Influence of water on performance of facial prosthetic adhesives

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Purpose: The purpose of this study was to investigate the bond strength performance of two facial prosthetic adhesives on human skin with or without immersion in water for different periods of time.
Materials and Methods: Two facial prosthetic adhesives (silicone-based Secure[2] Adhesive and acrylic polymer-based Daro B-200 ES) were used in this study. Silicone specimens (with the diameter of 5 mm) retained with facial prosthetic adhesive were submitted to tensile bond strength on five volunteers' forearms skin with immersion in distilled water. According to different disposal time, four groups of 0, 1, 10, and 30 minutes of two adhesives were divided, respectively. The specimens were pulled off by use of a desktop material tester with a crosshead speed of 1 mm/minute. Ten specimens of each group were tested, and a total of 80 tests were carried out.
Results: Statistical analysis showed that for Secure[2] Adhesive, tensile bond strength didn't change after immersion for 30 minutes ($p>0.05$), while for Daro B-200 ES, the tensile bond strength reduced significantly after 10 minutes in water ($p<0.05$). Observation of the rupture mode showed that Daro-200-ES left more adhesive residue on skin than Secure[2] Adhesive did ($p<0.05$).
Conclusion: Considering study methodology and limitations, it could be concluded that immersion in water didn't influence the bond strength of silicone-based adhesive, whereas affected that of acrylic polymer-based adhesive. **(Int Chin J Dent 2008; 8: 11-15.)**
Key Words: prosthetic adhesive, silicone elastomer, tensile bond strength.

Introduction

The success of facial restoration relies partially on the retention of prostheses. Facial prostheses can be retained by anatomic undercut, mechanical means, and skin adhesives or craniofacial implants.[1-4] Anatomic undercut is restricted when the compromised tissue is fragile or sensitive. Mechanical retention is less popular because of its unsightlessness. Therefore both anatomic undercut and mechanical retention are most tending to be used as assistant means. Osseointegrated implants can be applied to facilitate retention, stability, and support for facial prostheses used to restore head and neck defects.[4] Retention with implants has been preferred in clinic, for implant-retained facial prosthesis offers significant enhancement over an adhesive-retained prosthesis with respect to ease of use and retention during a variety of daily activities, resulting in greater use of the prosthesis.[5] Since some patients are not candidates for implant intervention (for various reasons, including tumor prognosis, compromised tissue beds, and financial limitations), however, many of them will have to depend on prosthetic adhesives to retain their facial prostheses.[6] What's more, adhesives are effective and commonly used with or without implants or magnets.

Dozens of researches have been carried out to evaluate the mechanical performance of facial prosthetic adhesives,[7-15] however, most of the researches focused on the bond strength of prosthetic adhesives under dry conditions. In daily life, facial prostheses retained with prosthetic adhesives may be wetted by water, sweat, saliva or other secretion. The influences of water on the retention of prostheses with prosthetic adhesive are not clear yet. Therefore the purpose of this study was to investigate the performance of two commercially available facial prosthetic adhesives on human skin with immersion in water for different periods of time.

Materials and Methods

Five male volunteers aged 23 to 29 years were recruited. This study has been obtained the subjects' consent and approved by the Ethical Review Committee of College of Stomatology, the Fourth Military Medical University. Before test forearms of the volunteers were washed with soap and water and cleaned with ethyl alcohol. Test specimens were fabricated with silicone elastomer (A-2186, Lot L40698, Factor II, Lakeside, AZ, USA). Two parts of A-2186 were mixed in a 10:1 ratio by weight according to the manufacturer's instructions. Special care was exercised to minimize bubble attraction. The mixture was packed into a two-piece dental stone mode immediately after mixing and cured at room temperature. The diameter of the silicone specimen was 5 mm according to Polyzois et al.[9]

Table 1. Facial prosthetic adhesives used in this study.

