Consideration of the actual stage of nanomaterials used in dentistry

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Abstract. The present paper is meant to be a short presentation of the actual stage of nanomaterials used in dentistry. It shows some theoretical consideration regarding characteristics of some nanomaterials used in dentistry. In recent years, increasing demands for dental reconstruction, have led to the development of new materials that have multiple applications in dental medicine and which must meet aesthetic requirements, biocompatibility requirements as well as hardness or durability. Surpassing the extraction period, dentistry has entered the "restorative era" in which it is desirable to introduce new materials that will lead to the most natural restorations with the physical and chemical closest properties to those of the dental tissues. The discovery of such materials has become a definite necessity in order to achieve consistent progress in this respect. Interest in using nanomaterials, composites with nanomaterials in restorative dentistry, as well as reconstruction, is constantly increasing. It is therefore important that the mechanical properties and not only, of these materials be carefully studied and especially improved.

1. Introduction

Nanotechnology has a strong impact on all areas (medicine, engineering, communications, the environment, cosmetics), being a multidisciplinary field based on the belief that new scientific discoveries will make it possible to manipulate and control each atom in different structures. Restorative dental medicine undergoes a period of rapid change as the pattern of the appearance and evolution of carious malosis changes, as well as the discovery of new materials and techniques.

The domain is interdisciplinary and complex, involving the simultaneous use of knowledge in several areas and scientific disciplines such as clinical / medical research, biology, chemistry, physics, mathematics, engineering, and robotics. Nanomedicine encompasses several interlocking and mutually reinforcing areas: nanomaterials and nanodispensers, molecular nanotechnology, nanoscale imaging, innovative drug delivery systems, nanotoxicolog.

Research into nanomedicine allows a deeper understanding of human body functioning at the molecular level, meeting patients' requirements in diagnosing and treating diseases and restoring certain functions of affected organs or tissues. In order to improve the characteristics of some nanomaterials used in dental medicine, in this paper I tried a thorough investigation of both components, nanocomposite materials and dental biomechanics.
2. The current state

In recent years, increasing demands for dental reconstruction have led to the development of new materials that have multiple applications in dental medicine and which have to meet several aesthetic requirements of biocompatibility as well as of hardness or resistance over time. Interest in the use of nanomaterials, composites with nanomaterials in restorative dental restoration and reconstruction is on the rise. That is why it is important that the mechanical properties and not only of these materials be carefully studied and especially improved. By diversifying dental restoration and reconstruction materials with an increasingly complex chemical composition can increase the risk of adverse reactions. Therefore, the dentist needs to know the structure and properties of the materials he uses and adapt them to each case. This progress in the field of composite nanomaterial technology has significantly changed the options of physicians. Composite materials combine into a single product, some components, which usually do not naturally associate. At small dimensions the materials have properties different from those on a macroscopic scale [1]. For example, nanoscale materials have a higher mechanical strength than macroscopic samples of the same material.

The ability of a material to deform without it. Breaking depends on the chemical bonds that keep the atoms together. In principle, ties chemical properties are the same, both in the nanoscale and in the macroscopic scale. But the evidence macroscopic include many defects, cavities, missing atoms, etc. which limits properties mechanical. The density of these defects can be much smaller on a nanometer scale, and like resulting nanomaterials become more resistant.

Different types of composite nanomaterials used in dental medicine differ in viscosity. Flow (fluid) composites are applied by syringes directly into small cavities, and condensable composites are designed for medium or large cavity reconstitution. The composite materials differ from each other, especially by the size of the filler particles.

The analysis of new methods and conceptual models on the synthesis of nanocomposites, however, should start from the identification of the disadvantages of the existing methods.

Nanotechnology, on a scale of less than 100 nm, can be said to be the artistic engineering that allows the design, properties and performance to be achieved on finished materials.

Remarkable studies have been made in this area over the past few years, going from theory to clinical studies. At present, there is a range of applications of these nanomaterials in different fields, which is to be improved both quantitatively and qualitatively.

