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Nanomaterials in Prosthodontics; a Concise Review.

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ABSTRACT:

BACKGROUND

The concept of nanomaterials referred to zero-dimensional, one-dimensional, two-dimensional, and three-dimensional materials with a size of less than 100 nm. Alot of research have been launched on nanomaterials for biomedical applications. It has been shown that the properties of many materials used in prosthodontics have been enhanced after incorporation of nanotechnology into it.

SUMMARY

This paper is an attempt to give an overview of nanomaterials and their applications in prosthodontics.

CONCLUSION

Future development of prosthodontics is mainly dependent on the progress of materials science. Nanomaterials plays a crucial role in basic scientific innovation and clinical technological change in prosthodontics.

KEYWORDS: Nanomaterials, Nanodentistry

I.INTRODUCTION

Lots of research have been introduced on nanomaterials for medical as well as dental applications. The “nanomaterials” concept formed in the early 1980s,with a size less than 100 nm.By comparing the dimension of other objects we will be able to appreciate how small the particle is.(Table 1:1)

Table 1:1 Objects and its dimensions

OBJECT	DIMENSON
DNA	Diameter 2nm
Computer chip structures	14 nm
Soap bubble membrane	Thickness .1 – 1 µm
Red blood cells	Diameter 6-8 µm
Grain of rice	Diameter 1mm
Cherry	Diameter 1.2cm
Football	Diameter 22 cm

Classically, these materials are broadly categorized into ceramics, resins, polymers, and metals.(Table 1:2)

SL.NO	CERAMICS	POLYMERS		INORGANIC MATERIAL		UNCONVENTIONAL
1	Metal oxide Zr,AlBased,Ca hydraulic silicate	Synthetic	Natural	Metals	Inorganic adducts	Carbon nanotubes
2	Glass infiltrated ceramics	Polymethyl methacrylate	chitosan	aluminium	Iron oxide	Graphene oxide
3	Lithium disilicate	Polyamidoamine	Pectin	gold	Titanium dioxide	Nanodiamonds

4	Leucite		Alginate	Silver	Calcium phosphate	
5	Silica		Hyaluronic Acid	zinc	hydroxyapatite	

Table 1:2 Categorization of nanomaterials

II.APPLICATIONS OF NANOMATERIALS IN PROSTHODONTICS

Nanotechnology significantly improved the properties of ceramics, impression materials, denture bases, types of cement used in prosthodontics.

Nanomaterial applications in removable(complete/partial) prosthodontics

In this category, Polymethylmethacrylate (PMMA) polymers and silicone elastomers are commonly used fordentures(partial/complete) and maxillofacial prostheses. Dimensional changes with PMMA polymers andpoor tensile and tearing strength of silicone elastomers lead to incorporation of nano materials into prosthodontics.

carbon nanotubes lead to a bond formation with PMMA resins/polymers by weak van der Waal force to improve its dimensional stability for better fit and tensile strength and also metal-based NPs (Ag, TiO2, etc.) reinforce PMMA polymers to improve their tensile strength and antimicrobial activity.

Polyhedral oligomeric silsesquioxanes (POS), a nano (1.5 nm) silica cage, and metal NPs support silicone elastomers to improve their tensile strength and physical properties .Nanotechnology improved the pathological states like denture stomatitis induced by adherence of biofilm of Candida albicans over the denture base materials.

Nanomaterials applications in Fixed prosthodontics

In this category, tooth and implant-supported nanomaterials, nanocomposites, and nanocoatings are primarily used as fixed prostheses. Conventional materials showed cytotoxic effects by leaching organic monomers into surrounding gum tissues . Nanocomposites based on nanofiller technology solve these issues. Silica or Zirconia-silica NPs were synthesized by treating silica particles with 3-methacryloxypropyl-trimethoxysilane to improve flexural strength and hardness.

Nanotechnology also brings hope and new vistas in improving the adhesion and durability of implants. Carbon nanotubes, polyvinyl alcohol, and silica-based NPs were used in addition to calcium phosphate to synthesize nanocomposites and sometimes scaffolds for improving mechanical strength and tissue regeneration .

