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DIMENSIONAL STABILITY AND ACCURACY OF SILICONE – BASED IMPRESSION MATERIALS USING DIFFERENT IMPRESSION TECHNIQUES – A LITERATURE REVIEW

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ABSTRACT

A quality-made dental impression is a prerequisite for successful fixed-prosthodontic fabrication and is directly dependent on the dimensional stability, accuracy and flexibility of the elastomeric impression materials, as well as on the appropriately used impression techniques. The purpose of this paper is to provide a literature review of relevant scientific papers which discuss the use of various silicone impression materials, different impression techniques and to evaluate their impact on the dimensional stability and accuracy of the obtained impressions. Scientific papers and studies were selected according to the materials used, the sample size, impression technique, storage time, type of measurements and use of spacer for the period between 2002 and 2016. In the reviewed literature several factors that influence the dimensional stability and accuracy of silicone impression molds, including the choice of the type of viscosity, impression material thickness, impression technique, retention of the impression material on the tray, storage time before the casting, number of castings, hydrophilicity of the material, release of byproducts, contraction after polymerization, thermal contraction and incomplete elastic recovery were presented. The literature review confirmed the lack of standardization of methodologies applied in the research and their great diversity. All findings point to the superiority of the addition silicone compared to the condensation silicone.

Key words: silicone impression material, impression technique, fixed partial dentures, dimensional stability, review

INTRODUCTION

A quality-made dental impression is a prerequisite for successful fixed-prosthodontic fabrication and is directly dependent on the dimensional stability, accuracy and flexibility of the elastomeric impression materials, as well as on the appropriately used impression techniques. Elastomers are most commonly used impression materials in everyday dental clinical practice for precise reproducing (recording) of tooth morphology and surrounding soft tissue. Three types of elastomers are distinguished: polyethers, polysulfides and silicones. Polyethers are characterized by excellent detailed reproduction and good resistance to tearing, while polysulfides have excellent resistance to tearing and good detailed reproduction. There are two types of silicones, condensation silicones and addition silicones [1].

Condensation silicone is obtained by cross-linking polycondensation reaction of hydroxyl terminated polysiloxane pre-polymers with tetra alkoxy silanes catalyzed by dibutyl-tin dilaurate, (DBTD). The polycondensation process releases alcohol that contributes to the contraction (reduction) of the impression [2]. The advantages of the condensation silicon are: precise impression if poured quickly after it is taken and good elastic restoration after removing the impression from the mouth. However, its disadvantages are: hydrophobic, contraction of the impression with the lapse of time and possible allergic reaction caused by the catalyst [3-5].

Addition silicone (vinyl polysiloxane) is obtained by cross-linking polyaddition reaction of vinyl terminal polysiloxane polymers with mediation of methylhydrogen silicone as cross-reaction agent in the presence of platinum catalyst. In the process of polymerization, platinum may cause a release of hydrogen from water or hydroxyl groups, being the reason for emergence of bubbles in the plaster model [2]. The advantages of the addition silicon are: precise impression, minor contraction, detailed impression, high elasticity and quick restoration, dimensional stability, non-toxic and non-irritating. Its disadvantages are: hydrophobic; inhibited by latex gloves; hydrogen is released which results in defects after casting [3-5].

Impression materials have to satisfy certain conditions of which the most important are:

accuracy, because it determines the precise fabrication of prosthodontic restorations. To achieve a higher precision, it is important to know the rheological features of the impression material which provide sufficient low viscosity when placed into the mouth in order to record the finest details, which requires suitable processing time, during which there will be no significant increase in viscosity (which is followed by the setting time);

dimensional stability, the dimensional changes related to setting or hardening of the material must be insignificant as well as the dimensional changes during the storage of the impression (by the casting);

elasticity: the impression material must be flexible during the extraction from the mouth so that all undermined points remain recorded without distortion [6].

The impression techniques are divided into mono-phase and double-phase techniques based on the materials used and the number of steps required for the impression. The mono-phase impression technique is performed in one step and uses impression material with medium or low viscosity for detailed impression of intraoral structures, because it is necessary to avoid sliding of the material from the tray [7]. The double phase technique uses impression materials with different viscosity (putty/wash or heavy/light body) and can be performed in 1 or 2 steps. The 1-step double-phase technique is performed by simultaneous use of materials with putty (heavy) and light consistency whereby the putty impression material is applied into a tray, while the light body is applied on the abutment and completely wrapped to be pressed with the tray containing the already placed heavy body material. The 2-step double phase technique is performed first by filling up the tray with the putty impression material and record the abutment. The second step continues after setting (hardening) of the impression and its extraction from the mouth where low viscosity material is afterwards applied on the first impression and is again returned into the mouth for correctional impression [7-10].