Table 1. Some current and future applications of nanomaterials

| Developing | In the initial phase | Existing products |
|------------|---------------------|-------------------|
| Nanocrystalline drugs for light absorption | Molecular labeling using quantum dots of CdSe | Antibacterial storage elements based on Ag |
| Insulin inhalable | "Carriers" for low solubility drugs | Gold for labeling and detection |
| Nanospheres for inhalable and injectable drugs | Instruments for implants with hydroxyapatite | Magnetic contrast imaging agents based on Fe2O3 |
| Computational biochemical computational nanometric modeling at hydrophobic-hydrophilic interface between tooth and composite material | Embedding nano-fibers dispersed through resin for reinforcement | Solar screens with ZnO and TiO2 |
| Detecting viruses using quantum dots | | |
| Magnetic particles for repairing the human body with prostheses or artificial parts | | |
| Bone growth promoters | | |
Table 2. Applications of nanomaterials in dental medicine and products on the market

| Field                          | Existing material       |
|-------------------------------|-------------------------|
| Restorative dental medicine   | Ketac™, Ketac N100      |
|                               | Filtek Supreme XT       |
|                               | Premise TM              |
|                               | Ceram XT                |
| Regenerative dental medicine  | Ostim                   |
|                               | Nano-bone               |
| Periodontology                | Arestin                 |
| Dental prevention             | NanoCareGold            |
| Orthodontics                  | KetacTM                 |
|                               | Filtek Supreme Plus Universal |
| Prosthetics                   | Nanotech elite H-D plus |
| Implantology                  | Nanotite™               |
| Endodontics                   | AH plus™                |
|                               | Guttaflow               |

The latest nanocomposites used in restorative dentistry due to their special properties (abrasion resistance, hardness, tear resistance, good adhesion to dental structures, etc.) are nanocomposites which containing a resin type matrix and nanoparticles or metal-ceramic for dental implants.

The interest in the field of these materials also concerns the possibilities to manipulate their structure, in the desire to modify and improve the mechanical, chemical or electrical properties. Following studies, it has been observed that changes in properties can be observed when the particle size reaches a level called critical size.

Table 3. Changes in material properties depending on the particle size

| The studied property                        | Particle size (nm) where the change of properties is observed |
|---------------------------------------------|---------------------------------------------------------------|
| Catalytic activity                          | <5                                                            |
| Transforming magnetic materials from hard to fine | <20                                                           |
| Changing the refractive index               | <50                                                           |
| Production of consolidation and quenching   | <100                                                          |
| Change in hardness and plasticity           | <100                                                          |

Although current nanotechnology-based products are modest, the international scientific community believes that this multidisciplinary field can influence people's lives through applications in most fields, including dental medicine, with the necessary potential. Determination of mechanical properties, physical and biological properties of these nanocomposite materials is a necessary step to assess the ability of these composites to cope with clinical needs.
Table 4. The specialized equipment required for the characterization and production of nanomaterials

| Naming                                                      | Characteristics                                                                 |
|--------------------------------------------------------------|---------------------------------------------------------------------------------|
| JEOL 5600 LV Electronic Scanning Microscope,                | Enlarge: x300000                                                                 |
| equipped with Oxford Instrument X-ray Spectrometer          | - possibility of changing the speeds of the containers and the disc;            |
| Planetary mill Fritsch, Pulverisette 4                      | - possibility of grinding in a controlled atmosphere;                           |
|                                                               | - afferent soft.                                                                |
| Planetary mill Fritsch, Pulverisette 6                      | - programmable disk and container speeds;                                       |
|                                                               | - lower energy range (especially for mechanical milling).                      |
| Heat treatment furnace                                      | - temperature working, up to 1700 ° C; - working ability in controlled atmosphere.|
| INEL Equinox 3000 Difractometer                             | Angular range can be recorded instantly                                         |
| Plasma sintering Equipment                                  | Control of temperature and electric current pulse                               |
|                                                               | Electric current 1500-2000 A                                                    |
|                                                               | -100tf                                                                          |
| Hydraulic press                                             | Maximum 1000x zoom, dedicated photo / video camera, Soft Olympus Analysis       |
| Metallographic microscope                                   | Sensitivity 0.0001g                                                             |
| Analytical balance Precision 200                            | Determination of granulometric distribution between 10nm and 2000μm           |
| Particle analyzer (LASER Analysette 22 Nanotec)             |                                                                                 |

2.1. Manufacture of nanostructures
Taking models from nature, researchers have developed two possible strategies for obtaining of nanostructured materials [2]. The top-down strategy (from sea to small) consists of reducing the size of larger particles by grinding and sifting. Bottom-up strategy [3] (from low to high) describes the development of nanoparticles starting from atoms and molecules, passing through the phenomenon of controlled-gel sol-gel or pyrolytic flame. Both strategies show the inconvenience of particle agglutination [4]. Nanoparticles have a larger area than the volume and hence a larger surface energy. Untreated they tend to agitate rapidly in 0.5 μm (500 nm) microparticles in diameter, losing its property. Nanoparticle surfaces need to be inactivated chemically in order to benefit from their special properties. Nanotechnology offers more possibilities for obtaining nanostructures. Among the most used techniques we list: i) Self-assembling; ii) Lithography at nanometric scale; iii) Transfer of a print; iv) Inkjet printing; v) Compliance by demolition (release); vi) Hybrid techniques; vii) Microscope recording with local probe. In the following, we will detail some of these method.

