

## Original Article

# Comparison of Time-dependent Two-dimensional and Three-dimensional Stability with Micro-computerized Tomography and Wettability of Three Impression Materials

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### ABSTRACT

**Objectives:** The objective of this study is to explore time-dependent dimensional stability of three different elastomeric impression materials – vinyl polyether silicone (VPES), vinyl polysiloxane (VPS), and polyether (PE) – through micro-computerized tomography ( $\mu$ -CT) imaging, allows three-dimensional (3D) imaging and measurement without sample preparation or chemical fixation.

**Materials and Methods:** Thirty specimens were created using 3 mm high, 30 mm wide Teflon molds ( $n = 10$ ). Specimens were scanned with  $\mu$ -CT on the 1<sup>st</sup> (T1) h and 1<sup>st</sup> (T2), 7<sup>th</sup> (T3), and 14<sup>th</sup> (T4) days. 3D models were created at the above-mentioned times, volumetric measurements were conducted and dimensional changes were calculated. Diameters and heights of each impression material were measured with 2D analyses. Furthermore, contact angle measurements of these elastomeric impression materials were collected using the sessile drop method during and after polymerization at 0, 2, 5, 20, 60, 120, and 240 s. These measurements were made on specimens ( $n = 10$ ) prepared in standard sizes using a 50  $\mu$ m deep stainless steel die with dimensions of 62 mm  $\times$  20 mm  $\times$  3 mm.

**Results:** Evaluation of the dimensional volume changes of the VPES, VPS, and PE measurements showed there to be no statistically significant differences between the T1, T2, T3, and T4 ( $P > 0.05$ ). Only the decreases in the volume averages of T3 and T4 in the VPES were statistically significant ( $P < 0.05$ ). As a result of binary comparisons, the evaluation of contact angle measurements of VPES, VPS, and PE materials during and after polymerization were compared. The average contact angle measurements of the VPS group were statistically significantly lower than the averages of the VPES and PE groups ( $P < 0.01$ ). **Conclusions:** VPS was found to be the most stable impression material concerning dimensional change and wettability.

**KEYWORDS:** Contact angle, dimensional stability, elastomeric impression materials, micro-computerized tomography

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## INTRODUCTION

The selection of the impression material appropriate for the existing conditions is an important issue.<sup>[1]</sup> The characteristics of the materials must be well known so that the selection could be made accurately.<sup>[2]</sup>

The dimensional stability of the impression material could have an influence on the accuracy of the final restoration. Nowadays, VPS and polyether (PE) are the

most preferred elastomeric impression materials due to their extraordinary clinical properties and minimal dimensional change.<sup>[3]</sup>

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Although VPS impression material is expensive, it is popular due to its excellent physical properties, superior dimensional stability, and ease of use. The only disadvantage of VPS impression material is its hydrophobic quality.<sup>[4]</sup> Anionic surfactants are added to the formulation to increase the wettability of VPS impression material. These molecules were reported to increase the surface energy of the polymerized material.<sup>[5]</sup> The VPS (Monopren transfer; Kettenbach) impression material is hydrophilic. It is viscose (thixotropic) under pressure, and the hardness grade is A.

PE impression materials are hydrophilic impression material with high dimensional stability. The only disadvantage of PE impression material is that deformations could occur when removed from the undercut zones. The impression material (Penta soft; 3M ESPE) could be used for the impressions of crown-bridge prostheses, inlay-onlay crowns, fixed prostheses, functional prostheses, on-implant structure, and partial prostheses.

In recent years, the use of new hybrid impression material has been introduced by corporations that combine the best features of VPS and PE impression material and eliminate the weaknesses.<sup>[6]</sup> These impression materials were marketed with names such as vinyl PE silicone (VPES) (EXA'lence; GC) or vinyl siloxane ether (Identium; Kettenbach) and are reported to have the superior tear resistance and dimensional stability of VPS, hydrophilic property, and wettability of PE.<sup>[7]</sup> The majority of the VPES impression material include a combination of vinyl siloxane ether (10%–50%), methyl hydrogen dimethylpolysiloxane (3%–10%), and silicon dioxide (65%–30%).<sup>[8]</sup>

The contraction rate of the elastomeric impression material varies within the 24 h after removal from the mouth. Approximately 50% of the contraction occurs within the 1<sup>st</sup> h after removal from the mouth.<sup>[9,10]</sup> Within the time from, the impression to casting of the mold, the change that occurs in the precision of the impression is called dimensional stability. There should be no dimensional change in an ideal impression material.

