in the first generation of dental biomaterials, only appropriate physical and mechanical properties were considered, and from a biological point of view, the harmlessness of these materials would be sufficient; With the emergence of the second generation, being bioactive or in other words creating chemical bonds with the surrounding tissues was also considered and the transition from material engineering to biological engineering showed its importance in the synthesis of dental biomaterials. [1]

Perhaps the biggest revolution in this science is the emergence of the third generation of dental biomaterials with the aim of stimulating cellular responses at the molecular level. [2] This transition is towards biological materials that are possible through tissue engineering and stem cells, nanomaterials, and self-assembled systems. Today, nanomaterials are widely used in various fields of dentistry, including diagnosis, treatment and prevention of oral and dental diseases. Some applications of nano in dentistry include the use of nanoparticles in composites, bonding, molding materials and dental ceramics. [3] Some nano materials are also used in drug delivery systems to treat diseases.

In line with these changes, the biology of dental materials with the help of tissue engineering and nano-engineering has moved from the side of synthetic dental materials to the production of biological materials, and without a doubt, this trend will continue in the future. In parallel with these developments, changes in existing materials should also be made, and in the use of materials, technology and their cost-effectiveness should be considered.

3.1. Nanocoatings in Dentistry

The application of nano coatings in this field includes a wide group including dental instruments, implants, parts and equipment [4].
The presence of electrolytic fluids in the human body has caused the internal environment of the body to be very corrosive and active even for titanium and stainless steel alloys. This issue necessitates the existence of coatings that have suitable mechanical properties and are chemically neutral. [5] One of the common examples in this case is dental implants. TiN nanocoating has found its place in the engineering industry due to its unique properties. These nano coatings are used in many dental instruments. [6]

One of the problems in dentistry is the materials used. The materials used in dentistry should have high hardness and resistance and have a beautiful appearance. Poorly formulated dental materials cause discomfort, side effects and increase health care costs. For this reason, companies and institutions related to dental care are trying to produce products with high quality and efficiency. The same features should also be present in the materials used in veneers. [7]

Recent developments in the field of nanotechnology have been considered significantly to solve these needs. One of the most important points regarding the use of nanotechnology in order to meet these needs is the possibility of producing separate nanoparticles without sticking to each other, and it is possible to distribute them uniformly in resins or coatings to produce nanocomposites. [8]

Polymer composite materials have existed since the beginning of polymer science. It has long been known that the addition of fillers with physical properties similar to the polymer structure can lead to the production of materials with interesting properties, including materials with enhanced mechanical properties. These types of polymer composites have been among the basic materials in the market of commercial dental materials for decades. [9] Currently, it is possible to prepare nanofillers and nanocomposites through nanotechnology. These materials have different optical, mechanical and chemical properties compared to the old microcomposites. Nano technology in dental restorations increases the hardness and beauty of the restored area compared to the old materials [10].

It is hoped that by using this technology, the problems that have already existed in various fields of dentistry, including the production of strong and beautiful restorative materials, will be solved.

3.2. Nano Whitening Toothpastes

Toothpaste companies are in fierce competition with each other to come up with toothpaste that attracts more customers because of its more whitening properties. Toothpastes based on nanohydroxyapatite (a type of calcium phosphate) are widely used in the construction and coating of implants. [11]

Nanohydroxyapatite shows higher mechanical properties and more favorable biocompatibility than micrometric samples and has shown great effectiveness in removing plaque from the tooth surface. These effects may be due to the physical properties of nanohydroxyapatite, which has a higher specific surface area than hydroxyapatite with micron dimensions and thus a higher efficiency for descaling. [12] The second hypothesis for the mechanism of nanohydroxyapatites is the acceleration of mineral descaling. which is involved in filling the cavities of the tooth surface. Therefore, it is possible to reduce the darkness of the teeth. Nanotechnology can increase the connection between the tooth structure and nano-sized filling particles and create a more natural and stable interface between the mineralized hard tissues of the tooth and advanced restorative biomaterials. [13]

One of the ingredients of this toothpaste is calcium peroxide, which penetrates into the smallest dental spaces in nano size. The color of dental grains (from coffee, tea or tobacco) becomes lighter [14]. They gently clean the dental plaque. Calcium peroxide is bioavailable, which means it binds better to the tooth and has a stronger effect. A type of nanostructured carbonated hydroxyapatite granule (Figure 1), this product consists of hydroxyapatite plates with a thickness of less than 30 nm, on the surface of the granules, which is used in restorative dental materials and materials used in jaw and oral implants.

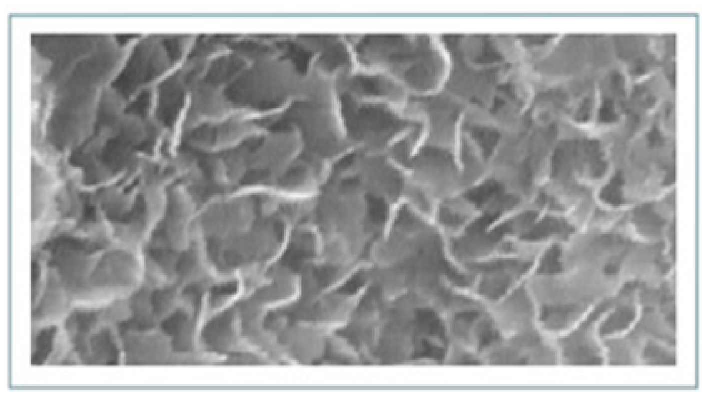

Figure 1: Nanostructured carbonated hydroxyapatite granule

3.3. Preparation of Self-Cleaning Dental Plaques with The Help of Silver Nanoparticles

The researchers of the Faculty of Teacher Education during their successful research on the preparation of dental plaques got silver nanoparticles, which have the property of self-cleaning and have high strength. One of the problems of plaques that are used in orthodontics today is their hygiene, which must be cleaned regularly, otherwise the possibility of microbial plaque accumulation increases. Since silver nanoparticles have high germicidal and bactericidal properties, they can be used in the manufacture of dental materials. [15] In this method, silver nanoparticles are first prepared by chemical reduction method in the presence of acrylic reducer. Prepared nanoparticles are added to the acrylic liquid phase and are added to methyl methacrylate powder in certain proportions and molded, and finally the prepared dental nanocomposite can be used as the basis of dental materials, which has antibacterial properties and high strength. [16]

