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ORIGINAL RESEARCH

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Quantification of flowability and hydrophilicity of elastomeric impression materials.

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Abstract

Introduction: Flowability and hydrophilicity are essential properties of accurate impressions and casts. Aim of study: This study aimed to quantify these characteristics of elastomeric impression materials. Material and Methods: A total number of eight impression materials, including vinyl polysiloxane (PVS), polyether (PE), and condensation silicone (CS) were thoroughly investigated in this study. The flowability of elastomers was proven with the shark fin test (SFT), and the hydrophilicity was determined with contact angle (CA) measurements. Results: The shark fins' (SF) of VPSs presented 11.57 mm (SD 3.49), while the PE 11.37 mm (SD 5.06) and CS 8.1 mm average values. Some of the products showed better flowability. Based on 128 measured CAs, the examined polyethers had the lowest CAs which indicate good hydrophilicity. Conclusions: A good performance of an impression material in one of the involved tests (SFT and CA) does not mean a similar result in the other analysis. All investigated impression materials could be considered hydrophilic as their CA was lower than 90°. The SFTs of light-bodied VPSs and PEs suggest reliable use of them in dental practice.

Keywords: elastomeric impression materials, hydrophilicity, flowability.

Introduction

A In dentistry, precise casts and impressions are still essential to achieve an excellent outcome. The accuracy of impressions can be impacted by physical and chemical characteristics of elastomers [1]. The reduced viscosity permits improved substance flow (flowability), which is essential for precisely documenting details such as gingival crevices, deep restorative preparations, and interproximal spaces [2]. Given that the impression materials are hydrophilic, they are capable to move across the mucous membrane and make a more intimate connection with the oral tissue, which results in greater capture of surface detail and fewer imperfections [3].

In the traditional impression-taking technique, vinyl polysiloxane (VPS) impression materials are widely used materials for final impressions. Their different consistencies (light body, medium body, heavy body, putty) are often combined during impression. To capture the fine details, the light-bodied material is placed around the preparation, while the heavy-bodied material in the tray serves as support. [2].

The used materials and techniques for dental impression vary among practitioners even within a country, presenting regional differences. In clinical dentistry, intraoral scanners (IOS) are becoming more and more common, displacing traditional impression-taking procedures and associated technologies [4]. In the case of accuracy, the opinion of the authors is divided. Intraoral scans are widely acknowledged to exhibit great accuracy and may be appropriate for use in clinical applications [5,6]. Tomita et al. found that IOS could be more accurate compared to alginate or VPS-based methods [5]. However, others note that the scans have some limitations in clinical practice [6,7]. A recently published network meta-analysis seems to support this statement [8].

The shark fin test (SFT) can be used to examine the flowability of impression materials in vitro [9]. By forcing the material to pass through a predetermined triangular, V-shaped small slit in the pressing stamp, this technique permits imitating the flow of elastomers under defined pressure [10]. The resulting impression specimens resemble a shark fin (SF) shape. Better flowability features are associated with higher fin height, which is interpreted as a marker for "high clinical reliability" [9].

The measure of wettability is the contact angle (CA or θ) defined as an angle between the liquid–vapor interface and the solid–liquid interface. The surface is considered to be perfectly wetted for $\theta=0°$, and it is hydrophilic for $\theta<90°$, while it is hydrophobic for $\theta>90°$ [11]. Water CAs are frequently used to determine the hydrophilic properties of impression materials both before and after they have been set [12]. From this consideration a drop of liquid is placed onto the solid surface using a syringe, and static CA is measured optically [11].

The objective of the present study was to measure the flowability and the hydrophilicity of elastomeric impression materials. According to our null hypotheses, there is no significant difference in flowability among the involved materials as measured by the SFT (1) and, additionally, there is no significant difference in hydrophilicity among these, as determined by CA measurements (2).

The null hypotheses tested were that the technique and method of toothbrushing have no effects on surface roughness of microhybrid composites (1) and there is no relationship between the bristles properties of brushes and wear (2).

Material and methods

The flowability and hydrophilicity of eight elastomers including VPS, condensation silicone (CS), and polyether (PE) materials were studied as shown in Table 1. Additionally, the very light consistency type of Oranwash was involved in the hydrophilic analysis part. The preparation of some of the mentioned impression materials assumed the use of cartridge dispensers. In the case of Elite HD+ Light Body both preparation methods, the manual mixing and handling of manual dispensers were used. The polyethers have been prepared based on hand-mix.

