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Original Articles

COMPARATIVE ACCURACY EVALUATION OF CONDENSING AND ADDITION IMPRESSION MATERIALS

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ABSTRACT

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Introduction The scientific selection of dental materials in modern dentistry requires the evaluation of their characteristics based on physical, chemical, and mechanical tests, in order to assess their typical properties. Comparative analysis of material characteristics for the right option in a specific application has demonstrated over time a close link between the clinical success of materials and certain of their properties.

Methodology The purpose of the study is to evaluate the basic characteristics, namely fidelity and dimensional stability, of some elastomeric addition and condensation materials. The experimental samples made of siloxane polyvinyl with different fluidity (medium and high) were placed in a fidelity test device (test block, mold), according to SR EN 4823:2002 standard, two samples of each, one being condensation and the other addition.

Results The study of the adaptation mode and the characteristics regarding the impressioning accuracy was carried out by three methods of analysis, namely: stereomicroscopy, photolithography and digital scanning. Stereomicroscopy showed that the material adapted well to the mold surface, but showed irregularities. Photolithography indicated that the material has good fidelity, even if some of the samples are less accurate, and digital scanning reinforces the idea that the materials used in this study show good fidelity.

Conclusion The results obtained are satisfactory for the experimental samples of addition and condensation polyvinyl siloxane, all the more so as their fluidity is higher and the comparative analysis of the results has provided conclusive information on the properties suitable for accurate impressioning.

KEYWORDS
Dental Impression; Fidelity, Accuracy, Dimensional Accuracy, Addition and Condensation Polyvinyl Siloxane.

1. INTRODUCTION

The selection of impression materials in dentistry is based on their characteristics [1,2,3,4,5,6,7,8] and mainly takes into account the impressioning techniques used [9,10,11] and the particularities of the prosthetic field. Among these characteristics, of particular practical importance are: *fidelity or accuracy* with which impression materials manage

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to reproduce the finest details of the prosthetic field, *plasticity*, defined by the ability of the material to be deformed and modeled under the action of minimal pressure, recording all morphological details of the prosthetic field without deforming its reliefs, *dimensional stability*, or a characteristic of the material that ensures the faithful preservation of the negative image of the prosthetic field from the moment of disinsertion of the imprint from the oral cavity until after the final grip of the material, *the time of socket*, or the characteristic that must satisfy the clinical requirements according to the particularities of each impressioning technique [12,13,14,15,16], *compatibility with model materials*.

Fidelity and dimensional stability are two essential physical characteristics characterizing the performance *of synthetic elastomers as impression materials* [17,18,19] as a result of remarkable advances in synthetic polymer chemistry. These characteristics express the ability of silicone and polyetheric impression materials to reproduce the surface details of dental preparations in a very precise way and to maintain these details over a period of time sufficient to allow precise patterns to be cast under optimal conditions. Factors affecting the fidelity and dimensional stability of elastomeric impression materials [20,21] include changes that occur during polymerization, such as volumetric reductions, loss of alcoholic groups, which cause contractions and, last but not least, temperature, disinfectants and impressioning techniques. Synthetic elastomers (polysulfides, polysiloxane polyethers), according to international norms (ISO) are classified as follows: type I - putty (Putty); type II - with increased viscosity for preliminary impressions (Heavy bodied); type III - medium viscosity for a wide range of impressions (Regular); type IV- low viscosity (fluids) for syringe injection techniques (Light bodied).

Silicone elastomers (silicones) are compounds

containing organic groups, one or more of which are covalently bonded to a silicon (Si) atom [22,23,24]. Silicones are sold in three viscosity variants (high, medium and low), each in a two-component system (base and catalyst). The base is packaged in tubes (silicones of medium and fluid consistency) or in cartons (those with chitous consistency), and *the catalyst* (activator) in vials, when in liquid form, or in tubes when presented as a paste. Silicone elastomers used for impressioning are obtained either by polycondensation reactions or by polyaddition reactions [25, 26]. *The addition silicones* are composed of *base paste* (polyvinylsiloxane) and *accelerator paste* (polyxyloxane with terminal vinyl group, organometallic catalyst – chloroplatinic acid). *Condensation silicones* are composed of *base paste* (polydimethylsiloxane, inert inorganic mass that ensures the necessary viscosity and rigidity consists of pyrolytic silica and titanium dioxide (plasticizer)) and *accelerator paste* (tin octotate, ethyl orthosilicate, sometimes chromium oxide or palladium metal particles with the role of capturing hydrogen that is not beneficial to the impression surface).

Siloxane polyvinyl materials are an improvement in condensation silicones. Both are based on polydimethyl siloxane polymer, but their hardening processes are distinct due to the presence of different terminal groups. In the basic substance, a polymer containing silane terminal groups called polymethyl hydrogen siloxane copolymer is present, which has a moderately low molecular weight. Vinyl polydimethyl siloxane is present in the accelerator substance.