3.4. Silver Nanoparticles

Silver nanoparticles (Ag NPs) have been used for caries prevention in several studies. [17] These studies used silver nanoparticles in the form of silver nanocomposites, toothpaste, coated orthodontic brackets, nanosilver fluoride solutions, sealants, and glass ionomer cement with silver nanoparticles. Laboratory research was conducted using silver nanoparticles and silver nanocomposites for the treatment and prevention of secondary caries. [18] Silver nanoparticles were also included in the resin of orthodontic materials (adhesives, elastomeric ligatures and mobile retainers) to prevent caries. [19] Silver nanofluoride solution was effective in regenerating primary caries of tooth enamel and preventing dental caries [20] Clinical studies have proven that silver nanoparticles on orthodontic brackets can be used to prevent tooth enamel decay [21] and dental sealant with silver nanoparticles can be better than traditional sealants in preventing enamel decay of permanent first molar teeth. [22]

3.5. Effect On Tooth Enamel And Dentin

Most of the studies conducted on enamel and dentin with silver nanoparticles were laboratory experiments. Silver nanoparticles can reduce lactic acid production in biofilm and may have the potential to reduce tooth demineralization. [23] Silver nanoparticles can adhere to hydroxyapatite crystals in the caries lesion. [24] In addition, silver ions released from silver nanoparticles can form insoluble silver chloride on dental hard tissue, which increases the mineral density of dental hard tissue. [25] Silver nanoparticles can maintain collagen exposed to tooth decay by inhibiting and inactivating bacterial collagenases as well as proteinases in saliva and dentin matrix such as active matrix metalloproteinases and cysteine cathepsins. [26] Therefore, preserved collagen acts as a scaffold for the deposition of a mineral crystal. Spindola Castro et al. showed that silver fluoride nanoparticles are able to stain dentin. However, the same laboratory model concluded that the brushing cycle removed the stain. [27]

3.6. Silver Nanoparticles In Caries Prevention

Silver nanoparticles were combined with other nanoparticles such as calcium glycerophosphate and zinc oxide to produce multi-functional nanocomposites for caries prevention. [28] Silver nanoparticles were also added to restorative materials such as adhesives and filling resins, which can prevent secondary caries without compromising mechanical properties. [29]

Acoustic enamel treated with silver nanoparticles had a lower lesion depth compared to enamel treated with water after biofilm challenge. In addition, microhardness increased when tooth enamel was treated with artificial caries with silver nanoparticles. [30] The amount of microhardness of enamel caries treated with silver nanofluoride was higher than enamel caries treated with sodium fluoride. [31] A clinical trial reported that mineral loss in first molars was reduced when treated with dental sealants containing silver nanoparticles [32] Silver nanofluoride also stopped tooth decay in children in two clinical trials. (33)

Laboratory studies claim that silver nanoparticles inhibit the growth of caries-causing bacteria. Bacterial collagenase activity is known to be inhibited by silver nanoparticles and also protects the collagen matrix. Therefore, silver nanoparticles can be useful in caries prevention. However, it is necessary to prove the same with well-designed randomized clinical trials. In addition, staining caused by Ag Nps should be considered before clinical use.

The main mechanism of antibacterial properties of silver nanoparticles is the release of silver ions. However, the mechanism of activity of silver ions from the point of view of molecular microbiology is not yet fully understood. Some of the main mechanisms are: damage to the cell membrane, production of reactive oxygen species and cellular attack by silver ions (or even silver nanoparticles due to the presence of membrane pores) and further damage to ATP products and inhibition of DNA replication. In many studies, damage to the cell membrane by silver ions has been reported. These reports are mainly based on the observation of large pits or holes in the bacterial membrane by TEM analysis. Silver ions may interact with sulfur-containing membrane proteins (for example, with the thiol group of the respiratory chain protein) and cause physical damage to the membrane [34].

Nam in his study, by adding silver nanoparticles with different weight percentages of 0.1% to 3% to materials in contact with oral tissue in a limited period with the aim of helping to return to healthy conditions (tissue conditioner), its antibacterial effect on showed on Staphylococcus aureus and Streptococcus mutans bacteria. So that with increasing concentration of nanoparticles, this effect was intensified [35].

Sondi and Salopek-Sondi showed the antibacterial effect of silver nanoparticles against Escherichia coli. They emphasized the theory that when exposed to silver nanoparticles, microorganisms lose their ability to replicate and cellular proteins become inactive [36]. Considering the availability of the studied plants in our country and the possibility of its preparation with lower costs compared to other drugs and also considering the antibacterial properties of nanoparticles biosynthesized with the extracts of these plants, the results of such research may be of interest to researchers, experts and manufacturers of drugs so that if it is prepared in the form of medicine or toothpaste, it can be used in the field of dealing with infections caused by these bacteria.

One of the limitations of this research was the lack of investigation of the role of effective factors and their interference in the size of nanoparticles, and only the ability to produce nano silver from the extracts of licorice and mint plants and its antimicrobial effect on the bacteria causing tooth decay was evaluated. Therefore, it is suggested to investigate the role of various factors involved in the particle size by using mathematical modeling and chemometrics, so that by changing the effective factors, the optimal conditions for the production of these nanoparticles in the desired particle size can be determined. (Figure 2)

Figure 2: Plasma brush

4. Gold Nanoparticles

In vitro experiments

Gold (Au) is reported to have a weak antimicrobial effect against bacteria and fungi. [37] A combination of gold nanoparticles (Au NPs) with tetracycline or with ampicillin can improve the antibacterial activity. Au NPs exhibit anti-inflammatory action by reducing reactive oxygen species (ROS) production by decreasing lipopolysaccharide-induced cytokine production such as interleukin (IL)-1b, IL-17, tumor necrosis factor, and modulating mitogen-activated protein kinase and phosphatidylinositol 3-kinase pathways. [38]

Hernández-Sierra et al. evaluated NPs of Ag, zinc oxide, and Au of 25 nm, 80 nm, and 125 nm average sizes. The results stated that a higher concentration of Au NPs than that of Ag NPs was required to observe bacteriostatic and bactericidal effects on S. mutans.(40) Junevičius et al.[39] compared the antimicrobial effect of toothpaste containing Ag NPs and Au. Au NPs containing toothpaste had a lower antimicrobial effect against Gram-negative bacteria when compared to Ag NPs containing toothpaste. The concentration of Au NPs required to achieve the desired effect is more compared to other nanoparticles. Furthermore, they are reported to have a weak antimicrobial effect which makes them less preferable compared to other nanoparticles used for caries prevention.

