CONSISTENCY MEASUREMENTS OF THREE COMMERCIAL AND FIVE NOVEL EXPERIMENTAL VINYL POLYSILOXANE (VPS) IMPRESSION MATERIALS

[1]SHAHAB UD DIN, [2]SADIA KHALID, [3]SHEHARYAR AKHTAR KHOKHAR, [4]SADIQ ALI, [5]SHAHREEN ZAHID KHAN, [6]MANGALA PATEL

ABSTRACT

The purpose of this study was to develop a medium bodied hydrophobic and hydrophilic experimental (Exp) vinyl polysiloxane (VPS) impression materials (ab initio) incorporating a novel cross-linking agent, tetra-functional (dimethylsilylorthosilicate (TFDMSOS) and a non-ionic surfactant, Rhodasurf CET-2, (ethoxylatedcetyl-oleyl alcohol), and to analyse their effects on consistency measurements and to compare it with commercial medium bodied VPS impression materials.

Five experimental formulations (Exp-I, II, III, IV and V) of VPS impression materials were developed. Three commercial VPS (Aquasil Ultra Monophase, Elite HD Monophase and Extrude) were used. The consistency measurements of five Exp materials were compared with each other and with three commercial VPS impression materials. The results were analysed with one-way ANOVA and post hoc Tukey's test using the SPSS PASW statistical 22 software.

The consistency measurements of the three brands of commercial VPS impression materials and Exp-I and II were not significantly different (p[illegible]0.05) from each other. The surfactant modified Exp VPS (Exp-III, IV and V) showed significantly lower consistency values than their controls (Exp-I and II) and all commercial products. It was also observed that by increasing the amount of the surfactant (Rhodasurf CET-2) there was a consistent decrease in the consistency for the experimental hydrophilic VPS (Exp-III, 31.20±0.78 mm; Exp-IV, 32.00±0.54; Exp-V, 31.00±0.62 mm) but these were not significant. The results for the average consistency measurements of all experimental materials prepared in the current study fulfil the criteria of ISO4823 for elastomeric impression materials for a medium-bodied impression material.

Key Words: *Impression materials; elastomers; vinyl polysiloxane; cross-linking agent; surfactant; consistency measurements.*

INTRODUCTION

Rheology refers to the study of the deformation of materials and their flow characteristics. The rheological or flow characteristics of elastomeric impression materials are important factors for the adaptation of the materials to hard and soft oral tissues, leading to replicate an accurate impression of the oral structures.[1-4] The viscosity of a fluid is its resistance to flow and it is the measure of consistency of the fluid.[2] A fluid with high viscosity will always flow with a lower rate compared to a fluid of low viscosity. Viscosity of an impression material is a very important factor in producing accurate impressions and dies with minimal bubbles and maximum fine details.[5-7] Dental elastomeric impression materials are characterised according to their consistency measurements as shown in Table 1 and 2.[8,9] Little work has been carried out to investigate the consistency measurements of VPS impression materials as demonstrated by the lack of literature available. According to Oh et al[10] the consistency measurement is performed by pressing 0.5 ml of mixed material between two glass plates and applying a load

[1] **Corresponding:** Dr Shahab ud Din, BDS, MSc., PhD (UK), Asst Prof, Dentistry and Allied Disciplines, Shaheed Zulfiqar Ali Bhutto Medical University, (SZABMU)/Pakistan Institute Medical Science PIMS, Islamabad, Cell: 0300-5640459 Email: drshahab728@hotmail.com

[2] Sadia Khalid, BDS, MDS, Dentistry and Allied Disciplines, Shaheed Zulfiqar Ali Bhutto Medical University, (SZABMU)/Pakistan Institute Medical Science PIMS, Islamabad, E-mail: rehmans28@yahoo.com

[3] Sheharyar Akhtar Khokhar, BDS, BSc, MCPS, FCPS, Dentistry and Allied Disciplines, Shaheed Zulfiqar Ali Bhutto Medical University, (SZABMU)/Pakistan Institute Medical Science PIMS, Islamabad, Email: sheharyar001@yahoo.com

[4] Sadiq Ali, BDS, MDS, Assistant Professor, Central Park Medical College, Lahore, E-mail: dr.sadiq.mds@gmail.com

[5] Shahreen Zahid Khan, BDS, MPhil, Assistant Professor, Army Medical College, Rawalpindi, E-mail: shahreen.khan@gmail.com

[6] Mangala Patel, BSc, MSc, PhD, Professor, Centre for Oral Bioengineering (Dental Physical Sciences Unit), Bart's and The London School of Medicine and Dentistry, Queen Mary University of London, E-mail: m.patel@qmul.ac.uk

Received for Publication:	July 3, 2018
First Revised:	Aug 16, 2018
Second Revision:	Sep 25, 2018
Approved:	Sep 26, 2018

of 147 N for 5 seconds. After 15 minutes of removing the load, the diameter of disc (across minor and major diameters) is measured and the material is classified according to the criteria given in Table 1.