2.1.1. Self-assembling. Is an inexpensive method of building materials and assemblies nanostructured. It is essential to mention that supramolecular structures are self-assembling without external intervention. These materials are formed by interactions interatomic and intermolecular, other than metallic, ionic or covalent bonding forces, traditional. This opens a new horizon for the development of nanostructures based on assembling molecular constituents. Thus, after molecular chemistry, founded on bonds which are established between atoms to form molecules, is another field, chemistry supramolecular - based on the association of two or more chemical species [5].
2.1.2. **Transferring a pattern.** Is a technique that starts from an object made by conventional or UV lithography, and a mold is produced resulting in a mold. One is applied elastomeric material (often polydimethyl and PDMS lax) which, after crosslinking, forms which can then serve for the replication of several (nano) structures where it started.

2.2. **Classification of composites**
- Organic matrix composites (OCM);
- Metal matrix composites (MMC) made of alloys, magnesium, titanium, nickel, copper, etc.
- Ceramic matrix composites (CMC) made of silicon carbides, aluminum oxides, ceramic materials. \[6\]

The second classification criterion refers to reinforcement: these include particle reinforcements, filaments, continuous fiber composites, and composites containing fabrics.

Bone tissue in the human body is also a composite. It is made up of a hard but crumbly material called hydroxyapatite (calcium phosphate) and a soft and flexible material called collagen (a protein). Collagen cannot give the bone system the resistance it needs, but in combination with hydroxyapatite this becomes possible.

Most composite materials consist of two phases: a phase called a matrix that is continuous and surrounds the second phase, called the dispersed phase. The properties of the composites depend on the properties of the component phases, the quantities in which they are present, as well as the shape and size of the particles and their orientation.

The bond between the fibres and the matrix is created during the composite material manufacturing phase. It has a fundamental influence on the mechanical properties of the material.

The properties of these materials are given by:
- particle size;
- the volumetric fraction of nanoparticles;
- granulometric distribution of particles.

2.3. **Properties of composite materials reinforced with nanoparticles**

The use of these materials is constantly increasing, due to the advantages they have, namely:
- Costs are lower compared to fibres;
- It is possible to obtain an isotropic material in the composite matrix;
- Matrix embedding technologies are simpler.

The size of these particles is very important because, for nanoscale particles, the relationship with the matrix manifests at the atomic level, which prevents the deformation of the matrix in the vicinity of each particle, and the matrix transfers to the particles much of the voltage to which the nanocomposite is subjected. \[7\]

The 10 to 100 nanometer-sized particles, evenly dispersed, give the composite material high mechanical strength and hardness, but make plastic deformation limited due to the fact that it prevents the movement of the dislocations.

2.3.1. **The mechanical properties of composite materials reinforced with nanoparticles.** The properties of these composites depend on the characteristics of the matrix, the size of the reinforcement particles, the nature of the particles, the way they are dispersed. Among the most important features of particle-reinforced composites, we mention the following:
- Traction tear strength - this can be caused by matrix breakage, breakage at matrix and particle interface, or tearing of reinforcement particles at the action of an external force;
- Compressive strength - this characteristic depends entirely on the nature and properties of the matrix, because under the action of compressive force, the composite begins to deform plastic.
2.3.2. Nature and properties of reinforcing particles. The main groups of reinforcement particles are:

- Metallic oxide particles (Al$_2$O$_3$, SiO$_2$, TiO$_2$, MgO, etc.)
- Metallic carbide particles (SiC, TiC etc.)