Adhesive	Composition	Manufacturer	Lot number
Secure^2 Adhesive	Silicone, Ethyl acetate, Tetra(trimethylsiloxy) silane, Xylene	Factor II, Lakeside, AZ, USA	R2266927-6
Daro B-200 ES	Acrylic polymer, Water, Ammonia, Residual monomers	Factor II	RLES507051

Two facial prosthetic adhesives, Secure^2 Adhesive and Daro B-200 ES, used in this tudy are shown in Table 1. Secure^2 Adhesive is a silicone-based adhesive and Daro B-200 ES an acrylic polymer-based adhesive. The adhesives were applied in a thin layer on the silicone specimen and allowed to dry according to the manufacturer's instructions. The silicone specimens were adhered to the volunteers' forearms skin 5 to 10 cm far away from their wrists, loaded with a pressure of 500 g for a 20-second period. The specimens retained with adhesives were submitted to tensile bond strength randomly with immersion in distilled water at 32±2˚C (Fig. 1). According to different disposal time in water, 1, 10, and 30 minutes groups of two adhesives were divided, respectively. The specimens tested without immersion in water (0 minute group) were taken as control. Ten specimens of each group were tested, two specimens once a time, and a total of 80 pull-off tests were carried out. The room temperature was 23˚C and the relative humidity was 65%. The tests were initiated by use of a desktop material tester (EZ-test, Shimadzu, Kyoto, Japan) with a crosshead speed of 1 mm/minute (Fig. 2). After test forearms of the volunteers were immediately washed with soap and water and cleaned with ethyl alcohol again.

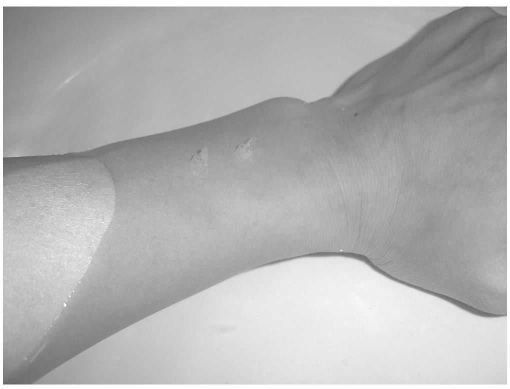
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Fig. 1. The forearm of the volunteer with specimens immersed in water.
Fig. 2. Tensile force applied to detach the silicone specimen from the skin.

The amount of tensile force F required to rupture the bond was used to calculate the tensile bond strength Ts according to the formula Ts=F/S (kPa), where S is the bonded surface area of the test specimen. Three-way analysis of variance (ANOVA) and LSD test were used to analyze the data of bond strength. The location of the rupture was observed, for instance, either interfacial between adhesive and skin (s) or between adhesive and silicone specimen (prosthesis) (p). To denote whether failure occurs at the silicone specimen or skin interfaces, Fisher exact test was used to analyze the data. P-values less than 0.05 were regarded as significant. All statistical analyses were done using statistical software (SPSS for Windows, Version 12.0, SPSS, Chicago, IL, USA).

Results

The tensile bond strengths of two adhesives with immersion in water for 0, 1, 10, and 30 minutes were 52.6, 51.4, 51.7, 50.6 kPa (Secure^2 Adhesive) and 23.7, 22.3, 14.8, 10.2 kPa (Daro B-200 ES), respectively, which was shown in Table 2. Secure^2 Adhesive showed higher bond strength than Daro B-200 ES did ($p<0.01$). Statistical analysis showed that for Secure^2 Adhesive, tensile bond strength didn't change after immersion for 30 minutes ($p>0.05$), while for Daro B-200 ES, the tensile bond strength reduced significantly after 10 minutes in water ($p<0.05$).

After the specimens bonded with Daro B-200 ES were immersed in water for more than 1 minute, around the fringe of specimen/skin bonding interface white emulsion was observed. With the time prolonged, the white exudation increased and diffused gradually. Observation of the failure mode showed that Secure^2 Adhesive mainly failed at the adhesive/skin interface (S) and left adhesive residue on silicone, whereas Daro B-200 ES mainly failed at the silicone/adhesive interface (P) with white adhesive residue left on skin.

