

Reinforcing the Maxillofacial Silicones: A Review

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Abstract:- Maxillofacial materials are used to replace missing facial parts which have been lost through disease or trauma. Although widely used, these materials are far from ideal. These materials have a very limited serving life due to lack of edge strength and color stability. Different methods have been tested to prevent the degradation due to aging and intrinsic and extrinsic discoloration of the material using various reinforcing agents. Limited evidence of compiled information related to maxillofacial silicone reinforcements is seen in existing literature. This article, therefore, reviews various reinforcing materials which have been used with maxillofacial silicones and is intended to be a helpful guide for budding researchers in the field of maxillofacial prosthodontics.

Keywords: Maxillofacial prosthesis, maxillofacial silicones, reinforcements, Nano-particles

1. INTRODUCTION

Maxillofacial prosthetics may be referred to as the art and science of anatomic, functional, or cosmetic reconstruction, by means of non-living substitutes, of those regions in the maxilla, mandible, and face that are missing or defective because of surgical intervention, injury, or congenital malformation.^[1]

Silicone elastomers are used in the fabrication of artificial external body parts such as ears, nose and eyes.^[2] Such loss can be due to surgical ablation of cancer, severe facial trauma or congenital craniofacial anomalies.^[3]

Gold, silver, leather, vulcanised rubber, gelatine, latex, polyvinyl chloride, polyurethane, chlorinated polyethylene, self cure and heat cure acrylics and silphenylenes have all been used at various stages of evolution of materials for such prostheses). All these materials have reported drawbacks. For example acrylics cause abrasion of skin, difficulty to match edges of skin to prosthesis and increased bulk and weight of prostheses.^[2]

Today, silicone elastomers are the most commonly used materials for fabrication of prostheses. They have been commercially available since the 1950s and have been researched upon extensively. Chemically, silicone elastomers are low surface energy cross linked polymers consisting of long chain molecules with repeating units. Silicone is

biocompatible, biodurable, easy to manipulate with adequate working time and good color stability.^[2]

Maxillofacial silicones must exhibit adequate tensile strength, tear strength, permanent deformation, hardness and other mechanical properties for its successful use as a facial prosthesis. However, the main limitation of silicone is the high chances of early deterioration which may exhibit modified texture, poorly fitting edges because of shape changes, reduced tear strength, and material discoloration. These changes are directly related to patient care during handling and hygiene and the type of exposure that the prosthesis undergoes (air pollution, ultraviolet rays, temperature fluctuations).^[4]

In a bid to improve the physical properties of maxillofacial materials, elastomers have been modified with additives like colouring agents and various fibrous and nano reinforcements.⁵

The reinforcements which have been tried till date can be mainly categorized as:

1. Fibrous reinforcements
2. Nano-reinforcements.

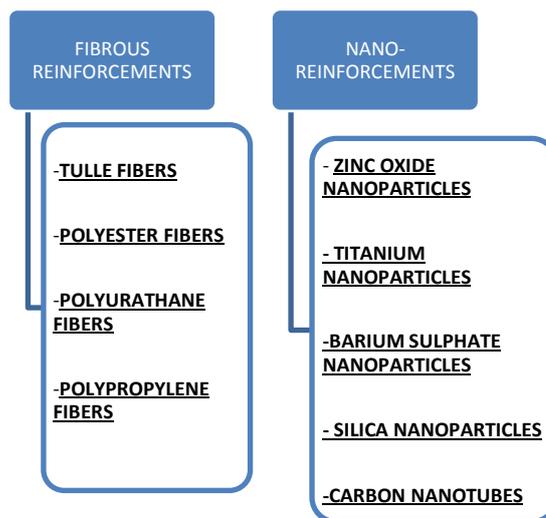


Chart -1: Classification of reinforcements

1.1 Fibrous Reinforcement

Reinforcement by fibers is depending on various variables including fiber type, length, and form, and arrangement, percentages of fibers in the polymeric

matrix and fiber matrix interaction and presence or absence of salination.^[6]

TULLE FIBERS:

Tulle is widely used to make artificial beards, moustaches, and eyebrows. These finished products are then used in theaters and operas together with prosthetic adhesives. Tulle used for these purposes is not affected by solvents, works seamlessly with prosthetic adhesives, and most importantly exhibits sufficient resistance to tearing and rupture.

