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Nanotechnology and its Application in Restorative Dentistry: A Review of Literature

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Abstract

Norio Taniguchi, in 1974 coined the term 'nanotechnology'. It includes the processing of separation, consolidation, and deformation of materials by one atom or one molecule. Nanotechnology has paved path for enhancing many material properties. Similarly so in dentistry it has led to enhancement of many traditional restorative materials such as dental composite and GIC which has made it possible to use these restorative materials in almost every region of the tooth. The aim of the present review article is to provide insights into recent developments in the field of restorative dentistry favored by nano technology such as, nano-composites, nano-bonding systems, nano-GIC, nano-varnish and sealants. It can be an aid to the dentist in clinical practice or in research field.

Key words: *nanotechnology, nano-composite, nano-GIC, nano-ceramics*

Introduction

In 1959, Richard P Feynman first described Nanotechnology in his in famous lecture "there's plenty of room at the bottom" [(1)]. It has been part of mainstream research with potential medical and dental uses. Nanotechnology has made notable contributions in dentistry with its various applications ranging from irrigating root canal system to regeneration of tooth. The restoration of tooth structure with nanomaterials has been one of the most widely applied aspects in dentistry. They offer advantages mainly in the smoothness, polishability and precision of shade characterization along with the flexural strength and micro-hardness [(2,3)]. Additionally incorporation of functional materials or structures of nano size in restorative materials can be used to control the formation of cariogenic bacterial biofilm adherence as they can deliver bioactive materials and antibiotics [(4)]. Nanomaterials are categorized as zero-dimensional (nanoclusters and nanoparticles), one-dimensional (nanotubes and nanowires), two-dimensional (nanoplates and nanolayers) and three-dimensional (nanospheres and nanorods) [(5)].

A wide variety of materials are available to restore the lost form and function of decayed teeth. Use of conventional dental amalgam was widely in use as restorative material in stress bearing areas due to its superior strength, but has compromised esthetics due to its metallic color. Esthetic demands have necessitated the use of tooth coloured restorative materials like dental composites and glass-inomer cements. Though they are superior as esthetic restorative materials in anterior tooth region, they could not effectively bear the occlussal forces in the posterior regions. Incorporation of nano particles into these materials has enhanced the physical properties and favored the use of these materials in the posterior tooth region. This led to the development of materials like nano-composites, nano-bonding systems,

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nano-GIC, nano-varnish and sealants.

Nano-composites

Nanocomposites are available as nanofills (1 to 100 nm size) and nanohybrids (0.4 to 5 μm) [6]. Nanofiller particles are available either as nanomeric particles or nanoclusters. Nanomeric particles are monodispersed colloidal silica in non-aggregated and non-agglomerated form [7]. These nano fillers are generally invisible as they are too small to absorb or scatter visible light and hence does not influence optical properties of resin.The fillers provide incremental improvement in the mechanical properties of the resin where, with the increased filler volume the strength increases proportionally and hence many studies have supported use of microfillers over nanofillers. Hence, to modify loading and distribution of filler particles 'nanofills' are introduced [8]. They are a combination of nano- and microsized filler to produce a hybrid material like 3M filtek (3m ESPE). Nanoclusters were later introduced as an alternative to the hybrid fillers. Nanoclusters are either zirconia-silica particles or silica treated with 3-methacryloxypropyltrimethoxysilane with size of 0.6 μm[7]. Additionally, ceramic nanofillers are being studied for its aesthetics and durability. Recently, Carbon nanotubes have proved to process good mechanical properties and bioactivity which can help to further reinforce the composite resin.

In recent days, restorative materials with anti caries properties are obtained by addition of remineralizing or anti cariogenic materials in the resin (figure 1). To increase mineral content calcium and phosphate ion-releasing fillers such as nanoparticles of dicalcium phosphate anhydrous and tetracalcium phosphate are used. Various calcium phosphate formulations, such as nano hydroxyapetite and nano-acidulated calcium phosphates are being used as fillers to incorporate remineralising properties in dental composites. Addition of nanobioglass has shown to facilitate fluoride release from dental composite (figure 2). For the anti cariogenic property various nano particles such as chlorhexidine and quarternary ammonium compounds have shown to be effective [9, 10].