Table 2. Tensile bond strength in kPa and failure mode of two prosthetic adhesives (n=10).

Immersion in water	0 minute			1 mimute			10 minutes			30 minutes		
Adhesive	Mean	SD	P/S	Mean	SD	P/S	Mean	SD	P/S	Mean	SD	P/S
Secure^2 Adhesive	52.6	8.4	3/7	51.4	7.9	4/6	51.7	8.6	3/7	50.6	9.1	2/8
Daro B-200 ES	23.7	6.9	6/4	22.3	6.2	7/3	14.8	7.2	8/2	10.2	7.5	8/2

SD, Standard deviation; P, Failed at the silicone/adhesive interface; S, Failed at the adhesive/skin interface.

Discussion

Traditional facial prosthetic adhesives are commonly classified as double-sided tapes, pastes, liquids, and spry-on adhesives.[16] According to the base of the adhesives, most of commercially available adhesives can be classified into two categories: silicone-based adhesive and acrylic polymer-based adhesive.[13] In the current study, Secure^2 Adhesive is a silicone-based adhesive and Daro B-200 ES is an acrylic polymer-based adhesive (Table 1). The shape of the silicone specimen was designed and fabricated according to Polyzois et al.[9] and our previous findings. To facilitate the test of tensile bond strength, the specimen was modified as a round patch with a bar on it to attach with a custom clasp (Fig. 2). The temperature of human body includes core temperature and shell temperature.[17] When the room temperature is 23˚C, the core temperature of human body is 36.8˚C and the shell temperature is usually 32˚C. So as to simulate the condition of normal human skin, the forearms of the volunteer with specimens were immersed in distilled water at 32˚C.

According to the manufacturer's instruction, Daro B-200 ES changed from white emulsion to clear adhesive film within the application procedure. While after immersion in water for more than 1 minute, white emulsion exudation was observed around the bonding fringe of specimen. This phenomenon was only noted in the usage of acrylic polymer-based adhesive, Daro B-200 ES. This could be due to the emulsifier in this kind of adhesive was dissolved by water. During the synthesis of acrylic polymer-based adhesive, emulsifier is usually used to combine the oil-phase and water-phase to graft each other. Besides, adhesive film expanded in aqueous environment after water absorption, which weakened the bonding interface. This result was proved by the observation of the rupture mode of both adhesives. For example, Secure^2 Adhesive mainly failed at adhesive/skin interface and left adhesive residue on silicone, whereas Daro B-200 ES failed at the silicone/adhesive interface with white adhesive residue left on skin. Water absorption of acrylic polymer-based adhesives reflects the capacity for water resistance. The higher water absorption, the lower capacity for water resistance and vice versa.[18] Water absorption of two kinds of traditional facial prosthetic adhesives needs to be evaluated further. New acrylic polymer-based adhesive modified with organic siloxane could be a direction.

With the time of immersion in water prolonged, tensile bond strength of Secure^2 Adhesive didn't change, whereas that of Daro B-200 ES reduced significantly after 10 minutes immersion in water. Considering study methodology and limitations, it could be concluded that immersion in water didn't influence the bond strength of silicone-based adhesive, whereas affected that of acrylic polymer-based adhesive. On one side, water can be used to wash off the acrylic polymer-based adhesive residue from skin, on the other side, in daily life facial prostheses shouldn't be exposed in water or sweat for a long period of time.

Haug et al.[11] reported the variance of bond strength from different subjects for different skin conditions. In the present study, no significant difference of bond strength for the same adhesive was found among the subjects. This could be due to the reason that the five volunteers were all young males with similar skin conditions, and the tests were carried out on both of the volunteers' forearms randomly. In this study, influence of water from outside on two prosthetic adhesives was investigated. When facial prostheses are adhered to normal skin with prosthetic adhesive, the secretion of sweat or other body liquid may influence the bonding interface inside. Therefore, tests of the volunteers wearing silicone specimens to imitate the sweaty condition are necessary to be investigated in future.

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