4.1. The Use Of Nanoparticles In Tooth Repair

Today, beauty has a special place in restorative dentistry, and the use of nanoparticles seems ideal in this way. Great beauty, especially that it has a convenient and fast application, is considered their most important feature. Zirconium oxide nanoparticles, which have high strength and transparency to light, but prevent the passage of X-rays, are used in dentistry. Diam nanoparticles have wide applications and high efficiency. [41] Diam is a very pure silica gel whose particles do not stick together and is non-porous and has a high volumetric weight. Due to these characteristics, it is possible to use these materials in dentistry as fillers. A product made of silicon nanoparticles that, when used in dental nanocomposites, cause more hardness, increased bending strength, transparency and create a more attractive appearance. In addition, the use of these nanoparticles reduces the fragility of filler materials by 50%.

Among the advantages of using nanoparticles in tooth restoration, we can mention the production of fillers with high polish, minimum polishing time, stability and resistance of materials to mechanical shocks, least adhesion to tools and the possibility of accurate color matching.

Increasing the durability of dental fillings with new nanocomposites

The mouth is a harsh environment, so dentists cannot guarantee the longevity of filled teeth. Despite many efforts, a filling may gradually break under various stresses, or over time, decay may develop in the place where the filling is attached to the tooth. Nanotechnology has the potential to reduce these damages by producing dental restoratives that are both more durable and stronger than today's fillings and more resistant to secondary decay. [42]

The problem with anti-caries composite fillers is caused by an additive in the powder that adds calcium and phosphate ions for sustained release. These ions are essential for the longevity of the filling, as they not only strengthen the crystalline structure of the tooth itself, but also protect it from decay-causing acid produced by bacteria in the mouth. But on the other hand, these ion-releasing compounds are structurally very weak and make the filler vulnerable. To solve this problem, a method has been designed in which the particle size of such compounds, one of which is anhydrous dicalcium phosphate, is around 50 nanometers, which is 20 times smaller than the one-micron particles in a conventional powder. The high surface-to-volume ratio of these particles makes them more effective in releasing ions, and in this way, a much smaller amount of these materials is needed to create the same effect. Calcium phosphate nanocomposite filling in a tooth can intelligently release anti-caries agents that protect the tooth from acid produced by bacteria [43].

In addition, it can restore the lost mineral content of the tooth by releasing ions into the demineralized area of the tooth. Dentists make this filling by mixing pure liquid resin with a powder that contains colorants, reinforcements, and other materials, place it inside the tooth cavity, and harden it with light.

In composite resin technology, the particle size and the presence of particles represent important information for the best use of composite materials. [44] The change of filler compounds has been the most important progress in the development of composite resins. This is the change in the amount and size of the filler which controls its performance in polishability as well as coverage and resistance to cracking. Nano technology can produce composite resins with smaller filler particles for us, which can be dissolved in higher concentrations and polymerized in the resin system. The molecules of these materials can be designed in such a way that they are compatible when paired with a polymer and create unique properties such as physical, mechanical and optical properties. The structures of hydroxyapatite crystals, small dental tubes and enamel rods are very different, and secondly, they act as an intermediate between macroscopic restorative materials (0.7 to 40 nm) and nanoscopic tooth structure (1 to 10 nm in size). potential for research in the field of nanotechnology. Nanotechnology can increase the connection between the tooth structure and nano-sized filling particles and create a more natural and stable interface between the mineralized hard tissues of the tooth and advanced bio-materials. [45]

4.2. Nanoscale Glass Powder For Dental Fillings

In the past, metal alloys such as gold and iron were used as fillers. These materials were electrically conductive, heat and cold and caused sensitivity in the teeth, also the mercury in the alloy of the fixture was considered as its disadvantages [46]. Many patients also tried not to use this material for their teeth, because it was dark and caused the appearance of the teeth to disappear. Optically, dental composites are very similar to natural tooth materials. These composite materials are a multi-resin that hardens when exposed to UV light. Glass powder is used as one of the key tools of dental composites. Dental fillings contain up to 80% glass powder, this powder has excellent mechanical properties, can easily withstand pressure, and is easily polished and polished [47]. Nano technology is used in the production of special glass powders for dental fillings, the particle size of which is 180 nanometers. Using smaller and finer fillers means longer fillers life and more attractive appearance. In these materials, in addition to the use of very pure special glasses, particle size is also a key indicator for the quality of these composite materials. The produced glass powder is opaque to X-rays; That is, the dentist can easily distinguish between healthy, decayed and filled teeth by X-ray.

4.3. Nanometer Dental Adhesive

Adper single Bond Plus Adhesive nanometer dental adhesive is prepared from nanometer silicate fillers, which creates a stronger bond with tooth enamel. [48] In addition, there is no need to shake to prevent particles from clustering, which reduces performance. Not before use. This product has the least sensitivity after use and due to the use of ethanol in it, it evaporates less than normal products in which acetone is used .

4.4. Using Nanoparticles With Plasma Laser In Dentistry

If the size of titanium oxide particles is reduced to nano sizes (20 to 50 nm) and used on the skin in the form of emulsion gels, they will have interesting properties [49]. If these particles are irradiated with laser pulses, the particles break apart and have collective effects. The created particles themselves turn into smaller particles and this causes instant kinetic movements. Therefore, this process can be used in the micro-exfoliation of hard tissues. In this method, in addition to increasing the speed and accuracy, the work is done cleaner and smoother without the need for anesthesia. Dental plasma laser combined with titanium oxide nanoparticles, using nano technology in several cases of dental treatments, including dental gum treatments, gum melanin removal, soft tissue cutting without anesthesia, tooth decay treatment, enamel cutting and tooth dentin cutting. It is effective [29]. The three main applications of plasma that have emerged in dentistry include:

1- Anti-inflammatory activity
2- Improving adhesion and homogenization of materials
3- Tooth enamel whitening

One of the most important uses of plasma in dentistry is related to killing bacteria on the surface of the tooth as well as bacteria inside the root canals of the tooth, which leads to some anti-inflammatory activities in those areas. The second application is to improve adhesion and homogenization of materials used in teeth, such as tooth filling materials. The third use of plasma in dentistry is also related to tooth enamel whitening, which is mostly cosmetic. Among recent promising results, we can mention the use of plasma brush (Figure 3) to eliminate bacteria inside the tooth root canals. The plasma brush is able to clean and disinfect tooth cavities and prepare them for filling in less than 30 seconds by performing chemical reactions. [50].