Although it comprises vinyl terminal groups, this polymer has a moderately low molecular weight. As a homogeneous metallic complex catalyst, chloroplatinic acid is also a component of the accelerator material. When silane and vinyl groups are combined, an addition process takes place. The properties of siloxane polyvinyl vary greatly in terms of viscosity, working and grip time, breaking energy, elastic recovery and deformation, dimensional stability, conformity to stress-rupture life, radiopacity, etc. [27]. It is common when fluid silicone, with low viscosity, is used for the second time in impressioning techniques, after using chitous material. Each material has its own advantages and disadvantages, and its choice is made based on factors such as accuracy, ease of use and patient comfort [28]. They must demonstrate excellent detail reproduction, good tear resistance, be biocompatible and non-toxic, etc. The evaluation of basic characteristics such as fidelity and dimensional stability, but also the comparative analysis of the results obtained when evaluating them by the three study methods, demonstrates the possibility of successful use of elastomeric addition and condensation materials [30, 37, 38, 39].

2. MATERIALS AND METHOD

The material used in the experiments is polyvinyl siloxane of different fluidities. For each high and medium fluidity, two samples were obtained, one condensation and the other addition.

2.1. Preparation of test samples

a) The medium fluidity condensation polyvinyl siloxane sample is prepared from Zhermack Zetaplus chitous silicone and Zhermack catalyst, indurent gel. The two components were thoroughly mixed to remove air bubbles (mixing time about 30 seconds) until a homogeneous, *grey mixture was obtained* (Fig. 1a).

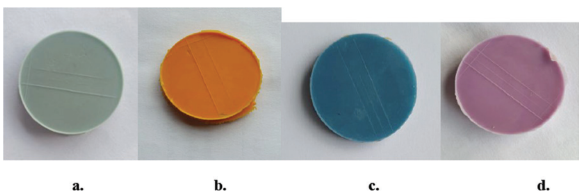


Fig. 1. Polyvinyl siloxane samples: a. condensation medium fluidity; b. addition type silicone medium fluidity; c. condensation silicone high fluidity; d. high fluidity addition type silicone.

b) The medium fluidity addition polyvinyl siloxane sample was prepared from Zhermack elite HD+ chitous silicone and a Zhermack elite HD+ catalyst by manually mixing the two components to eliminate air bubbles for about 30 seconds. A *homogeneous yellow-orange material was obtained* (Fig. 1b).

c) The high fluidity condensation polyvinyl siloxane sample was prepared from Lascod silicone Silaxyl Light body, together with a universal catalyst, Coltene Speedex activator. Mixing these two materials was done on waxed paper, by mixing vigorously with a spatula and pressing on waxed paper to remove air bubbles. The mixing time is approximately 30 seconds until a homogeneous blue material is obtained (Fig. 1c).

d) The high-fluidity addition polyvinyl siloxane sample was prepared from a Zhermack elite HD+ super light body consistency. A pink sample of suitable consistency (neither hard nor soft) was obtained (Fig. 1d).

The four samples of different colors, respectively of the four impression materials, were placed in a fidelity testing device (a stainless steel test block) in accordance with SR EN 4823:2002 standard (Fig. 2), for the evaluation of elastomeric impression materials.

The preparation of the samples consists in preparing the paste from the studied impression material, placing it in the mold (standard) and evenly distributing throughout the mold mass (Fig. 3) to eliminate gaps and air bubbles. After about 3-5 minutes the sample is subjected to analysis.

2.2. Methods for analysing experimental samples

The study of adaptation mode and impressioning *accuracy characteristics* was carried out by *three methods of analysis: stereomicroscopy, photolithography and digital scanning.*

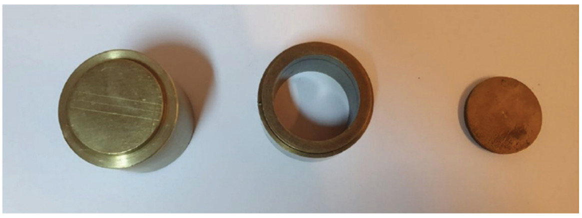


Fig. 2. The three components of the test piece

Fig. 3. Magnified image of the mold from which the samples were obtained.

