Journal of Research in Medical and Dental Science
2022, Volume 10, Issue 2, Page No: 760-764

Available Online at: www.jrmds.in
eISSN No.2347-2367: pISSN No.2347-2545

The Effect of Nanoparticles Addition on the Physical Properties of the Maxillofacial Silicone: A Literature Review

Abdullah Jasim Mohammed*, Reem N Alirhayim

Department of Prosthetic Dentistry, College of Dentistry, Mosul University, Iraq

ABSTRACT

Replacing missing parts in the maxillofacial area due to congenital or traumatic reasons, still of great interest of clinicians concerned with this type of prostheses. Unfortunately, materials used for this purpose is still developing and it serves for relatively short period of time because of limited physical properties. Many attempts to improve the physical properties of the maxillofacial silicones were witnessed over many years. One of these encouraging attempts was the addition of a variety of nanoparticles to achieve better physical properties of the facial rubbers. Many studies found that the addition of certain types of nanoparticles were beneficial in producing facial elastomers with better physical properties.

Key words: Maxillofacial elastomers, Facial silicone, Nanoparticles

HOW TO CITE THIS ARTICLE: Abdullah Jasim Mohammed, Reem N Alirhayim, The Effect of Nanoparticles Addition on the Physical Properties of the Maxillofacial Silicone: A Literature Review, J Res Med Dent Sci, 2022, 10(2): 760-764

Corresponding author: Abdullah Jasim Mohammed
e-mail✉: AbdoAlla2009@uomosul.edu.iq
Received: 17/02/2022
Accepted: 08/02/2022

INTRODUCTION

Missing parts of the maxillofacial area due to congenital or acquired reasons like trauma or surgeries can compromise the life and self-confidence of such patients. In many cases these defects are large enough to make reconstructive, and plastic surgery difficult or even impossible, for this reason a maxillofacial prosthesis that reproduce an acceptable appearance and function might be the best treatment choice when the defects are large [1-4]. Many materials have been proposed for construction of maxillofacial prosthetic parts like polymethyl methacrylate, metals, polyurethanes, and silicone elastomers [1,5]. Since their use in the first-time silicone elastomers became the prime material for construction of the maxillofacial prostheses [6]. However, these materials are still developing to meet the ideal properties required like tear resistance, strong thin margins, flexibility, color stability, ease of handling, in addition to the length of time to serve as a maxillofacial prosthesis. Unfortunately, silicone elastomers used in construction of these prostheses do not meet these requirements at a time, and they do not serve for long period of time, where they serve for about six months due to changes in their physical properties and color instability when expose to environmental conditions [7-9]. Many attempts were proposed to improve the properties of the facial elastomers one of these attempts were the addition of nanoparticles into the silicon to improve their physical properties and color stability. Recently, nanoparticles have attracted more attention, their unique properties and microstructure made these materials a rich field for many scientists and researchers concerned with biomaterials [10,11].

Maxillofacial materials

Maxillofacial appliances are constructed of prosthetic substitutes such as silicone for replacement of missing facial parts that are missing due to congenital or acquired causes. They are often used to restore esthetic and function and maintain the integrity of the surrounding tissues, such replacement would have the ability to enhance better psychological adaptation of patients with facial defects [6,12]. Some of these materials that are used for construction of maxillofacial prostheses produce wide range of clinical outcome, where high quality prostheses should be produced and the ability of these materials to resist contamination and environmental factors [9,13,14].

Silicone

The silicones, produced for the first time in 1946, and it was used as a maxillofacial material for construction of extra-oral appliances for the first time by Barnhart in 1960, since then the silicone materials became one of the most popular materials in the field of maxillofacial prosthetics [13,15,16]. Silicones constitute of an organic and inorganic elements combination, the method by which the crosslinking happens is termed vulcanization. silicones are present in two types, the first one requires heat for vulcanization (HTV), and the second type vulcanizes readily at room temperature (RTV) [15].

RTV silicones

It is a type of silicone materials that vulcanizes readily at room temperature and its hardness ranging from 15-40

Shore. platinum or a tin catalyst [15]. The properties of this materials such as high tear resistance, flexibility and hardness degrees that are comparable with that of the human tissues and compatibility with the adhesive agents, increased the popularity of (RTV) in the construction of maxillofacial appliances [15,17,18].

Cosmesil

Cosmesil is an acceptable and biocompatible material that can be used safely for construction of the maxillofacial materials which is a type of silicone polymer that is fortified by amorphous silica to enhance the mechanical properties and strength. Maxillofacial silicone elastomers are the best available materials for replacing craniofacial defects [19].