Nano-Bonding system

Incorporation of nano-particles in dentin bonding agents have shown to improve tubular penetration and thereby increasing the mechanical properties of the restoration (eg : prime&bond NT, Dentsply). Nano silver particles, Nano amorphous calcium phosphate and Nano quaternary ammonium dimethacrylate (nQADM) are few of the widely studied materials [11]. Recently, Colloidal platinum nanoparticles have shown to increase the bond strength of resin [12]. Similarly, Spherical zirconia nanoparticles are used in bonding systems which aids in stabilizing the hybrid layer. Newly, the concept of nanogels has been introduced. They are 10- to 100-nm particles which on interaction with monomers get swollen. This property allows penetration of adhesives deep into dentin and increase the bond strength [10].

Nano-GIC

Wilson and Kent in 1971 introduced GIC [13], ever since it has been a widely used in dentistry like Ketac Nano (3m ESPE). But, it had lower mechanical properties than other traditional restorative materials. The incorporation of nanoparticles favored to increase particle size distribution and thereby increasing the mechanical values of GIC. Forsterite nanoparticles, when incorporated in GIC enhanced the fluoride release [14]. Nano-fluorapatite or nano fluoro hydroxyapatite has also showed similar properties [15]. Use of nano agglomerated glass has improved the compressive strength if GIC [15]. Similarly so, titanium nano particles are also used. Various antibacterial agents, zinc, silver nanoparticles are also incorporated to provide anti cariogenic properties [16].

Recently, resin modified glass ionomers are modified by addition of nanoparticles and nanoclusters in fluoro-aluminosilicate glass. It resulted in the aesthetic improvement of the final restoration and polishablilty. It has led to the improvement is setting reaction, Improvement in poly salt bridge formation, Better bonding with dentin and More compressive strength. Similarly, Nanoparticles of CHX hexametaphosphate are used as an anti microbial agent but nano-chlorhexidine modified GIC shows less fluoride release than conventional one which is a drawback [9].

Nano-Varnish and sealants

Hydroxyapetite and fluorapatite bioceramic nano-fibers have nanostructure solubility which aids in effective release of fluorine ions. Which when incorporated

in sealant system can cause caries prevention. The nano-sealants provide wear resistance and a reduced shrinkage [17]. Another application of nanotechnology is the development of a nano-filled light curing varnish. It is used to protect GIC during early maturation phase. It prevents water sorption ad dehydration of GIC thereby, improving its mechanical properties. Eg., EQUIA ('Easy-Quick- Unique-Intelligent-Aesthetic') [18].

Nano coating of restorations

Nano-filled, light-cured preparations are used as a protective coating for composite and acrylic indirect composites like the Optiglaze Glossy Protective Coating Agent (GC Corporation, Japan). These solutions provide an aesthetic glossy surface and can be used in difficult to polish areas such as posterior fissures or interproximal areas of indirect composite restorations. It can be used on indirect composite restorations, artificial teeth, removable dentures, temporary crowns and individual acrylic trays to provide a glossy finish.

Nano polishing system

Polishing of dental surfaces is a known practice in dentistry which is used to make it difficult for plaque and cariogenic bacteria to accumulate on tooth surfaces. Thus, polishing is a preventive procedure used as a primary defense against dental problems. Micron-sized silica particles are a typical component of conventional polishing pastes. The smaller the abrasive particle size the smoother the polished surface. Chemical-mechanical planarization process is one such approach, used in the semiconductor industry which uses various nanometer-sized particles to polish surfaces of semi-conductor wafers to a sub-nanometer level. This was adopted to polish dental surfaces by R.M. Gaikwad and I. Sokolov (2008), where they have used siver nano particles and demonstrated that it is easier to remove bacteria from areas polished with silica nanoparticles. And it can be used for dental polishing [19].