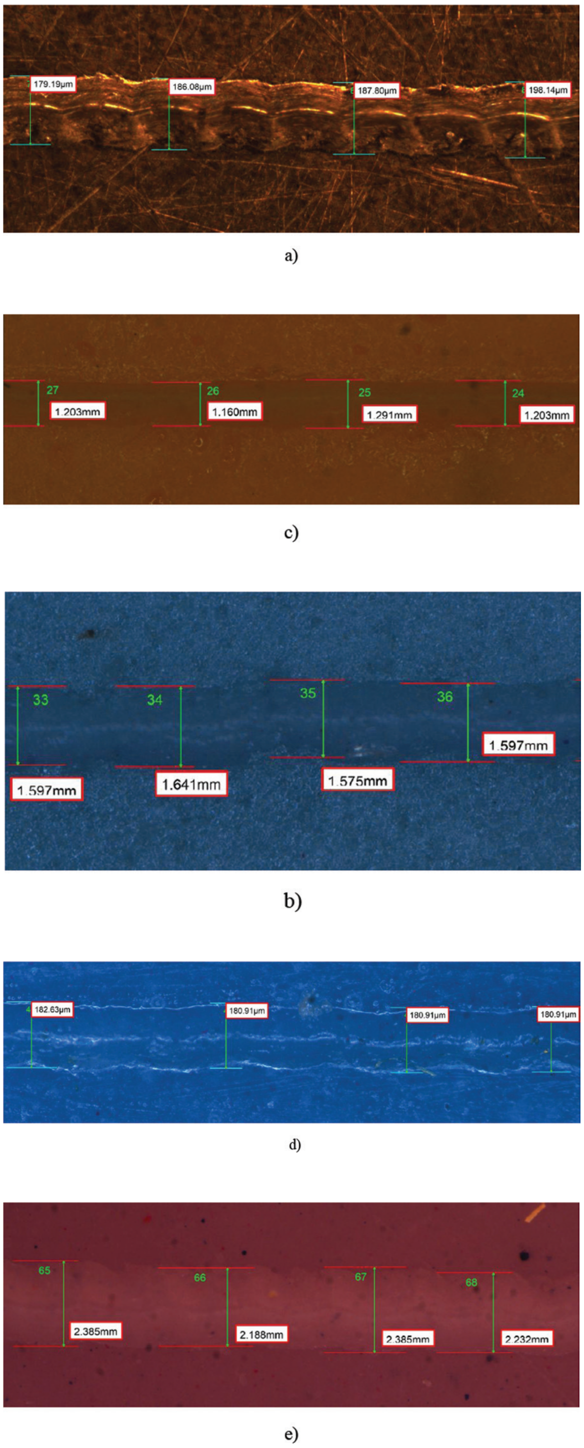


Fig. 4. Examples of images measuring the width of the grooves (a. on the metal part; b. on the sample of Zhermack zetaplus putty; c. on the sample of Zhermack elite HD+ putty; d. on the sample of Lascod Silaxil light body; e. on the sample of Zhermack elite HD+ light body).

Table 1. Mean values of the grooves width in different areas on the five samples

The width of the grooves	Standard	Zhermack Zetaplus putty (gray)	Zhermack elite HD+ putty (yellow)	Lascod Silaxil light body (blue)	Zhermack elite HD+ light body (violet)
Groove 1	187.80µm	1.60mm	1.21 mm	181.34µm	2.30 mm
Groove 2	182.63µm	167.13µm	656.36µm	149.47µm	2.09 mm
Groove 3	169.71µm	103.81µm	161.96µm	123.62µm	1.39 mm

