

THE IMPACT OF FABRICATION METHODOLOGIES ON THE FLEXURAL STRENGTH OF COMPLETE DENTURES: AN INVESTIGATION INTO TECHNOLOGICAL INFLUENCES

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ABSTRACT

Aim of the study. In this study, we examined how the choice of fabrication technology impacts the flexural strength of denture bases, considering the potential long-term consequences of permanent stresses on these structures. Such stresses can eventually result in cracking, fracture, or a loss of adaptation within the prosthetic field, which undergoes dynamic changes over time. **Material and methods.** The flexural strength was tested on specimens made of the same material (based on thermopolymerizable PMMA), using three different technologies: the classic press packing process and traditional polymerization, the injection technology and polymerization under constant pressure and an original suction-injection process (vacuum-pressure alternation), with polymerization under continuous pressure. The actual testing of the flexural strength was carried out in collaboration with the Department of Strength of Materials within the Faculty of Civil Engineering and Architecture Timișoara. **Results & Conclusions.** Superior outcomes were achieved through the suction-injection method, with polymerization under sustained pressure, in comparison to injection techniques associated with polymerization under constant pressure. These results surpassed those attained through manual press packing procedures and traditional hot polymerization methods.

Key words: dental prostheses technology, polymers injection, suction-injection procedure, flexural strength

INTRODUCTION

Every denture base must be firm, as the firmer it is, the more symmetrically the chewing pressure will be transmitted to the underlying mucosa, bone structure, and/or remaining teeth (1-3).

In this regard, it is not advisable to use polymers with a low modulus of elasticity,

i.e., those that offer minimal resistance to the application of bending forces, resulting in elastic deformation. On the other hand, the strength of the material should not be exaggerated, as it may become brittle. It must possess sufficient resistance to impact in order to, for example, prevent the prosthesis basis from breaking (4, 5).

When selecting the technology for the fabrication of removable denture bases, it is essential to consider that varying forces act on dental prostheses during each chewing cycle or swallowing event. These forces occur consistently during different movements of the mandible, causing the prosthesis to bend to varying degrees while maintaining occlusal contact. After the force exertion, dependent on the quality of the material used in denture fabrication, the prosthesis may not fully return to its original form (6). This continuous cyclic bending stress over time can lead to the fracture or breakage of the prosthesis and the loss of its adaptation to the prosthetic field, which itself undergoes changes (7-11).

In the present study, we tested the flexural strength on specimens fabricated from the same material (based on thermopolymerizable PMMA) using three different technologies. The actual testing of the flexural strength was carried out in collaboration with the Department of Strength of Materials within the Faculty of Civil Engineering and Architecture Timisoara.

MATERIAL AND METHODS

In order to determine the influence of manufacturing technology on the endurance bending strength of removable and mobilizable prosthesis bases, we fabricated the following specimens with dimensions of 40 x 40 x 3 mm (length - width - thickness): 8 specimens using the classical technology (manual packing-press method) and traditional hot polymerization method, 8 specimens fabricated using the SR-Ivocap (IVOCLAR) injection technology and polymerization under constant pressure (the corresponding equipment is available in the facilities of our department), 8 specimens each manufactured using the an original suction-injection process (vacuum-pressure alternation), with polymerization under continuous pressure, which, along with the relevant apparatus, was developed within a

research program in our department (12) (fig.1).

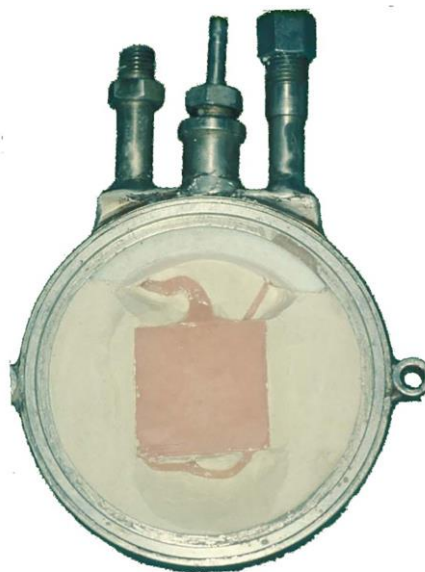


Figure 1. Making the specimens by the suction - injection procedure

In the fabrication of the specimens using all three mentioned methods, we utilized the same material, namely the commercially available product SR-Ivocap "Plus" High Impact (IVOCLAR), which is based on esterified polymethacrylic acid. This material is pre-dosed in capsules, consisting of powder composed of PMMA and copolymer (98.5%), as well as dibenzoyl peroxide (1.5%), while the liquid comprises MMA (94%) and copolymer (6%). The material undergoes automatic kneading for 5 minutes in the Cap Vibrator device (IVOCLAR). The thermal polymerization regime adhered to the protocol of each respective procedure.

