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Original Article

A New Method for Evaluating the Retentive Efficacy of Different Denture Adhesives

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Aim: The aim of this study was to evaluate a new method for measuring the retention values of different denture adhesives. **Methods:** The adhesive strength values of three different commercial denture adhesives (Corega powder, Corega adhesive tape and Ultra Corega cream) were evaluated using three different moisturizing agents (distilled water, artificial saliva and natural saliva). The adhesive test was performed on a universal testing machine, after applying the adhesive products to acrylic resin specimens, under two different test conditions (wetting or dipping). Tensile bond strength values in MPa were obtained for each denture adhesive presentation and test condition. Viscosity of the denture adhesives mixed with the different moisturizing agents was determined using a rotary rheometer. Maximum viscosity values were analyzed using the one-way ANOVA test. Tensile bond strength data was analyzed using Kruskal-Wallis and the Tukey's test. Pooled data of each denture adhesive presentations for all test conditions was also carried out. Correlation between viscosity and pooled tensile strength values was analyzed through linear regression analysis. A significance level of α=0.05 was set for all analyses. **Results:** Results showed that statistically higher adhesion strength was obtained with tape and cream adhesives when using natural saliva as moisturizing agents ($p<0.05$). The adhesive strength values obtained with the dipping method were similar to those obtained with the conventional wetting method. The denture retention strength was influenced by both the denture adhesive type and moisturizing agent used. **Conclusion:** The dipping method showed to be a reliable test capable to simulate the oral conditions and should be better explored in further studies.

Keywords: Tensile strength. Denture bases. Denture retention.

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Introduction

Although the prevalence of complete tooth loss has decreased over the last years, edentulism continues to be a common condition worldwide, especially among the elderly population, exceeding 10% in adults aged ≥ 50 years[1–3]. However, in low- and middle-income countries, this prevalence is higher, mainly resulting from increasing incidence of periodontal diseases and caries[4]. At present, implant-supported overdentures are a suitable alternative to be explored for oral rehabilitation of these patients, however, conventional muco-supported dentures are still the most common treatment, particularly due their affordability and lack of risks to patients[5].

Among the intended goals to achieve when fabricating conventional dentures, adequate retention and stability are of major interest, since they are directly related to patient comfort and safety[6]. The use of denture adhesives has been recognized as an auxiliary agent in denture retention, stability and function. These adhesives can optimize denture retention by increasing the properties of adhesion and viscosity between the dental prosthesis and oral mucosa, thus eliminating gaps between them[7–9]. Moreover, adhesives may also be indicated for patients with low saliva secretion[10], poor muscle tone, neurological deficiencies, or those who have undergone the surgical trauma of alveolar ridge changes[11].

As these materials are classified as cosmetics in most countries, regulatory rules only cover questions of composition before they reach the market, leaving their effectiveness in the background. The widespread use of commercial denture adhesives nowadays[11,12], has made it important to investigate the factors related to their properties of adhesion and consequent retention of the complete dentures. Viscosity and adhesion strength are considered the most important properties of denture adhesives, since they influence their efficacy during the clinical use. Several studies have examined the retention values of denture adhesives with different commercial presentations: powder, cream or tape. Generally, tape presentation has been shown to be more retentive, while paste and powder had lower retention values[7,13,14].

Although there is a standard test recommended by ISO 10873 for measuring the adhesion strength of denture adhesives, some authors have used alternative methods for evaluating this property[7,15-18]. This trend is due the difficulties with carrying out the adhesion strength test in accordance with the guidelines recommended by the cited standard, which require special equipment and processing, especially to fabricate the test specimens. This situation has contributed to a lack of validated test and comparative reference values for denture retention products. Considering this, the aim of this study was to evaluate a new method for measuring the retention values of different denture adhesives. The hypothesis tested was that adhesive types, different wet environments and adhesion test conditions would not influence denture retention strength.

Materials and methods

Experimental design

In this *in vitro* study, the viscosity and tensile adhesive strength (TAS) of denture adhesives were tested according to the following factors: (1) denture adhesive at three

Table 1. Commercial denture adhesives evaluated.

Commercial Presentations*	Formulation† (%wt)
Powder	Gantrez-77 (50%); carboxymethylcellulose (49.6%); other components (0.4%)
Cream	Gantrez (15-30%); pharmaceutical grade petrolatum (26-30%); sodium carboxymethyl cellulose (24-34%); light mineral oil (15-18%); l-menthol (<0.5%); propylparaben (<0.1%)
Adhesive Tape	Sodium carboxymethylcellulose (10-28%); Gantrez-251 (35%); Gantrez-77 (35%); Gantrez acid (1%); other components (>30%).