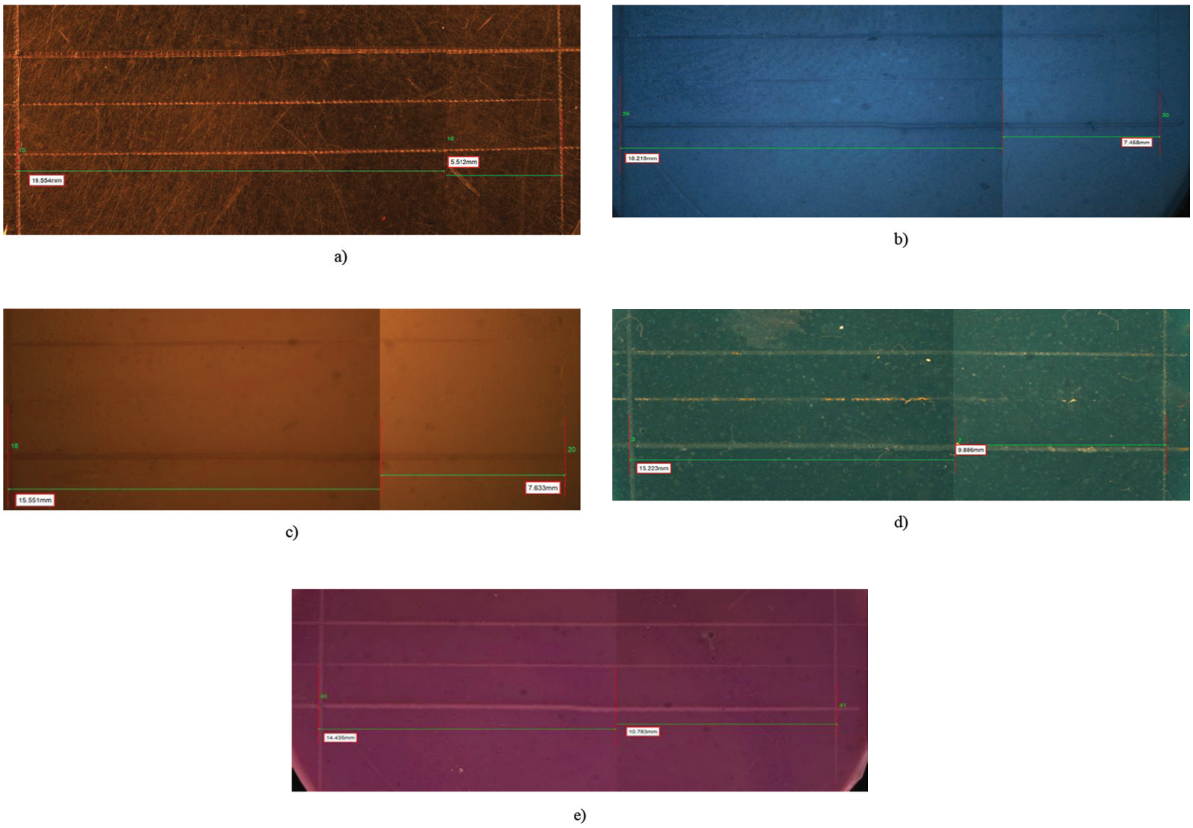


Fig. 5. Examples of images measuring the length of groove 1 (a. on the metal part; b. on the sample of Zhermack zeta plus putty; c. on the sample of Zhermack elite HD+ putty; d. on the sample of Lascod Silaxil light body; e. on the sample of Zhermack elite HD+ light body).

Table 2. Values of the groove length in different areas, on the five samples

The width of the grooves	Standard	Zhermack Zetaplus putty (gray)	Zhermack elite HD+ putty (yellow)	Lascod Silaxil light body (blue)	Zhermack elite HD+ light body (violet)
Value 1	25.066 mm	25.677 mm	23.184 mm	25.109 mm	25.218 mm

2.2.1. Stereomicroscopy analysis

For this experimental study, the Nikon SMZ1270 stereomicroscope was used with a wide range of accessories (trinocular tubes and diascopic lighting holders with thin LEDs), which has a number of advantages, such as zoom ratio, the highest in its class, and high-resolution viewing of 640LP/mm.

2.2.2. Analysis by photolithography

Photolithography has the ability to manipulate the geometry of features with very good precision and can produce patterns with very small characteristics, down to several tens of nanometers.

2.2.3. Analysis by digital CAD/CAM scanning

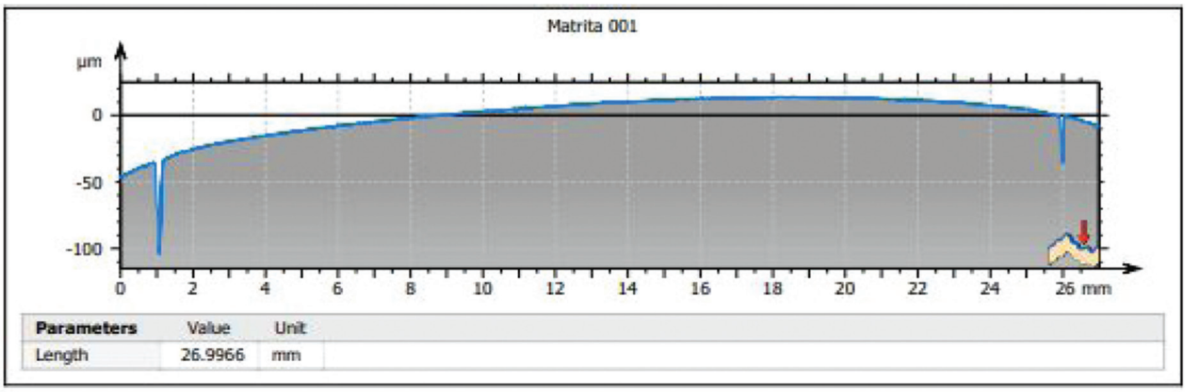
The study used PlanScan Lab scanner from PlanMeca. Gypsum patterns and impressions can be scanned quickly and accurately using this desktop scanner, with a wide range of applications including full arch bridges, implant bars and crowns.

3. RESULTS

The results regarding the fidelity and dimensional stability were obtained, recorded and studied, expressed by the dimensions (widths and length) of the three parallel grooves on the standard (mold) and on the experimental samples.

