ORIGINAL ARTICLE

Journal of Research in Dental and Maxillofacial Sciences

DOI:10.61186/jrdms.8.3.171

Effect of One- and Two-Step Processing Techniques on Flexural Strength of Denture Base Acrylic Resin in Dry and Wet Conditions

Sarira Mehraban Jahromi [1], Mohammad Alidad Naeeni [2], Reza Mostafa pour [3], Reza Nahidi [1], Ali Kaboudanian Ardestani [2]

[1] Department of Prosthodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
[2] Faculty of Dentistry, Tehran Medical Science, Islamic Azad University, Tehran, Iran
[3] Department of Prosthodontics, Faculty of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Corresponding author:
Reza Nahidi, Department of Prosthodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

r.nahidi@iautmu.ac.ir

Article History
Received: 29 August 2022
Accepted: 15 November 2022

Abstract

Background and Aim: This study compared the flexural strength (FS) of heat-cure acrylic resin following one- and two-step processing techniques in dry and wet conditions.

Materials and Methods: In this in vitro study, 60 acrylic specimens (3×10×65 mm) were fabricated (ISO20795-1) and flasked using a type III dental stone. The specimens were heated to 70°C for one hour and baked for 30 minutes at 100°C. After cooling and polishing, 30 specimens were randomly selected; of which, 15 were stored in 37°C water, and 15 in dry condition for one month. The remaining 30 were flasked again, baked, and divided into two subgroups for storage in dry and wet conditions. The FS of specimens was measured by a universal testing machine. Data were analyzed by one-way ANOVA and Tukey's post-hoc test (α=0.05).

Results: The mean FS was 57.5±4.8 MPa and 61.7±4 MPa for specimens subjected to one-step processing and stored in wet and dry conditions, respectively. These values were 56.6±4 MPa and 64.7±2.9 MPa for specimens subjected to two-step processing and stored in wet and dry conditions, respectively ($P<0.05$). The difference in FS of specimens stored in dry and wet conditions was significant ($P<0.05$).

Conclusion: The two-step processing technique increased the FS while water storage decreased the FS of acrylic resin. FS of specimens subjected to one-step processing with water storage was slightly higher than that of specimens subjected to two-step processing with water storage. FS experienced a greater reduction following two-step processing in a wet environment compared with one-step processing.

Key Words: Acrylic Resins; Flexural Strength; Polymethyl Methacrylate

Cite this article as: Mehraban Jahromi S, Alidad Naeeni M, Mostafa pour R, Nahidi R, Kaboudanian Ardestani A. Effect of One- and Two-Step Processing Techniques on Flexural Strength of Denture Base Acrylic Resin in Dry and Wet Conditions.
J Res Dent Maxillofac Sci. 2023; 8(3):171- 178.

Introduction

Flexural strength of acrylic denture base has always been a concern for prosthodontists [1]. Strength is an important requirement for prostheses [2]. In the fabrication process of temporary bases for dentures, the acrylic base is heated once; whereas, permanent bases are baked twice, and the acrylic denture is processed in two separate heating steps. This results in a greater possibility of dimensional changes in the manufacturing process of permanent compared with temporary bases. However, it should be noted that permanent record bases are more accurate than temporary bases. Laboratories and clinicians more commonly use temporary bases due to the shorter fabrication time, lower cost, easier handling, and better accessibility than permanent bases; however, as stated earlier, permanent bases are a better representative of the anatomy of the adjacent edentulous region [3, 4]. Polymethyl methacrylate (PMMA) has long been the most commonly used heat-cure acrylic denture base. It still remains the material of choice for this purpose due to its acceptable esthetics, cost-effectiveness, and compatibility with the oral environment, as well as its simple use and maintenance [2].