After embedding the specimens, they were processed and finished using conventional methods. A total of 24 samples were obtained and submerged in distilled water at a temperature of 37°C for one week. Subsequently, the specimens underwent a 3-point bending test according to ISO 20795-1 (13), using a hydraulic press available in the Department of Strength of Materials within the Faculty of Civil Engineering and Architecture Timisoara. This press allows the

determination of the force applied to the test specimen until it yields, using a scale of 10000 N to an accuracy of 50 N (fig. 2).

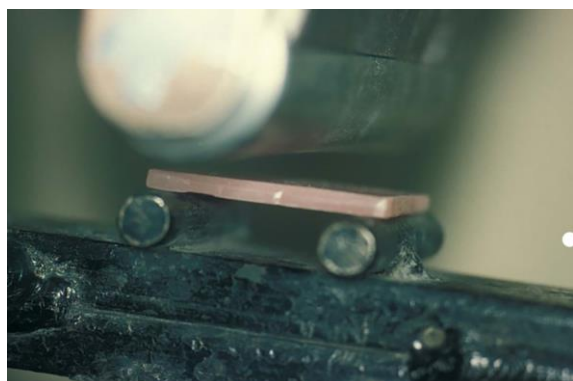


Figure 2 . Bending test of the specimens

In reality, it was determined the value of the bending force at which the specimens yielded. The flexural strength was calculated using the following formula:

$$R_f = \frac{3}{2} \times \frac{P_{\max} \times L}{B \times H^2}, \text{ in which}$$

R_f = flexural strength (N/mm^2),

P_{\max} = the maximal force at which the specimen yielded (N)

L = length of the specimen (mm)

B = width of the specimen (mm)

H = thickness of the specimen (mm)

Statistical calculations were performed using SPSS (Version 20, IBM) and Microsoft Excel (2016, Microsoft Corporation, Redmond, WA, USA). Elements of descriptive statistics were determined (mean, standard deviation, minimum and maximum values and 95% confidence interval for the mean) and to determine significant differences, the Kruskal-Wallis test and the Mann Whitney test were applied (14, 15).

RESULTS

After subjecting all 24 specimens to the 3-point bending test, they yielded to fracture under the influence of a certain force (specific to each individual specimen), rather than yielding through flow, as characteristic for plastics. The

fracture surfaces obtained for all 24 specimens are clean, indicating that the material used for fabricating the specimens is brittle regardless of the processing and polymerization technology.

The flexural strength of the specimens was calculated using the specific formula provided earlier, and the obtained results are summarized in Table 1. Accordingly, for specimens fabricated using the classical packing-press technique, the endurance bending stress ranged between 69.28 N/mm^2 and 103.92 N/mm^2 , with a mean value of $86.6 \pm 12.62\%$ N/mm^2 .

In the case of the SR-Ivoclar (IVOCLAR) injection technology and polymerization under constant pressure, the endurance bending stress ranged between 110.08 N/mm^2 and 140.11 N/mm^2 , with a mean value of $125.1 \pm 11.93\%$ N/mm^2 .

The specimens fabricated using the suction-injection procedure (vacuum-pressure alternation), with polymerization under continuous pressure exhibit a flexural strength ranging from 114.67 N/mm^2 to 145.93 N/mm^2 , with a mean flexural stress of $130.3 \pm 12.30\%$ N/mm^2 .

Therefore, it is noticeable that comparable values of flexural strength were obtained through the aspiration-injection technique, slightly higher than those achieved by the SR-Ivoclar injection method (IVOCLAR) and significantly greater than those obtained through the classical packing-press procedure. The specimens produced by the manual packing-press method exhibit low values of flexural strength. The highest obtained value is lower than the lowest value achieved by the two injection methods used (Table 1, Fig.3).

Technology	Mean ± Standard Deviation	95% Confidence Interval for Mean		Minimum	Maximum
		Lower Bound	Upper Bound		
Classic	86.6 ± 12.62	76.05	97.15	69.28	103.92
SR-IVOCAP	125.1 ± 11.93	115.12	135.08	110.08	140.11
Suction - Injektion	130.29 ± 12.30	120.01	140.59	114.67	145.93

Table 1. Descriptive characteristics associated with flexural strength depending on the technology used.

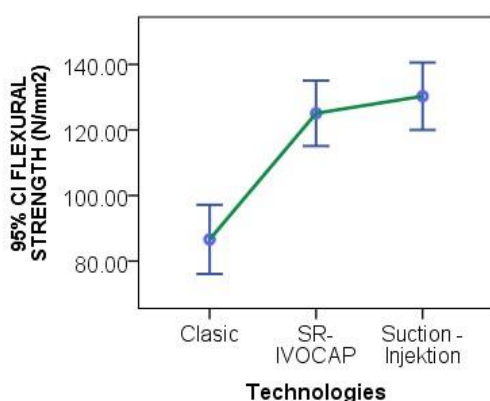


Figure 2 . Mean and 95% CI for Flexural Strength according to the technology used

To determine the significant differences between the results obtained by the three technologies, the Kruskal-Wallis test was applied. The difference between the rank totals of 4.50 (Classic), 15.13 (SR-IVOCAP) and 17.88 (Suction-Injektion) were significant ($H(2, N=24)=15.965, p=0.000$).