According to the American National Standards Institute (ANSI)/American Dental Association (ADA)[11] specification 19, elastomeric impression materials are divided into different categories depending on the consistency and their intended purpose as shown in Table 2. These materials are dispensed in various consistencies depending on the amount of the filler and the molecular weight of the polymer.[12,13] The amount of filler (for example Aerosil R812S) is regulated according to the required consistency of the materials (Very high consistency, High consistency, Medium consistency, Light-bodied). The molecular weight (Mw) and temperature also affects the consistency and setting time of these materials, and mainly it is the molecular weight of the pre-polymer (e.g. vinyl polydimethylsiloxane) which is adjusted to finalize the consistency of the material.[14,15]

The purpose of the current study was:

- To formulate novel experimental medium bodied VPS impression materials *ab initio*.
- To investigate the rheological properties of medium bodied commercial VPS impression materials after incorporating different agents i.e. cross-linking agent, tetra-functional (dimethylsilylorthosilicate (TFDMSOS) and a non-ionic surfactant, Rhodasurf CET-2, (ethoxylatedcetyl-oleyl alcohol).
- To compared the consistency measurements of these novel experimental VPS impression materials with commercial VPS impression materials.
- To determine consistency measurements of commercial and experimental VPS impression materials following the ISO4823 methods for elastomeric impression materials.

The current study will provide important background knowledge, which will hopefully point the way forward in developing medium bodied VPS impression materials with improved consistency for clinical applications of these materials.

MATERIALS AND METHODS

The different commercial medium-bodied VPS impression materials used in this study are shown in Table 3. All the commercial VPS materials used are hydrophilic according to the literature provided by the manufacturer. These materials were supplied as auto-mixed cartridge delivery systems (Centrix, DS50-1:1/2:1, Geogia, USA).

Preparation of experimental VPS impression materials

`Initial formulations for pilot studies were prepared following Oh et al[10] and Lee *et al's*[16] methods for VPS impression materials. A total of 113 compositions were prepared and five Exp compositions (Exp-I, II, III, IV and V) according to ISO4823 elastomeric impression materials[17], were appropriate and suitable for use. Some of the basic components (pre-polymer, conventional cross-linking agent, platinum catalyst and filler) were used in all formulations but in varying amounts. The details about the % amounts of the components are given in the published part of this study[18]. Consistency of the materials (medium-bodies) were developed by adjusting the amount of filler (Aerosil R 812) and molecular weight of the pre-polymer [vinyl-terminated poly(dimethylsiloxane), Mw 62700]. Further details of the formulations are given in the published part of present research.[14] The main differences between these five formulations (Exp-I, II, III , IV and V) included the incorporation of a novel cross-linking agent tetra-functional (dimethylsilyl) orthosilicate (TFDMSOS), to enhance the tear strength and a non-ionic surfactant, Rhodasurf CET-2, (ethoxylatedcetyl-oleyl alcohol) to improve the wetting properties of these materials. The catalyst paste was same for both the formulations (Exp-I and II). Exp-I was used as control for Exp-II and for Exp-III, IV and V the control was Exp-II. For all the hydrophilic compositions (Exp-III, IV and V) the catalyst paste was identical.[18]

Consistency measurement

Following Oh *et al*[10] and Lee[16] methods, two glass plates (measuring 60 x 60 x 3 mm^3) covered with acetate sheets were used to measure the consistency of commercial and experimental VPS impression materials. The test material (0.5 g) was extruded onto the centre of the bottom glass plate/acetate sheet. The other acetate sheet/glass plate was placed on top, followed by placement of a 1500 g ± 2 g load on the top surface using a weighing stone. The load was allowed to rest on the assembly for 5 seconds. After 15 minutes two diametral measurements of the specimen were taken (one across the major diameter and one across the minor diameter of the disc). The average of the two measurements was considered as the disc diameter. These measurements (n=5 per material) were used to classify the material's consistency, as a medium-bodied material, according to the standard values given in Tables 1 and 2 (ISO4823, 2007; ADA, 1977 respectively).

RESULTS

Fig 1 shows the mean consistency measurements for all commercial and experimental VPS impression materials. One way Analysis of Variance (one way ANOVA) revealed significant differences ($p<0.05$) between the consistencies of all materials tested. The data was further analysed by using a post hoc test (Tukey's Honest Significant Difference [HSD] test;

TABLE 1: CHARACTERISTIC PHYSICAL PROPERTIES OF ELASTOMERIC IMPRESSION MATERIALS WITH RESPECT TO CONSISTENCY ACCORDING TO ISO4823 (8).