AIM

The aim of this paper is to provide a literature review of relevant scientific papers which discuss the use of various silicone impression materials, different impression techniques and to evaluate their impact on the dimensional stability and accuracy of the obtained impressions.

METHODS

For the purposes of this review article, electronic search was done in April and May 2017, using the Scopus and PubMed databases. The search was performed using the following keywords: elastomeric impression material and dimensional stability; elastomeric impression material and impression techniques; condensation silicone and addition silicone; accuracy and dimensional stability. Abstracts of papers were considered, examined and sorted according to the following inclusion and exclusion criteria. Inclusion criteria: all experimental studies that examine the accuracy and dimensional stability of elastomeric impression materials by presenting a number of samples and explained laboratory tests and measurements, written in English language, published in scientific journals. Exclusion criteria: papers that study the relationship between humidity, including autoclaving and disinfection, and dimensional stability.

RESULTS

The performed search resulted in 69 articles that were published between 2002 and 2016. Based on the inclusion criteria, we selected 29 in-vitro studies. Table 1 below shows the selected papers according to the materials used, the sample size, impression technique, storage time, type of measurements and use of spacer for the period between 2002 and 2016.

DISCUSSION

In the reviewed literature several factors that influence the dimensional stability and accuracy of silicone impression molds, including the choice of the type of viscosity, impression material thickness, impression technique, retention of the impression material on the tray, storage time before the casting, number of castings, hydrophilicity of the material, release of byproducts, contraction after polymerization, thermal contraction and incomplete elastic recovery were presented [11, 12].

The process of setting (polymerization) of silicones starts from the very beginning with the mixing i.e. the contact of the basic material and the reactor (activator). The first elastic particles appear, multiply and interconnect during time, leading to full polymerization of the impression material and its transformation from plastic to elastic condition.

Two stages can be distinguished in the process of setting of silicones. The first stage is the hardening of the material which, in clinical terms, enables extraction of the impression from the mouth without any deformation. The second stage comes after the extraction of the impression and lasts in some materials up to an hour, until the polymerization is fully completed. During that time, some dimensional changes on the impression material are possible, and, with its completion, the time convenient for casting of the impression begins [13].

Despite the fact that silicones have absolute dimensional accuracy, especially addition silicones, Samet et al. [14] showed in his research that nearly 90% of the cast models have one or more visible errors and therefore require further research and improvement.

In the study of Vitti et al. [15] a measurement and comparison of the dimensional accuracy of the plaster models cast of two different condensation silicones and two different addition silicones is done by applying three impression techniques (mono-phase, double-phase 1-step and double-phase 2-step technique). The measurements of all distances of the plaster models show altered dimensions with significant negative linear changes (contraction) compared to the standard (control) model, cast in a stainless steel. The plaster models obtained from the tested addition silicones were dimensionally more precise than the tested

Table 1. Included studies based on Scopus and Medline searches performed in April and May 2017, considering the materials, sample size, impression technique, storage time, type of measurement and use of spacer, during the period from 2002-2016.

Author (year)	**Materials***	**Sample size** (impressions or models)	**Impression technique**	**Storage time**	**Type of measurements**	**Spacer**
Nissan (2002)[26]	PVS	N=15	Double-phase 2-step	1 h	Microscopic measurement of models	1 mm 2 mm 3 mm
Chen (2004)[5]	AL, PVS, CS	N=10	Mono-phase	AL-24 h S-30 min	Photomicrography digitized measurements	
Shah (2004)[29]	PE, PVS	N=10	Double-phase 1-step	1 h	Measurements using laser scanner with 3D superimpositional software	
Faria (2007)[18]	AL, PS, PE, CS, PVS	N=5	Double-phase 1-step, 2-step (S only)	PE-30 min PVS-1 h	Measurements using software image tool (photographed)	1 mm
Caputi (2008)[7]	PVS	N=15	Mono-phase; Double-phase 1-step, 2-step; novel 2-step injection	1 h	Measurements were made with a scanner	2 mm
Franco (2011)[10]	PE, PVS	N=10	Double-phase 1-step, 2-step	2 h	Microscopic measurement of models	2 mm
Kumar (2011)[11]	PE, CS, PVS	N=12	Mono-phase; Double-phase 2-step	8, 16, 24 h	Microscopic measurement of models	2 mm
Garrofe (2011)[12]	CS, PVS	N=3	Double-phase 1-step	0, 15, 30, 60, 120 min; 24 h; 7 and 14 days	Measurements using software image tool (photographed)	
Chugh (2012)[9]	PVS	N=10	Double-phase 1-step, 2-step	No	Coordinate measurement machine	1mm, 2mm