* (Corega®, GlaxoSmithKline, London, UK) † According to manufacturer's safety data sheet

levels, Corega® powder, Ultra Corega® cream and Corega® adhesive tape (Table 1); (2) moisturizing agent at three levels, distilled water, artificial saliva and natural saliva; and (3) adhesion test conditions at two levels, wetting or dipping.

The artificial saliva solution was prepared according to a previously reported method[13]. Natural saliva stimulated by paraffin film (Parafilm M®; American National Can, Chicago, USA) was collected from a healthy volunteer. The collected saliva was inserted into a sterile graduated tube and immediately homogenized in a vortex mixer (Biomixer QL-901; Biomol Equipment and Products for Laboratories, Ribeirão Preto, Brazil).

Viscosity

Viscosity of the denture adhesives was determined using a rotary rheometer (RS-CPS+; Brookfield, Middleboro, MA). For viscosity measurements (n=3), 0.3 g of each denture adhesive were thoroughly mixed with 0.5 mL of distilled water, natural saliva or artificial saliva in a glass plate and then directly placed on the rheometer plate. For measuring the viscosity of the adhesive tape, a small piece (about 10 mm^2) was cut out to give a mass of 0.3 g and then 0.5 mL of the moisturizing agents were placed over the material. The moisturizing agent was dispersed throughout the sample with the help of a plastic spatula until the adhesive acquired a pasty consistence. Measurements were taken at a controlled shear rate (CSR) from 0 to 3 1/s. The rheological parameters were calculated by using the Rheo3000 program.

Adhesion test

A cylindrical shaped (25 mm diameter x 50 mm height) specimen was fabricated using self-polymerizable acrylic resin. After curing, the specimen was transversely sectioned using a diamond blade in order to obtain two cylindrical appliances (25 mm diameter x 25 mm height) of acrylic resin with flattened surfaces where the denture adhesive was applied (surface area: 19.64 cm^2). Surfaces were wet polished with 600 grit abrasive paper for 60 s and rinsed with distilled water for 15 s. The cylinders were then aligned and attached to a universal testing machine (DL 500; EMIC, São José dos Pinhais, Brazil) using a tensile test jig. Amounts (0.3g) of each denture adhesive was weighted and applied on the polished surface of the lower part of the cylindrical specimen. Then, denture adhesives were pre-wetted using 0.5 ml of distilled water, artificial saliva or natural saliva and immediately covered by the upper part of the cylindrical specimen and a 20 N force was applied on the upper part of the cylindrical

specimen for 30s to simulate an occlusal force. Excess material that flowed out from the cylindrical specimen was trimmed using a scalpel blade. To perform the adhesion strength test in dipping condition, a device containing 20 mL of artificial saliva and coupled to testing machine.

Finally, the materials were (individually) submitted to a tensile strength test with load cell of 100N and a crosshead speed of 1.0 mm/min (Figure 1). Tensile bond strength values were obtained in MPa. Each test was repeated 12 times. After each test, the inner surfaces of the cylindrical appliances were cleaned with neutral soap, washed with water and dried with paper towel. Then, new portions of denture adhesives were applied in the inner surface of the cylindrical specimen.

Statistical analysis

Maximum viscosity values of denture adhesives tested were analyzed using the one-way ANOVA test. Tensile bond strength data for each denture adhesive presentation and test conditions were individually analyzed using Kruskal-Wallis and the Tukey's test. An additional analysis using pooled average tensile bond strength data of each denture adhesive presentations for all test conditions was also carried out. Correlation between viscosity and pooled tensile strength values was analyzed through linear regression analysis. A significance level of $\alpha=0.05$ was set for all analyses. All statistical analyses were performed using the Sigma Plot 12.0 software.

Results

Figure 2 shows the initial viscosity of the materials after wetting with the different moisturizing agents used. Tape-type denture adhesives achieved the highest viscosity values. On the other hand, the powder-type achieved the lowest values ($p<0.0001$).

