Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9291
ISSN on-line: 1807-8648
Doi: 10.4025/actascihealthsci.v37i1.21318

Evaluation of the mechanical properties of acetic-cure silicone with the addition of magnesium silicate

Ronald Vargas Orellana[1], Neide Pena Coto[1*], Igor Studart Medeiros[2] and Reinaldo Brito e Dias[1]

*[1]Departamento de Cirurgia, Prótese e Traumatologia Maxilofaciais, Faculdade de Odontologia, Universidade de São Paulo, Avenida Lineu Prestes, 2227, 05508-000, Cidade Universitária, São Paulo, São Paulo, Brazil. [2]Departamento de Biomateriais, Faculdade de Odontologia, Universidade de São Paulo, São Paulo, São Paulo, Brazil. *Author for correspondence. E-mail: npcoto@usp.br*

ABSTRACT. Current study evaluates the mechanical properties (tensile and tear strength) of an acetic-cure silicone with the addition of 10 or 20% vol. magnesium silicate. Magnesium silicate was added to the silicone at concentrations of 10 (MS-10) and 20% (MS-20) volume, followed by the analysis of tensile strength, maximal elongation during tensile and tear strength. Results were compared to control group of silicone without additives (CG). Mean rates were determined and compared by analysis of variance and Tukey's test ($p < 0.05$). Control group had the greatest elongation when subjected to tensile strength (650%), whereas the MS-10 group statistically showed a better tensile strength (8.8 MPa) when compared to CG (7.5 MPa) and MS-20 (7.5 MPa) groups. Both magnesium silicate groups exhibited statistically similar tear strength, whereas MS-20 group demonstrated statistically greater tear strength. The addition of 10% magnesium silicate increased tensile strength, but tear strength and elongation were similar to control. The addition of 20% magnesium silicate did not affect tensile but increased tear strength.

Keywords: silicone elastomers, magnesium silicate, rehabilitation.

Avaliação das propriedades mecânicas de silicone de cura acética, com a adição de silicato de magnésio

RESUMO. O objetivo deste estudo foi avaliar as propriedades mecânicas (resistência à tração e ao rasgamento) de um silicone de cura acética com adição de 10 ou 20% em volume de silicato de magnésio. O silicato de magnésio foi adicionado ao silicone em concentrações de 10 (MS-10) e 20% (MS-20), em volume, avaliado por análise de resistência à tração, deformação máxima em tração e resistência ao rasgamento. Os resultados foram comparados com um grupo de controle sem aditivos de silicone (GC). Os valores médios foram determinados e comparados através de análise de variância e teste de Tukey ($p < 0,05$). O grupo de controle apresentou o maior alongamento quando submetido à tensão (650%). O grupo MS-10 exibiu estatisticamente melhor resistência à tração (8,8 MPa) em relação ao GC (7,5 MPa) e MS-20 (7,5 MPa) grupos. Ambos os grupos de silicato de magnésio exibiram médias de resistência ao rasgamento estatisticamente semelhantes, enquanto que o grupo de EM-20 demonstrou estatisticamente maior resistência ao rasgamento em comparação com o grupo de controle. A adição de 10% de silicato de magnésio em volume propiciou maiores valores de resistência ao rasgamento e resistência à tração. A adição de 20% de silicato de magnésio não afetou a resistência à tração, mas produziu aumento na resistência ao rasgamento.

Palavras-chave: silicone, talco, reabilitação.

Introduction

Automobile accidents and cancer surgeries are the main causes of facial injuries. When plastic surgery is contraindicated or impossible, a facial prosthesis is employed (CARVALHO et al., 1993). The success of the prosthesis is directly linked to the skill of the healthcare professional, the site and extent of the injury and the use of appropriate materials. In fact, there is an ongoing search for the ideal material for facial prosthesis. One of the desired characteristics of such materials is the concealment of the prosthesis, the success of which depends on a soft skin-like texture, mechanical strength, flexibility and durability (ROMMERDALE, 1995; MORTELLARO et al., 2006).

Silicones are currently used for maxillofacial prosthesis and provide a degree of comfort, combining esthetics and safety. However, the greatest limitation of these materials is translucency which may be minimized with the addition of opacifying agents (HAUG et al., 1999; HAN et al., 2008; GUIOTTI et al., 2010). Magnesium silicate, an excipient base compatible with a great diversity of materials and substances, is used in cosmetics, biochemistry and pharmaceutical sciences and drug vehicle, due to its high degree of biocompatibility. Biocompatibility is very important for the material used in maxillofacial prosthesis since the addition of magnesium silicate may affect the silicon´s mechanical properties.

