International Journal of Adhesion & Adhesives 54 (2014) 206–213

Contents lists available at ScienceDirect

International Journal of Adhesion & Adhesives

journal homepage: www.elsevier.com/locate/ijadhadh

Bonding of facial silicon with nanoparticles to an acrylic resin substrate

Marcela Filié Haddad [a], Marcelo Coelho Goiato [a,*], Daniela Micheline dos Santos [a], Aldiéris Alves Pesqueira [a], Amália Moreno [a], Lucas Zago Naves [b], Mariana Vilela Sonego [a]

[a] Department of Dental Materials and Prosthodontics, Araçatuba Dental School, UNESP, Araçatuba, São Paulo, Brazil
[b] Department of restorative dentistry, dental materials division, Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil

ARTICLE INFO

Article history:
Accepted 6 June 2014
Available online 7 July 2014

Keywords:
Acrylic resin
Silicone elastomer
Nanoparticles
Maxillofacial prostheses
Aging

ABSTRACT

The aim of this study was to evaluate the influence of different adhesive techniques and accelerated aging on the bonding of maxillofacial biomedical silicone to an acrylic resin substrate. 960 acrylic resin samples (PMMA) were manufactured and bonded to the silicone with or without oil painting and/or opacifier. Both materials were bonded through mechanical retentions and/or application of primers (DC 1205 primer and Sofreliner primer S) and adhesive (Silastic Medical Adhesive Type A) or not (control group). The samples dimension were 75-mm length, 10-mm width and 6-mm thickness.The samples were divided in 4 groups ($n=240$) for the pigmentation variable, and 12 subgroups ($n=20$) accordingly to the bonding technique. Half of the samples of each group underwent the peel test at baseline and the fracture pattern was measured through direct observation and SEM and then classified into adhesive, cohesive and both failure. The remaining samples were submitted to accelerated aging (8 hours – ultraviolet light irradiance was at a temperature of 60 ± 3 °C and 4 h – a dark condensation period was at a temperature of 45 ± 3 °C) during 1008 hours and the peel test, direct observation and SEM were performed. The peel value needed to separate the resin from silicone (PS) was statistically analyzed with the ANOVA variance test and the Tukey test ($p < 0.05$). The failure pattern was assessed statistically through the qui square test and the fisher exact test. The bond strength test results indicated a statically significance ($p < 0.05$) for all factors. These values raised after the aging period, and the oil painting group presented the higher mean value (PS=3.53 N/mm). Groups with were applied the Sofreliner Primer presented higher bond strength values than other subgroups for both periods of evaluation. The factors time and technique influenced significantly in failure pattern, the most common failure was mixed failure ($n=671=69.9\%$) and the least common was the cohesive one ($n=109$). Greater PS values were presented by the subgroups pigmented with oil painting, without scratches and that received the sofreliner primer after the accelerated aging period. The sofreliner primer promotes a higher adherence between acrylic resin and facial silicone and the incidence rate of both failure augmented after the aging period.

1. Introduction

The facial rehabilitation through implant retained prostheses is a valid treatment to re-establish esthetics, function and quality of life to many patients who suffered facial mutilation due to cancer, trauma or burns [1]. Silicon is widely used to manufacture facial prostheses for its unique characteristics such as biocompatibility, texture similar to skin and for being easy to pigment [2,3].

Facial prostheses made of silicon that are retained by dental implants require a retention matrix, made of acrylic resin, where clips and/or magnets are installed. The silicone is positioned over the matrix, so it is very important to have enough adherence at the interface so the patient can use the prostheses in a secure and comfortable way [4].

These maxillofacial prostheses may undergo color change and delamination during its usage [5–7].

The pigmentation with oil painting in addition to opacifiers is a valid solution to the imminent chromatic changes, but the loss of bond between the matrix and the silicone remains a problem. Clinical and experimental studies suggest several techniques to position the acrylic matrix like the association with a fiber glass structure, utilization of different primers and adhesives that can be

* Correspondence to: Faculdade de Odontologia de Araçatuba, Universidade Estadual Paulista – FOA-UNESP, Rua José Bonifácio, 1193, Vila Mendonça, CEP. 16.015-050, Araçatuba, São Paulo, Brazil. Tel.: +55 18 3636 3287; fax: +55 18 3636 3245.
E-mail addresses: amarcelahaddad@hotmail.com.br (M. Filié Haddad), goiato@foa.unesp.br (M. Coelho Goiato), danielamicheline@foa.unesp.br (D.M.d. Santos), aldiodonto@uol.com.br (A. Alves Pesqueira), amalia_moreno@yahoo.com.br (A. Moreno), lznaves@yahoo.com.br (L. Zago Naves), mah_vs@hotmail.com (M. Vilela Sonego).

http://dx.doi.org/10.1016/j.ijadhadh.2014.06.011
0143-7496/

applied in many ways associated or not with mechanic retention [4]. But this is still a treatment limitation, it is not rare for patients rehabilitated with implant retained prostheses to report looseness or tear up of the prostheses esthetic portion during its removal [4,8,9].

Tests developed to evaluate the adhesive bond strength of materials include peel, tensile, shear, fatigue, creep, impact, and cleavage tests. The most commonly used methods to measure the bond strength of resilient lining materials to acrylic materials have been peel, tensile, and shear tests. The peel test is believed to simulate the horizontal component of forces that causes lateral displacement of the prosthesis. The tensile test gives information on the strength of the bond in comparison to the tensile strength of the material. In shear testing, the stresses are unevenly distributed. At the edges the stresses are much greater [10].

The bond strength test was used as an evaluation method (peel test) which simulates the prostheses removal act through a mechanical test and interface adhesion analysis that can present different failure patterns classified as adhesive (only the detachment of the surfaces happen), cohesive (when only tears happen), and mixed (when both types of failure are presented) [3,4,11].