Hence in a bid to increase the tear resistance of maxillofacial prostheses materials, tulle was incorporated in silicone elastomer in a recent research. Tulle was chosen as the candidate material because its inherent flexibility would not cause any damage to the elastic behaviour of the silicone material, thus preventing the latter from tearing at the edges.^[5]

Yumushan et al(2008) concluded tulle successfully reinforced a maxillofacial silicone elastomer by providing it with better mechanical properties and augmented strength – especially for the delicate edges of maxillofacial prostheses and also found that incorporation of tulle to RTV silicone improve the tensile when compared to non-reinforced silicone^[5]

POLYESTER FIBERS:

Polyester fibers are available in filament form and considered as thermoplastic polyester group. They are sensitive to temperature and have hydrophobic behavior^[7].

Main advantages of these reinforcements are:

- Low moisture absorption
- High resiliency and dimensional stability
- Excellent wear resistance
- Good weather and light resistance,
- Good abrasion resistance.

They are relatively flame resistant, resistant to micro-organisms growth and biologically inert.^[6]

Jaber et al. (2018) studied the effect of polyester fiber incorporation into RTV maxillofacial silicone elastomer on tear strength, tensile strength, surface roughness and shore 'A' hardness. They concluded that for maxillofacial silicone elastomer mechanical properties could be improved when 0.25% by weight of 2 mm length polyester fibers were added to it.^[6]

POLYURETHANE AND POLYPROPYLENE FIBER SHEETS

M.Y. Abd El-Fattah et al. conducted a study to evaluate the effect of addition of polyurethane sheets and polypropylene fibers as reinforcing materials to silicone that was used in auricular prostheses. It was

concluded that reinforcing silicone with polyurethane sheets and polypropylene fibers improved the tear strength, tensile strength and modulus of elasticity thus providing better marginal integrity and durability of prostheses. None of the tested prostheses showed any clinically detrimental effects on the underlying tissues.^[8]

Surface of polyurethane and polypropylene lined prosthesis was very smooth thus easier to clean and less likely to harbour microorganisms and hence maintains its color in comparison to non reinforced silicone which imparts rough surface with good medium for bacterial and fungal growth giving it a darker color.^[8]

1.2 Nano Reinforcements

Nano-particles when added into a polymeric matrix improve its properties, this may be due to the higher surface energy and chemical reactivity of the particles, allowing them to interact with the silicone elastomer matrix and form a 3D network within the silicone structure. The addition of nano-sized particles results in the improvement of the material characteristics and the control of biological, mechanical, electrical, magnetic, and optical characteristics.^[9]

Nano-particles exhibit intrinsic surface reactivity, high surface areas and can chemically absorb many substances.^[9] Nano particles are smaller than UV light wavelength, their electrons vibrate when they are heated by such radiation, thereby dissipating one portion of the light, which explains its use in manufacture of sunscreens to protect human skin against UV rays.^[4] Hence various nanoparticles have tried as reinforcing agents for maxillofacial elastomers to improve its optical, physical and mechanical properties.

ZINC OXIDE NANOPARTICLES

Most preferentially, among different metal oxide nanoparticles, zinc oxide (ZnO) nanoparticles have their own importance due to their vast area of applications, e.g., gas sensor, chemical sensor, bio-sensor, cosmetics, storage, solar cells and drug-delivery.

Zinc oxide has been used along with other metal oxide nanoparticles in the in vitro studies, in which metal oxide nanoparticles have been added to maxillofacial silicones and based on the findings, the use of ZnO nanoparticles is recommended since they did not negatively affect the properties of the materials evaluated.^[11]

TITANIUM NANOPARTICLES

They are used in the manufacture of sunscreens to protect human skin against UV rays because they have

a high refractive index. As the nanoparticles are smaller than the UV light wavelength, their electrons vibrate when they are hit by such radiation, thereby dissipating one portion of the light while absorbing another. Thus, the smaller the nanoparticles, the better the shielding against solar radiation. [4]

Han., et al. indicated that incorporation of TiO₂ and ZnO nano-particles at concentrations of 2 to 2.5% by weight into A-2186 elastomer improves hardness, tear strength, tensile strength, and elongation. [10]

BARIUM SULPHATE NANOPARTICLES

BaSO₄ nanoparticles have been seen to be associated more strongly with silicone chains, increasing tear strength values.