3.1. Results of stereomicroscopy analysis

The results of *the stereomicroscopy* analysis are shown in the images below (Fig. 4) and in Table 1, which shows the average of the width values of the three parallel grooves on the five samples. The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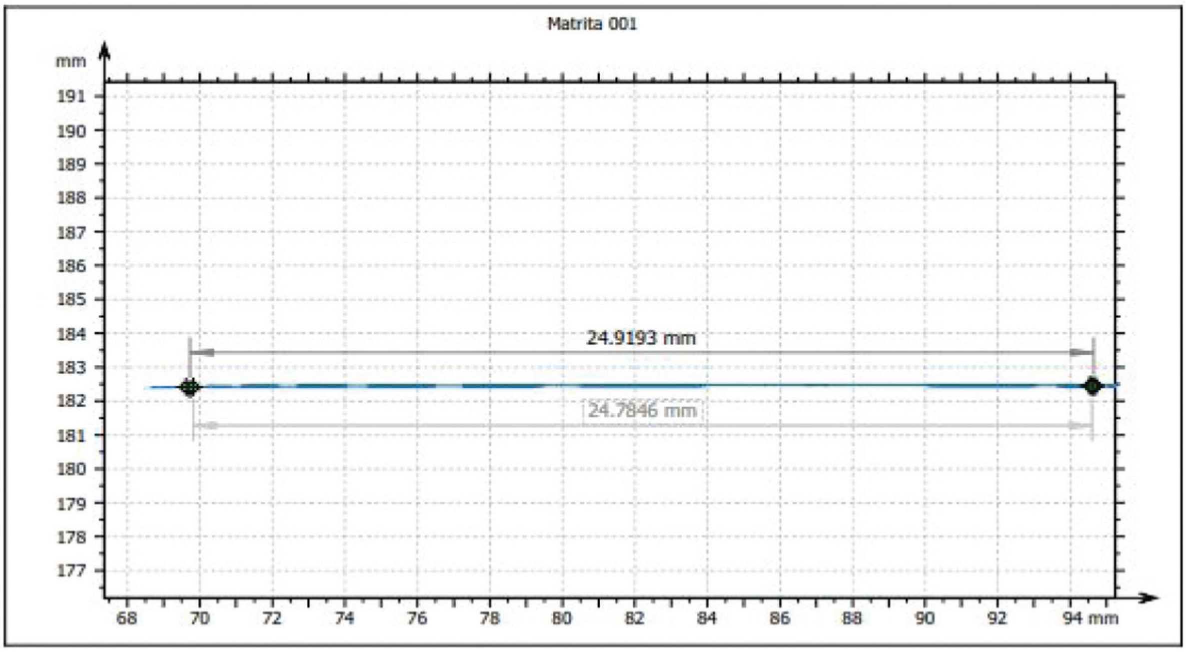
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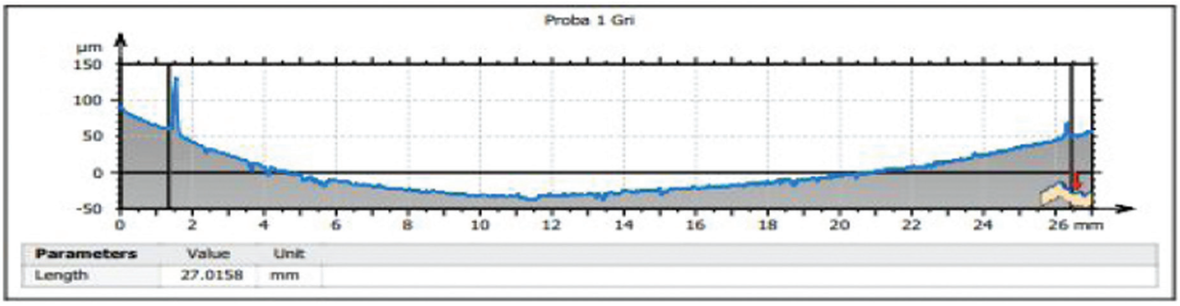
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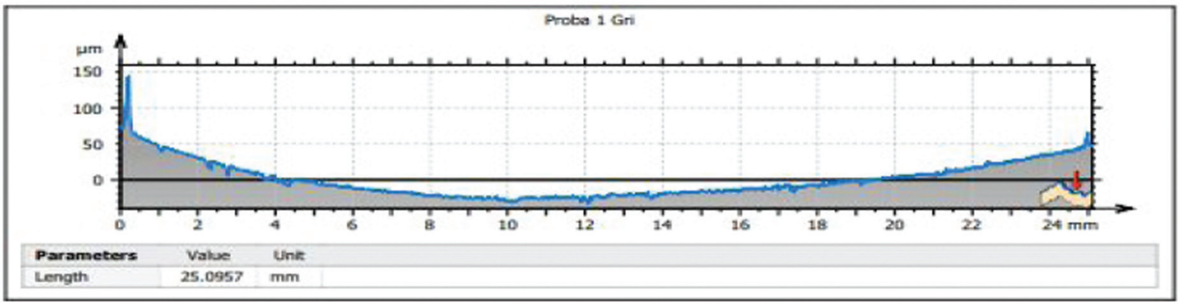
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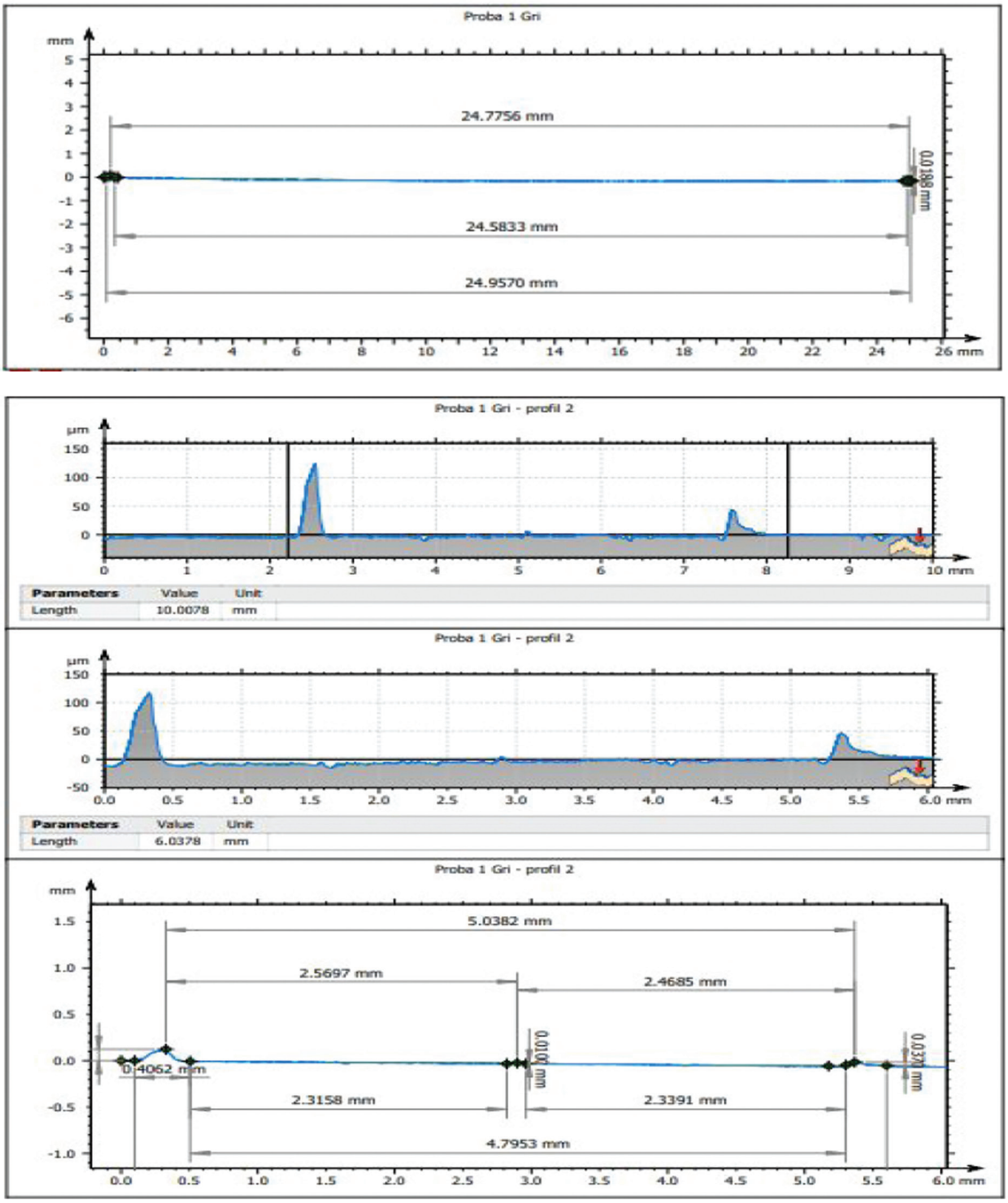