Fracture of acrylic denture base is a common clinical occurrence [5]. Most dentures fracture within the oral cavity, mainly due to resin fatigue, and midline fractures generally occur. Out of the oral cavity, fractures occur due to the impact of falling. Denture base acrylic resin is exposed to different types of masticatory forces during intra-oral function, leading to fatigue. Consequently, fracture of denture base may occur [6]. The acrylic resin base absorbs water in the oral environment, which affects the dimensional stability and structure of denture base [7]. PMMA is a polymer that directly absorbs small amounts of water when placed in an aqueous environment. Water sorption significantly affects the dimensional stability and mechanical properties of polymers [8]. Water sorption of material means adsorption and absorption of water in the oral cavity. Following water sorption, the acrylic resin can act as a plasticizer and cause softening, discoloration and loss of mechanical features of acrylic resin, such as hardness, transverse strength, and fatigue limit. Also, water sorption causes three-dimensional expansion and can affect the dimensional stability of acrylic resin. Water molecules penetrate into the porosities and gaps in-between polymer chains and decrease the flexural strength (FS) [9]. If not prevented, this can lead to fracture of denture base even after mild trauma and imposes high costs on patients [10]. To overcome this problem, the FS should be increased [11] by increasing the polymerization rate [12] or addition of fiberglass and reinforcement of PMMA resin [13, 14]. Another method to increase the FS is the two-step processing of denture base (permanent base) since this method decreases the number of free monomers. In this technique, denture base is heated twice in water at 100°C. Previous investigations mainly focused on the conventional methods recommended by the manufacturers such as efficient baking or addition of fillers to increase the FS of acrylic resin bases. Accurate two-step processing technique of permanent heat-cure acrylic resin bases decreases their dimensional changes, and results in significantly more accurate recording of intermaxillary relations especially by the beginners [15]. This study aimed to assess the changes in FS following one- and two-step processing techniques and also to evaluate the effect of water storage on FS of heat-cure acrylic resins.

The current study compared changes in FS following one-step and two-step processing of acrylic denture bases stored in wet and dry conditions.

Materials and Methods

In this in vitro, experimental study, six metal molds measuring 65 x 10 x 3 mm were fabricated and flasked using type III dental stone (Tara, Isfahan, Iran). The present study was approved ethically by the Research Council, Dental Faculty of Islamic Azad University. Metal molds were removed from the stone. Acrylic powder and monomer (Bayer, New Burg, Germany) were mixed in percentages recommended by the manufacturer, and the paste was applied in the spaces created in the stone. Acrylic resin was then baked according to ISO20795-1 standard. Sixty acrylic specimens were fabricated as such [1].

Figure 1. Manufacturing process

Specimens were first divided into two groups of 30. Group 1 specimens were processed once and were put aside while group 2 specimens were flasked and processed (heat-cure) for the second time as described above. Next, each of the two groups was divided into two subgroups of 15 specimens (two subgroups had been processed once while the remaining two had been processed twice).

In each group of one- and two-step processing, one subgroup was stored in dry (room temperature, 23°C) and one in wet (37±1°C) conditions for 30 days (Figure 1) as follows:

Group 1. Specimens were processed once and stored in wet conditions.

Group 2. Specimens were processed once and stored in dry conditions.

Group 3. Specimens were processed twice and stored in wet conditions.

Group 4. Specimens were processed twice and stored in dry conditions.

Processing method (heat-curing):

Flasking was done using type III dental stone. Metal molds were used instead of wax patterns in order to eliminate errors due to dimensional changes. Acrylic specimens were fabricated using a conventional flasking and pressure-pack technique (Meliodent acrylic resin, Bayer, New Burg, Germany) [16, 17]. We used ISO1567 Type 1 Class 1 denture base material in this study (heat-polymerizing polymer powder and liquid).

Flasks containing acrylic resin were placed in a water bath and heated to 70°C for an hour and were then boiled at 100°C for 30 minutes. Next, the water and the specimens were allowed to cool down to room temperature [16]. Acrylic specimens were then removed from the flasks. A laboratory technician removed acrylic residues using a conical carbide bur (Dia-Tessin, Vanetti SA, Switzer-land), and specimens were polished using three types of abrasive papers from coarse to fine [5, 18].

To prevent fungal growth on the acrylic surfaces during the one-month water storage, the water was refreshed daily and maintained at 37±1°C temperature [19]. Specimens were then subjected to FS testing in a universal testing machine (Zwick Roell, Germany) using the three-point bending test. For this purpose, 100 kg load was applied to the center of specimens at a crosshead speed of 5 mm/min (Figure 2) [5, 20].