Nano ceramics

With the integration of nanotechnology and ceramics a new CAD/CAM block of monolithic esthetic material was developed as Lava Ultimate (3M ESPE). It is a mix of nano particles agglomerated in clusters and individual bonded nano particles embedded in a highly cross-linked polymer matrix. The main advantage of this material is said to be the easier clinical finishing and polishing, without the need for a porcelain oven, with the strength, surface gloss and finish retention similar to ceramic materials which has been the main limitation of composite blocks. It's typical composition is made up of non-agglomerated/non-aggregated silica (20 nm), aggregated zirconia (4 to 11 nm particles) or silica clusters (20 nm particles) and non-agglomerated or non-aggregated zirconia (4 to 11 nm) with approximately an 80% ceramic load. Though there are a few in vitro studies showing its resistance to toothbrush abrasion and retention of the initial glossy surface finish similar to glass ceramics, clinical evaluation is yet to be obtained regarding its marginal integrity and survival [20].

A nano optimized mouldable ceramics are developed recently and marketed by the name XircOn Ultra, which is approved by FDA. It is a hybrid nano-ceramic that can bend and flex in the mouth. It is made by a combination of nano-ceramics and polymers. It is said to be one of the closest material to human teeth. Nano fillers enhance polishability reduce wear. The use of nano pigments adjust the shade of the restoration by chameleon effect and nano modifiers increases the stability of the material thereby prevent sticking to instruments.

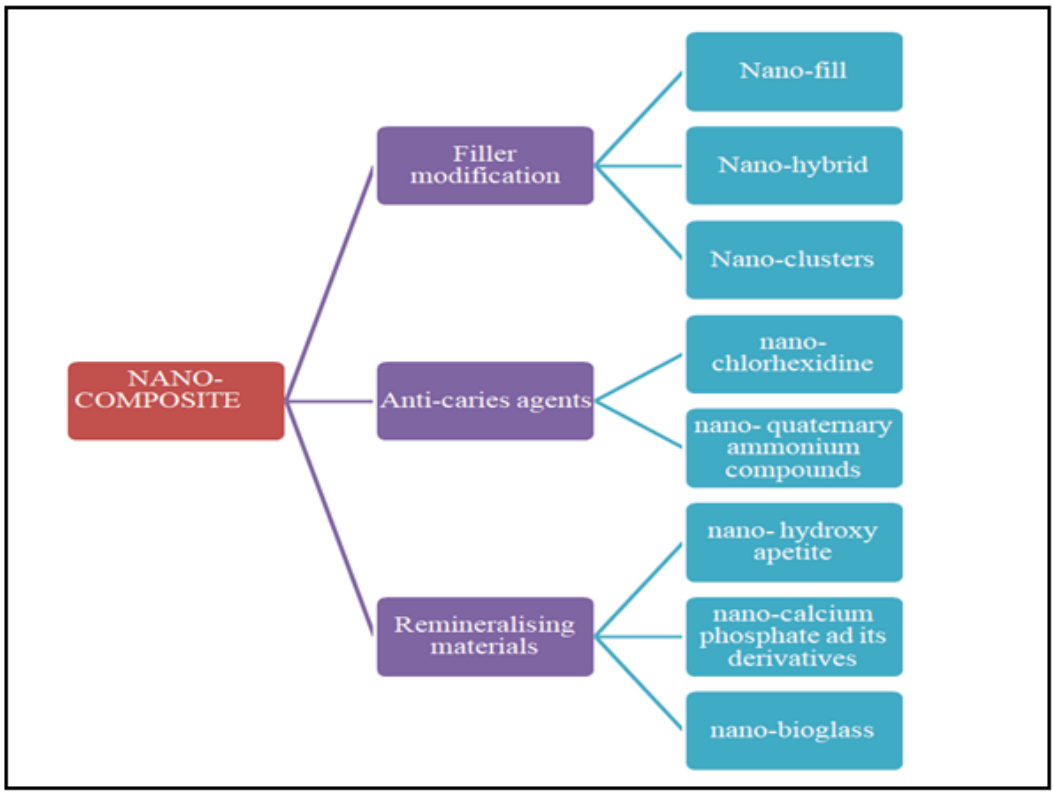

Figure 1: Nano-composite materials.