Table 5. Properties of some particles used to obtain composite materials

| Material | Density g/cm$^2$ | Expansion coefficient $10^{-6}/^{\circ}C$ | Traction resistance MPa | Young's module GPa |
|----------|-----------------|--------------------------------|-------------------------|-------------------|
| Al$_2$O$_3$ | 3.98 | 7.92 | 221 | 379 |
| C | 2.18 | -1.44 | - | 690 |
| SiC | 3.21 | 5.40 | - | 324 |
| MgO | 3.58 | 11.61 | 41 | 317 |
| SiO$_2$ | 2.66 | 1.08 | - | 73 |
| TiC | 4.93 | 7.60 | 55 | 269 |

According to research in this field, the most common are systems where the particles are with reduced size (<100 μm) in proportions of 10% -30%.

2.4. New aspects followed in manufacturing dental nanocompositions

Most of the efforts made in recent years in research have focused on adhesive systems, composites, ceramics and dental aesthetics (teeth whitening techniques). The future dental medicine composites is becoming more and more promising. Silanic agents long used in composite manufacturing are optimized and much better controlled to obtain an excellent adhesion interface [8]. Loading with composite filler, which directly influences the properties of the material (wear resistance, for example) is increasingly based on nanomaterials (nanoparticles). Nanoparticles cause the appearance very small distances between the composite components, increasing wear resistance a resin matrices [9]. Also, some nanofillers induce chromatic changes and radioactivity in systems. The current interest is to move from photopolymerization techniques to those of homogeneous polymerization. Despite the positive interest sparked among practitioners photopolymerization methods, they do not provide a certain depth of polymerization or a degree of conversion, especially in hard-to-reach cavities, so are being tested polymerization methods [10].

Generally, a larger amount of filler leads to increased hardness, elasticity, fracture and wear resistance. We will stop on the last aspect. The force itself does not explain the relationship between the filler and the wear resistance. Wear in the case of composites used in dentistry involves several different mechanisms [11]. In oral environment wear on occlusal surfaces is caused by abrasive particles with dimensions ≈ 0.1 μm found in food and which it is assumed to be silicon-based. The composite matrix is subject to wear, but not to the fillet which is tougher.

Thus, the protection of the matrix is possible by designing particles of load that is in close contact to protect the particle impact matrix abrasives from food. These are called microprotection [12] and have long been studied for composites with microparticles. It is obvious that this has improved for microhybrid composites and newer ones for nanohybrids.

In recent years, the increasing demands for aesthetic reconstructions have led to the development of new classes of composites for direct reconstitution, with excellent physical, mechanical, aesthetic and durable properties. The latest material is composites containing a conventional resin matrix in which were embedded nanoparticles or nanocomponents (clusters).

Clinicians need to understand exactly the nanometric concept, which is equivalent to 103 μm, in other words 1μm = 1000 nm. In dental medicine the nanofiller is a particle inorganic in the approximate size of 40 nm = 0.04 μm. This size, however, is not is innovative in terms of dental
composites, as microfilaments have been touched this size of the filler since the 70's. What is absolutely new is the possibility of nano fillers to improve inorganic phase loading.

An increase in filler content implies an improvement in mechanical properties [13]. The objective of nanotechnology is to develop a dental restorative material that can be used in any area (anterior or posterior) of the dental arcade. This material must combine the qualities of a microfil composite with that of a hybrid composite: through finishing and polishing results in a smooth and weather-resistant surface and mechanical properties to provide them with resistance to stress [14].

3. Types of dental nanocomposites

3.1. Nanocomposites of the polymer-ceramic type
Polymeric composites are those materials having in their composition at least two components of different chemical structure, thermodynamically compatible, mutually dispersed or associated, at least one of which is a polymeric phase. [15]

They have the following advantages:
- they are lighter due to the low density of the matrix;
- shows the resistance / density ratio higher than classical materials;
- they have good resistance to fatigue;
- they have resistance to the corrosive action of environmental factors;
- they have low energy consumption with regard to the technology of forming the parts;
- a high performance / price ratio.

Matrix and reinforcement usually have opposite properties. Thus, from a soft matrix and a hard fitting, or from a hard matrix and a soft reinforcement, a composite can be obtained several times more resistant to the weaker component. The distribution of the reinforcement in the matrix may be different; the particles can be evenly or unequally distributed, in linear strings or agglomerations on certain planes, resulting in variations in mechanical properties. Polymeric composites with good mechanical and tribological characteristics have to meet certain requirements, such as low wear and friction coefficients, good mechanical characteristics at high temperatures [16].