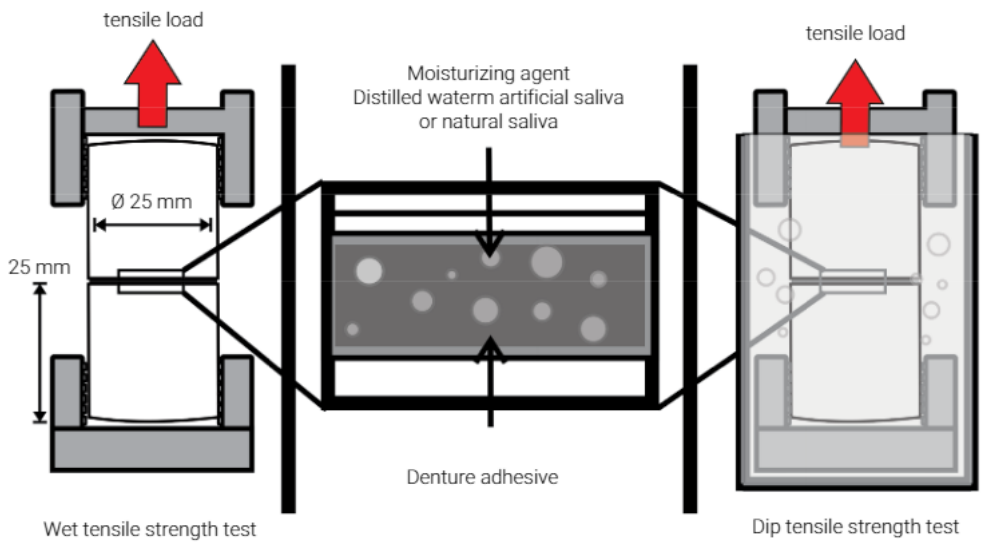

Figure 1. Schematic representation of cylindrical apparatus used in denture adhesion strength test in wet and dip condition.

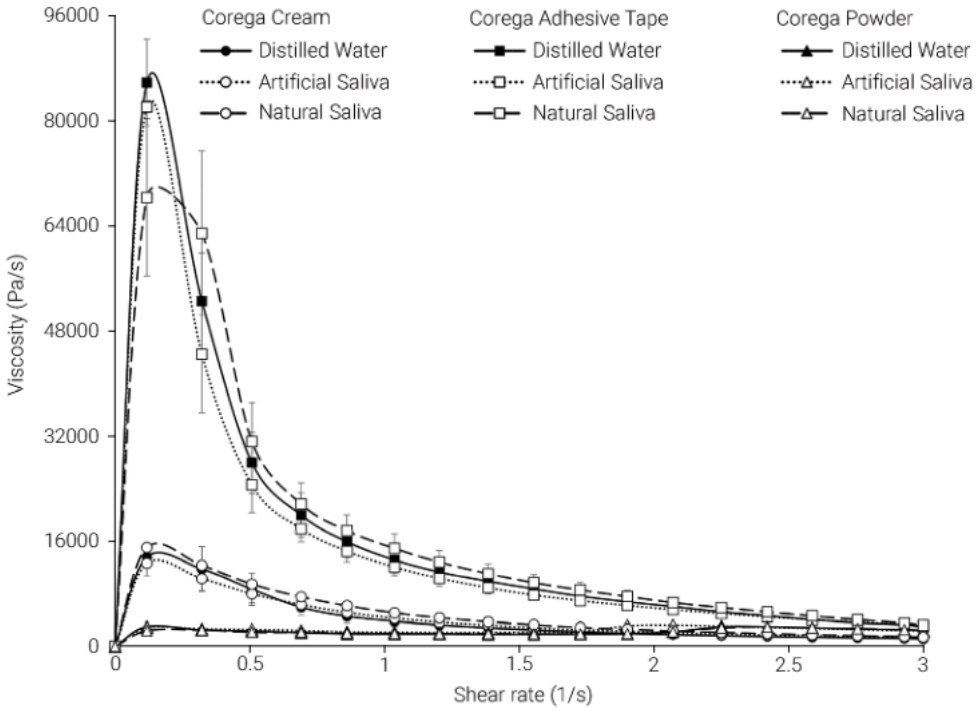

Figure 2. Viscosity versus shear rate for cream, powder and tape-type denture adhesives in different moisturizing media (DW=distilled water, AS=artificial saliva, NS= natural saliva).

Table 2. Median denture retention strength (in MPa, brackets contain interquartile range) of different denture adhesive presentations tested under different test conditions.