Current study evaluates the mechanical properties (tensile and tear strength) of an acetic-cure silicone with the addition of 10 and 20% magnesium silicate by volume when compared to specimens without additives.

Material and methods

Five test specimens were produced for each of the three groups using acetic-cure silicone (Siliflex, Vedacit, Brazil): control group (CG) – without the addition of magnesium; group with addition of 10% magnesium silicate by volume (MS-10); and group with addition of 20% magnesium silicate by volume (MS-20). The amount of magnesium silicate was measured with 50-ml Falcon tubes (Corning Incorporated, Midland, USA). The mixtures were immediately spatulated during one minute for homogenization and the elimination of bubbles, and then pressed. Silicone blades measuring 10 x 15 x 0.30 cm were cut with knives provided by the Instituto de Pesquisa e Tecnologia of the Universidade de São Paulo, following ASTM norm D 412-87 (ASTM, 1987).

Tensile strength and maximum elongation (n = 5)

Test specimens were placed in the universal testing machine (KRATOS Inc) at an operating velocity of 50 mm $min.^{-1}$, at 25°C and 50% relative humidity. The tests were filmed with a digital camera (Sony HD S41) for greater safety and for the measurement of maximum tensile tolerated before breaking. A millimeter ruler was placed next to the specimen-supporting brackets to determine the elongation measurement upon breaking. Maximal load and stretching were recorded for the calculation of tensile strength (MPa) and maximal elongation (%).

Tear resistance (n = 5)

ASTM norm D 624-86 (ASTM, 1986) was applied for the assays, implying cutting the test specimens and measuring tear resistance. Assays were executed in the universal testing machine (KRATOS Inc) at an operating velocity of 50 mm $min.^{-1}$, at 25°C and 50% relative humidity.

Data on tensile and tear strength were submitted to analysis of variance (ANOVA) and Tukey's test with Statigrafics Program at a significance level of $p \leq 0.05$.

Results

The mean rates of maximal elongation during tensile assay were 650% in the CG, 507 in the MS-10 and 538% in the MS-20 groups. Table 1 shows mean tear strength and tensile strength rates. Statistical analysis revealed that the two magnesium silicate groups achieved similar tear strength rates, whereas that obtained for the MS-20 group was significantly statistically higher than that obtained for the CG group. MS-10 group achieved a mean tensile strength rate of 8.7 MPa, which was statistically higher than the rates achieved in CG and MS-20 groups, both of which reached 7.5 MPa (Figure 1).

Table 1. Tensile Strength, tear strength and elongation means.

Silicone	Tensile strength (MPa)	Tear strength (KN m^{-1})	Elongation (%)
Control	7.5 (0.8)^{b}	65.8 (6.9)^{b}	650
+ 10% magnesium silicate	8.8 (0.7)^{a}	72.7 (8.2)^{ab}	507
+ 20% magnesium silicate	7.5 (0.6)^{b}	79.1 (3.8)^{a}	538

Same letters show statistically similar means.

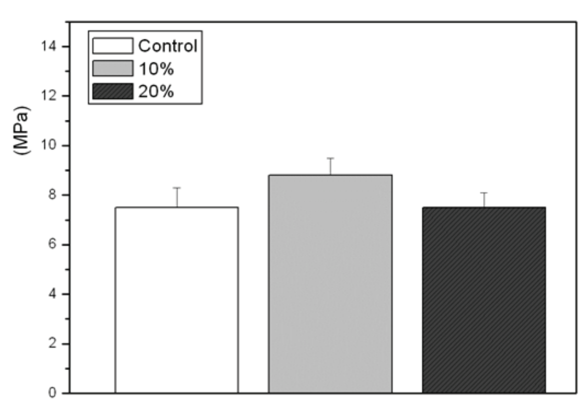

Figure 1. Tensile strength in different groups.