From the studies carried out, it was shown that the introduction of polymer addition materials meant to reduce the negative effects induced by the temperature increase of the parts in contact, the interaction of the surfaces, the applied loads and the working environment. Particles and fibers, especially short, are used to add polymers, but solid lubricants, such as PTFE and graphite, can also be used to reduce the friction coefficient.

3.2. Nanocomposites of metal-ceramic type
Ceramic nanomaterials are generally refractory polycrystalline compounds, such as: silicates, metal oxides, carbides, refractory hydrides, sulphides, selenides, with atomic and ionic bonds, whose complex crystalline structure is obtained by sintering. General for their hardness and wear resistance, in applications such as hip and tooth joint surfaces, but also for bone restoration initiator properties as bone-binding surfaces in implants.

Ceramic materials have recently received particular attention as potential candidates for manufacturing bone replacement / tooth replacement implants. They are already widely used in dentistry due to their aesthetic appearance, high resistance to compression and lack of reaction to human body fluids, although they are currently not widely used in nano-level composites.

Bio ceramic from calcium phosphates is the closest bio ceramic to the composition of the natural bone. The stabilization of the phases in the system, especially in the C3P - apatite zone, is of great interest for bio ceramic materials.

Metallic materials can be sterilized by common techniques, while ceramic materials only by dry heat. It can be seen that the biocompatibility and mechanical properties of the materials are inverse, the materials with high mechanical strength being biotolerated and the bioactive ones having properties reduced mechanical properties.
Table 6. Physical and mechanical properties of ceramic materials used in orthopedic and implantological prosthetics

| Ceramic material          | Porosity % | Density g/cm³ | Young's Modulus GPa | Resistance to Compression MPa | Resistance to Tearing MPa | Resistance to Flexure MPa |
|--------------------------|------------|---------------|---------------------|-------------------------------|--------------------------|--------------------------|
| Aluminium oxide          | ≈0         | 3.93-3.95     | 380-400             | 4000-5000                     | 350                      | 400-560                  |
| Hydroxyapatite           | 0.1-3.0    | 3.05-3.15     | 7-13                | 350-450                       | 38-48                    | 100-120                  |
| Vitreous carbon          | -          | 1.4-1.6       | -                   | -                             | -                        | 70-200                   |
| Zirconium dioxide        | ≈0         | 4.9-5.56      | 150-190             | 1750                          | -                        | 150-700                  |

3.3. Nanocomposites based on hydroxyapatite

Hydroxyapatite ceramics are widely used for reparative operations in the human body due to the fact that it has excellent biocompatibility. This material has numerous applications in implants such as hip bonds, bone substitutions, dental implants. However, low mechanical strengths and low tensile strength are restrictive conditions when used. In order to eliminate these inconveniences, in the hydroxyapatite ceramics, reinforcement materials are introduced, among which the zirconium dioxide most commonly used for this purpose [17].

3.3.1. Ceramo-hydroxyapatite. The starting material is pentachlorohydroxy-triphosphate, (Ca₅ (OH) (PO₄) ₃); Synthesis process results in ceramic hydroxyapatite.

Physical and Mechanical Properties [18]
- mechanical resistance - is very high, given by the ceramic structure. Dense ceramics have greater resistance than porous ceramics.
- ph - neutral - 7.
- electric charge - neutral
- chemical - the structure corresponding to the naturally occurring bone mineral hydroxyapatite.

3.3.2. Hydroxyapatite powders doped with silver. It is well-known that in surgery the risk of infection of post-operative wounds is an important issue. To prevent such problems, broad spectrum antibiotics are now being used against which microbial strains have developed resistance. An alternative to the use of antibiotics could be the use of silver, an element known from ancient times to possess antibacterial properties and disinfectants. Thus, there are some studies on silver-doped hydroxyapatite that could reduce the risk of post-operative infections (for example: after installing a dental prosthesis or an implant).

Following the doping of hydroxyapatite with silver, a single mineralogical phase is formed, namely hydroxyapatite. Silver also replaces calcium in the hydroxyapatite structure, and there are studies that have shown that with the increase in silver concentration, the average size of crystallites decreases.

Vitreous ceramics have ceramic constituents based on oxyapatite, fluorapatite, hydroxyapatite etc., which activate tissue-implant reactions and lead to stimulation of bone regeneration in the implanted area. Bioactive composites can also be used as superficial bioactive glass layers deposited on metallic surfaces.