Different methods have been used to evaluate the dimensional change of the impression material. With micro-computerized tomography ( $\mu$ -CT), which is a new method, three-dimensional (3D) impressions could be taken without damaging the material.<sup>[11-13]</sup>  $\mu$ -CT scanning and 3D model analysis of the specimens allows us to obtain more accurate data.<sup>[14]</sup>

In addition to its excellent physical properties, superior dimensional stability and ease of use, VPS is hydrophobic. Water contact angles are often used to determine the

hydrophilic properties of impression materials.<sup>[15]</sup> It has been reported that some new types of VPS impression material introduced in recent years exhibit similar or even lower contact angle values when compared to PE impression material.<sup>[16]</sup> The hydrophilicity of the impression material is gaining importance both at the clinical and laboratory stages. Very limited information is available regarding the 3D stability change and hydrophilicity of impression materials.

The  $H_0$ , a hypothesis of this study was that there were no significant differences in the dimensional stability of VPES, VPS, and PE during 14 days.  $H_0$ , b hypothesis states that there was no difference between the contact angles of utilized impression material.

## MATERIALS AND METHODS

Elastomeric impression materials used in the study were VPES (EXA'lence 370 Monophase; GC), VPS (Monopren Transfer 1:1; Kettenbach), and PE (Impregum Penta Soft; 3M ESPE). These impression materials are shown in Table 1.

Automatic mixers were used to create a homogeneous mixture of the three impression material pastes. According to ADA/ANSI classification No: 19, standard Teflon mold specimens in 3 mm height and 30 mm diameter were prepared by a single individual [Figure 1]. While each sample was being prepared, the first 2 cm inhomogeneous portion of the mixture was discarded. Ten specimens were prepared using each impression material ( $n = 10$ ). A glass plate and a 1 kg load were placed on the impression material that was placed in the mold until the polymerization was completed. Thus, specimens of standard thickness were obtained. Each polymerized specimen was kept in a 2% glutaraldehyde solution for 10 min. The samples were then laved with distilled water for 15 s and stored in vacuumed storage bags. The same procedures were applied to all of the impression materials.

All specimens prepared with elastomeric impression materials were scanned with the  $\mu$ -CT (Sky Scan 1172; Bruker). Each sample was fixed on the rotating platform of the tomography device. Then, the scanning process was initiated. A total of 200–220 sections of 13.6 micron cross-sections were taken from each specimen [Figure 2]. Digital Imaging and Communications in Medicine compatible images of the sections were converted into bitmap picture (BMP) format. Processing and modeling of registration data in CTAn (SkyScan, Contich, Belgium) software was performed as follows:

- a. Transferring the data to the record (Import): The data in BMP format have been moved into the software with the help of the import function in the CTAn basic module

- b. Segmentation: The decomposition was done. A 3D model was created in a format in which the desired region was separated from other structures and displayed in different colors
- Profile Line: Determination of density profile and the working range with Hounsfield unit values of the area to be separated on the axial sections
  - Thresholding: After determining the maximum and minimum intensity of the evaluated values, it was noted that the desired region to be included in the 3D model is within these values
  - Region Growing: This function is intended to remove unwanted image contamination. Image artifacts were eliminated, and the unthinkable constructions included in the 3D model were removed from the evaluation area
- c. Model control and measurement: The obtained 3D model was confirmed by simulated interventions, and the diagnostic evaluation was performed after the desired region was measured. In this step, the software “CTVox” module was used.

Each scanned sample was stored at  $23^{\circ}\text{C} \pm 10^{\circ}\text{C}$  in storage bags. All specimens were scanned with  $\mu\text{-CT}$  on the 1<sup>st</sup> h, 1<sup>st</sup>, 7<sup>th</sup>, and 14<sup>th</sup> days. 3D modeling and volumetric measurement of the three different impression materials were used to calculate the dimensional change after 1<sup>st</sup> h, 1<sup>st</sup>, 7<sup>th</sup>, and 14<sup>th</sup> days [Figure 3]. After volumetric measurements were conducted, diameters and heights of each impression material were measured at three different points to conduct 2D analyses.

In the present study, contact angle measurements for VPES, VPS, and PE impression material were conducted during and after the polymerization using sessile drop technique and postpolymerization by means of stationary dropping method.