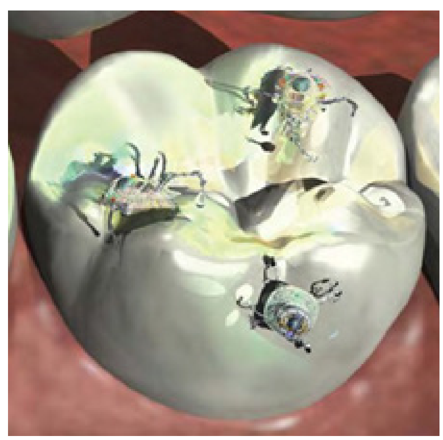

Figure 3: Nanorobots moving on the tooth surface to restore caries

In addition to the bactericidal properties, the cold flame of the plasma brush creates a better bond between the filling material and the tooth. The chemical reactions resulting from the plasma brush practically change the surface of the tooth and cause a strong and strong bond with the filling material. This purple beam of cold plasma, as part of the dental cavity treatment system, is able to destroy bacteria and germs in the tooth.

4.5. Bone Restoration Using Nanoceramics

Nanotechnology has provided a series of new spaces with a large surface area and biocompatibility by means of nanomaterials, which can be used for bone repair and bone cavity filling. [51] High-strength nanoceramics can be made into a flowable and moldable paste that turns into solid bones. If this type of material is used in the bone, biocompatibility increases to a great extent. In addition, compared to synthetic cements, nanoceramics have the ability to be used in both types of bones that bear weight and that do not bear weight. The necessary materials for bone ceramics have been studied at the University of South Carolina, and these materials form a bone-like solid structure inside the body in the presence of serum and are able to fix a broken bone or replace it.

4.6. Revival Of Decayed Teeth With Nanotechnology

Through nanotechnology, researchers have created hope that dead and problematic teeth can be given life back. A group of researchers have claimed that instead of using conventional methods, the tooth can be repaired by filling the tooth with a new pulp by making a soft pulp-like material from nano. Researchers in Regenerative endodontics also say that with a new type of dental film in nano dimensions, it is possible to achieve extraordinary results in the root canal therapy process and bring the tooth back to life [52]. According to Nadia Jessil, one of the researchers of this project, the tooth decay of millions of people in the world can be prevented with this method. During the dental treatment, the doctor removes the defective pulp, but if instead of removing the pulp, it can be replaced with nano pulp, then there will be a great revolution in dentistry.

Scientists have achieved a new substance by combining a substance called alpha melanocyte Alpha-MSH or stimulating hormone with a type of polymer that has the property of fighting bacteria. This new substance is a type of artificial pulp with the same natural properties [35]. The nano film resulting from this technology, which has alpha melanocytes, can greatly help in reviving the damaged tooth and even completely change the canal therapy method and its process. In fact, pulp pulp is a fibroblast that becomes microbial and causes destruction in the tooth. The material made also restores and permanently protects the pulp. [33] (Figure 4)

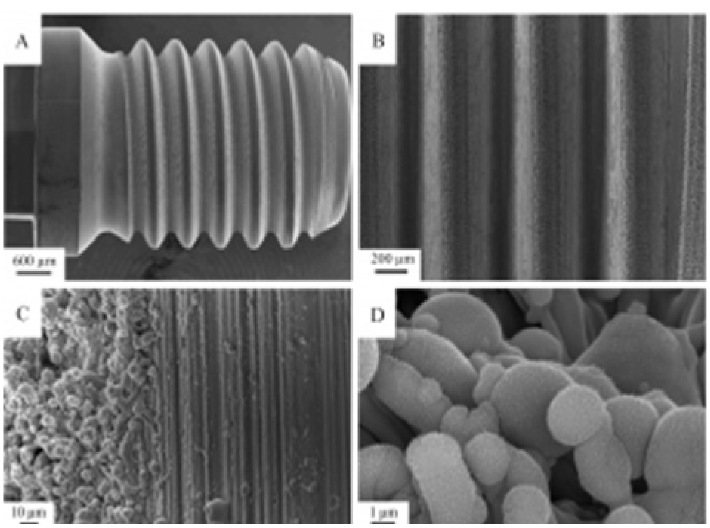

Figure 4: Dental implant with nano technology

4.7. Oral Local Anesthesia

In the course of nanodentistry, a colloidal suspension containing millions of active and pain-relieving dental robots on a micron scale will be slowly injected into the patient's gums. After contacting the surface of the tooth crown or mucosa, the nanorobots moved by different methods reach the dental pulp or nerve.

After being placed in the pulp, the pain-relieving dental robots can, on the order of the dentist, cause the loss of any sensation in the specific tooth that needs treatment. After the treatment process is completed, the dentist commands the nanorobots to restore all senses and exit the tooth the same way they entered. [53]

4.8. Nano Robotic Mouthwashes

Nanorobot mouthwashes can enter the mouth from mouthwashes or toothpastes and will be able to protect all the upper and lower surfaces of the gums from corrosion and turn trapped metabolic organic substances into a harmless gas. and make them smell bad and remove the layers of crime. [54]

These nano-braces will be small and invisible teeth with dimensions of 1 to 10 microns, which move on the surface of the tooth at a speed of 1 to 10 microns per second, and their characteristics include cheapness and safety; Because they can deactivate themselves easily if eaten.