Singh (2012)[17]	PVS	N=5	Mono-phase; Double-phase 1-step, 2-step	24 h	Coordinate measurement machine	0,3mm 2mm
Markovic (2012)[13]	CS, PVS	N=1	Mono-phase	30 min 1, 2, 4, 6, 8,10, 12, 24, 36, 48, 96 h	Coordinate measurement machine	2mm
Pande (2013)[8]	PVS	N=15	Double-phase 1-step, 2-step	No	Microscopic measurement of models	1.5 mm, 3 mm
Dugal (2013)[21]	PVS	N=15	Double-phase 1-step, 2-step	No	3D laser scanned and measurement taken by Rhino 3D software program	0.5 mm, 1 mm, 1.5 mm
Vitti (2013)[15]	CS, PVS	N=5	Mono-phase; Double-phase 1-step, 2-step	30 min	Microscopic measurement of models	2 mm
Pandey (2014)[30]	PE, PVS, VSE	N=15	Mono-phase; Double-phase 1-step	30 min	Microscopic measurement of models	
Rathee (2014)[31]	PVS	N=20	Mono-phase; Double-phase 1-step	24 hours	Microscopic measurement of models	2 mm
Leao (2014)[28]	PVS	N=5	Double-phase modified 2-step	1 h, 2 days, 7 days	Measurement using Zirkonzahn Modellier software and scanning	1.5 mm
Kumari (2015)[16]	PVS	N=10	Double-phase 1-step2-step	24 h	Measurements using profile projector	1.5 mm
Sayed (2015)[32]	PVS	N=7	Double-phase 2-step	2 h	Stereomicroscopic measurement of models	Al foil
Haralur (2016)[27]	PE, PVS	N=6	Mono-phase; Double-phase 1-step, 2-step	1 h, 12h 24h, 48h	Microscopic measurement of models	2 mm 5 mm
Sayed (2016)[33]	PVS	N=10	Double-phase 2-step	No	Photomicrography digitized measurements	2 mm

* The tested materials are abbreviated as follows: AL alginate; PS polysulfide; PE polyether; CS condensation silicone; PVS polyvinyl siloxane; VSE vinyl siloxanether.

condensation silicones, while no difference was noted in the impression techniques applied. This study minimizes the effect of elastic changes in the extraction of the tray from the standard model, which is not the case in everyday clinical practice.

The research goal of Kumari et al. [16] is to evaluate and compare the linear dimensional change in three different representative polyvinyl siloxane (PVS) impression materials, i.e. addition silicones and to compare the accuracy of the double-phase 1-step impression with the double-phase 2-step impression. The measurements in this study confirm that there is no significant difference between the tested brands (trademarks) of addition silicones and that they are within the allowed deviation, while the comparison of impression techniques confirms that the double-phase 2-step impression showed better results compared to the double-phase 1-step impression.

The in-vitro study of Pande et al. [8] aims at evaluating the dimensional accuracy, the effect of undermining in three different abutments and the elastic restoration of the addition silicone by indirect assessment, measuring the dimensions of the cast plaster models obtained by impressions from the master model, using the double-phase 1-step impression and the double-phase 2-step impression. Moreover, measurements were also made to evaluate the horizontal or linear and vertical dimensional changes of the corresponding abutments of the master steel model. Upon examining the results, it was concluded that the dimensional accuracy of the impression material of addition silicone is unmatched, i.e. it can reproduce details because it almost has no byproducts in the process of polymerization. Comparing the two impression techniques, the double-phase 1-step impression has statistically better dimensional accuracy with respect to the double-phase 2-step impression.

Singh et al. [17] evaluated the linear dimensional accuracy of the elastomeric impressions using different impression techniques and multiple combinations of viscosity of the impression materials. Based on the research conditions and results obtained, the conclusions are in favor of the double-phase 2-step impression, with a remark that it requires further research and studies to generalize the accuracy of the double-phase 2-step impression of silicones with different viscosity.

