Nanomaterials in Prosthetic Rehabilitation of Maxillofacial Defects: A Review

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Abstract
Problem: The maxillofacial material has some limitations. The main problem with the currently maxillofacial material is its reduced clinical longevity of the prosthesis. Because of its colour instability and material deterioration, for example, it exhibits modified texture, poorly fitting edges because of reduced tear strength. *Approach:* To review the impact of nanoparticle incorporation into maxillofacial material on its hardness, tear strength and colour stability. *Findings:* Several nanoparticles added at a concentration ranging from 1% to 3% improved the hardness, tear strength, tensile strength, percentage elongation, and colour stability. Nano-ceo2 improved the colour stability at 1% concentration and at 3% improved the hardness and tear strength. Nano-zno and Tio2 at a concentration of 2% and 2.5% improved the hardness, tear strength, tensile strength, percentage elongation, and color stability. *Conclusion:* With the available evidence in the literature, it can be concluded that addition of nanoparticles at various concentrations may improve the physical and mechanical properties and colour stability of the prosthesis made from the silicone elastomers.

Keywords: maxillofacial prosthesis, nanomaterials, silicones, nasal defect, auricular defect, maxillofacial reconstruction.

Introduction

Maxillofacial prosthetics restore the facial parts that have been lost due to congenital abnormalities, developmental disturbances, tumors and trauma. The main goal of maxillofacial prosthesis is life like production of missing parts and thereby providing patients a normal appearance, social acceptance and psychological wellbeing.[1-4] Maxillofacial prosthesis is defined as many prosthesis used to replace part or all of any stomatognathic and/or craniofacial structures.[5]

Many materials have been introduced to make a maxillofacial prosthesis. This material possesses a texture similar to that of human skin; its flexibility provides the patient with both well-being and comfort.[6-10] However, these materials have some limitations. The main problem with the currently used material is its reduced clinical longevity of the prosthesis because of its color instability and material deterioration.[11-15] These changes are directly related to the patient's personal hygiene, use of cleaning agents and the type of exposure that the prosthesis undergoes such as temperature fluctuations, UV radiation, solar radiation, moisture, air pollution and climate changes.[16,18,19]

Several techniques have been tried to overcome this polymer deterioration. The addition of nanoparticles has become the new trend as nanotechnology has become one of the main growing sciences.[6, 8, 9]

According to the NNI, nanotechnology is defined as: "Research and technology development at the atomic, molecular and macromolecular levels in the length scale of approximately 1-100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.[17, 20-23]

Nano-sized zinc oxide (zno), titanium dioxide (tio2), and cerium oxide (ceo2) are mainly used as UV protectors as they have UV absorbing and scattering effect.[24-27] Nano-sized silicone dioxide (sio2), tio2, and zno are smaller in size, have large specific area, active function, and strong interfacial interaction with the organic polymer. Therefore, they can improve the physical properties and optical properties of material, as well as provide resistance to environmental stress caused aging.[28-32]

Various studies on nanoparticles have confirmed the effectiveness of nanoparticles in improving the color stability by acting as UV shield and also in improving the color stability, hardness, tear strength, tensile strength, percentage elongation, UV protection, and antifungal properties of silicone material. The aim of this review is to summarize the outcome of research conducted on the nanomaterial in maxillofacial application. In addition, future prospects of nanomaterials in the field of maxillofacial prosthetics have been highlighted.

History

Nanotechnology is not a new term. Although nanotechnology has been around since the beginning of time, the discovery of nanotechnology is widely attributed to the American Physicist and Nobel Laureate, Dr. Richard Phillips Feynman. The first use of the word "nanotechnology" has been attributed to Taniguchi in 1974.[33,34,35,36] In 1986, Eric Drexler introduced and popularized the term "nanotechnology" in his book "Engines of Creation". Dr. Robert A. Fretias Jr. Is one among the pioneer scientists who has written about nanomedicine, nanodentistry, and their future changes. It was introduced into dentistry as nanocomposites in the year 2002 by FiltekSupreme.[37-39]

Materials for maxillofacial prosthesis

Nowadays, the materials used to fabricate maxillofacial prostheses includeacrylic resins, vinyl plastisol based on polymethyl methacrylate (PMMA), polyvinyl chlorides, copolymers, chlorinated polyethylene, polyurethanes, latex, and silicone polymers. The most widely used materials for maxillofacial reconstructionareSilicones and acrylic resins. Fabrication of facial prosthesesmaterial of choice is silicone polymers that are classified as one of two types: room temperature vulcanizing silicone and high-temperature vulcanizing silicone. Newer materials are silicone block copolymer and polyphosphazenes.[40-43] Several advantages of silicone polymersincluding chemical inertness, durability,strength, and ease of manipulation.Silicone polymers have major disadvantages that are, color degradation and instability, caused by exposure to ultraviolet rays, temperature variation,air pollutionand humidity.Silicones are widely used but still need to improvement because they last for short periods, such as 6 months, and it need to frequent replacement. Acrylic resins have been widely used to fabricate intraoral prostheses, such as obturators and ocular prostheses. It can be thermopolymerized or autopolymerized.[44-47]