4.9. The Effect Of Dental Implants With Nanotechnology

These features include cell growth capability and biomechanical properties that play an important role in initial bone-implant stability. The porous structure and holes with the right size are the determining factors of the growing bone. The mechanical properties of the implant must be adjusted according to the properties of the tissues around it, these mechanical properties include the porosity of the implant structure (cavity size, cavity shape, porosity), implantation time, biocompatibility and implant strength. [55]

Advances in materials engineering have led to the production of porous scaffolds that mimic the structural and mechanical properties of natural bone. The porous structure acts as a framework for the growth of bone cells, and these cells penetrate into the implant cavity and lead to fusion with the implant. [38]

Titanium, which has porosity with long-term stability and the ability to withstand high load and bone growth, should have several characteristics:

- High porosity and interconnected structure to allow the growth of new bone origin and transfer of biological fluids.
- The size of pores and holes is usually between 150 and 500.
- Mechanical properties adjusted to the surrounding tissues for load bearing and load transfer

In the past, efforts were made to accelerate the process of shilling (integration) by making changes on the surface of the implant, such as creating micron-sized roughness on titanium. Today, several methods such as sandblasting - acid washing and their combination have been proposed to achieve micron roughness. Current researches in changing the alloy, structure and terms are superficial, for example, in the case of titanium, efforts are made to increase the biocompatibility of commercial species, in this case, its toxicity is prevented.

Recently, nanostructures have been shown to improve mechanical, biological and chemical properties to an acceptable extent. Improving the physical, chemical and mechanical properties of titanium implants is done by microstructure control (SPD) and mechanical alloying. Another method that is used to change the properties of titanium and its alloys is the production of composites, which actually combines the excellent mechanical properties of titanium with the biocompatibility of ceramics. Among the main ceramics used are (Hyroxyapatite) and (BIOGLASS). Ceramic coating increases the biocompatibility of the surface, but its weak adhesion with metal may cause its failure. But due to the adjustable design and its properties, they are considered as one of the promising alternatives in bone tissue and the process of bone fusion. [39]

4.10. Nano Technology In Dental Implants

Nanotechnology is actually the development and application of techniques that allow the production of structures with dimensions of 1 to 100 nanometers and have dental applications. [56] Making titanium-based nanomaterials and increasing their industrial use is still a challenge.

The aim of the current research is to create a new generation of titanium ceramic nanocomposites. By preparing porous structures and surface modification that lead to improved surface adhesion, increased hardness and corrosion resistance, and high biocompatibility, an ideal nanocomposite can be achieved. Scientists succeeded in preparing titanium nanotubes with excellent mechanical and medical properties that can be used in implants, this is an important point. that the maximum modification of metal particles to the nano-morphology scale creates a favorable surface that increases the adhesion and growth of living cells. By reducing the particle size of titanium tubes, the final strength of titanium was doubled. Also, the strength of titanium containing nanostructure is almost twice the previous sample.

Biocellular tests were performed using rat fibroblast cells. The results showed that the process of nanoization causes a significant increase in the transfer of fibroblasts. Therefore, it is predicted that the amount of titanium nanocomposite containing 10% silica showed high hardness and also the amount of cells attached to the porous surface was more than the smooth surface, which leads to more adhesion and growth of cells. The bioactivity of silica is due to The formation of apatite hydrocarbonate layer on it. The rate of tissue adhesion is dependent on the rate of HCA formation, which leads to reactions between the implant and surrounding tissues and fluids.

4.11. Implants With Nano Surfaces

Many researches have focused on improving the interaction of implant and bone, two approaches have been investigated to reach the optimal interface.

1. Chemical composition of inorganic phases such as calcium phosphate on the TIO2 layer
2. Physical modification of surface topography

Each approach aims to increase the speed of bone formation and decrease the time of fusion and integration and overall treatment time. At the micron scale, the concept of changing the topography of the surface is that we have a larger area in the rough surface than a smooth surface, which strengthens the adhesion and mechanical engagement of the implant and bone; But on the nanoscale, increasing the roughness increases the surface energy, so the absorption of growth protein and the transfer of bone cells and finally the integration happens faster.

4.12. The Use Of Nanodiamonds In The Mouth And Teeth

Scientists at the University of California discovered that diamonds on a very small scale (invisible to the human eye) can be used to stimulate bone growth, treat oral diseases and improve the condition of dental implants. "When nanotechnology is used in dentistry, you have to try materials that make sense," says Dr. Dean Ho, professor of oral biology and director of the Jerry Weintraub Center for Regenerative Biotechnology at the UCLA School of Dentistry. We need materials that are safe and secure and widely manufactured or found. Nanodiamond matches these characteristics." [57] Nanodiamonds, which are about 20,000 times smaller than a strand of hair, have specific surface properties that help deliver proteins that accelerate bone growth, and are more effective in this field than other conventional approaches. Nanoscale diamonds are elongated ovals (like a rugby ball) that are extracted as byproducts of mining and refining operations.

The findings of this research can be used to improve the treatment of bone necrosis (severe analysis of the jaw bone) and to deal with bone loss that may occur after implant placement.

Dr. Hu's research group studied the use of nanodiamonds as a method to deliver a solution containing bone growth-enhancing proteins in some operations such as jaw, face, and oral surgeries. Dr. Ho says that these proteins are usually sent to the surgical site through bulky collagen sponges. [58]

By using nanodiamonds, this solution can be delivered to the desired location in a non-invasive way, such as injection or mouthwash.

5. Conclusion

With the entry of nanotechnology into the field of human knowledge, the field of dentistry has not been left without this technology. Because the resulting new materials are much smaller; As a result, their use in dental restorations will lead to a better result. This technology is used in various sectors including dental materials, dental health and dental equipment. Many products empowered with nanotechnology have also become commercial products and have entered the market now. New developments in the field of nanotechnology to solve people's needs have received much attention. It is hoped that by using this technology, the problems that have existed in various fields of dentistry will be solved.

Colloidal nanoparticles are distributed as microscopic particles; Therefore, they can easily penetrate into bacterial cells and in this study, the produced nanoparticles showed a good antimicrobial effect on the oral bacteria examined; Therefore, the use of these nanoparticles based on their biological effects can be effective in dealing with infections caused by the studied oral bacteria. The application of nano-antimicrobials to control oral infections, as a function of their biocidal, anti-adhesion and transmission capabilities, is of increasing interest. Their use as components of prosthetic device coatings, agents that are applied locally, and in dental materials is currently being investigated. Future developments will likely focus on those nanoparticles with maximum antimicrobial activity and minimum host toxicity.