Faria et al. [18] aimed in their research to make a comparison of the accuracy of different impression materials used in the fabrication of fixed partial dentures. For the purpose of this research, a master (steel) model was cast which is a half arch of the partial edentulous mandible, where the teeth are prepared for fixed partial dentures. In terms of accuracy, condensation silicones showed a discrepancy in a negative context, compared to addition silicones. On the other hand, differences were noticed between the impression techniques when addition silicone was used and a conclusion is however drawn that the double-phase 1-step impression is more accurate than the double-phase 2-step impression. These results are in favor of the findings in the study of Hung et al. [19] where a comparison of the double-phase technique in 1-step and 2-steps is done by using addition silicones, which confirmed that the double-phase 1-step technique is more precise than the double-phase 2-step technique.

Chugh et al. [9] in their study compared the accuracy of plaster models obtained by applying various impression techniques (double-phase 1-step and 1-step techniques) using several spacers around the abutments and concluded that the double-phase impression with equal and controlled spacer of 0.5 mm is recommended for obtaining a plaster model that will result in precise fixed partial dentures. The clinical application of this study is the use of temporary crowns as a controlled spacer for low viscosity silicone.

Nissan J. [20] recommended in his study the use of the double-phase 2-step technique since an accurate impression requires equal inter-space so that the low viscosity silicone (light consistency) can be evenly polymerized.

The study of Dugal et al. [21] is intended to compare the dimensional accuracy of the models obtained by the double-phase 1-step and 2-step impression techniques with polyvinyl siloxane (addition silicone) as impression material, using three different spacers of 0.5 mm, 1 mm and 1.5 mm to determine which impression technique shows maximum dimensional accuracy. For the purposes of this study, a steel model is made with two abutments and a suitable metal tray, perforated for retention of the impression material. All impressions were left on the model twice the time prescribed for adhesion. This was done in order to compensate for the time of polymerization that takes place at room temperature (~25ºC) which is lower than the oral cavity temperature (~32ºC) [22]. Special attention is paid to the metal contact of the model and the tray as confirmation of proper second contact of the metal tray on the base of the model. The metal on metal contact is achieved by finger pressure on the tray. The study examines the accuracy of four (one double-phase 1-step and three double-phase 2-step with spacer) impression techniques because some authors [19] argue that there is no difference between them, while other criticize the double-phase 1-step technique [23, 24]. Their criticism is underpinned by the lack of control over the amount of light body silicone and the risk of recording the prepared marginal edge by the heavy body silicone, which is inadequate for detailed reproduction. It is thereby concluded that the double-phase 2-step technique with 1 mm spacer showed the slightest dimensional variation of the tested models compared to other impression techniques, while the double-phase 1-step technique produced models that showed the greatest dimensional variation in all measured distances compared to other groups.

In their experimental study Heidari et al. [25] assessed the effect of the spacer on the accuracy of the cast models taken with the double-phase 2-step technique with two different addition silicones (heavy/light body). The results showed that the accuracy of the double-phase 2-step technique without controlled light body spacer is preferable. The effect of the controlled light body spacer of 0.5 mm, 1 mm, 1.5 mm and 2 mm and of the one without a spacer in the final dimensional accuracy showed no significant difference.

Nissan J et al. [26] conducted a research to determine the necessary amount of light body with the double-phase 2-step technique with controlled spacer to capture the maximum of the impression which will then be cast and used as a working model. The results showed that the double-phase 2-step technique with controlled spacer of 2 mm is the best choice for taking impression.

In their study Haralur et al. [27] examined the accuracy of cast models gained from the master steel model with the double-phase 1-step and 2-step techniques (heavy/light body) with spacers of 2 mm and 5 mm, as well as after multiple repeated casting at an interval of 12, 24 and 48 hours. The results showed that the cast abutments were relatively larger in diameter with the double-phase 1-step technique due to the polymerization contraction towards the wall of the tray by the heavy body silicone. All impression techniques showed statistically significant differences (polymerization contraction towards the wall of the tray) after multiple repeated casting of impressions.

The study of Leão et al. [28] examines i.e. compares the dimensional stability of the double-phase 2-step technique with the modified double-phase 2-step technique where the impressions are cast immediately after the impression, namely in the first hour, after 2 and 7 days. The model is scanned in a CAD-CAM system which produces a plate with three abutments whose distances obtained by the impression and casting will be examined. Based on the results, it can be concluded that there is no significant difference between the impression techniques and the casting time, while a significant difference is measured between the double-phase 2-step technique and the modified double-phase 2-step technique only in terms of the immediately cast impression.