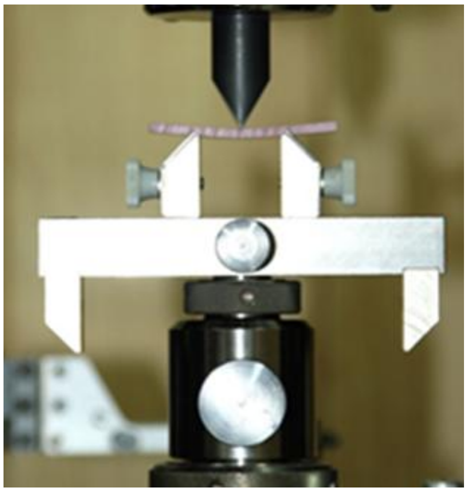

Figure 2. Deflection of specimens before fracture

Data were recorded by a laboratory technician blinded to the group allocation of specimens (specimens were coded), and the results were tabulated and statistically analyzed using SPSS version 21 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used for analysis of FS in the four subgroups. Afterwards, one-way ANOVA was applied to find out whether significant differences existed between the two different processing techniques (i.e., one- and two-step processing techniques), followed by the Tukey's post-hoc test for pairwise comparisons. Level of significance was set at 0.05.

Results

The mean FS of specimens is shown in Table 1.

- The highest (64.7±2.9 MPa) and the lowest (56.6±4 MPa) FS belonged to group 4 (two-step processing, dry condition) and group 3 (two-step processing, wet condition), respectively. The difference in this regard between groups 4 and 3 (8.1 MPa, 14.3%) was statistically significant (P≤0.0001).

Table 1. Flexural strength of the four groups (n=15)

Processing technique/ Storage conditions		FS (Mean + Std. deviation)	Coefficient of variation
One step processing	Wet	57.5± 4.8	8.3
	Dry	61.7± 4	6.4
Two-step processing	Wet	56.6± 4	7
	Dry	64.7± 2.9	4.5
Result of statistical test		P < 0.05	

- The FS of group 1 (one-step processing, wet condition) (57.5±4.8 MPa) was close to that of group 3 (two-step processing, wet condition) (56.6±4 MPa), and the two values were not significantly different (P= 0.58).
- The difference in FS of groups 1 (one step processing, wet condition) and 2 (one step processing, dry condition) was 4.2 MPa (7.3%), and this difference was statistically significant (P=0.014).
- The difference in FS of groups 1 (one step processing, wet condition) and 4 (two-step processing, dry conditions) was 7.2 MPa (12.5%) and this difference was statistically significant (P≤0.0001).

The difference in FS of groups 2 (one-step processing, dry condition) and 4 (two-step processing, dry condition) was 3 MPa (4.9%) and this difference was statistically significant (P=0.02).

The highest FS belonged to the group subjected to two-step processing and storage in dry condition (64.7±2.9 MPa) followed by one-step processing and storage in dry condition (61.7±4 MPa). The lowest FS belonged to two-step processing with water storage group (56.6±4 MPa). ANOVA revealed that the difference in FS among the four groups was statistically significant (P=0.0017). The Tukey's test showed significant differences in FS between groups stored in wet and dry conditions. The FS of one-step and two-step processed specimens stored in wet condition was not significantly different (P=0.58) but the FS of two-step processed specimens stored in dry condition was significantly higher than that of one-step processed specimens stored in dry condition (P=0.02). Changes in flexural modulus of the 4 groups were almost similar (between 4-8%).

Discussion

In dentistry, treatment outcomes affect patients' quality of life. FS is an important feature of acrylic resins because repair of acrylic prostheses would be costly [21]. The prostheses may crack due to fatigue caused by prolonged wear and degradation of the material or by the application of extreme masticatory loads, exceeding the plastic phase of the material. High FS is crucial for the success of dentures [8]. The maximum FS of materials affects their capacity to resist catastrophic failures under flexural loads. Various types of fibers, carbon, aramid, glass, and metal wire reinforcements have been tried to overcome this issue and improve the mechanical properties of denture base. Carbon and aramid fibers helped reinforce PMMA but produced significant clinical problems, complicated polishing, and yielded poor esthetic results. The inclusion of metal wires had the same problems as well [22].