Fig. 6. Examples of recordings of dimensions:a . Profile 1 / Mold length, b. Profile 2 / The depths of the mold grooves, c. Profile1 / Length of medium fluid condensation polyvinyl siloxane sample (gray material), d. Profile 2 / Groove depths of medium fluid condensation polyvinyl siloxane sample (gray material).

Table 3. Groove length values on the five samples

Length of the groove	Groove depth	Mold	Gray sample	Yellow sample	Blue sample
Value	24.9193mm	25.0957 mm	25.3846 mm	25.3893 mm	25.5502 mm

Table 4. The values of the depth of the grooves on the five samples

Groove depth	Mold	Gray sample	Yellow sample	Blue sample	Sample purple
Groove 1	0.1424 mm	0.1200 mm	0.1280 mm	0.1170 mm	0.1711 mm
Groove 2	0.0560 mm	0.0100 mm	0.0260 mm	0.0098 mm	0.0230 mm
Groove 3	0.0937 mm	0.0370 mm	0.0611 mm	0.0624 mm	0.0780 mm

Table 5. Groove width values on the five samples

Groove depth	Mold	Gray sample	Yellow sample	Blue sample	Sample purple
Groove 1	0.3366 mm	0.4062 mm	0.3700 mm	0.3791 mm	0.3803 mm
Groove 2	0.2120 mm	0.1404 mm	0.2080 mm	0.0001 mm	0.1858 mm
Groove 3	0.2480 mm	0.1890 mm	0.2970 mm	0.3297 mm	0.2344 mm