It is also reported that it was difficult to incorporate and dissolve these nanoparticles homogeneously into the silicone matrix during specimen confection, which may be because of their size. [4]

SILICA NANOPARTICLES

Silicon dioxide nanoparticles (SiO₂) have increasingly been exploited for numerous biomedical and biotechnological applications. Drug molecules are loaded into silica nanoparticles. Its biocompatibility makes it a benign molecule. SiO₂ nanoparticles are characterized by their small size, large interface area, active function, and strong interfacial interaction with the organic polymer. Therefore, they can improve the physical, mechanical, and optical properties of the organic polymer and provide resistance to environmental stress-caused cracking and aging. [12]

Zayed S. and et al studied the effect of surface treated silicone dioxide nanoparticles on mechanical properties of maxillofacial silicone elastomers and concluded that the incorporation of surface treated SiO₂ nanoparticles for the reinforcement of maxillofacial silicone elastomer (A-2186) provided it with more favourable mechanical properties, especially in terms of tear strength. [12]

CARBON NANO-TUBES

Silicone based elastomers have been mixed with single-wall carbon nanotubes or larger carbon nanofibrils. Tensile tests show a dramatic enhancement of the initial modulus of the resulting specimens as a function of filler load. This shows that the unique properties of the carbon nanoparticles are important and effective in the reinforcement. [13]

2. CONCLUSIONS

The ultimate challenge to a maxillofacial prosthetic material is its clinical performance. Future research should concentrate on improving the physical and mechanical properties of the material with more

innovative reinforcing agents, so that it will mimic the human tissue and increase the service life of the prosthesis.

REFERENCES

- [1] Bulbulian AH. Maxillofacial prosthetics: evolution and practical application in patient rehabilitation. *Journal of Prosthetic Dentistry*. 1965 May 1;15(3):554-69.
- [2] K. Mohit, S. Tania. Silicene elastomers-their role in maxillofacial prosthetic rehabilitation 2012 *Vol. 2 (2) May-August*, pp.263-266
- [3] Dr. Shaily Tyagi, Dr. Syamantak Srivastava, Dr. Divya Ratan Dahiya, Dr. Ram Kumar Srivastava. MAXILLOFACIAL SILICONE: A LITERATURE REVIEW *International Journal of Scientific Research*, Vol : 5, Issue : 4 APRIL 2016
- [4] Nobrega, Agda M, Amalia et al. Influence of adding nanoparticles on the hardness, tear strength, and permanent deformation of facial silicone subjected to accelerated aging. *J Prosthet Dent*. 2016;116(4):623-9.
- [5] Gunay Y, Kurtoglu C, Atay A, Karayazgan B, Gurbuz CC. Effect of tulle on the mechanical properties of a maxillofacial silicone elastomer. *Dental materials journal*. 2008;27(6):775-9.
- [6] Jaber AN, Jassim RK, Moudhafar M, Fatihallah AA. Effect of Polyester Fiber Incorporation into RTV Maxillofacial Silicone Elastomer on Tear Strength, Tensile Strength, Surface Roughness and Shore A Hardness: A Pilot Study. *International Journal of Medical Research & Health Sciences*. 2018 Feb 28;7(2):92-101.
- [7] Hachim, Thikra M., Zainab S. Abdullah, and Yasamin T. Alausi. "Evaluation of the effect of addition of polyester fiber on some mechanical properties of heat cure acrylic resin." *Journal of Baghdad College of Dentistry*, Vol. 25, Special Is, 2013, pp. 23-29.
- [8] El-Fattah MA, Rashad HM, Kashef NA, El Ebiary MA. Evaluation of two different reinforcing materials used with silicone auricular prostheses. *Tanta Dental Journal*. 2013 Aug 1;10(2):31-8.
- [9] Zayed SM. Mechanical Properties of Maxillofacial Silicone Elastomer and Approaches for their Improvement: A Literature Review. *EC Dental Science*. 2018;17.
- [10] Han Y., et al. "Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer". *Journal of Prosthetic Dentistry* 100.6 (2008): 465-473.
- [11] Vaseem M, Umar A, Hahn Y. ZnO Nanoparticles: Growth, Properties, and Applications. *Metal Oxide*

Nanostructures and Their Applications. Chapter: 4, Publisher: American Scientific Publishers,1-36.

- [12] Zayed SM, Alshimy AM, Fahmy AE. Effect of surface treated silicon dioxide nanoparticles on some mechanical properties of maxillofacial silicone elastomer. International journal of biomaterials. 2014..
- [13] Frogley MD, Ravich D, Wagner HD. Mechanical properties of carbon nanoparticle-reinforced elastomers. Composites Science and technology. 2003 Aug 1;63(11):1647-54.

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