Discussion

Researchers have proposed several indispensable characteristics for the ideal material in facial prosthesis. The main materials to replace lost tissues are silicone (GOYAL et al., 2012; ANAND et al., 2013) and resin (NOMURA et al., 2013; HADDAD et al., 2012). Some properties involve mechanical characteristic to support function movements, including: high tensile strength, high percentage of elongation, tear strength, dimensional stability, resistance to chemical products and ultraviolet light, anti-allergic properties, cleaning ease, light weight and compatibility with human tissues. Manipulation characteristics comprise low degree of viscosity, extended working time, non-toxicity, capacity for extrinsic and intrinsic characterization, ease handling during use, translucency, similarity to human skin and elasticity (BULBULIAN, 1945; CARVALHO et al., 1993; POLYZOIS; PETTERSEN, 1998; LAI; HODGES, 1999; ANAND et al., 2013).

Although due to its rubbery nature, silicone complies with many of the above-mentioned requirements, silicones are deficient in mechanical properties. So that the deficient aspects of silicone for use in facial prosthesis may be overcome, other substances are added to the formula. They include magnesium oxide, micronized quartz colloidal silica, zinc dimethacrylate, inorganic salts, pigment, kaolin, fiber, adhesives used in medicine and others (BULBULIAN, 1945; GONZALEZ et al., 1978; FARAH et al., 1987; CARVALHO et al., 1993; LIU et al., 2013). However, the addition of these materials may change the silicone´s characteristics and mechanical properties (UDAGANA; DRANE, 1982; ROMMERDALE, 1995; MORTELLARO et al., 2006; HADDAD et al., 2012). Since all additives must be compatible, researchers must seek bases or vehicles that may form a new material with better characteristics than the individual components when analyzed separately (VERES et al., 1990).

The addition of 10% magnesium silicate to silicone in current assay significantly increased tensile strength. This pronounced effect is due to the synergic effect of the powder reinforcement provided by the magnesium silicate particles. However, the addition of 20% magnesium silicate did not yield an increase in tensile strength when compared to that of control. This fact indicated a greater difficulty with regard to the even distribution of particles and to the formation of agglomerates, thereby failing to provide a reinforcement effect.

The addition of magnesium silicate led to a reduction in the maximal elongation of the material. This phenomenon may be related to magnesium silicate particles which constitute a hindrance or a barrier to the sliding of the polymeric chains during tensile loads, with a consequent reduction in elongation. However, elongation rates remained substantially high (507 and 538% in the MS-10 and MS-20 groups, respectively).

Tear strength is linked to the energy necessary to rupture the material along its long axis. Current study´s results demonstrated a direct proportionality between the addition of magnesium silicate and tear strength, evidenced as tear strength ~10% increased for MS-10 and 20% increased for MS-20. The silicate proved to be a material which, when added to the silicone in the percentage indicated in this study, overcame results found by Haug et al. (1999) when they studied pigment accretions. The study by Han et al. (2008) with the addition of nano-oxide particles of Ti, Zn or Ce showed similar results to current assay.

Besides the aspects analyzed in the assays, the visual observation of the silicone test specimens revealed that the addition of magnesium silicate provided a surface texture and opacity similar to human skin, which are indispensable characteristics for the concealment of prosthetic parts designed to replace an organ´s lost portion. Complementary studies should be carried out for the determination of the optical characteristics and translucency of the material.

Conclusion

The addition of 10% magnesium silicate increased tensile strength in current assay but tear strength and elongation were similar to control. The addition of 20% magnesium silicate did not affect tensile strength although increased tear strength.

References

ANAND, V.; HARIBABU B,VIMAL A.; GNANASAMBAND, V. A laboratory silicone for preclinical training in ear prosthesis. **Journal of Pharmacy and Bioallied Sciences**, v. 5, n. 2, p. 22-24, 2013.

ASTM-American Standards of Testing Materials. **ASTM D412-87 standard test method for rubber properties in tension**. Philadelphia: ASTM, 1987.

ASTM-American Standards of Testing Materials. **ASTM D624-86 standard test method for rubber property tear resistance**. Philadelphia: ASTM, 1986.

BULBULIAN, A. H. Maxillofacial prosthetics: evolution and practical application in patient rehabilitation. **The Journal of Prosthetic Dentistry**, v. 15, n. 3, p. 554-569, 1945.

CARVALHO, J. C. M.; DIAS, R. B.; MATOS, B. S. C. Comparative evaluation of tensile strenght and rupture elongation of two Brazilian silicones for facial prosthesis. **Brazilian Dental Journal**, v. 4, n. 2, p. 137-141, 1993.