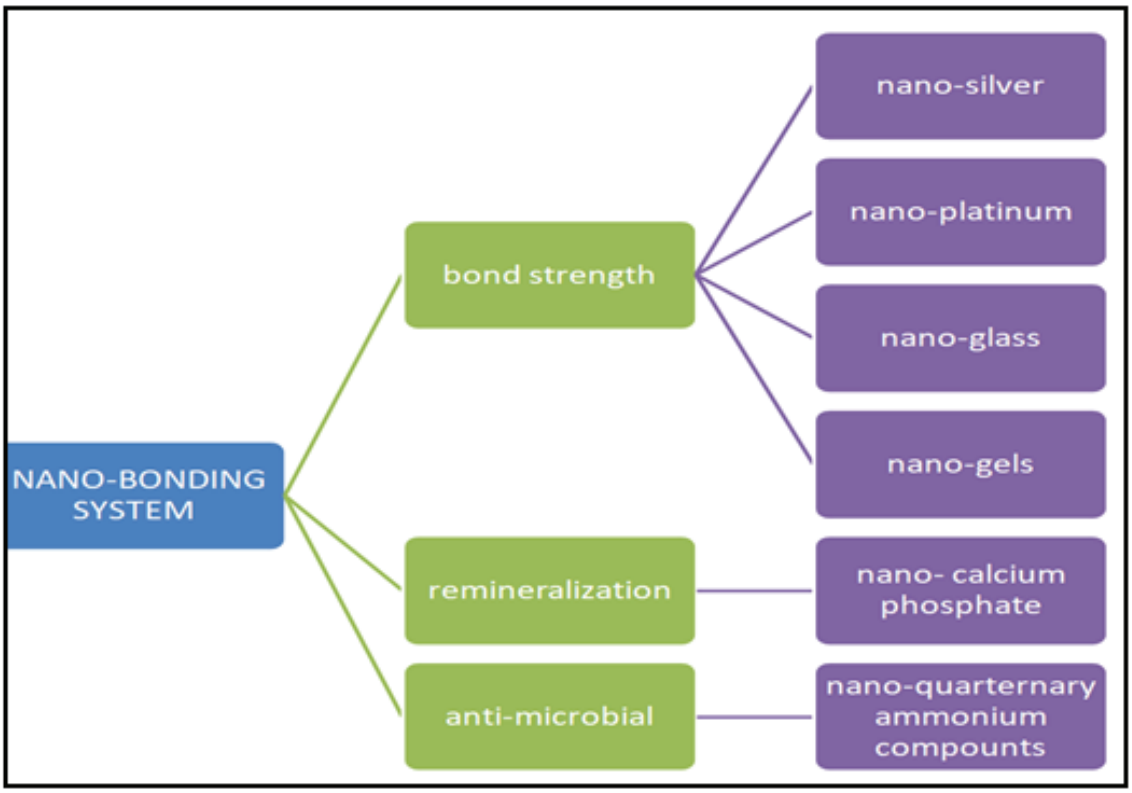

Figure 2: nanoparticles used in bonding systems.

Conclusion

With evolution of material science, newer dental materials are being developed for improving the ease of use and mechanical properties. Nanotechnology is playing a key role in such product development and has proven to be an efficient method for this purpose. A thorough knowledge of these nano restorative materials and its applications helps in efficient use in dentistry. In future, the use of nano-robotos seems to be the effective way in restoring early tooth surface defects and carious lesions. But it is still a clinically unexplored arena and the wait doesn't seem too far to explore it.

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