#### Wettability measurements during polymerization

The standard specimens were prepared by a single individual with a 50  $\mu\text{m}$  deep 62 mm  $\times$  20 mm  $\times$  3 mm stainless steel mold. A total of 30 specimens were prepared, 10 specimens for each impression material that would be evaluated ( $n = 10$ ). Each impression material was placed in the stainless steel mold according to the manufacturer’s recommendations and using an automatic mixing gun or mixing device. During sample preparation, the first 2 cm nonhomogeneous section of the mixture was not used. The surface was leveled after the samples were placed in the mold. To standardize the effects of humidity and temperature on measurements, ambient conditions were set to 40% humidity and  $20^{\circ}\text{C} \pm 10^{\circ}\text{C}$ . Contact angle measurements of the samples were conducted with OCA 30 (DataPhysics

Instruments GmbH, Filderstadt, Germany). After each sample was placed on the measurement table, the digital video camera was focused on the sample surface, and the test liquid was dropped onto the sample by the software in the desired amount. Distilled water was used as test liquid in the study. A volume of 0.05 ml distilled water was fixed at a 2.5 cm distance and dropped on the impression material [Figure 4]. The contact angle measurement was calculated by taking the arithmetic average of the left and right contact angles of the droplet separately using the digital image.

Contact angles of the impression material were measured at 0, 5, 10, 20, 60, 120, and 240 s in 7 different time periods while the contact angle in the first 25 s was 0 s to compare their wettability due to ISO 4823:2000, the initial contact angle was measured from frozen frames of the video recordings at 25 s after the start of mixing or initial contact (0 s).

#### Postpolymerization contact angle measurements

The measurement instrument used in the postpolymerization wettability measurements, the test measurement conditions, utilized test liquid and the amount, the evaluation time periods were the same as the wettability measurements conducted during polymerization. The standard specimens were prepared by a single individual with a 50  $\mu\text{m}$  deep 62 mm  $\times$  20 mm  $\times$  3 mm stainless steel mold. A total of 30 specimens were prepared, 10 specimens for each impression material that would be evaluated ( $n = 10$ ). A glass plate and a weight of one kilogram were applied until the polymerization of the measuring material placed in the mold was completed. Thus, samples of standard thickness were prepared. The samples were wrapped in aluminum foil and stored for 24 h until contact angle measurements were conducted to avoid surface contamination. Postpolymerization contact angle measurements were conducted 24 h after the preparation. Postpolymerization contact angle measurements were conducted similar to the process conducted during the polymerization.

#### Statistical analysis

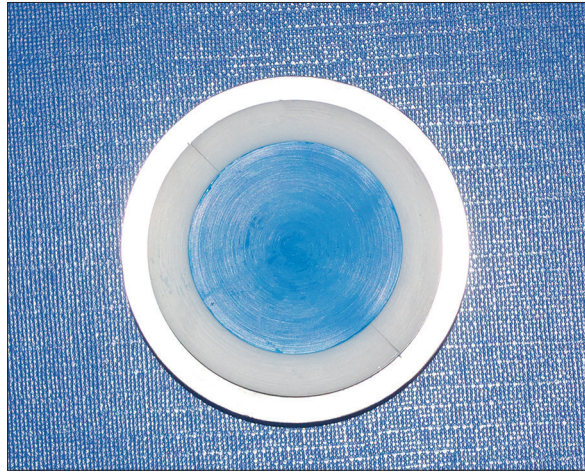
For the statistical analyses, the statistical software (SPSS v22.0, Armonk, NY; IBM Corp) was used to evaluate the findings obtained in the study. Kruskal–Wallis test was used to compare the parameters between groups. Mann–Whitney U-test with Bonferroni correction was used as *post hoc* test when a difference between the groups was identified, and the statistical significance level was accepted as  $P < 0.01$ . The Friedman test was used for intragroup comparisons, and the Wilcoxon Sign Rank test was used to determine the time that is the cause of the difference. Statistical significance was accepted as  $P < 0.05$ .