References

1. Jeevanandam J, Barhoum A, Chan YS, Dufresne A, Danquah MK. Review on nanoparticles and nanostructured materials: History, sources, toxicity and regulations. Beilstein J Nanotechnol. 2018; 9: 1050-74. https://www.ncbi.nlm.nih.gov/pubmed/29719757
2. Corrie SR, Thurecht KJ. Nano-bio interactions: Guiding the development of nanoparticle therapeutics, diagnostics, and imaging agents. Pharm Res. 2016; 33: 2311-3. https://www.ncbi.nlm.nih.gov/pubmed/27503179
3. Allaker RP. The use of nanoparticles to control oral biofilm formation. J Dent Res. 2010; 89: 1175-86. https://www.ncbi.nlm.nih.gov/pubmed/20739694
4. Almaguer-Flores A, Ximenez-Fyvie LA, Rodil SE. Oral bacterial adhesion on amorphous carbon and titanium films: Effect of surface roughness and culture media. J Biomed Mater Res B Appl Biomater. 2010; 92: 196-204. https://pubmed.ncbi.nlm.nih.gov/19810113
5. Clarkson BH, Exterkate RA. Noninvasive dentistry: A dream or reality? Caries Res. 2015; 49: 11-7. https://www.ncbi.nlm.nih.gov/pubmed/25871414
6. Selwitz RH, Ismail AI, Pitts NB. Dental caries. Lancet. 2007; 369: 51-9. https://pubmed.ncbi.nlm.nih.gov/17208642/
7. Ozsvath DL. Fluoride and environmental health: A review. Rev Environ Sci Biotechnol. 2009;8:59-79. https://link.springer.com/article/10.1007/s11157-008-9136-9
8. Sambhy V, MacBride MM, Peterson BR, Sen A. Silver bromide nanoparticle/polymer composites: dual action tunable antimicrobial materials. J Am Chem Soc. 2006; 128: 9798-9808. https://pubmed.ncbi.nlm.nih.gov/16866536
9. Ray SS, Okamoto M. Biodegradable polylactide and its nanocomposites: Opening a new dimension for plastics and composites. Macromol Rapid Commun. 2003; 24: 815-40. https://onlinelibrary.wiley.com/doi/abs/10.1002/marc.200300008
10. Mohanty A, Drzal L, Misra M. Nano reinforcements of bio-based polymers-the hope and the reality. J Am Chem Soc. 2003; 225: 33. https://www.academia.edu/28961821/064_pdf
11. Reyes L, Herrera D, Kozarov E, Roldán S, Progulske-Fox A. Periodontal bacterial invasion and infection: Contribution to atherosclerotic pathology. J Clin Periodontol. 2013; 40: S30-50. https://www.ncbi.nlm.nih.gov/pubmed/23627333
12. Seil JT, Webster TJ. Antimicrobial applications of nanotechnology: Methods and literature. Int J Nanomedicine. 2012; 7: 2767-81. https://www.ncbi.nlm.nih.gov/pubmed/22745541
13. Aydin Sevnic B, Hanley L. Antibacterial activity of dental composites containing zinc oxide nanoparticles. J Biomed Mater Res B Appl Biomater. 2010; 94: 22-31. https://pubmed.ncbi.nlm.nih.gov/20225252
14. Baehni PC, Takeuchi Y. Anti-plaque agents in the prevention of biofilm-associated oral diseases. Oral Disk. 2003; 9(Suppl 1): 23-29. https://pubmed.ncbi.nlm.nih.gov/12974527
15. Metin-Gursoy G, Taner L, Akca G. Nanosilver coated orthodontic brackets: In vivo antibacterial properties and ion release. Eur J Orthod. 2017; 39: 9-16. https://www.ncbi.nlm.nih.gov/pubmed/26787659
16. Ahmadian E, Shahi S, Yazdani J, Dizaj SM, Sharifi S. Local treatment of the dental caries using nanoparticles. Biomed Pharmacother. 2018; 108: 443-7. https://www.ncbi.nlm.nih.gov/pubmed/30241047
17. Ahmed F, Prashanth ST, Sindhu K, Nayak A, Chaturvedi S. Antimicrobial efficacy of nanosilver and chitosan against Streptococcus mutans, as an ingredient of toothpaste formulation: An in vitro study. J Indian Soc Pedod Prev Dent. 2019; 37: 46-54. https://www.ncbi.nlm.nih.gov/pubmed/30804307
18. Wu R, Zhao Q, Lu S, Fu Y, Yu D, Zhao W. Inhibitory effect of reduced graphene oxide-silver nanocomposite on progression of artificial enamel caries. J Appl Oral Sci. 2018; 27: e20180042. https://www.ncbi.nlm.nih.gov/pubmed/30540069
19. Hernandez-Gomora AE, Lara-Carrillo E, Robles-Navarro JB, Scougall-Vilchis RJ, Hernández-López S, Medina-Solís CE, et al. Biosynthesis of silver nanoparticles on orthodontic elastomeric modules: Evaluation of mechanical and antibacterial properties. Molecules. 2017; 22: 1407. https://www.ncbi.nlm.nih.gov/pubmed/28841178
20. Tirupathi S, Svsg N, Rajasekhar S, Nuvvula S. Comparative cariostatic efficacy of a novel Nano-silver fluoride varnish with 38% silver diamine fluoride varnish a double-blind randomized clinical trial. J Clin Exp Dent. 2019; 11: e105-12. https://www.ncbi.nlm.nih.gov/pubmed/30805113
21. Teixeira JA, Silva AV, Dos Santos VE, de Melo PC, Arnaud M, Lima MG, et al. Effects of a new nano-silver fluoride-containing dentifrice on demineralization of enamel and Streptococcus mutans adhesion and acidogenicity. Int J Dent. 2018; 2018: 1351925. https://www.ncbi.nlm.nih.gov/pubmed/29853891
22. Salas-Lopez EK, Pierdant-Perez M, Hernandez-Sierra JF, Ruiz F,