Table 1. Elastomers used in this study

Product	Manufacturer	Used for		Type	Consistency according to ISO 4823	Manufacturer's setting time (min:s)
		SFT	CA			
Elite HD+ Light Body	Zhermack S.p.A. (Badia Polesine, Italy)	Yes	Yes	VPS	Type 3 (Light-Bodied Consistency)	Manual mixing 5:30 1:1 dispenser gun 4:00
Virtual Light Body Fast Set	Ivoclar Vivadent AG (Schaan, Liechtenstein)	Yes	Yes	VPS	Type 3	2:30
Presigum	President Dental GmbH (Allershausen, Germany)	Yes	Yes	VPS	Type 3	4:30
Variotime Medium Flow	Kulzer GmbH (Hanau, Germany)	Yes	Yes	VPS	Type 2 (Medium Consistency)	2:30
Oranwash Light	Zhermack S.p.A. (Badia Polesine, Italy)	Yes	Yes	CS	Type 3	5:00
Impregum Medium	3M ESPE (Seefeld, Germany)	Yes	Yes	PE	Type 2	6:00
Impregum Soft	3M ESPE (Seefeld, Germany)	Yes	Yes	PE	Type 3	3:00
Oranwash Very Light	Zhermack S.p.A. (Badia Polesine, Italy)	No	Yes	CS	Type 3	5:00

The elastomers were stored and mixed at room temperature (23±1 °C). As directed by the manufacturer, the hand-mixed impression elements were evenly combined on a glass plate using a metal spatula. Before each measurement, we cleaned the glass plate, the metal spatula, and the used device with alcohol to ensure that there was no base or catalyst left over from the previously used material.

The flowability of the materials listed was examined using SFT. For this purpose, the flow of elastomers into the sulcus was simulated under controlled pressure using a specially designed device shown in Figure 1.

The capacity of the reservoir was projected to be 8 ml. During operation, the 147 g weighted indenter caved into the elastomer, allowing the material to flow off to the side as surplus or enter through a 1 mm slot. To prevent any mistakes, every material was examined twice, resulting in a total of 16 SF specimens. The specimens were removed from the device following polymerization and standardized photographs were made with an SLR camera (Nikon D3100, Nikon Corporation, Japan), a 90 mm macro lens (Tamron SP AF-S 90 mm f/2.8), cable shutter (Nikon MC-DC2), photo tent with a scattered light source and a millimeter scale for calibration. The measurement of the height of the fins was made using Image Pro Insight 8.0 (Media Cybernetics, USA) two-dimensional digital image analysis software.

Figure 1. The specially designed device used for SFT.

Hydrophilicity was tested with drop shape analysis during and after the polymerization of investigated materials by two drops of water dripped with a pipette on the flat surface of specimens, and photographs were taken. The photographic documentation was ensured by a Huawei P30 Pro (Huawei Technologies Co. Ltd., Shenzhen, China) device using the Super Macro function, which takes 40-megapixel images. In these standardized photographs, the CA of the water droplets with the impression material was measured using the ruler tool of Adobe Photoshop software (Figure 2). Each test was repeated four times, and then an average value was calculated.

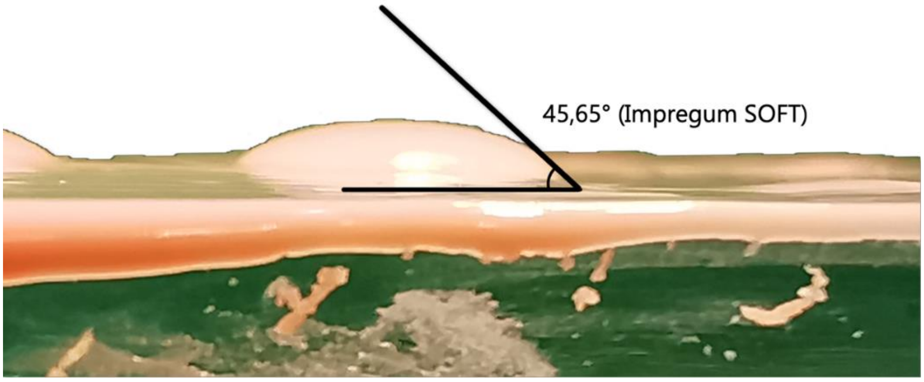

Figure 2. The measured CA value between the liquid–vapor interface and the solid–liquid interface of a polyether sample

With the aid of the statistical testing software GraphPad InStat (GraphPad, San Diego, CA, USA), data were gathered. To evaluate the differences between the groups, paired Student's t-tests were used. In light of the topic and design of the study, it is noteworthy to mention that ethical approval was not necessary.

Results

The performed shark-fin tests showed averages of all groups assumed to be statistically not significant (p= 0.51). The cumulated group of VPSs presented 11.57 mm (SD 3.49), while the polyethers 11.37 mm (SD 5.06) mean values and Oranwash Light 8.1 mm.

Although there were no statistically significant outliers within the groups, the obtained fin-heights presented variable values. The difference between the best and worst results is more than twofold. The highest measured fin could be detected in case of Virtual Light (16.36 mm) VPS-based material which was followed by Impregum Soft (14.96 mm) polyether material. On the other hand, the lowest heights were measured at Variotime Medium Flow (7.56 mm) and Impregum (7.79 mm), followed by Oranwash Light (8.1 mm). The results are presented in Table 2.