High temperature vulcanized silicone (HTV)

HTV Silicones has better mechanical characteristics precisely tear resistance than RTV Silicones [20]. This material has addition type of polymerization reaction which utilizes Platinum salts as a catalyst and dichlorobenzoyl peroxide as a catalyst for the condensation type of polymerization. The elasticity of the (HVT) material is not high when it is compared to the (RTV) materials, so that it is hardly used when mobile tissues are involved [21]. It is usually white, biocompatible materials that has a considerable amount of strength especially at the feathered borders of the prosthesis. The (HTV) silicones have high color and thermal stability when it is subjected to U.V. light. Heat vulcanized elastomers shows high values of tensile strength and tear resistance [8,16,20-22].

Nanoparticles used as additives to facial elastomers

The silicon elastomers that are used in maxillofacial appliances fabrication gave wide range of clinical outcome in regard matching of the surrounding tissues and the ability to keep this matching for longer periods without being affected by the environmental factors [12,13]. Nanoparticles of silver was added to the facial prosthesis, their incorporation was effective in reducing candida albicans accumulation on the surface of the prosthesis an addition silver nanoparticle caused no toxic to the dermal cells of the patients [23]. Other studies have investigated the effect of titanium dioxide nanoparticles on the physical characteristics of the facial elastomers [24-26]. Zinc oxide nanoparticles were added to the silicon elastomer as another attempt to improve the internal physical and mechanical characteristics of the silicon rubbers used for fabrication of maxillofacial appliances 24, another types of nanoparticles such as silicone dioxide and Yttrium Oxide, were presented in many studies as an additives to the facial elastomers.

Physical properties under investigation

Tear resistance

One of the most important physical characteristics of the maxillofacial prosthesis in clinical respect is the strength of tear resistance. The maxillofacial rubbers that have high resistance to tearing forces are highly desirable, especially, in areas around the nose and eyes due to the need of thin margins fabrication. The thin borders aid in blending the borders of a maxillofacial appliance to the nearby facial tissues. These thin borders are retained usually with a medical adhesive [27-29]. When the maxillofacial prosthesis is detached by the patient for cleaning purposes for example, these feathered borders are susceptible to a force that could tear these edges. In such cases the maxillofacial prosthesis could be damaged permanently and cannot be used anymore and there will be a need for new prosthesis to be constructed [27,29-31]. For this reason, many attempts were conducted to improve the tear resistance of the materials used for construction of the maxillofacial prostheses. One of these attempts were accomplished by adding of nanoparticles to the facial elastomers, TiO2 nanoparticles were added in many studies to the maxillofacial elastomers to increase their tear strength, the addition of TiO2 found to be beneficial in increasing the tear strength of the facial elastomers, but only when it is added in certain concentration (2-2.5%) by weight [26,32], addition in lower concentrations did not have an impact on the tear strength of the facial elastomer, and an increased concentrations, may have an adverse effect on the tear strength. Other studies used different forms of silica nanoparticles like fumed SiO2, TiSiO4, and Ytterium oxide were also used for the same purpose [33-36]. An increased tear strength due to incorporation of the TiO2 were explained as the ability of the polymerized silicone reinforced with nanoparticles to distribute the energy at the end of the growing cracks, when a tearing force starts to take place within the polymer, suggesting that the participation of the nanoparticles in the cross-linking continuous polymerization reaction of the silicone elastomer [37].

Tensile strength

The measurement of the tensile strength of the maxillofacial rubbers offers an idea not only about the strength of the elastomers but, also about the elongation ability of the prosthesis before it is breaking down, where, higher elongation of the facial elastomer is a desirable property as long as, it means that the maxillofacial silicone has high ability to flex under peeling strength and, also the material will bend and flex in almost the same manner the facial tissues surrounding the prosthesis does [12,29]. The addition of TiO2, and TiSiO4 nanoparticles to the facial elastomers significantly increased the ability of the material to undergo elongation under tensile stress. SiO2, and silica nanoparticles had the same impact on the elongation ability and the tensile strength of the maxillofacial silicone. Ytterium oxide nanoparticles were added to the silicone used as maxillofacial prostheses, and the results of the addition of the Ytterium oxide nanoparticles showed that there is a significant increase in elongation, and tensile strength of the facial elastomers [26,33-36]. These results were in contrast with the results found by Cevik and Ersalan (2016) who stated that the addition of

Silaned Silica Nanoparticles have increased the tensile strength significantly, while the addition of TiO2 had an adverse result on the elongation ability and tensile strength of the facial silicone [32]. The increased tensile strength and elongation of the maxillofacial silicone can be explained by the formation of strong chemical bond between the filler and the facial polymer, this allows the chains of the polymer to uncoil and slide nanoparticles increasing the crystallization between the polymer chains [26].