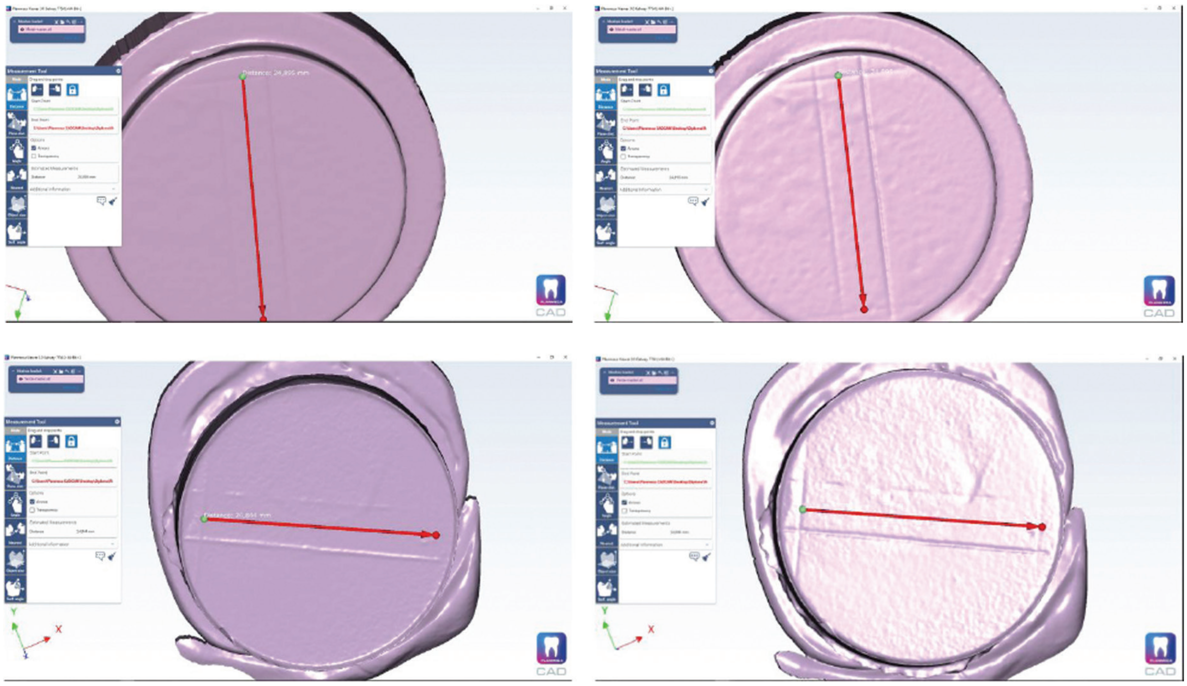

Fig. 7. Examples of recordings of different samples a. mold scan b. silicone sample.

Table 6.

Groove depth	Mold	Gray sample	Yellow sample	Blue sample	Sample purple
Value	24.895 mm	24.844 mm	25.114 mm	24.834mm	24.849 mm

groovees have different widths, groove 1 is the thickest, groove 2 is medium width and groove 3 the thinnest.

Also with the help of the stereomicroscope, the length of the groove was measured on each sample, the measurement results are shown in the images below (Fig. 5) and in Table 2.

3.2. Results of photolithography analysis

The images below (Fig. 6) present the experimental results for each sample in which two profiles were recorded, one representing the length of the sample, and the other the depths of the three grooves. For this analysis, in addition to photolithography, advanced metrology (Metrology 4.0 Analysis 9.1.9957) was used to study surface roundness and to measure important structural factors such as size, depth, geometry and surface quality.

3.3. Analysis results from digital scanning

The images below (Fig. 7) show the results of the analysis from the digital scan. These images show the samples in 3D CAD plane, but also the measurements made for the length of the groove. The samples were placed on the scanner stand, scanned, and then converted into 3D images. Table 6 shows the lengths for each of the 5 samples.

4. DISCUSSIONS

The stereomicroscope analysis highlighted the impressioning characteristics of the experimental samples by evaluating the size values (width and length) of the three parallel grooves on the five experimental samples and the differences recorded from those on the block (standard) test. From the measured width values (Table 1) it follows that the three parallel grooves (1, 2 and 3) are uneven, starting with the first groove where there is a large difference between the samples and the block test. More accurate results in width compared to the standard were obtained in the case of the sample of addition polyvinyl siloxane with medium fluidity (yellow). Groove length measurements (Table 2)

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show very close values between samples. The medium fluidity addition polyvinyl siloxane sample has a slightly lower value, and the high fluidity condensation polyvinyl siloxane sample (blue) has values close to the block test length. Compared to the other samples, high-fluidity condensation polyvinyl siloxane has the values closest to standard. Having greater fluidity means that it also has a large contraction when sets (hardens), which leads to high dimensional stability, but distortions can occur if the setting contraction is greater than it should be. When assessing the setting shrinkage, it is observed how much the material has entered the groove (fidelity) and how much it has contracted between the edges (stability).