FARAH, J. D.; ROBINSON, J. C.; KORAN, A.; CRAIG, R. G.; HOOD, J. A. A. Properties of a modified cross-linked silicone for maxillofacial prosthesis. **Journal of Oral Rehabilitation**, v. 14, n. 6, p. 599-605, 1987.

GONZALEZ, J. B.; CHAO, E. Y. S.; AN, K. N. Physical and mechanical behavior of polyurethane elastomer formulations used for facial prosthesis. **The Journal of Prosthetic Dentistry**, v. 39, n. 3, p. 307-318, 1978.

GOYAL, A.; HINGRAJIA, D.; CHAWLA, N.; SHAH, R. J. Prosthetic rehabilitation of a patient with an orbital defect: a simplified approach. **Journal of Indian Prosthodontic Society**, v. 12, n. 3, p. 187-190, 2012.

GUIOTTI, A. M.; GOIATO, M. C.; SANTOS, D. M. Evaluation of the shore a hardness of silicone for facial prosthesis as to the effect of storage period and chemical disinfection. **Journal of Craniofacial Surgery**, v. 21, n. 2, p. 323-327, 2010.

HADDAD, M. F.; GOIATO, M. C.; SANTOS, D. M.; CREPALDI, N. M.; PESQUEIRA, A. A.; BANNWART, L. C. Bond strength between acrylic resin and maxillofacial silicone. **Journal of Applied Oral Science**, v. 20, n. 6, p. 649-654, 2012.

HAN, Y.; KIAT-AMNUAY, S.; POWERS, J. M.; ZHAO, Y. Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer. **The Journal of Prosthetic Dentistry**, v. 100, n. 6, p. 465-473, 2008.

HAUG, S. P.; ANDRES, C. J.; MOORE, B. K. Color stability and colorant effect on maxillofacial elastomers. Part II: weathering effect on physical properties. **The Journal of Prosthetic Dentistry**, v. 81, n. 4, p. 423-430, 1999.

LAI, J. H.; HODGES, J. S. Effects of processing parameters on physical properties of the silicone maxillofacial prosthetic materials. **Dental Materials**, v. 15, n. 1, p. 450-455, 1999.

LIU, Q.; SHAO, L. Q.; XIANG, H. F.; ZHEN, D.; ZHAO, N.; YANG, S. G.; ZHANG, X. L.; XU, J. Biomechanical characterization of a low density silicone elastomer filled with hollow microspheres for maxillofacial prosthesis. **Journal of Biomaterials Science, Polymer Edition**, v. 24, n. 11, p. 1378-1390, 2013.

MORTELLARO, C.; GARAGIOLA, U.; LUCCHINA, A. G.; GRIVETTO, F.; MILONE, G.; PAPPALARDO, S.; PALMERI, A.; SCORSONE, D.; SAMMARTINO, G. The use of silicon elastômero in maxillofacial rehabilitation as a substitute for or in conjunction with resins. **Journal of Craniofacial Surgery**, v. 17, n. 1, p. 152-162, 2006.

NOMURA, T.; SATO, J.; MATSUURA, M.; KAWAGUCHI, K.; SEKIGUCHI, R.; HORIE, A.; SETO, K. Lightweight acrylic resin facial prosthesis for maxillofacial defects: A fabrication and retention method. **Journal of Prosthetic Dentistry**, v. 110, n. 4, p. 326-330, 2013.

POLYZOIS, G. L.; PETTERSEN, A. H. Physicomechanical and cytotoxic properties of room temperature vulcanizing silicone prosthetic elastomers. **The Journal of Prosthetic Dentistry**, v. 56, n. 4, p. 245-248, 1998.

ROMMERDALE, E. New technique for surface flattening in facial reconstruction. **Trends and Techniques in the Contemporary Dental Laboratory**, v. 12, n. 3, p. 35-41, 1995.

UDAGAMA, A.; DRANE, J. B. Use of medical-grade methyl triacetoxy silane crosslinked silicone for facial prosthesis. **The Journal of Prosthetic Dentistry**, v. 48, n. 1, p. 86-88, 1982.

VERES, E. M.; WOLFAARDT, J. F.; BECKER, P. J. An evaluation of the surface characteristics of a facial prosthetic elastomer. Part III: Wettability and hardness. **The Journal of Prosthetic Dentistry**, v. 63, n. 4, p. 466-470, 1990.

Received on September 3, 2013.
Accepted on January 14, 2014.