Denture adhesive	Wet condition		Dip condition		
	Distilled water	Natural Saliva	Artificial saliva	Artificial Saliva	Pooled average
Cream	B 4.90 (3.4 - 7.9)^{b}	B 4.65 (3.4 - 7.2)^{b}	A 7.70 (4.8 - 9.2)^{a}	A 4.65 (3.5 - 6.4)^{b}	A 5.50 (3.5 – 7.9)
Adhesive Tape	A 7.30 (4.7 - 9.1)^{a}	A 7.45 (5.0 - 8.6)^{ab}	B 3.45 (1.5 - 5.7)^{c}	A 5.30 (3.9 - 7.8)^{b}	A 5.90 (3.9 – 8.1)
Powder	C 1.80 (1.4 - 4.7)^{c}	B 4.65 (3.4 - 6.0)^{a}	B 3.55 (3.1 - 5.3)^{b}	A 4.85 (3.0 - 6.5)^{ab}	B 4.00 (2.5 – 5.4)
Pooled average	4.75 (2.2 - 7.5)^{b}	5.40 (4.0 – 8.0)^{a}	4.50 (2.9 – 7.2)^{b}	5.00 (3.5 – 7.0)^{ab}	

Different uppercase letters (A-C) represent statistically significant differences among different adhesives in a same column, whereas lowercase letters (a-c) indicate differences between conditions tested in a same row.

As regards the use of different moisturizing agents, none of them had a significant influence on the viscosity of any type of presentation (cream, p=0.428; tape, p=0.119; and powder, p=0.358).

Table 2 shows the adhesive strength values obtained according to presentation type, moisturizing agent and test condition. For wet condition testing, the tape-type denture adhesive achieved the highest values when distilled water and natural saliva were

used as moisturizing agents ($p<0.001$). When denture adhesives were tested under the dipping condition, no statistical differences were observed ($p=0.05$). Pooled values analysis demonstrated that powder-type adhesive had the lowest adhesive tensile strength ($p<0.05$). No significant correlation between viscosity and tensile strength values was found (Rsqr = 0.425; $p=0.548$).

Discussion

The results of this study showed that denture retention strength depends on both denture adhesive type and moisturizing agent, thus the tested hypothesis was rejected. Overall, the findings of this study showed that denture adhesives with higher viscosity have higher adhesion strength. The tape type adhesive was the material who achieved the highest viscosity and adhesion strength values, however no significant correlation was found. The denture adhesive mechanism depends on the combination of physical and chemical forces. Physical forces, based on Stefan's principle, state that the force required to separate two discs is directly proportional to viscosity of fluid between them[19]. On the other hand, fluid materials had higher possibility of flowing out from between the tested discs after application, due to their lower viscosity, which would cause a reduction in their adhesive properties.

According to Figure 2, the adhesive tape presentation achieved the highest maximum viscosity values. Since denture adhesives act by producing a highly viscous layer between the denture and its supporting tissues, achieving a high viscosity is considered necessary for retention[20]. On the other hand, this higher viscosity reduces the ease of manipulation and could be the responsible for problems with hygiene[21]. The differences in viscosity among types of denture adhesives can be attributed to their composition; the larger amount of water-soluble components produces materials with higher levels of viscosity[22]. The adhesive tape presentation contains large quantities of water-soluble polymers (Gantrez-251 and 77) in its composition, which become viscous by absorbing the water from saliva. Moreover, the higher molecular weight of these components, and their larger particle size lead to higher viscosity.

The adhesive strength of a denture adhesive is considered the most important factor to be analyzed with the purpose of predicting the clinical performance of these materials. Considering the analysis of pooled values, the powder was the commercial presentation that was less retentive and on the other hand, the adhesive tape and cream were the most effective adhesives in terms of retention strength. Previous studies have shown contradictory results, without a consensus about which commercial type provided better results[7,14,20], however, the reliability of the comparisons of adhesive strength values are hampered because of the different evaluation methods used. Nevertheless, an important to point out is that the composition of denture adhesives has remarkable influence on their short and long-term denture retention strength[22]. The materials evaluated in this study differed in their quantity of water-soluble components; Corega adhesive tape and Ultra Corega cream could be considered more hydrophilic materials than Corega powder, this being due to the presence of blends of polymer salts with a higher degree of water solubility. The inclusion of polymers with different degrees of solubility in water is intended to produce short and long-acting adhesives; as the water solubility increases, a faster dissolution reaction of the adhe-

sive components occurs, leading to higher initial adhesion strength values. However, higher solubility of the product components, tends to result in faster elimination of the active ingredients, limiting its long-term performance[7,9]. Actually, it is considered that the adhesive tape presentation does not contain a long-acting synthetic polymer, and further tests must be conducted in order to determine its retention values over time.