Hardness

The hardness of the facial silicone is also, a measurement of the strength of the prosthesis and, flexibility, anyway, it is essential property in the maxillofacial prostheses that the silicone used has nearly the same hardness of the facial tissues surrounding the prosthesis to increase the harmony between the prosthesis and the tissue around it [38-41]. An increased hardness of the maxillofacial elastomers due to addition of the nanoparticles, could be the result of higher concentration of the nanoparticles incorporated between the polymer chains, making these chains less in number which leads to increased rigidity and penetration resistance of the silicone polymers [33]. Studies conducted which were concerned with investigation of the effect of the nanoparticles on the hardness of the maxillofacial silicone elastomers, showed variable response to the addition of the nanoparticles in regard to the type of the particles used and their concentration. Silver dioxide nanoparticles when added to the facial silicone showed significant decrease in the surface hardness of the elastomer [42,43]. TiO2 nanoparticles at low concentrations less than 2% by weight, and high concentrations more than 3% by weight have decreased the surface hardness of the maxillofacial silicone, TiO2 at a concentration about 2-3% had a significant increase in the hardness of the facial silicone significantly [26,32,34,35,44].

The addition of TiSiO4, Ytterium oxide, and SiO2 nanoparticles showed a significant increase in the hardness of the maxillofacial elastomers 33–36. ZnO, and Ceo2 nanoparticles at 2-2.5% by weight have increased the surface hardness of the maxillofacial silicone [44].

Color stability

The maxillofacial prosthesis should be esthetically acceptable for the patient [45]. As aforementioned in the current study, silicone materials could have color stability more than many other materials used in this field, however, color stability of the silicone elastomers could be temporary and may not last for a considerable period due to natural condition such as weather temperature, and contamination [30,46]. Factors such as ultraviolet irradiation from the sun, moisture, temperature, air, contamination, and dust may have a great impact on the color stability of the maxillofacial prosthesis [47,48]. Many studies have investigated the role of addition of the nanoparticles on the color change resistance of the maxillofacial silicone under specific conditions that simulates the natural weathering factors. The addition of ZnO nanoparticles, in many studies which found that this addition can significantly increase the color change resistance of the maxillofacial silicone [49-51], the addition of AgO2 nanoparticles had insignificant impact on the shade stability of the maxillofacial silicones [42]. On the other hands many studies showed that the addition of TiO2 nanoparticles can increase the color stability of the facial silicones [52]. Reflection and scattering of a great amount of UV light present in the sunlight because of the presence of nano oxides due to their ability to reflect and scatter the UV rays because of their high refractive index [53].

CONCLUSION

Under the limitation of the current study the following can be conclude:

The addition of different types of nanoparticles have improved physical properties of the facial elastomers in addition to better stability of the color of these elastomers.

The addition of nanoparticles should be at certain concentrations recommended by many authors otherwise, an adverse effect might be evident.

REFERENCES

1. Guttal SS, Vohra P, Pillai LK, et al. Interim prosthetic rehabilitation of a patient following partial rhinectomy: A clinical report. Eur J Dent 2010; 4:482-486.
2. de Bree R, Leemans CR. Recent advances in surgery for head and neck cancer. Curr Opin Oncol 2010; 22:186-193.
3. Raghoebar GM, Van Oort RP, Roodenburg JLN, et al. Fixation of auricular prostheses by osseointegrated implants. J Investig Surg 1994; 7:283-290.
4. Wilkes GH, Wolfaardt JF. Osseointegrated alloplastic versus autogenous ear reconstruction: Criteria for treatment selection. Plast Reconstr Surg 1994; 93:967-979.
5. Bal BT, Yılmaz H, Aydın C, et al. In vitro cytotoxicity of maxillofacial silicone elastomers: Effect of accelerated aging. J Biomed Mater Res Part B 2009; 89:122-126.
6. Aziz T, Waters M, Jagger R. Analysis of the properties of silicone rubber maxillofacial prosthetic materials. J Dent 2003; 31:67-74.
7. Kheur MG, Sethi T, Coward T, et al. A comparative evaluation of the change in hardness, of two commonly used maxillofacial prosthetic silicone elastomers, as subjected to simulated weathering in tropical climatic conditions. Eur J Prosthodont Restor Dent 2012; 20:146-150.
8. Barhate AR, Gangadhar SA, Bhandari AJ, et al. Materials used in maxillofacial prosthesis: A review. Pravara Med Rev 2015; 7.