We included 128 measured CAs in the hydrophilicity test. Before the polymerization of elastomers, the smallest angles could be measured by Impregum Medium (29.58°) and Impregum Soft (45.65°) polyethers, while the materials with the largest angles were Presigum Light (83.45°) and Virtual Light Body (83.92°) VPSs. After the full set time, Variotime Medium Flow (40.4°) and the two Impregum polyethers had the smallest angles (47.13° and 53.15°), and Virtual Light Body (86.2°) displayed the largest. The results are presented in Table 3.

Table 4 summarizes the average values of the drop angles for the various types of elastomers. The paired-t test results showed that there is a non-significant difference between before and after polymerization at all three types of elastomers (p>0.05).

Table 2. Summary table of individual and average SFT values

Category	Average SFT	Products	SFT
VPS	11.57 mm (SD 3.49)	Elite HD+ Light Body	13.82 mm
		Virtual Light Body Fast Set	16.36 mm
		Presigum	10.53 mm
		Variotime Medium Flow	7.56 mm
CS	8.1 mm	Oranwash Light	8.1 mm
PE	11.37 mm (SD 5.06)	Impregum Medium	7.79 mm
		Impregum Soft	14.96 mm

Table 3. Average drop angle values measured during and after the polymerization of elastomer specimens.

Elastomer	Angle during setting (°)	Angle after setting (°)
EliteHD+ Light Body	46.35	81.20
Virtual Light Body	83.92	86.20
Presigum Light Body	83.45	85.52
Variotime Medium Flow	75.30	40.40
Oranwash Light	78.65	79.95
Oranwash Very Light	69.80	71.75
Impregum Medium	29.58	53.15
Impregum Soft	45.65	47.12

Table 4. A summary of the average drop angle values by elastomer type

Type of elastomer	**Angle during setting (°) + SD**	**Angle after setting (°) + SD**	***p* value [a]**
VPS	72.25 (SD 17.71)	73.33 (SD 22.06)	*0.94*
Condensation silicone	74.22 (SD 6.25)	75.85 (SD 5.79)	*0.12*
Polyether	37.61 (SD 11.36)	50.13 (SD 4.26)	*0.46*

Discussions

Our results highlighted that both VPS and PE light body materials could produce outcomes with high flowability. However, it is important to notice that there exist products on the market whose shark fin (SF) heights are almost the same as the investigated condensation silicone from our study.

Balkenhol et al. as pioneers of independent SFTs searched for a correlation between shark fins (SF) heights and physical properties. They discovered that the SFT results had no correlation with the phase angle, storage modulus, or surface detail reproduction of impression materials that were measured after mixing within the suggested working time of the manufacturer [9].

Lawson et al. compared the flow of elastomers over time. According to their study, the shark fin (SF) heights significantly decreased with the use of VPSs and hybrid materials, starting at a 30-second period. The fast and regular polyether material (Impregum) performed better, showing later significant decreases in heights [2]. According to the authors, polyether flowability is superior compared to other materials [2,9,10,13]. Our results confirmed this tendency in the case of Impregum Fast (14.96 mm) elastomer, which performed the second-best result after Virtual Light (16.36 mm) VPS-based impression material.

Based on the results, the polyethers have a stronger hydrophilic character in comparison with VPSs or condensation silicones. Both Impregum Medium (29.58°) and Soft (45.65°) materials had the lowest CAs during setting. These findings coincide with the results of other authors [14–16]. In comparison to polyether, some authors reported reduced water CAs on hybrid polyvinylsiloxanether (PVXE) light body [10,17]. After setting, the hydrophilicity decrease was not significant. In the case of Impregum Medium the CA change after setting (53.15°) is noticeable, however, it has remained one of the most hydrophilic materials. The opposite phenomenon could only be detected in a single case of a PVS material (Variotime Medium Flow).

The values of static CA measured for the same drop can significantly differ depending on the time interval between placing the drop on the solid surface and the time of measurement [11]. Huettig et al. state that all elastomers exhibit a statistically significant decrease in CA at drop ages between 1 and 5 s. [10].

The measured values of static CA are influenced by evaporation, absorption, and other chemical or physical interactions. The volume of the drop also affects the accuracy, it should be in the range of 2-6 mm. If smaller drops are dispensed, more spherical shapes are formed due to the surface tension, and CA values will be overestimated. Otherwise, if the drops are larger due to the effect of gravity the CAs will be underestimated [11].

Conclusions

A good performance of an impression material in one of the involved tests (SFT and CA) does not mean a similar result in the other analysis. However, an ideal elastomer is expected to present high grades of flowability and hydrophilicity. In our study one PE performed excellently on both test methods, the rest of the materials presented various performances. The formulated null hypotheses were partially accepted. All investigated impression materials could be considered hydrophilic as their CA was lower than 90°. The SFTs of light-bodied VPSs and PEs suggest reliable use of them in dental practice. It is important to mention that other physical properties, not examined in our paper, highly influence the quality of the final impression (e.g., tear strength, dimensional stability).

Conflict of interest: None to declare.

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