The carboxymethylcellulose (CMC) and methoxyethylene/maleic anhydride copolymer (PVM-MA) are examples of short and long-acting salts, respectively. The CMC salts provide a strong initial retention, however due to their high solubility they dissolve rapidly and lose their effectiveness within a short period. The PVM-MA salts, however, have a low solubility and it takes longer to activate them, but they have a longer period of action. In both cases, when the active ingredients come into contact with a moisturizing medium, this leads to an increase in volume of approximately 50 to 150 %, which helps to fill the spaces between the denture base and the supporting tissues.

Furthermore, the denture adhesive viscosity increases, and it becomes viscous and sticky via electrovalent linkages within carboxyl groups present in the material, which helps to improve its adhesion strength[23]. The composition of insoluble types of denture adhesives varies among brands (trademarks); essentially, they all include a manufactured lamina impregnated with a water-based active component. Examples of adhesive ingredients include sodium alginate or Poly(ethylene oxide) – Polymers that become sticky when activated by a moisturizing agent[24]. Relative to the moisturizing agents evaluated in this study, pooled values showed that the use of natural saliva achieved the significant highest retention values. This behavior could be explained by the differences in the biophysical properties between water, artificial and natural saliva. As stated by Preetha[25], in terms of viscosity and surface tension, contemporary saliva substitutes are far away from natural saliva. Considering this, the use of natural saliva as moisturizing agent could be considered for positive control in future studies on the adhesion strength of denture adhesives.

In the present study, an immersion (dipping) method was proposed for evaluating the adhesive strength of denture adhesives, with the purpose of simulating *in vivo* conditions. This new test also proposes the use of use of samples which are easy to manufacture, and in addition, the use of the same sample to perform the whole test is allowed since the surfaces of the cylindrical appliances can be effectively cleaned by the use of water. Considering these characteristics, the dipping method described in the present manuscript could result affordable for both manufactures and researchers. On the other hand, when compared with the wet test, the results obtained with this new method were similar, suggesting that the dipping method could be appropriate for evaluating denture retention with the use of denture adhesives, since this methodology seemed to be the most similar to the conditions that occurred in the oral cavity. Although this condition could be advantageous in terms of simulating the complex environment of oral cavity, other factors such as the presence of keratinized mucosa, muscle movement, intaglio surface features of a denture base, pH, thermal and mechanical cycling and influence of dye should be considered in the design of future tests. The use of a reliable and reproducible method capable of measuring the retention values of different denture adhesives, simulating

the oral cavity conditions is necessary, since standardization of the methodology would allow comparisons between studies, and thereby guide clinicians to indicate an effective denture adhesive.

The authors were able to conclude that the conditions in which the retention strength tests of denture adhesives are performed, is essential to the validity of their results. The denture retention strength depends on both the denture adhesive type and moisturizing agent used. Overall, higher denture retention values were obtained with tape as denture adhesive, and natural saliva as immersion medium. The dipping method showed to be a reliable test capable to simulate the oral conditions and should be better explored in further studies.

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REFERENCES

1. Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? J Prosthet Dent. 2002 Jan;87(1):5-8.
2. Nordenram G, Davidson T, Gynther G, Helgesson G, Hultin M, Jemt T, et al. Qualitative studies of patients' perceptions of loss of teeth, the edentulous state and prosthetic rehabilitation: A systematic review with meta-synthesis. Acta Odontol Scand. 2013 May-Jul;71(3-4):937-51. doi: 10.3109/00016357.2012.734421.
3. Peltzer K, Hewlett S, Yawson AE, Moynihan P, Preet R, Wu F, et al. Prevalence of loss of all teeth (Edentulism) and associated factors in older adults in China, Ghana, India, Mexico, Russia and South Africa. Int J Environ Res Public Health. 2014 Oct 30;11(11):11308-24. doi: 10.3390/ijerph111111308.
4. Tyrovolas S, Koyanagi A, Panagiotakos DB, Haro JM, Kassebaum NJ, Chrepa V, et al. Population prevalence of edentulism and its association with depression and self-rated health. Sci Rep. Sci Rep. 2016 Nov 17;6:37083. doi: 10.1038/srep37083.
5. Carlsson GE, Omar R. The future of complete dentures in oral rehabilitation. A critical review. J Oral Rehabil. 2010 Feb;37(2):143-56. doi: 10.1111/j.1365-2842.2009.02039.x.
6. Psillakis JJ, Wright RF, Grbic JT, Lamster IB. In practice evaluation of a denture adhesive using a gnathometer. J Prosthodont. 2004 Dec;13(4):244-50.
7. Chowdhry P, Phukela SS, Patil R, Yadav H, Singh S. A Study to Evaluate the Retentive Ability of Different Denture Adhesive Materials: An In Vitro Study. J Indian Prosthodont Soc. 2010 Sep;10(3):176-81. doi: 10.1007/s13191-010-0039-4.
8. Folse GJ. Denture adhesives: when, why, and how. Dent Today. 2004 Dec;23(12):70-1.
9. Kalra P, Nadiger R, Shah FK. An investigation into the effect of denture adhesives on incisal bite force of complete denture wearers using pressure transducers - a clinical study. J Adv Prosthodont. 2012 May;4(2):97-102. doi: 10.4047/jap.2012.4.2.97.
10. Sato Y, Kaiba Y, Hayakawa I. Evaluation of denture retention and ease of removal from oral mucosa on a new gel-type denture adhesive. Nihon Hotetsu Shika Gakkai Zasshi. 2008 Apr;52(2):175-82.