Types (consistency)	Consistency (test disc diameter, mm)	
	min.	max.
Type 0: Very high consistency (putty like)	-	35
Type 1: High consistency (heavy-bodied)	-	35
Type 2: Medium consistency (monophase)	31	41
Type 3: Low consistency (light-bodied)	36	-

TABLE 2: CONSISTENCY MEASUREMENTSOF ELASTOMERIC IMPRESSION MATERIALS ACCORDING TO ADA (11).

Viscosity description	Diameter of consistency disc (mm)
Type 0: Very high consistency (putty like)	13-20
Type 1: High consistency (heavy-bodied)	20-32
Type 2: Medium consistency (monophase)	30-40
Type 3: Low consistency (light-bodied)	36-55

TABLE 3: COMMERCIAL VPS IMPRESSION MATERIALS USED IN THE CURRENT STUDY.

Commercial VPS	Lot/batch number	Manufacturers
Aquasil Ultra Monophase (Medium-Bodied), (Aq M)	090505	Dentsply, USA
Elite HD Monophase (Medium-Bodied), (Elt M)	95503	Zhermack, Italy
Extrude (Medium-Bodied), (Extr M)	0-1068	Kerr, USA

TABLE 4: CONSISTENCY MEASUREMENTS OF COMMERCIAL AND EXPERIMENTAL VPS IMPRESSION MATERIALS (STATISTICAL ANALYSIS)

One way ANOVA - 0.000							
Tukey's HSD test							
	Elt M	**Extr M**	**Exp-I**	**Exp-II**	**Exp-III**	**Exp-IV**	**Exp-V**
Aq M	0.434	0.771	1.000	0.622	0.000	0.000	0.000
	Elt M	0.999	0.657	1.000	0.065	0.005	0.002
		Extr M	0.925	1.000	.017	0.001	0.000
			Exp-I	0.828	0.001	0.000	0.000
				Exp-II	0.031	0.002	0.001
					Exp-III	0.965	0.854

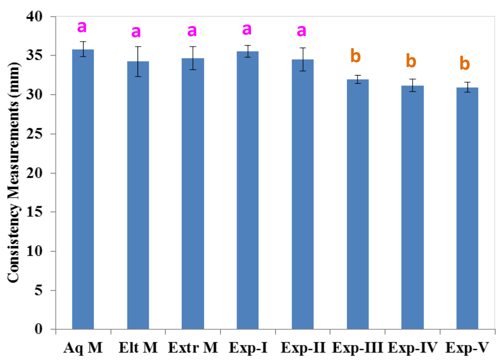

Fig 1: Mean (± standard errors; n=5) consistency measurements of commercial and Exp VPS impression materials. Similar letters indicate no significant difference (p>0.05).

Table 4) to determine which means of the materials were significantly different from each other. There were no significant differences (p>0.05) among the three brands of commercial VPS and Exp-I and II. The surfactant modified Exp VPS (Exp-III, IV and V) showed significantly lower consistency values than their controls (Exp-I and II) and all commercial products. It was also observed that by increasing the amount of the surfactant (Rhodasurf CET-2) there was a consistent decrease in the consistency for the Exp hydrophilic VPS (Exp-III, 31.20±0.78 mm; Exp-IV, 32.00±0.54; Exp-V, 31.00±0.62 mm) but these were not significant (Fig 1 and Table 4).

The results for the average consistency measurements of all Exp formulation (Exp-I, II, III, IV and

V) prepared in the current study fulfil the criteria of ISO4823 for elastomeric impression materials (17) for a medium-bodied impression material, according to ISO4823 (8) and ADA (11) (shown in Tables 1 and 2 respectively).

DISCUSSION

The consistency of an impression material has a major role in recording an accurate impression of the patient's mouth. Impression materials with required consistency are very important to record the accurate impressions of dental arches, tight inter-proximal areas and sub-gingival regions. In these situations, materials with required consistency are used to avoid defects in the impressions. If required consistency is not used then it can cause defects in the impression leading to the construction of a faulty final restoration. Therefore, in the current study consistency measurements of the medium bodied Exp formulations (Exp-I, II, III, IV and V) were developed and compared with medium bodied commercial VPS (Aquasil Ultra Monophase, Elite HD Monophase and Extrude) impression materials following the ISO4823[8] and Oh *et al's*[10] study.