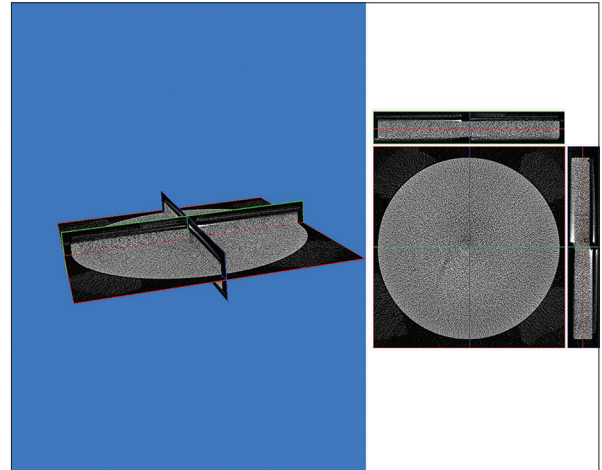
## RESULTS

The mean values and standard deviations of the volumetric measurements are shown in Table 2. After evaluating the dimensional volume changes of

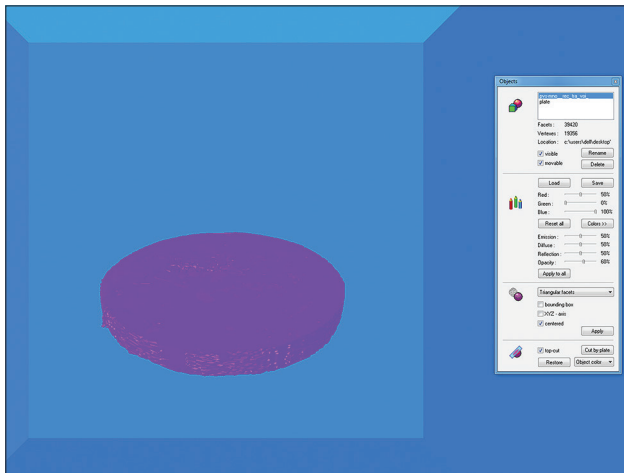
the VPES, VPS, and PE measurements statistically significant differences between the groups of T1, T2, T3, and T4 were not detected in terms of



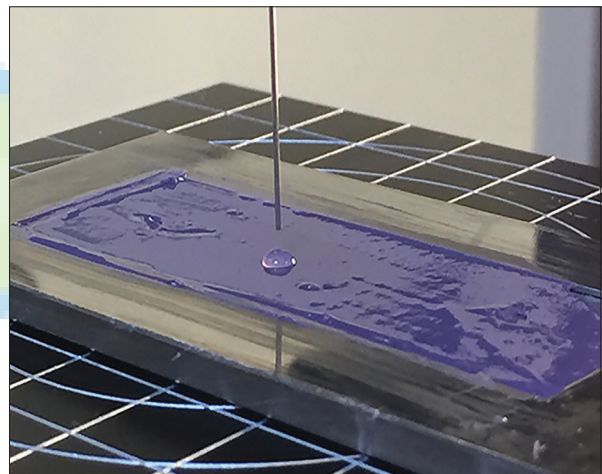
**Figure 1:** The specimen was created using 3 mm high, 30 mm wide Teflon mold



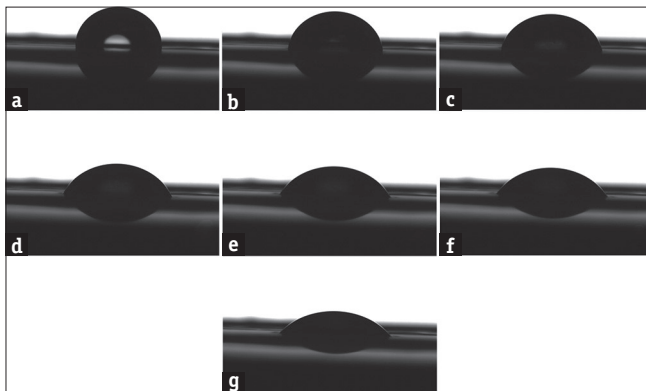
**Figure 2:** Sectional view of the impression material in DataView (V.1.5.1.2; Skyscan)