11. de Oliveira da Rosa WL, de Oliveira SGD, Rosa CH, da Silva AF, Lund RG, Piva E. Current trends and future perspectives in the development of denture adhesives: an overview based on technological monitoring process and systematic review. J Biomed Sci. 2015;4(1):1–7. doi: 10.4172/2254-609X.10003.

12. Coates AJ. Usage of denture adhesives. J Dent. 2000 Feb;28(2):137-40.

13. Chew CL. Retention of denture adhesives-an in vitro study. J Oral Rehabil. 1990 Sep;17(5):425-34.

14. Ghani F, Picton DC, Likeman PR. Some factors affecting retention forces with the use of denture fixatives in vivo. Br Dent J. 1991 Jul;171(1):15-21.

15. An Y, Li D, Roohpour N, Gautrot JE, Barber AH. Failure mechanisms in denture adhesives. Dent Mater. 2016 May;32(5):615-23. doi: 10.1016/j.dental.2016.01.007.

16. Cartagena AF, Esmerino LA, Polak-Junior R, Olivieri Parreiras S, Domingos Michel M, Farago PV, et al. New denture adhesive containing miconazole nitrate polymeric microparticles: Antifungal, adhesive force and toxicity properties. Dent Mater. 2017 Feb;33(2):e53-e61. doi: 10.1016/j.dental.2016.09.039.

17. Mañes JF, Selva EJ, De-Barutell A, Bouazza K. Comparison of the retention strengths of three complete denture adhesives: An in vivo study. Med Oral Patol Oral Cir Bucal. 2011 Jan;16(1):e132–6.

18. Polyzois G, Lagouvardos P, Frangou M, Stefaniotis T. Efficacy of denture adhesives in maxillary dentures using gnathodynamometry: a comparative study. Odontology. 2011 Jul;99(2):155-61. doi: 10.1007/s10266-011-0003-8.

19. Johnson RW. Handbook of Fluid Dynamics. 2nd ed. Boca Raton: CRC Press; 2016.

20. Han JM, Hong G, Dilinuer M, Lin H, Zheng G, Wang XZ, et al. The adhesive strength and initial viscosity of denture adhesives. Acta Odontol Scand. 2014 Nov;72(8):839-45. doi: 10.3109/00016357.2014.913309.

21. Han JM, Hong G, Hayashida K, Maeda T, Murata H, Sasaki K. Influence of composition on the adhesive strength and initial viscosity of denture adhesives. Dent Mater J. 2014;33(1):98-103.

22. Kano H, Kurogi T, Shimizu T, Nishimura M, Murata H. Viscosity and adhesion strength of cream-type denture adhesives and mouth moisturizers. Dent Mater J. 2012;31(6):960-8.

23. Gill SK, Roohpour N, An Y, Gautrot JE, Topham PD, Tighe BJ. Hydrophobic and hydrophilic effects on water structuring and adhesion in denture adhesives. J Biomed Mater Res A. 2018 May;106(5):1355-62. doi: 10.1002/jbm.a.36341.

24. Zhang F, An Y, Roohpour N, Barber AH, Gautrot JE. Hydration dependent mechanical performance of denture adhesive hydrogels. Dent Mater. 2018 Oct;34(10):1440-8. doi: 10.1016/j.dental.2018.06.015.

25. Preetha A, Banerjee R. Comparison of artificial saliva substitutes. Trends Biomater Artif Organs. 2005 Jan;18(2):178-86.