A new type of composite material is used in implantology; it consists of a metal substrate (Ti-Al-V) which is coated with bioactive hydroxyapatite. This type of composite facilitates the infiltration of bone tissue by providing a biological binding of the tissue to the ceramic implant. As a result, a very good anchoring of the inorganic bone implant is achieved. The bending strength of the HA / Ti composite is about 150 MPa, so with high mechanical properties, which provides sufficient resistance to the inorganic implant, which is included in the hard bone tissue and thus ensures the biological and functional stability of the implant.
4. Anatomical and biomechanical aspects of teeth
First of all, we must say that the teeth are the toughest structures of the body, namely the dental enamel. Therefore, the characteristics of the materials for restoration or reconstruction are difficult to obtain because they must have parameters at least similar to those of the natural tooth, both mechanically, as well as biocompatibility and dental aesthetics.

Dental treatments of any kind are supposed to restore the morphology of maxillary dental system functions lost or altered following various specific conditions. Such an objective is impossible to achieve in its ideal sense by virtue of the limited possibilities of the human being.

The teeth are formed in two parts:
1. Dental crown - This is the visible part of the tooth cavity. Hence the name of the prosthetic work "dental crown" because this part of the tooth is trying to replace it.
2. Dental Radiation - It is the part located in the maxillary bone that assures the implantation of the tooth. A tooth may have one or more roots. Also, their shape and size differ from tooth to tooth.

Denture plays a vital role in digesting food, helping to fragment it into smaller pieces by biting and mastication. Dental enamel consists of 98% hydroxyapatite. Hexagonal apatite crystals are tightly wrapped and aligned perpendicular to the tooth surface. The excellent hardness of the tooth enamel provides excellent resistance to abrasion and wear; the high content of ceramic material makes it very tough but with a low tear strength. A tooth that would only consist of enamel would be prone to rupture, so enamel is the garment of a softer substrate but more resistant to tearing, the dentin. Dentine has a chemical composition similar to cortical bone, having also similarities in structure.

The root of the tooth is covered with cement, a fibrillated bone substance with a porous structure. The pulp occupies the central cavity and contains circularly aligned collagen fibres, nerve cells and blood vessels, the periodontal membrane fixes the root of the tooth into the alveolar bone.

Application of engineering principles at the level of living systems (biomedical engineering) opened a new era in the diagnosis and therapy of various diseases. Biomechanics studies the response of living organisms to different demands.

The various types of fixed prosthetic restorations that solve a wide range of edentations (supun) subject maxillary dental system to various force, which translate through a series of displacements in different directions or plans of the space (translation, rotation) and / or deformations (flexion, torsion), the way of response of the involved tissues being different.

5. Conclusions
Nanotechnology has the power to revolutionize the scientific world, allowing scientists to manipulate matter at atomic or molecular level using physical, chemical, biological or engineering techniques. It allowed researchers to understand the relationship between macroscopic properties and the structure of materials.

Dental nanocomposites have to meet a number of requirements: to have the color, resilience and hardness similar to natural teeth, to be easy to apply and to allow predictable results every time. They also have to be biocompatible and adhere to enamel and dentin. Composites with nanofilling, state-of-the-art nanoparticle materials have outstanding properties in terms of aesthetics and gloss over time as well as mechanical strength and predictability.

The development of completely new and innovative technologies, nanomaterials and nanosystems have led to a new generation of products that will improve the quality of life and the environment in the coming years. The progress of science at the nano level through the smaller dimensioning of the particles that are part of the restorative composite materials is preceded by the so-called "dento-mimetic" reconstructions, which will follow the reproduction of the dental enamel in detail. Embedding in the matrix structure of composites nanoparticles with antibacterial and remineralization based on fluoride or amorphous calcium phosphate represents the latest trends in nanotechnology with applications in dental medicine currently in the experimental phase.

As a coating of a metal, hydroxyapatite offers the mechanical integrity of the metallic device and the biocompatibility of the mineral composition of the bone. Hydroxyapatite coatings can eliminate
the need to use cements to fix the device to the existing bone and minimize the appearance of corrosion products resulting from direct metal-body fluid contact. Because worn fragments of cements and corrosion products are the main sources of irritation and inflammation of tissues associated with implants, the deposition of hydroxyapatite could intensify the healing process and reduce the convalescence period.

It can be said that nanotechnology applied in dental medicine can be categorized as an innovative project, thus having a strong potential to revolutionize the diagnosis and treatment, as well as regeneration of tissues.

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