This study compared the FS of heat-cure acrylic resin bases after one-step and two-step processing and storage in wet and dry conditions. The results showed that the processing steps and the storage conditions affected the FS of acrylic resin. The highest FS belonged to specimens subjected to two-step processing with storage in dry condition (64.7±2.9 MPa), followed by one-step processing with storage in dry condition (61.7±4 MPa). The lowest FS belonged to specimens subjected to two-step processing with water storage (56.6±4 MPa). Some previous studies assessed the association of FS of acrylic resin with the curing time and storage conditions [23]. Takahashi et al. [24] in 2012 assessed the FS of denture base after long-term water storage. They evaluated a microwave-energy processed acrylic resin. They showed that the FS significantly decreased six months after water storage while the flexural modulus increased. They reported no significant difference in FS of conventional heat-processed and microwave-processed specimens. They concluded that microwave processing had no superiority to conventional heat processing in water bath [24]. In the current study, we used one type of acrylic resin and assessed the effect of increasing the processing steps instead of two different methods of processing. We also included 15 specimens in each group for storage in dry and wet conditions (versus 10 specimens in each group in the study by Takahashi et al. [24]). This might have increased the validity of the present results. Nonetheless, the present results were in accord with those of Takahashi et al. [24] indicating that water storage decreased the FS. Islam et al. [25] in 2012 assessed the effect of curing time on FS of heat-cure acrylic resin. They concluded that no significant difference existed in FS of heat-cure acrylic denture bases cured at 100°C for different periods of time (20, 40 and 60 minutes). Their sample size was adequate and increasing the baking time should have increased the FS but no such correlation was reported [25]. In our study, steps of curing were increased instead of extending the curing time, and the results showed that the two-step processing technique significantly increased the FS. We also evaluated the effect of storage in wet conditions on FS. Elhadiry et al. [7] in 2010 evaluated the effect of cavity preparation during thermal repair, and moisture on FS. They concluded that water storage had no significant effect on FS. But, since our result revealed significant differences in this regard, it appears that water storage can decrease FS. Specimens were stored in water for 30 days and the results showed significant reductions in FS of specimens stored in wet conditions in both one-step and two-step processing techniques. The results of Elhadiry et al. [7] differed from the present findings because they evaluated the FS of specimens that had already been cracked and repaired. However, in the present study, we assessed the FS of denture base without using any repairing materials. Arıkan et al. [26] evaluated the transverse strength of acetal resin denture base material and that of heat-cured PMMA in wet conditions. The results showed that increasing the duration of water storage from 50 hours to 180 days caused a significant reduction in transverse strength ($P<0.05$). The main limitation of their study was small sample size, which decreased the validity of the results. Nonetheless, their results were in line with ours. In another study, Khan et al. [27] in 2022 investigated the FS of different resin bases in different environments. They concluded that water absorbed into the material acts as a plasticizer and changes the mechanical properties such as hardness, transverse strength, fatigue limit, color, and dimensional stability. Decreasing water sorption improves the flexural properties [27, 28]. Lee and Okubo [29] in 2018 evaluated different types of thermoplastic denture resins and showed that dry and wet conditions were significantly different, which was in agreement with the present findings. Silva et al, [30] in 2021, examined the difference in flexural strength of thermal and self-cure acrylic resins and concluded that the brand of acrylic resin did not affect the strength. However, thermal acrylic resins had higher strength than self-cure acrylic resins. As mentioned earlier, there are different methods to increase the FS of acrylic dentures; the critical point is that this study aimed to change the laboratory process without adding material to the denture base to find a way to increase the FS of dentures [30].

In general, FS of specimens decreased in wet conditions in the one-stop and two-step processing techniques. However, this reduction was slightly greater in specimens subjected to two-step processing maybe because better-polymerized acrylic resins experience a greater decrease in FS in wet conditions (like the oral cavity). The difference in this regard between the one-step and two-step processing groups in wet conditions was statistically insignificant and, thus, it can be considered negligible. Evidence shows that dimensional changes of acrylic resin are minimal after two-step processing [31, 32]. Considering the advantages of permanent base compared with temporary base in accurate recording of intermaxillary relations by beginners and equal FS of permanent and temporary bases in wet conditions, permanent bases should be preferred for use in the clinical setting. Since permanent base is placed in the oral environment after two-step processing and is part of the final denture delivered to patient, its higher FS in dry conditions cannot be considered as an advantage. But, equal FS of temporary and permanent bases in wet conditions and other advantages of permanent bases in terms of stability and accurate recording of intermaxillary relations encourage the clinicians to use permanent bases. Since in our study water storage decreased the FS, future studies are required to assess the behavior of other materials with FS values lower than that of PMMA in wet conditions.