In addition, the improvement of calcium carbonate-silicone dioxide NPs improves tear strength and hardness of maxillofacial silicone elastomers . In another study, Persson et al. synthesized glass-ceramic in Zirconia silica NPS using the sol-gel method to improve the corrosion resistance and hardness.

Nanomaterial application in Dental Implants

For many decades, dental implants have been used and applied to restore or replace teeth. However, attaining osseointegration and managing infection associated with implants (metallic type) are still an issue to explore. Various studies have been reported for using different surface modifications to improve these issues, as surface modification also affects the biological regenerative process (adsorption of proteins, adhesion, differentiation, and proliferation of cells, which further initiates tissue regeneration).

Nanotechnology-based coating over the surface of titanium and tetragonal Zirconia implants was studied to improve the biological and mechanical properties.Further, Silica nanocomposites were utilized and coated over the surface of implants to improve mechanical strength and bone growth . Moreover, the implant surface can be treated/modified by HA nanocrystals and Calcium-phosphorus NPs for ameliorating bone regeneration . In addition to the advantages of metal and ceramic-based dental implants, several limitations like toxicities and corrosive behavior are also associated with them.

To overcome these challenges, less toxic plant-derived biomaterials are used in the production of dental implants A recent study reported that gold NPs were photo-fabricated from aqueous bark extract of Salacia chinensis and applied in dental implants, where it was shown itsbiocompatibility with blood and high osseoinductive potential when evaluating the cell viability with MG-63 bone osteosarcoma cell lines . Another approach to improving osseointegrity of dental implants is the use of calcium phosphate nanoparticles coated over the surface of TiO2 implants . In another study of rats with ovariectomized induced osteoporosis, where chitosan gold NPs carrying the c-myb gene improved the osseointegration of dental implants

III. FUTURE OF NANODENTISTRY

Undoubtedlynanodentistry confers numerous advantages over conventional systems, such as higher bio-regeneration, a notable antimicrobial effect due to anti-biofilm properties, increased hardness of composites, and better sealing of fillers ,But at the same time, its overpricing, precise placement, associated toxicity, costly development, and international regulations limit the clinical exploration. Though despite all the stated hurdles, scientists are now working hard to find the least expensive methods to synthesize NP scaffolds that fits in the regulatory framework as well as assist in placing the NPs into the right place.

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In another study of rats with ovariectomized induced osteoporosis, where chitosan gold NPs carrying the c-myb gene improved the osseointegration of dental implants. There are multiple unconventional NPs, including nanodiamonds, quantum dots, nanoshells, and carbon nanotubes, which have been explored widely in research and have better outcomes to be used in future commercial markets. Its superior surface and chemical nature make it a very suitable candidate for use as a filler in dental nanocomposite fabrication.

IV.DISCUSSION

Weingwei et al in 2024 concluded that many properties, such as modulus elasticity, surface hardness, polymerization shrinkage, and filler loading, of materials used in prosthodontics can be significantly improved after their scales were reduced from micron-size into nanosize by nanotechnology and that the performances of composites can be also enhanced by adding appropriate nanomaterials.

Han., et alin 2008 has investigated the nano oxides of Ti, Zn, and Ce at 2%–2.5% concentrations into silicone elastomers and showed improvement in their mechanical properties.

Vikram., et al., in 2020 has investigated the flexural strength of PMMA resins with zinc oxide nanoparticles in different concentrations of 0, 0.4, 0.6, 0.8, 1.2, and 1.4% concluded an increase in flexural strength.

Mohammed Gad et al, in 2016 investigated nano-zirconia (1.5%) on PMMA and concluded an increase in flexural, transverse and impact strength, reduction in wear, and also shown good antifungal and antibacterial properties.

V.CONCLUSION

Future development of prosthodontics technology has been recognized to be dependent on the progress of materials science. Nanomaterials have been playing a significant role in basic scientific innovation and clinical technological change of prosthodontics.

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