Effect of incorporating nanoparticles in maxillofacial prosthetic materials

Addition of nanoparticles improved the color stability and mechanical and biological properties of maxillofacial prosthetic material.Their high surface area to volume ratio nano-sized particles differ in their physical, chemical, and biological properties compared to their macro-sized counterparts.Depending on their size and concentration properties of nanoparticles have been varied. Based on their concentration, nanoparticles improve the physical, chemical, mechanical, and biological properties of the material in which they are incorporated.[48-52] Various nanoparticles have been incorporated to maxillofacial prosthesis materials like titanium dioxide(TIO2), silver nanoparticles, silica, zinc oxide(zno), zirconium oxide(zro), cerium oxide(ceo2) and silicone dioxide(sio2).[53,54,55]

Mechanical properties

Hardness

The texture of silicone should match with that of the skin of that particular anatomic area to be restored, wherein it also depends on the hardness of the material.[56-59] To mimic, skin covering the orbital, nasal, and ear areas of the maxilla, the silicone should exhibit hardness values between 25 and 35 Shore A.[60-64] Incorporation of nano-sized oxides of Ti, Zn, or Ce at the concentrations of 2.0%, 2.5%, and 3% by weight, respectively, into a silicone based elastomer increased the hardness of the material. Most of the commercially available maxillofacial silicone elastomers have hardness values between 25 and 35 Shore A, however these increases in hardness values were well within the specification limits of 25–35 Shore A. Hence, addition of nanoparticles may not enhance the hardness properties of the silicone materials.[65,66,67]

Tear strength

It is clinically very important the tear strength of silicone elastomer, as the margins surrounding the facial prosthesis is thin and is highly susceptibility to tear. During chewing, talking and laughing muscles actions are there which cause the remodeling of facial structures. Thus, the ideal facial prostheses should have a certain degree of flexibility.[68-72] Addition of Ti, Zn, or Ce nano-sized oxides at the concentrations of 2.0%–2.5% by weight increases the tear strength, tensile strength, and percentage elongation. However, at a concentration of more than 3%, the same nanoparticles decreased the tear strength, tensile strength, and elongation.[73-76] This may be due to the fact that nanoparticles at higher concentration it showed a certain degree of agglomeration because of their high chemical reactivity and high surface energy. Effectively using these nanoparticles improved these mechanical properties of elastomer and these materials need to overcome the agglomeration of nanoparticles. However, it can be achieved by surface treatment of nanoparticles to reduce its clumping and also improve its dispersion into the silicone matrix.[77, 78, 79, 80] Zayed *et al.* Carried out that this surface treated sio2 nanoparticles which showed improvement in its distribution within the silicone matrix and prevented its agglomeration, thereby improving the overall mechanical properties especially in terms of tear strength.[19]

Color stability

Silicone prosthesis often needs to be refabricated because of their color instability. It can be attributed to photooxidative attack, which is a combined action of oxygen and sunlight on the chemical structure of elastomer. Studies have shown that addition of nanoparticles to a silicone elastomer could improve its color stability. Han*et al.* Reported addition of 1% nano-ceo2 and 2% and 2.5% nano-tio2 by weight to the silicone along with pigments exhibited the least colorchanges.Nano-tio2, zno, and ceo2 are widely used as inorganic UV absorbers.[81-83]

Bangera and Guttal evaluated the UV protecting capacity of nanooxides in different concentrations and they carried out that compared to tio, zno in lesser concentration provided more consistent UV protection to Cosmesil M511 elastomer.[84, 85, 86]

Biological properties

Since maxillofacial prosthesis is exposed to human saliva and nasal secretions, which are susceptible to microbial colonization, and also moisture, body temperature, and nutrient rich residue from skin secretions promote fungal growth on the silicone prosthesis.[87] Silver nanoparticles are also used as antifungal agents in maxillofacial silicone and proved their biocompatibility and antifungal properties. Meran *et al*. Coated Ag nanoparticles on the surface of the silicone maxillofacial prosthesis and resulted good antifungal activity of the Ag nanoparticles without any adverse effects. [87, 88]

Several nanoparticles added at a concentration ranging from 1% to 3% improved the hardness, tear strength, tensile strength, percentage elongation, and color stability. Nano-ceo2 improved the colour stability at 1% concentration and at 3% improved the hardness and tear strength. Nano-zno and tio2 at a concentration of 2% and 2.5% improved the hardness, tear strength, tensile strength, percentage elongation, and color stability.

Conclusion

Materials currently available for use in maxillofacial prosthesis do not completely meet required needs. It can be carried out that addition of nanoparticles at various concentrations may improve the color stability, hardness, tear strength, tensile strength, and percentage elongation of the prosthesis made from the silicone elastomer.

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