Conclusion

The results showed that the two-step processing technique increased the FS while water storage decreased the FS of acrylic resin. FS of specimens subjected to one-step processing with water storage was slightly (but not significantly) higher than that of specimens subjected to two-step processing with water storage. This indicates that FS experiences greater reduction following two-step processing in wet environment compared with one-step processing.

Conflict of interest

The authors declare no conflict of interests.

Acknowledgments

The authors would like to acknowledge colleagues who gave valuable comments.

Funding

There was no financial support.

References

1. Chhabra M, Nanditha Kumar M, RaghavendraSwamy KN, Thippeswamy HM. Flexural strength and impact strength of heat-cured acrylic and 3D printed denture base resins- A comparative in vitro study. J Oral Biol Craniofac Res. 2022 Jan-Feb;12(1):1-3.

2. AlQahtani M, Haralur SB. Influence of Different Repair Acrylic Resin and Thermocycling on the Flexural Strength of Denture Base Resin. Medicina (Kaunas). 2020 Jan 21; 56(2): 50.

3. Irelan JP. Mitigating distortion of light-polymerized composite trial bases [Thesis]. United States: Marquette University; 2009. 347 p.

4. Browning JD. A permanent-base denture technique using fluid resin. J Prosthet Dent. 1973 Oct;30(4 Pt 1):468-71.

5. Aguirre BC, Chen JH, Kontogiorgos ED, Murchison DF,

Nagy WW. Flexural strength of denture base acrylic resins processed by conventional and CAD-CAM methods. J Prosthet Dent. 2020 Apr;123(4):641-6.

6. Gad MM, Rahoma A, Abualsaud R, Al-Thobity AM, Akhtar S, Helal MA, Al-Harbi FA. Impact of different surface treatments and repair material reinforcement on the flexural strength of repaired PMMA denture base material. Dent Mater J. 2020 Jun 5;39(3):471-82.

7. Elhadiry SS, Yunus N, Ariffin YT. Effect of cavity preparation on the flexural strengths of acrylic resin repairs. J Appl Oral Sci. 2010 Dec;18(6):546-50.

8. Galav A, Deogade SC, Mantri S, Sumathi K, Galav S. Effect of Water Storage on the Flexural Strength of Heat-cured Denture Base Resin Reinforced with Stick (s) Glass Fibers. Contemp Clin Dent. 2017 Apr-Jun;8(2):264-71.

9. Hemmati MA, Vafaee F, Allahbakhshi H. Water Sorption and Flexural Strength of Thermoplastic and Conventional Heat-Polymerized Acrylic Resins. J Dent (Tehran). 2015 Jul; 12(7):478-84.

10. Golbidi F, Mousavi T. Transverse strength of repaired denture base material with wire and two auto polymerized acrylic resin. Front Dent. 2007;4(4):183-7.

11. Zafar MS. Prosthodontic Applications of Polymethyl Methacrylate (PMMA): An Update. Polymers (Basel). 2020 Oct 8;12(10):2299.

12. Raszewski Z, Nowakowska D, Wieckiewicz W, Nowakowska-Toporowska A. Release and Recharge of Fluoride Ions from Acrylic Resin Modified with Bioactive Glass. Polymers (Basel). 2021 Mar 27;13(7):1054.

13. Al-Thobity AM. The Impact of Polymerization Technique and Glass-Fiber Reinforcement on the Flexural Properties of Denture Base Resin Material. Eur J Dent. 2020 Feb;14(1):92-99.

14. Hada T, Kanazawa M, Iwaki M, Katheng A, Minakuchi S. Comparison of Mechanical Properties of PMMA Disks for Digitally Designed Dentures. Polymers (Basel). 2021 May 26;13(11):1745.

15. Lee JH, Lee CJ, Lee HH. Adaptation accuracy and mechanical properties of various denture base resins: a review. The Journal of the Korean dental association. 2019;57(12):747-56.

