ROLE OF NANOMATERIALS IN PROSTHODONTICS : A REVIEW

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Introduction: 'Nano' simply means One Billionth/10^{-9}/0.000000001.[1] Nanotechnology is engineering at the atomic and molecular scale. Materials fabricated at nanoscale demonstrate superior properties as compared to what they exhibit on a macroscale, facilitating exclusive applications. For example, opaque substances become transparent such as copper; inert materials become catalysts (e.g. platinum); stable materials turn combustible (e.g. aluminum); solids turn into liquids at room temperature (e.g. gold); insulators become conductors (e.g. silicon).[2]

The evolution for nanotechnology dates to around late 19th century. The term 'nanotechnology' was conceived and popularized by Prof. Kerie E Drexler in 1977.[3] The potential benefit includes its ability to exploit the atomic and molecular properties of materials and to foster newer materials with better properties.

The growth of nanotechnology and scope of its application has revolutionized the medical field progressing to emergence of "Nanomedicine" that is - applications of nanotechnology for treatment, diagnosis, monitoring and control of biological systems.

Similarly, development of "nanodentistry" will make the maintenance of near-perfect oral health conceivableusing nanomaterials biotechnology including tissue engineering and nanorobotics.

New treatment modalities have been suggested in literature, such as remineralization, tooth hypersensitivity, orthodontic nanorobots, dental cosmetics, local anesthesia, photosensitiserscarriers, impression materials, nanoencapsulation, nanoneedles, bone replacement materials and dentifrices etc.

Prominent developments are the nanocomposites, bonding agents, emerging of link between biomolecules and nanotechnology through the generation of biomaterials.

Nanorobots being suspended in liquid and able to swim about, devices would be able to reach surfaces beyond reach of toothbrush bristles or the fibers of floss. As short-lifetime medical nanodevices, they could be built to last only a few minutes in the body before falling apart into materials of the sort found in foods (such as fiber). With this sort of daily dental care from an early age, tooth decay and periodontal disease can be prevented.[4]

The regeneration of hard and soft tissues around a solid implant, or development of new tissues to replace implanted biodegradable material will provide new vistas in the field of tissue regeneration.

The article reviews the concept of nanomaterials and its application in the Prosthodontics.

Concept of nanomaterials: Materials reduced to the nanoscale can suddenly show very different properties compared to what they exhibit on a macroscale, enabling unique applications.

The unique properties of the nanomaterial includes[5]–

- Small size effect,
- Quantum size effect
- Quantum tunnelling effect
- Surface effect

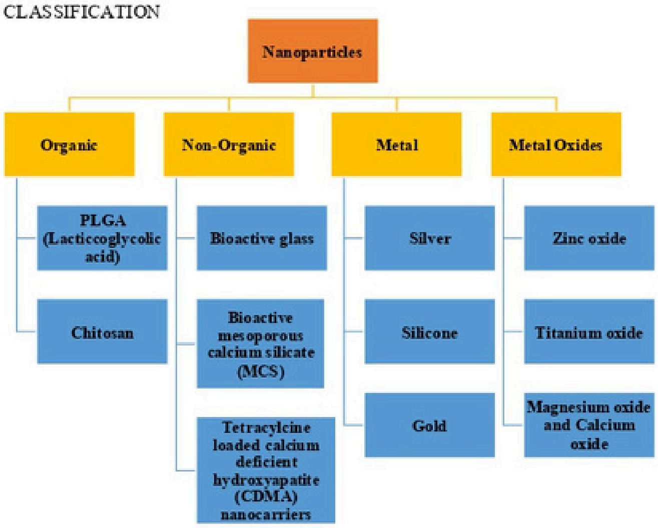
The small size effect[5] is the minimum amount of energy that is required for interactions between nanoparticles (interactions like dissolution, melting, boiling, bonding, molecular reactions). This effect can be of particular use in the dental materials to improve flexure strength as unlike the usual sized particle they do not resist the shear strength rather get accommodated to it.

Also, the extensive aggregation prevents the material from developing discontinuity that is the Quantum size effect.

The Quantum tunnelling effect is that when a nanoparticle is made to pass through a thin barrier (eg - a cell membrane) it would not require much energy as it passes through the area of least resistance (the membrane in this case), this phenomenon explains the antimicrobial activity by membrane disintegration.

The surface effect can be explained by the fact that nanoparticles have multiple surfaces which leads to more area for interactions (precisely the high surface energy).

CLASSIFICATION



Nanomaterials in prosthodontics:

1 Nanometals

- Framework for Removal Partial Denture

Cobalt-chromium alloy or cobalt-chromium-molybdenum alloy and titanium alloys are most frequently used for fabricating metal stents of partial denture framework.

The cobalt chromium binary alloy is developed into cobalt chromium-tungsten alloy and later into cobalt chromium molybdenum alloy. It displays superior mechanical properties and corrosion resistance as compared to stainless steel or gold alloy[4,5].

- Modification of Titanium surface (Implant)

Though titanium has superior properties like specific strength, high corrosion resistance, good biological security and elastic modulus, biological integration is the most crucial element for perennial success of implants.

Therefore, use of titanium nanoparticle was experimented by Dorkhan et al in his study. He altered the surface of titanium implant by anodic oxidation into nanoscales with 50 nm range pores. It was noted that similar level of adherence of soft-tissue cells i.e keratinocytes and fibroblasts amongst altered and unaltered implant surfaces. While, attachment of oral streptococci was significantly lower on the nanostructured surface.[6]

Anodization is a simple and less expensive process to promote osteoblastic adhesion according to the various studies. This was demonstrated by Yao et al (2015) in his study to create nano-surface on titanium and Ti6Al4V implant by anodization. It was observed that the anodized surface had higher roughness at nanoscale dimensions than the un-anodized Ti-based surfaces. Thus, enhancing osteoblastic adhesion on the anodized metal substrates.[7]

Nanoceramics: Routinely used alumina ceramics though have superior mechanical properties but one of its major drawback is that it is more likely to crack.