9. Dubey SG, Balwani TR, Chandak AV, et al. Material in maxillofacial prosthodontics: A review. J Evol Med Dent Sci 2020; 9:3319-3325.
10. Siang Soh M, Sellinger A, Uj Yap A. Dental nanocomposites. Curr Nanosci 2006; 2:373-381.
11. Roy I, Stachowiak MK, Bergey EJ. Nonviral gene transfection nanoparticles: Function and applications in the brain. Nanomed Nanotechnol Biol Med 2008; 4:89-97.
12. Lewis DH, Castleberry DJ. An assessment of recent advances in external maxillofacial materials. J Prosthet Dent 1980; 43:426-432.
13. Montgomery PC, Kiat-Amnuay S. Survey of currently used materials for fabrication of extraoral maxillofacial prostheses in North America, Europe, Asia, and Australia. J Prosthodont Implant Esthet Reconstr Dent 2010; 19:482-490.
14. Hooper SM, Westcott T, Evans PLL, et al. Implant-supported facial prostheses provided by a maxillofacial unit in a UK regional hospital: Longevity and patient opinions. J Prosthodont Implant Esthet Reconstr Dent 2005; 14:32-38.
15. Khindria SK, Bansal S, Kansal M. Maxillofacial prosthetic materials. J Indian Prosthodont Soc 2009; 9:2.
16. Puppala P, Shetty O, Chandrasekhar P. Materials in maxillofacial prosthodontics: A review of trends. Indian J Contemp Dent 2014; 2:44.
17. Mitra A, Choudhary S, Garg H, et al. Maxillofacial prosthetic materials-an inclination towards silicones. J Clin diagnostic Res 2014; 8:ZE08.
18. Mahajan H, Gupta K. Maxillofacial prosthetic materials: A literature review. J Orofac Res 2012 ; 87-90.
19. Ariani N, Visser A, Van Oort RP, et al. Current state of craniofacial prosthetic rehabilitation. Int J Prosthodont 2013; 26:57-67.
20. Al-Harbi FA, Ayad NM, Saber MA, et al. Mechanical behavior and color change of facial prosthetic elastomers after outdoor weathering in a hot and humid climate. J Prosthet Dent 2015; 113:146-151.
21. Reddy JR, Kumar BM, Ahila SC, et al. Materials in maxillo-facial prosthesis. J Indian Acad Dent Spec Res 2015; 2:2.
22. Polyzois G, Lyons K. Monitoring shore a hardness of silicone facial elastomers: The effect of natural aging and silicone type after 1 year. J Craniofac Surg 2014; 25:1217-1221.
23. https://pearl.plymouth.ac.uk/handle/10026.1/2877
24. González N, Custal M del À, Rodríguez D, et al. Influence of ZnO and TiO 2 particle sizes in the mechanical and dielectric properties of vulcanized rubber. Mater Res 2017; 20:1082-1091.
25. Çevik P. Evaluation of shore a hardness of maxillofacial silicones: The effect of dark storage and nanoparticles. Eur Oral Res 2018; 52:99-104.
26. Shakir DA, Abdul-Ameer FM. Effect of nano-titanium oxide addition on some mechanical properties of silicone elastomers for maxillofacial prostheses. J Taibah Univ Med Sci 2018; 13:281-290.
27. Goldberg AJON, Craig RG, Filisko FE. Tear energy of elastomers for maxillofacial applications. J Oral Rehabil 1980; 7:445-451.
28. Gunay Y, Kurtoglu C, Atay A, et al. Effect of tulle on the mechanical properties of a maxillofacial silicone elastomer. Dent Mater J 2008; 27:775-779.
29. Begum Z, Kola MZ, Joshi P. Analysis of the properties of commercially available silicone elastomers for maxillofacial prostheses. Int J Contemp Dent 2011; 2.
30. Kiat-amnuay S, Waters PJ, Roberts D, et al. Adhesive retention of silicone and chlorinated polyethylene for maxillofacial prostheses. J Prosthet Dent 2008; 99:483-488.
31. Wolfaardt JF, Chandler HD, Smith BA. Mechanical properties of a new facial prosthetic material. J Prosthet Dent 1985; 53:228-234.
32. Cevik P, Eraslan O. Effects of the addition of titanium dioxide and silaned silica nanoparticles on the mechanical properties of maxillofacial silicones. J Prosthodont 2017; 26:611-615.
33. Zayed SM, Alshimy AM, Fahmy AE. Effect of surface treated silicon dioxide nanoparticles on some mechanical properties of maxillofacial silicone elastomer. Int J Biomater 2014; 2014.
34. Alsmael MA, Ali MMM. The effect of nano titanium silicate addition on some properties of maxillofacial silicone material. J Res Med Dent Sci 2018; 6:127-132.
35. Tukmachi MS, M. Ali MM. Effect of nano silicon dioxide addition on some properties of heat vulcanized maxillofacial silicone elastomer. J Pharm Biol Sci 2017; 12:37-43.
36. Al-Mohammad YN, Abdul-Ameer FM. Evaluation the effect of nano yttrium oxide addition on the mechanical properties of room temperature-vulcanized maxillofacial silicone elastomers. Indian J Forensic Med Toxicol 2020; 14:803-809.
37. Sun L, Gibson RF, Gordaninejad F, et al. Energy absorption capability of nanocomposites: A review. Compos Sci Technol 2009; 69:2392-2409.
38. Hatamleh MM, Watts DC. Mechanical properties and bonding of maxillofacial silicone elastomers. Dent Mater 2010; 26:185-191.
39. Mousa MA. Influence of weather on hardness and surface roughness of maxillofacial elastomeric materials. J Contemp Dent Pract 2020; 21:678-682.
40. Dootz ER, Koran A, Craig RG. Physical properties of three maxillofacial materials as a function of