Shah et al. [29] used a 3D laser scanner to measure the plaster models obtained with a double-phase 1-step impression in examining the accuracy of polyether and polyvinyl siloxane as impression materials and concluded, based on the results obtained, that the polyether has a better accuracy than the polyvinyl siloxane. This paper emphasizes the use of 3D scanner and adequate software as a new method for evaluation and analysis of the dimensional stability and accuracy of the impression materials and techniques through digital measurement and comparison of the cast plaster models.

Different impression techniques play an important role in transferring an accurate copy of the prepared teeth and the surrounding soft tissue complex for further work. The application of impression materials of different consistencies and their use in multiple steps contributes in recording of the finest details of the original. The mono-phase impression technique which uses a material with the same viscosity (consistency), usually light or medium body, enables a complete wash and penetration into the whole relief and undermined areas of bone and surrounding soft tissue structures and maximum utilization of the resilience of the oral mucosa and its precise recording. The disadvantage of this technique is that there is no control over the amount of impression material used and the possibility of contraction of the material upon polymerization [30].

Certain control of the amount of impression volume is needed because a large amount of impression volume does not mean good impression. On the contrary, better results are achieved when the impression layer is of moderate thickness and evenly distributed. It implies application or use of strictly controlled spacers with defined thickness or an individual tray. The silicone with evenly distributed layer covers the impression surface, penetrating into the undermined areas and adheres well to the tray after the polymerization. Most important is however the fact that in the evenly distributed layer with a moderate thickness the total value of the permanent deformations in the silicones is insignificant [31, 34].

CONCLUSION

The literature review confirmed the lack of standardization of methodologies applied in the research and their great diversity. The main differences relate to the number of samples, spacers used in the double-phase 2-step technique, different impression techniques and their modified equivalents up to the impression measurement models and cast plaster models, not excluding the storage time of the impressions by the time of their casting. All findings point to the superiority of the addition silicone compared to the condensation silicone in all parameters as well as to other elastomers. The double-phase 2-step impression technique, with 2 mm spacer, increases the accuracy and dimensional stability because the heavy body material acts as an individual tray. The purpose of the spacer is to control the amount of the used light body volume and thus limits the contraction of the impression.

The use of 3D scanner in the experimental trials is a major step towards full digitalization of the impressions and has great potential as a forerunner of contactless 3D intraoral scans which the authors believe will be brought to perfection in the coming decade and will become available for widespread use in everyday clinical practice.

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ДИМЕНЗИОНАЛНАТА СТАБИЛНОСТ И ПРЕЦИЗНОСТ НА СИЛИКОНСКИ ОТПЕЧАТОЧЕН МАТЕРИЈАЛ КОРИСТЕЈЌИ РАЗЛИЧНИ ОТПЕЧАТОЧНИ ТЕХНИКИ – РЕВИСКИ ТРУД

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Резиме

Квалитетниот отпечаток е предуслов за успешна фиксно-протетичка изработка и зависи директно од димензионалната стабилност, прецизност и еластичноста на еластомерните отпечаточни материјали и од соодветно употребените отпечаточни техники. Целта на овој ревијален труд е литературен преглед на релевантни научни трудови во кои е разгледувана употребата на различни силиконски отпечаточни материјали, различните отпечаточни техники и евалуација на нивното влијание врз димензионалната стабилност и прецизност на добиените отпечатоци. Избраните трудови беа селектирани врз база на користените материјали, бројот на примероци, отпечаточните техники, времето на чување на отпечатоците, типот на мерења и употребата на меѓупросторот во периодот од 2002 до 2016-та година. Во литературата се презентирани повеќе фактори кој влијаат на димензионалната стабилност и прецизност на силиконските отпечаточни материјали, вклучувајќи го изборот на типот на вискозност, дебелината на материјалот, отпечаточната техника, ретенцијата на отпечаточниот материјал за лажицата, времето поминато до излевањето, бројот на излевања, хидрофилноста на материјалот, ослободување на нуспроизводи, контракцијата после полимеризацијата, топлинската контракција и нецелосно еластично обновување. Литературниот преглед потврди недостаток на стандардизација на методологиите применети во истражувањата и нивната голема разновидност. Сите сознанија упатуваат на супериорноста на адиционит силикон во однос на кондензациониот силикон.

Клучни зборови: силиконски отпечаточен материјал, отпечаточна техника, фиксно-протетичка изработка, ревиски труд