Zirconia ceramics have significantly overcome the shortcomings of alumina ceramics but they lack toughness.

'Nanoceramic' refers to the ceramic material with nanoscale dimensions in the microstructures phase.[8] Ceramic is essentially a kind of brittle material; however, nanoceramic shows good toughness and ductility, this is due to the arrangement of atoms in nanoceramics interface.

Series of studies were conducted with regards to toughness and strength of nanoceramics like, Wang et al (2006) in his experiment, compared addition of 20% of Nano ZrO_2 to a composite of AL_2O_3

and conventional ZrO_2 in terms of toughness. Nanoceramic yielded better results.[5]

Li et al (2011) through his study revealed the hardness of traditional ZrO_2 was 1500 while that of nano ZrO_2 is 1750.9

V. Raj et al (2014) compared the micro hardness and toughness of Conventional TiO_2 Ceramics Vs Nano TiO_2 Ceramics. Nano TiO_2 exhibited 13000kN/m2 micro hardness and superior hardness while conventional TiO_2 ceramics had value less than 2000kN/M2.[2]

In general, the advantages of nanoceramics that could be summarized are:

Super plasticity.

Superior mechanical properties

Nanoresins: PolyMethylMethacrylate [PMMA] has good mechanical properties such as high hardness, rigidity, biological compatibility, aesthetics, and easy processing characteristics.

The major drawbacks include instability of color, poor wear resistance, volumetric shrinkage, oral mucosa irritation, and discoloration.

Low fatigue strength, low abrasion resistance and microbial adhesion are the other disadvantages of PMMA.

Fusion of PMMA and nanoparticles display an array of superior properties. Nanoparticles like Tio_2, ZrO_2, CNT have been used to enhance PMMA material.[2,5]
Hua et al (2013) performed a study in which the saturation of reinforcing effect was studied for conventional PMMa and TiO_2 reinforced PMMA. Results were:

A Nano particle with aspect ratio larger than 30 could nearly make the reinforcing effect reach saturation.

Saturation at 3% volume increase is equivalent to 6% volume increase of glass fibre.

Cooper et al(2002) showed that addition of small amount of CNT will significantly improve the impact strength of PMMA. Hong et al (2003) added methcryloxypropyltrimethoxysilane (MPS) modified silica nanoparticles to PMMA which increased the tensile strength and tensile modulus.[6]

Mudhaffar (2012) evaluated the effect of addition of different percentage of modified ZrO_2 to heat activated PMMA. He concluded that significant results were obtained at 3% and 5% nanofillers in terms ofabrasion resistance, tensile and fatigue strength.[4,5,8]

In the quest of exploring the antimicrobial properties of nanoparticles, Yoshida et al(1999) demonstrated that a resin composite mixed with silver nanoparticles had a long-term inhibitory effect against S. mutans.[1]

Laura et al(2011) prepared the PMMA composites along with addition of TiO_2 and Fe_3O_2 nanoparticles, for simultaneously coloring and/or improving the antimicrobial properties. The study concluded that PMMA containing nanoparticles demonstrated lower rate of Candida albicans (C. albicans) cell adhesion and a lower porosity, compared to standard PMMA.[9]

Nanomaterials in Maxillofacial materials: Meran et al (2017) : conducted an in-vitro study to check the efficacy of silver nanoparticles against C.albicans by coating it on silicone, the study was carried out of human fibroblasts.[6] He found that when fibroblasts grown on silver coatings were challenged with C. albicans, the Ag NP coating was effective at preventing fungal growth as measured by ethanol production by the yeast, and without damaging the fibroblasts.

Shakir DA et al (2018) evaluated the effects of adding titanium oxide (TiO_2) nanofillers on the tear strength, tensile strength, elongation percentage, and hardness of room-temperature-vulcanized (RTV) VST50F and high temperature- vulcanized (HTV) Cosmesil M511 maxillofacial silicone elastomers. The findings of the study were:

The addition of 0.25 wt% and 0.2 wt% TiO_2 nanofiller into VST50F and Cosmesil M511 elastomers, respectively, resulted in a statistically significant increase in the mean values of tear strength, tensile strength, elongation percentage, and hardness of the materials.[12]

Summary:

Category	Nanomaterial Used	Property Improved
Nano metals	Deposition of nanostructure Ti on the surface of pure titanium, Ti6 Al4 V and CoCrMo surfaces	Lower adhesion of oral streptococci on the nanostructured surfaces than on the pure titanium, increased adhesion to osteoblasts
	TiN, ZrO_2/Al_2O_3, Si_3N_4/TiO_2, and ZrO_2/SiO_2	Increases wear resistance
Nano Ceramics	ZrO_2	Increases the hardness and toughness of the ceramic
	Zirconia-Silica sol-gel nano addition	Higher hardness
	Hot presses Alumina-CNT	Improved tribological and mechanical properties
Nano Resin	TiO_2 reinforced PMMA	Increases the saturation per unit area in polymers
	TiO_2 and Fe_3O_2	Increased Anti-fungal property against C.Albicans
	Ag-PMMS nanoparticles	Improved anti-microbial properties

Fate of expansion of prosthodontics technology is interlinked with the progress of materials science. Nanomaterials have been the forerunner in basic scientific innovation and clinical technological advancement of prosthodontics. Incorporation of nanoparticles enhance many mechanical properties of various dental materials applied in the field of Prosthodontics.

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