accelerated aging. J Prosthet Dent 1994; 71:379-383.

41. Goiato MC, Pesqueira AA, Santos DM, et al. Evaluation of hardness and surface roughness of two maxillofacial silicones following disinfection. Braz Oral Res 2009; 23:49-53.
42. Sonnahalli NK, Chowdhary R. Effect of adding silver nanoparticle on physical and mechanical properties of maxillofacial silicone elastomer material-an in-vitro study. J Prosthodont Res 2020; 64:431-435.
43. Nobrega AS, Andreotti AM, Moreno A, 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; 116:623-629.
44. Han Y, Kiat-amnuay S, Powers JM, et al. Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer. J Prosthet Dent 2008; 100:465-473.
45. Ishigami T, Tanaka Y, Kishimoto Y, et al. A facial prosthesis made of porcelain fused to metal: A clinical report. J Prosthet Dent 1997; 77:564-567.
46. Haug SP, Andres CJ, Moore BK. Color stability and colorant effect on maxillofacial elastomers. Part III: Weathering effect on color. J Prosthet Dent 1999; 81:431-438.
47. Eleni PN, Krokida MK, Polyzois GL, et al. Effect of different disinfecting procedures on the hardness and color stability of two maxillofacial elastomers over time. J Appl Oral Sci 2013; 21:278-283.
48. Kiat-Amnuay S, Mekayarajjananonth T, Powers JM, et al. Interactions of pigments and opacifiers on color stability of MDX4-4210/type A maxillofacial elastomers subjected to artificial aging. J Prosthet Dent 2006; 95:249-257.
49. Bangera BS, Guttal SS. Evaluation of varying concentrations of nano-oxides as ultraviolet protective agents when incorporated in maxillofacial silicones: An in vitro study. J Prosthet Dent 2014; 112:1567-1572.
50. Akash RN, Guttal SS. Effect of incorporation of nano-oxides on color stability of maxillofacial silicone elastomer subjected to outdoor weathering. J Prosthodont 2015; 24:569-575.
51. Charoenkijkajorn D, Sanohkan S. The effect of nano zinc oxide particles on color stability of MDX4-4210 silicone prostheses. Eur J Dent 2020; 14:525-532.
52. Nada H E, Ahmad MA, Moustafa NA. Evaluation of intrinsic color stability of facial silicone elastomer reinforced with different nanoparticles. Alexandria Dent J 2016; 41:50-54.
53. Yang H, Zhu S, Pan N. Studying the mechanisms of titanium dioxide as ultraviolet-blocking additive for films and fabrics by an improved scheme. J Appl Polym Sci 2004; 92:3201-3210.