The samples were submitted to artificial aging [12] for 1008 hours [13,14] in which the they were submitted to different temperatures, darkness and ultraviolet light cycles, simulating one year of clinical use of the prostheses [15,16].

The aim of this study was to evaluate the influence of nanopalticles (oil painting or barium sulfate), of different bonding techniques and of the accelerated aging for 1008 hours on the bonding of facial silicone to an acrylic resin substrate. The hypothesis of this study is that by adding the nanoparticles no difference will be perceived on the bond strength values or the failure patterns; that the association between mechanical imbrications and primer application provides higher bond strength values, that the accelerated aging influences negatively the silicone-resin adhesion and that failure pattern most commonly found is the one that presents both kinds of failure.

2. Materials and methods

2.1. Specimens fabrication

Each sample consisted of two bars of autopolymerized acrylic resin [17,18] (Orto cor, VIPI, Pirassununga, SP, Brazil) and facial silicone (Silastic MDX 4-4210, Dow Corning Corporation, Midland, MI, USA). A metallic matrix with ten rectangular spaces with 75-mm length, 10-mm width and 3-mm thickness [4] was used to fabricate the acrylic resin bars.

The powder and liquid of the autopolymerized acrylic resin were manipulated in a ratio of 3:1, according to the manufacturer's instructions, and was poured into the metallic matrix. The matrix was closed and a 17.78 PSI of pressure was applied during 10 min with a hydraulic press (Midas Dental Products Ltd, Araraquara, SP, Brazil).

Afterwards, the matrix was placed in a curing resin device (Metalvander, Piracicaba, São Paulo, Brazil) during 20 min under hydrostatic pressure of 25 PSI. The matrix was opened and the acrylic resin bars removed. P220 sandpaper (Tigre, Rio Claro, SP, Brazil) was used as a finishing procedure [4].

A total of 960 acrylic resin bars were obtained, and 480 bar did not receive any mechanical retention (scratches), and the remaining bars were scratched with a number 2135 diamond bur (KG Sorensen, Barueri, SP, Brazil). The bur was placed in a high-speed hand piece, and the long axis of the bur was parallel to the bar and tilted 45° in relation to the horizontal axis during the scratches fabrication. Each scratch presented the same diameter of the bur and it was performed 25 mm in length of the bar in the bond area between the acrylic resin and silicone. The distance of each scratch had the same diameter of the bur [19].

Another metallic matrix was used to fabricate the facial silicone bar and to bond the acrylic resin bar to the facial silicone bar. This matrix had ten rectangular spaces with 75 mm in length, 10 mm in width and 6 mm in thickness [4].

Initially, the acrylic resin bars were cleaned with gauze and acetone and then placed into the matrix. An adhesive tape was positioned covering 50 mm in length of the acrylic resin bar (unbonded portion), and the remaining 25 mm length were used to bond the silicone to the acrylic resin [4]. Bars were divided into 4 groups, according the pigmentation, and 12 groups according to the adhesive system used and the presence of surface scratches (Fig. 1) [3,8,20,21].

The application of primer on the acrylic resin surface was used to enhance the adhesive penetration. Therefore, a 30-min period was allowed after Dow Corning 1205 Prime (Dow Corning Corporation, Midland, MI, USA) or Sofreliner Prime S (Tokuyama Corp., Taitou-ku, Tokyo, Japan) application so that the prime reacts with the resin surface.

Before placing the silicone mixture into the matrix, some groups (Fig. 1) received a thin layer of Silastic Medical Adhesive Type A (Dow Corning Corporation, Midland, MI, USA) [3,20] applied directly on the primed acrylic resin surface.

Afterwards, the MDX 4-4210 facial silicone was weighted in a digital precision scale (BEL Equipamentos Analíticos, Piracicaba, SP, Brazil) and manipulated according to manufacturer's instructions, mixing one part of curing agent with 10 parts by weight of the base elastomer, under controlled temperature ($23 \pm 2\ ^{\circ}C$) and humidity ($50 \pm 10\%$), in order to obtain a homogeneous mixture. Groups 2, 3 and 4 (Fig. 1) was pigmented with nanoparticles (oil pigment and/or barium sulfate opacifier). Pigments were weighed with a precision digital scale, equivalent to 0.2% by weight 3, 4, 16, 29 of the necessary silicone to fill up the space of the metallic flask [15,16,22].

The silicone mixture was then used to overfill the matrix and its surface was flattened with a steeling steel spatula and its thickness was standardized. The matrix was placed in a curing resin device with 25 PSI of pressure to avoid bubbles formation into the silicone. A total of 72 hours under room temperature were allowed so the silicone polymerizes and the formaldehyde releases, following manufacturer's instructions [15,16,22]. After silicone polymerization, the specimens were separated from the matrix, and the adhesive tape, used to create the unbonded area of 50 mm in length and to allow the placement of the specimens in the universal testing machine, was removed [4].

Half of the specimens ($n=480$) were subjected to the bond test 24 h after their fabrication, and the other 480 specimens were subjected to artificial aging test.

2.2. Bond test (T-peel test)

An universal testing machine (Emic DL-3000, EMIC, São José dos Pinhais, PR, Brazil) was used to conduct the bond test at a crosshead speed of 10 mm/min [4,23].

The applied load and the limit load were recorded for each specimen. The T-peel strength for each specimen was determined using the average load divided by specimen width, as described in ASTM Standard D 1876-72 [23] according to the following formula:

$$PS = \frac{F}{W} \cdot \left(\frac{1+\lambda}{2} + 1 \right)$$

where F is the maximum force recorded (N), W is the width of the specimens (mm), and $\cdot$ is the extension ratio of the silicone elastomer (the ratio of stretched to unstretched length).