The photolithography analysis that records the profiles of the experimental samples assessing the length and depth of the three grooves revealed that the samples have the same diameter as the mold (profile 1), with very small differences between them, of 0.003-0.100 mm (Table 3). Groove length measurements show similar values for all of them, namely 25 mm. Compared to the groove length in the mold, which is 24.9193 mm, samples show that the material is adapted to the mold, in other words it contracted well between the edges of the mold. Profile 2 shows the depths of the grooves, values measured on the standard and on the experimental samples. The values in the mold range from 0.1424 mm (groove 1) and 0.0937 (groove 3) to 0.0560 mm (groove 2), but it is noticeable that the material did not insinuate itself very well in all cases (Table 4).

Knowing that impression materials usually present shrinkage on setting, with this method of analysis, one can see how much the material has entered the groove (fidelity), but also how much it has contracted between the edges (stability).

It is visible, both from the graphs and from the tabulated values, that the fluidity of the material influenced its adaptation, groove 2 being almost invisible, and in the case of the addition polyvinyl siloxane sample with medium fluidity (yellow) the material did not even enter the groove. On the high fluidity addition polyvinyl siloxane sample (violet) all groove depths are observed, the measurement values being even closer to those in the mold. If we consider the widths of the grooves, the mold shows the following values: 0.3366 mm (1), 0.2120 mm (2), 0.2480 (3), and the samples have different values from each other, but are close to those measured in the mold (Table 5). Here, too, the experimental sample of addition polyvinyl siloxane with high fluidity is the one with values much closer to the mold. We can also appreciate that the medium fluidity condensation polyvinyl siloxane sample (gray sample) did not adapt very well to the mold, and the high fluidity addition polyvinyl siloxane sample (purple sample) has better fidelity.

The digital scanning analysis method confirms the previous results and highlights once again that these materials have adapted well with the respective mold. The differences between the values are very small. Only the medium-fluidity addition polyvinyl siloxane sample has a bigger length than the other samples. What is important, however, is that the shape of the grooves in the samples is similar to the mold (scan images). This means that the materials have good stability and entered the groove very well, the sample closest to the mold was the purple sample, made of addition polyvinyl siloxane with higher fluidity.

5. CONCLUSIONS

The precision with which the impression material records tissue details will determine the quality and how well the restoration or final prosthesis fits. This accuracy of the impression material depends both on its properties and on the techniques for obtaining the impression.

The study meets the proposed objective, which is to evaluate the basic characteristics, namely fidelity and dimensional stability of elastomeric addition and condensation materials with different fluidity. Experimental research aimed at studying the impressioning accuracy of polyvinyl siloxane as an impression material. The comparative analysis of the experimental results on way to adapt and the accuracy of impressioning by the three study methods (*stereomicroscopy, photolithography and digital scanning)* highlighted the following important aspects with practical utility:

- photolithography is the method of analysis that has the best accuracy;
- elastomeric impression materials with high fluidity reproduce details better compared to those with increased consistency;
- regardless of consistency (fluid or chitous) addition silicones are more dimensionally stable than condensation silicones;
- the highest fidelity (accuracy of detail reproduction) was demonstrated in experiments by addition silicone (Elite HD superlight body), probably also due to the high fluidity remarked also during application;

The results of the study shall also provide useful information on methods of study and analysis in establishing the essential characteristics of impression materials in order to obtain an accurate impression.

AUTHOR CONTRIBUTIONS

All authors have read and agreed to the published version of the manuscript.

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This research received no external funding.

DATA AVALLABILLITY STATEMENT

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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CV

Vlad Gabriel Vasilescu is a graduate of the "Carol Davila" University of Medicine and Pharmacy. He presents numerous courses completed over the years as well as published works. He specializes in implantology and has submitted research work on the most suitable materials. Vlad Gabriel Vasilescu started his career as a university assistant at the "Carol Davila" University of Medicine and Pharmacy, and in the meantime, he has also completed his doctoral studies.

Questions

1. What is the correct order

❑a. Putty, heavy-bodied, regular, and light-bodied;
❑b. Heavy-bodied, putty, regular and light-bodied;
❑c. Light-bodied, putty, regular and heavy-bodied;
❑d. Regular, putty, heavy-bodied, light-bodied.

2. What is the difference between Polyvinyl siloxane materials and condensation silicones

❑a. None, they are the same;
❑b. Condensation silicone contains vinyl;
❑c. They differ in the terminal ends;
❑d. Polyvinyl siloxane materials have a condensation reaction.

3. What are the factors by which we choose an impression material

❑a. Money and mental state;
❑b. The choice is made based on factors such as accuracy, ease of use, and patient comfort;
❑c. The material with the highest polymerization contraction is chosen;
❑d. The choice is made strictly based on the patient's preferences.

4. What materials were used in the study

❑a. Alginate and reversible hydrocolloids;
❑b. Thermoplastic materials;
❑c. Condensation silicones;
❑d. Polyvinyl siloxane with different fluidity.