Mandeville P, Pozos-Guillen AJ. Effect of silver nanoparticle-added pit and fissure sealant in the prevention of dental caries in children. J Clin Pediatr Dent. 2017; 41: 48-52. https://www.ncbi.nlm.nih.gov/pubmed/28052214

23. Wu R, Zhao Q, Lu S, Fu Y, Yu D, Zhao W. Inhibitory effect of reduced graphene oxide-silver nanocomposite on progression of artificial enamel caries. J Appl Oral Sci. 2018; 27: e20180042. https://www.ncbi.nlm.nih.gov/pubmed/30540069
24. Nozari A, Ajami S, Rafiei A, Niazi E. Impact of nano hydroxyapatite, nano silver fluoride and sodium fluoride varnish on primary teeth enamel remineralization: An in vitro study. J Clin Diagn Res. 2017; 11: ZC97-100. https://www.ncbi.nlm.nih.gov/pubmed/29207844
25. Xiao S, Liang K, Weir MD, Cheng L, Liu H, Zhou X, et al. Combining bioactive multifunctional dental composite with PAMAM for root dentin remineralization. Materials (Basel). 2017; 10: 89. https://www.ncbi.nlm.nih.gov/pubmed/28772450
26. Espíndola-Castro LF, Rosenblatt A, Galembeck A, Monteiro G. Dentin staining caused by nano-silver fluoride: A comparative study. Oper Dent. 2020; 45: 435-41. https://www.ncbi.nlm.nih.gov/pubmed/32053463
27. Fernandes GL, Delbem AC, do Amaral JG, Gorup LF, Fernandes RA, de Souza Neto FN, et al. Nanosynthesis of silver-calcium glycerophosphate: Promising association against oral pathogens. Antibiotics (Basel). 2018; 7: 52. https://www.ncbi.nlm.nih.gov/pubmed/29954143
28. Zhang K, Li F, Imazato S, Cheng L, Liu H, Arola DD, et al. Dual antibacterial agents of nano-silver and 12-methacryloyloxydodecylpyridinium bromide in dental adhesive to inhibit caries. J Biomed Mater Res B Appl Biomater. 2013; 101: 929-38. https://www.ncbi.nlm.nih.gov/pubmed/23529901
29. Nozari A, Ajami S, Rafiei A, Niazi E. Impact of nano hydroxyapatite, nano silver fluoride and sodium fluoride varnish on primary teeth enamel remineralization: An in vitro study. J Clin Diagn Res. 2017; 11: ZC97-100. https://www.ncbi.nlm.nih.gov/pubmed/29207844
30. Fernandes GL, Delbem AC, do Amaral JG, Gorup LF, Fernandes RA, de Souza Neto FN, et al. Nanosynthesis of silver-calcium glycerophosphate: Promising association against oral pathogens. Antibiotics (Basel). 2018; 7: 52. https://www.ncbi.nlm.nih.gov/pubmed/29954143
31. Teixeira JA, Silva AV, Dos Santos VE, de Melo PC, Arnaud M, Lima MG, et al. Effects of a new nano-silver fluoride-containing dentifrice on demineralization of enamel and Streptococcus mutans adhesion and acidogenicity. Int J Dent. 2018; 2018: 1351925. https://www.ncbi.nlm.nih.gov/pubmed/29853891
32. Nozari A, Ajami S, Rafiei A, Niazi E. Impact of nano hydroxyapatite, nano silver fluoride and sodium fluoride varnish on primary teeth enamel remineralization: An in vitro study. J Clin Diagn Res. 2017; 11: ZC97-100. https://www.ncbi.nlm.nih.gov/pubmed/29207844
33. Naimi-Shamel N, Pourali P, Dolatabadi S. Green synthesis of gold nanoparticles using Fusarium oxysporum and antibacterial activity of its tetracycline conjugant. J Mycol Med. 2019; 29: 7-13. https://www.ncbi.nlm.nih.gov/pubmed/30709721
34. Fan Y, Pauer AC, Gonzales AA, Fenniri H. Enhanced antibiotic activity of ampicillin conjugated to gold nanoparticles on PEGylated rosette nanotubes. Int J Nanomedicine. 2019; 14: 7281-9. https://www.ncbi.nlm.nih.gov/pubmed/31686808
35. Saliminasab M, Jabbari H, Farahmand H, Asadi M, Soleimani M, Fathi A. Study of antibacterial performance of synthesized silver nanoparticles on Streptococcus mutans bacteria. Nanomedicine Research Journal, 2022; 7(4): 391-396. http://www.nanomedicine-rj.com/article_696643.html
36. Salas-Lopez EK, Pierdant-Perez M, Hernandez-Sierra JF, Ruiz F, Mandeville P, Pozos-Guillen AJ. Effect of silver nanoparticle-added pit and fissure sealant in the prevention of dental caries in children. J Clin Pediatr Dent. 2017; 41: 48-52. https://www.ncbi.nlm.nih.gov/pubmed/28052214
37. Scarpelli BB, Punhagui MF, Hoeppner MG, de Almeida RS, Juliani FA, Guiraldo RD, et al. In vitro evaluation of the remineralizing potential and antimicrobial activity of a cariostatic agent with silver nanoparticles. Braz Dent J. 2017; 28: 738-43. https://www.ncbi.nlm.nih.gov/pubmed/29211131
38. Dos Santos VE, Filho AV, Targino AG, Flores MA, Galembeck A, Caldas AF, et al. A new "silver-bullet" to treat caries in children-nano silver fluoride: A randomised clinical trial. J Dent. 2014; 42: 945-51. https://www.ncbi.nlm.nih.gov/pubmed/24930870
39. Hernández-Sierra JF, Ruiz F, Pena DC, Martínez-Gutiérrez F, Martínez AE, Ade JG, et al. The antimicrobial sensitivity of Streptococcus mutans to nanoparticles of silver, zinc oxide, and gold. Nanomedicine. 2008; 4: 237-40. https://www.ncbi.nlm.nih.gov/pubmed/18565800
40. Junevičius J, Žilinskas J, Česaitis K, Česaitienė G, Gleiznys D, Maželienė Ž. Antimicrobial activity of silver and gold in toothpastes: A comparative analysis. Stomatologija. 2015; 17: 9-12. https://pubmed.ncbi.nlm.nih.gov/26183852/
41. Agarwal H, Nakara A, Shanmugam VK. Anti-inflammatory mechanism of various metal and metal oxide nanoparticles synthesized using plant extracts: A review. Biomed Pharmacother. 2019; 109: 2561-72. https://www.ncbi.nlm.nih.gov/pubmed/30551516
42. Padovani GC, Feitosa VP, Sauro S, Tay FR, Durán G, Paula AJ, et al. Advances in dental materials through nanotechnology: Facts, perspectives and toxicological aspects. Trends Biotechnol. 2015; 33: 621-36. https://www.ncbi.nlm.nih.gov/pubmed/26493710
43. Cousins BG, Allison HE, Doherty PJ, Edwards C, Garvey MJ, Martin DS, Williams RL. Effects of a nanoparticulate silica substrate on cell attachment of Candida albicans. J Appl Microbiol. 2007; 102: 757-765. https://pubmed.ncbi.nlm.nih.gov/17309625
44. Feng QL, Wu J, Chen GQ, Cui FZ, Kim TM, Kim JO. A mechanistic study of the antibacterial effect of Ag+ ions on Escherichia coli and Staphylococcus aureus. J Biomed Mater Res. 2000; 52: 662-668. https://pubmed.ncbi.nlm.nih.gov/15537697
45. Furno F, Morley KS, Wong B, Sharp BL, Arnold PL, Howdle SM, Bayston R, Brown PD, Winship PD, Reid HJ. Silver nanoparticles and polymeric medical devices: a new approach to prevention of infection? J Antimicrob Chemother. 2004;54:1019–1024.