All the commercial and experimental VPS exhibited consistencies within the limits of the criteria set by ISO4823[8] and American Dental association (ADA, 1977)[11] for a medium bodied VPS impression materials as shown in Tables 1 and 2. It was observed the novel cross-linking agent, TFDMSOS, did not affect the consistency measurements of Exp-II when compared with Exp-I (control). There was no significant difference seen between the three brands of commercial VPS and Exp-I and II. However, after adding the non-ionic surfactant (Rhodasurf CET-2) into the three Exp hydrophilic VPS, the consistency of Exp-III, IV and V increased significantly compared to their controls (Exp-I and II) and the three commercial products. The increase in consistency measurement of hydrophilic VPS was also concentration dependent; with the increasing amount of surfactant the consistency measurements were also increased significantly. However, the consistencies of all the hydrophilic Exp VPS (Exp-III, IV and V) were still within the set criteria mentioned in the (ISO4823[8] and ADA[11].

CONCLUSIONS

Within the limitations of this study, it was found that:

- There were no significant differences in the consistency measurement among the three brands of commercial VPS and Exp-I and II.
- The surfactant modified experimental VPS (Exp-III, IV and V) showed significantly lower consistency values than their controls (Exp-I and II) and all commercial products.
- The results for the mean consistency measurements of all experimental materials prepared in the current study fulfil the criteria for a medium bodied VPS impression material, according to ISO4823.

REFERENCES

1 Eyre D, van Noort R, Ellis B. The rheology of silicone rubber impression materials. J Dent. 1989;17(4):171-6.

2 Martinez J, Combe E, Pesun I. Rheological properties of vinyl polysiloxane impression pastes. Dent Mater. 2001;17(6):471-6.

3 McCabe J, Bowman A. The rheological properties of dental impression materials. Br Dent J. 1981;151(6):179.

4 Arora M, Kohli S, Kalsi R. Influence of Custom Trays, Dual-Arch Passive, Flexed Trays and Viscosities of Elastomeric Impression Materials on Working Dies. J Clin Diagn Res. 2016;10(5):Zc112-6.

5 Hamalian TA, Nasr E, Chidiac JJ. Impression materials in fixed prosthodontics: Influence of choice on clinical procedure. J Prosthodont. 2011;20(2):153-60.

6 Anusavice KJ. Phillips' Science of Dental Materials. 11 ed: Elsevier Saunders; 2003. xxv, 805 p. : ill ; 27 cm.p.

7 Tolley L, Craig R. Viscoelastic properties of elastomeric impression materials: polysulphide, silicone and polyether rubbers. J Oral Rehabil. 2007;5(2):121-8.

8 ISO4823. Dentistry - Elastomeric Impression Materials - ISO 4823:2000/Amd.1.2007(E). 2007. p. 1-33.

9 Ud Din S, Noor N, Humayoun S, Khalid S, Parker S, M P. Tensile strength of novel experimental hydrophilic vinyl polysiloxane impression materials compared to control and commercial VPS impression materials. J Islamabad Med Dent Coll. 2018;7(1):69-72.

10 Oh Y, Lee D, Hwang S, Kim K, Kim K. Effect of non-ionic surfactants on surface properties of hydrophilic polyvinyl siloxane impression materials. Colloids Surf A Physicochem Eng Asp. 2003;229(1-3):9-17.

11 ADA. Specification No. 19 for non-aqueous, elastomeric dental impressions. J Am Dent Assoc. 1977;94:733-41.

12 Helvey GA. Elastomeric impression materials: factors to consider. Compendium of continuing education in dentistry (Jamesburg, NJ : 1995). 2011;32(8):58-9.

13 Latham DP. Controlled release of salicylic acid from silicone delivery systems. Queen Mary, University of London: Queen Mary, University of London; 2006.

14 Ud Din S, Parker S, Braden M, Tomlins P, Patel M. Experimental hydrophilic vinyl polysiloxane (VPS) impression materials incorporating a novel surfactant compared with commercial VPS. Dent Mater : Official publication of the Academy of Dental Materials. 2017;33(8):e301-e9.

15 Ud Din S, Hassan M, Parker S, Patel M. Setting Characteristics Of Three Commercial Vinyl Polysiloxane Impression Materials Measured By An Oscillating Rheometer. Pak Oral Dent J. 2016;36(3).

16 Lee DY, Oh YI, Chung KH, Kim KM, Kim KN. Mechanism study on surface activation of surfactant modified polyvinyl siloxane impression materials. J Appl Polym Sci. 2004;92(4):2395-401.

17 ISO. Dentistry-Elastomeric Impression Materials. 2000. p. 1-33.

18 Ud Din SH, M. Khalid, S. Zafar, S. M. Ahmed, B. Patel, M. Effects of surfactant's molecular weight on the wettability of vinyl polysiloxane impression materials after immersion disinfection. Mater Express. 2018;8(1):85-92.