Post hoc comparison were conducted using Mann Whitney tests. The difference between classic technology and SR-IVOCAP technology ($U(N_{\text{Classic}}=8, N_{\text{SR-IVOCAP}}=8)=0.000, z=-3.361, p=0.001$), respectively between classical packing-press technique and suction-injektion technology was statistically significant ($U(N_{\text{Classic}}=8, N_{\text{Suction-Injektion}}=8)=0.000, z=-3.361, p=0.001$). The Mann-Whitney test applied between the SR-IVOCAP technology and the suction-injektion procedure (vacuum-pressure alternation), with polymerization under continuous pressure indicated that this difference was not statistically significant

($U(N_{\text{SR-IVOCAP}}=8, N_{\text{Suction-Injektion}}=8)=21.000, z=-1.155, p=0.248$).

Simultaneously, it also demonstrates the largest deviations in flexural strength values. This fact is undoubtedly influenced by the manual packing and pressing of the acrylic paste into the mold. At this level, human error occurs at a fairly high percentage, as well as the empirically controlled thermal polymerization system and the absence of shrinkage compensation during material polymerization.

The higher values achieved in the case of specimens fabricated using the aspiration-injection technique compared to the SR-Ivocap method (IVOCALAR) are likely due to controlled thermobaropolymerization, following vacuuming of the mold cavity, injection of the polymer under pressure, and continuous temperature monitoring both in the water bath and at the interface of the embedding material (plaster) - polymer.

DISCUSSIONS

As we noted earlier, for a complete denture to be retained in the oral cavity, it must faithfully adapt to the provided prosthetic field. In this regard, regardless of the used material, any shrinkage occurring during polymerization must be compensated, so that the prosthesis mirrors the wax model created on the corresponding working model of the prosthetic field (1, 2).

The prosthetic end product must also maintain its constant form under the conditions of mechanical (chewing pressure) and thermal demands (alternating hot and cold foods) occurring within the oral cavity. In the mouth, the prosthesis should not absorb excessive moisture, as it may alter its shape through saturation and/or subsequent water loss if not worn and stored in a dry environment (4, 5, 16).

Dental polymers must not alter their shape, dimensions, or qualities in the oral environment. Therefore, temperature variations, mechanical stresses, as well as chemical conditions such as saliva, foods, liquids, and medications, must not attack and destroy the surface layer of a dental prosthesis. Additionally, dental polymers must not change their appearance under the influence of food or medication dyes (6, 7, 9, 17). Therefore, the chemical and mechanical stability of dental plastics in the oral environment represents a crucial property that must be considered when selecting a material or a method for fabricating a dental prosthesis (18,19).

In this context, various researchers have comparatively tested the mechanical fracture resistance of specimens fabricated through several methods (20, 21). These studies highlight the following results regarding the fabrication techniques of complete dentures: the adaptability of denture bases has been noticeably improved by the application of a polymerization shrinkage compensation technique. Fracture resistance is a crucial element in the qualitative assessment and longevity of the prosthesis (22, 23). With the current techniques of biopolymer injection, fracture of a denture base results from shock loading, as fractures due to fatigue and misfit are nearly eliminated (11, 24-26).

Other studies assess the endurance bending stress of denture bases made from PMMA plastics following their lining with various types of materials applied in different thicknesses (27-30). Evaluation is

performed by tracking the plastic deformation resulting from the influence of a known bending force. The test is applied separately to the material of the denture base without and with the various lining materials. All lined denture bases exhibited significantly lower resistance compared to the base's own mass. The endurance bending stress of improved denture bases decreases proportionally with the increase in thickness of the lining material (31, 32).

Our study is subject to certain limitations, notably the focus solely on the mechanical examination of flexural strength. Thus, it is advisable for future research to explore additional mechanical properties such as compressive strength, impact strength, surface microhardness and fatigue limit. Additionally, it should be noted that the experimental conditions may not fully replicate clinical scenarios.

CONCLUSIONS

As a result of our study, where we investigated the flexural strength after conducting a 3-point bending test according to ISO 20795-1 (13) in specimens fabricated from the same material (denture polymer) using three different technologies, the following conclusions can be drawn:

- The suction-injection procedure (vacuum-pressure alternation) yielded comparable, slightly higher values of flexural strength compared to the SR-Ivoclar injection method (IVOCLAR) and significantly greater values than those obtained through the classical manual packing-press method.
- Specimens fabricated using the classical manual packing-press method exhibited lower values, with the maximum achieved value being lower than the minimum value obtained through the two injection methods used, and also demonstrated the

- greatest fluctuations in resistance values under bending conditions.
- The maximum values obtained for specimens fabricated through the suction-injection procedure (vacuum-pressure alternation), compared to the SR-Ivoclar method (IVOCLAR), are likely attributed to the controlled thermobaropolymerization, following vacuuming of the mold cavity, injection of the polymer under pressure, and continuous thermal monitoring, both in the water bath and at the interface of the embedding material (plaster)-polymer.

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Conflicts of Interest: The authors declare no conflict of interest.

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