doi: 10.1093/jac/dkh478. [PubMed] [CrossRef] [Google Scholar]

46. Saliminasab M, Jabbari H, Farahmand H, Asadi M, Soleimani M, Fathi A. Study of antibacterial performance of synthesized silver nanoparticles on Streptococcus mutans bacteria. Nanomedicine Research Journal, 2022; 7(4): 391-396. http://www.nanomedicine-rj.com/article_696643.html
47. Espinosa-Cristóbal, LF, GA. Martínez-Castañón, RE Martínez-Martínez, JP Loyola-Rodríguez, N Patiño-Marín, JF Reyes-Macías, et al., Antibacterial effect of silver nanoparticles against Streptococcus mutans. Materials Letters, 2009. 63(29): p. 2603-2606. https://www.sciencedirect.com/science/article/abs/pii/S0167577X09006934
48. Rautela, A. and J. Rani, Green synthesis of silver nanoparticles from Tectona grandis seeds extract: characterization and mechanism of antimicrobial action on different microorganisms. Journal of Analytical Science and Technology, 2019. 10(1): p. 1-10. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9704479/
49. Prabhakar AR, Arali V. Comparison of the remineralizing effects of sodium fluoride and bioactive glass using bioerodible gel systems. J Dent Res Dent Clin Dent Prospects. 2009; 3: 117-21. https://pubmed.ncbi.nlm.nih.gov/23230498/
50. Vollenweider M, Brunner TJ, Knecht S, Grass RN, Zehnder M, Imfeld T, et al. Remineralization of human dentin using ultrafine bioactive glass particles. Acta Biomater. 2007; 3: 936-43. https://www.ncbi.nlm.nih.gov/pubmed/17560183
51. Sheng XY, Gong WY, Hu Q, Chen X, Dong YM. Mineral formation on dentin induced by nano-bioactive glass. Chin Chem Lett. 2016; 27: 1509-14. https://www.sciencedirect.com/science/article/abs/pii/S1001841716300602
52. Aras A, Celenk S, Dogan MS, Bardakci E. Comparative evaluation of combined remineralization agents on demineralized tooth surface. Niger J Clin Pract. 2019; 22: 1546-52. https://www.ncbi.nlm.nih.gov/pubmed/31719276
53. Dafar MO, Grol MW, Canham PB, Dixon SJ, Rizkalla AS. Reinforcement of flowable dental composites with titanium dioxide nanotubes. Dent Mater. 2016; 32: 817-26. https://www.ncbi.nlm.nih.gov/pubmed/27059772
54. Dias HB, Bernardi MI, Bauab TM, Hernandes AC, de Souza Rastelli AN. Titanium dioxide and modified titanium dioxide by silver nanoparticles as an anti-biofilm filler content for composite resins. Dent Mater. 2019; 35: e36-46. https://www.ncbi.nlm.nih.gov/pubmed/30528295
55. Yan H, Yang H, Li K, Yu J, Huang C. Effects of chlorhexidine-encapsulated mesoporous silica nanoparticles on the anti-biofilm and mechanical properties of glass ionomer cement. Molecules. 2017; 22: 1225. https://www.ncbi.nlm.nih.gov/pubmed/28753997
56. Garner S, Barbour ME. Nanoparticles for controlled delivery and sustained release of chlorhexidine in the oral environment. Oral Dis. 2015; 21: 641-4. https://www.ncbi.nlm.nih.gov/pubmed/25703954
57. Bellis CA, Nobbs AH, O'Sullivan DJ, Holder JA, Barbour ME. Glass ionomer cements functionalised with a concentrated paste of chlorhexidine hexametaphosphate provides dose-dependent chlorhexidine release over at least 14 months. J Dent. 2016; 45: 53-8. https://www.ncbi.nlm.nih.gov/pubmed/26756881
58. Vieira AP, Arias LS, de Souza Neto FN, Kubo AM, Lima BH, de Camargo ER, et al. Antibiofilm effect of chlorhexidine-carrier nanosystem based on iron oxide magnetic nanoparticles and chitosan. Colloids Surf B Biointerfaces. 2019; 174: 224-31. https://www.ncbi.nlm.nih.gov/pubmed/30465997
59. Souza BM, Comar LP, Vertuan M, FernandesNeto C, Buzalaf MA, Magalhães AC. Effect of an experimental paste with hydroxyapatite nanoparticles and fluoride on dental demineralisation and remineralisation in situ. Caries Res. 2015; 49: 499-507. https://www.ncbi.nlm.nih.gov/pubmed/26278685