16. Neshati A, Kouchak Dezfouli N, Sadafi M, Omidi S. Compressive Strength of Three Types of Heat-Cure Acrylic Resins:Acropars, Acrosun, and Meliodent. J Res Dent Maxiilofac Sci. 2021;6(4):14-17.

17. Durkan R, Oyar P. Comparison of mechanical and dynamic mechanical behaviors of different dental resins polymerized by different polymerization techniques. Niger J Clin Pract. 2018 Sep;21(9):1144-9.

18. Jaikumar RA, Karthigeyan S, Ali SA, Naidu NM, Kumar RP, Vijayalakshmi K. Comparison of flexural strength in three types of denture base resins: An in vitro study. *Journal of Pharmacy & Bioallied Sciences*. 2015; *7*(Suppl 2): S461.

19. Bayraktar G, Guvener B, Bural C, Uresin Y. Influence of polymerization method, curing process, and length of time of storage in water on the residual methyl methacrylate content in dental acrylic resins. J Biomed Mater Res B Appl Biomater. 2006 Feb;76(2):340-5.

20. Choksi RH, Mody PV. Flexural properties and impact strength of denture base resins reinforced with micronized glass flakes. J Indian Prosthodont Soc. 2016 Jul-Sep; 16(3): 264-70.

21. Gad MM, Al-Thobity AM, Fouda SM, Näpänkangas R, Raustia A. Flexural and Surface Properties of PMMA Denture Base Material Modified with Thymoquinone as an Antifungal Agent. J Prosthodont. 2020 Mar;29(3):243-50.

22. Somani MV, Khandelwal M, Punia V, Sharma V. The effect of incorporating various reinforcement materials on flexural strength and impact strength of polymethylmethacrylate: A meta-analysis. J Indian Prosthodont Soc. 2019 Apr-Jun; 19 (2):101-12.

23. Sotto-Maior BS, Jóia FA, Meloto CB, Cury AA, Rizzatti-Barbosa CM. Effect of double flasking and investing methods on artificial teeth movement in complete dentures processing. Gerodontology. 2012 Jun;29(2):e435-9.

24. Takahashi Y, Hamanaka I, Shimizu H. Flexural properties of denture base resins subjected to long-term water immersion. Acta Odontol Scand. 2013 May-Jul;71(3-4):716-20.

25. Islam KZ, Moral MAA, Rahman MM. Effect of Curing Time on the Flexural Strength of Heat Cured Acrylic Resin. City Dental College Journal. 2012;9(2):15-8.

26. Arikan A, Ozkan YK, Arda T, Akalin B. Effect of 180 days of water storage on the transverse strength of acetal resin denture base material. J Prosthodont. 2010 Jan;19(1):47-51.

27. Khan AA, Fareed MA, Alshehri AH, Aldegheishem A, Alharthi R, Saadaldin SA, Zafar MS. Mechanical Properties of the Modified Denture Base Materials and Polymerization Methods: A Systematic Review. Int J Mol Sci. 2022 May 20;23 (10):5737.

28. Agarwal B, Patel C, Kumar A, Singh B. Water Sorption and Solubility of Denture Base Resins-An Evaluation. Indian J Appl Res. 2015;5(8):41-4.

29. Lee HH, Lee JH, Yang TH, Kim YJ, Kim SC, Kim GR, Kim HR, Lee CJ, Okubo C. Evaluation of the flexural mechanical properties of various thermoplastic denture base polymers. Dent Mater J. 2018 Nov 30;37(6):950-6.

30. Silva AS, Carvalho A, Barreiros P, de Sá J, Aroso C, Mendes JM. Comparison of Fracture Resistance in Thermal and Self-Curing Acrylic Resins-An In Vitro Study. Polymers (Basel). 2021 Apr 11;13(8):1234.

31. Fenlon MR, Juszczyk AS, Rodriguez JM, Curtis RV. Dimensional stability of complete denture permanent acrylic resin denture bases; A comparison of dimensions before and after a second curing cycle. Eur J Prosthodont Restor Dent. 2010 Mar;18(1):33-8. PMID: 20397501.

32. Silva-Concílio LR, Meloto CB, Neves AC, Cunha LG, Rizzatti-Barbosa CM. Influence of different flasking and polymerizing methods on the occlusal vertical dimension of complete dentures. Acta Odontol Latinoam. 2012;25(3):312-7.