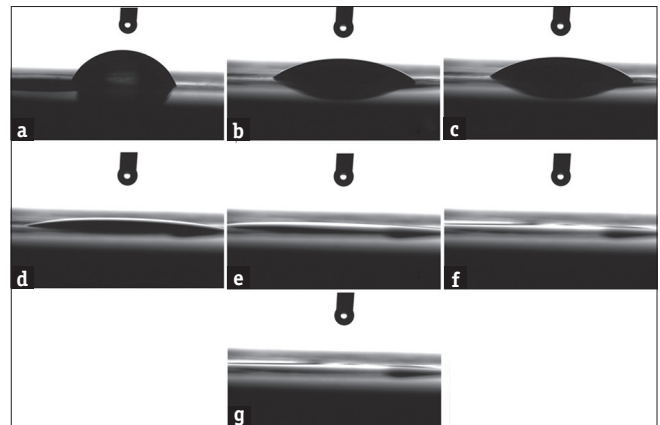
**Figure 3:** Three dimensional image of the impression material in CTAn



**Figure 4:** The drops of distilled water on the impression material



**Figure 5:** During polymerization of contact angle measurements of vinyl polyether silicone using distilled water at each time period (a) 0. s, (b) 5. s, (c) 10. s, (d) 20 s, (e) 60 s, (f) 120 s, (g) 240 s

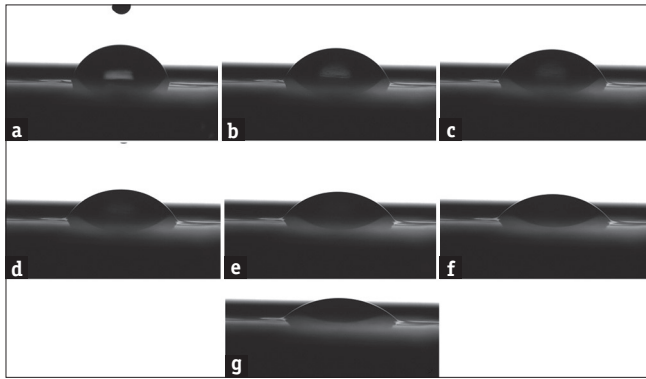


**Figure 6:** During polymerization of contact angle measurements of VPS using distilled water at each time period (a) 0 s, (b) 5 s, (c) 10 s, (d) 20 s, (e) 60 s, (f) 120 s, (g) 240 s

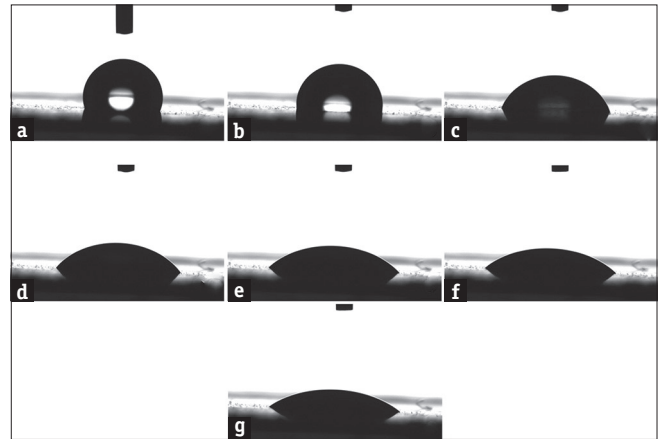
**Table 1: Impression materials and manufacturers**

Product	Type of impression material	Manufacturer	Automatic mixers	Automatic mixer manufacturers
EXA'lence 370 Monophase	Regular set VPES	GC America Inc Alsip, Ill	Modulmix	Zhermack, DS-50, Rovigo, Italy)
Monopren transfer	VPS	Kettenbach, USA	DispenserD2	Zhermack, DS-50, Rovigo, Italy)
Impregum Penta Soft	Medium body PE	3M ESPE AG Seefeld, Germany	Pentamix II	3M ESPE, Seefeld, Germany

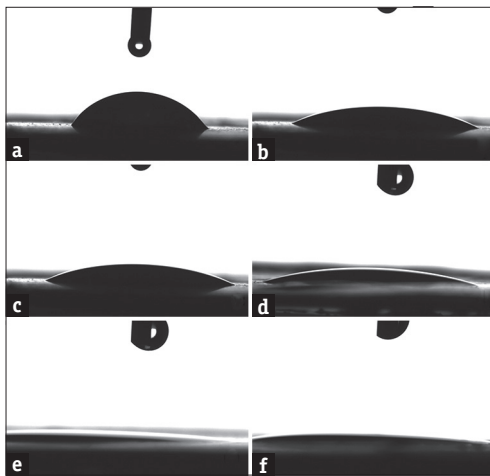
VPES=Vinyl polyether silicone; VPS=Polyvinyl silicone; PE=Polyether



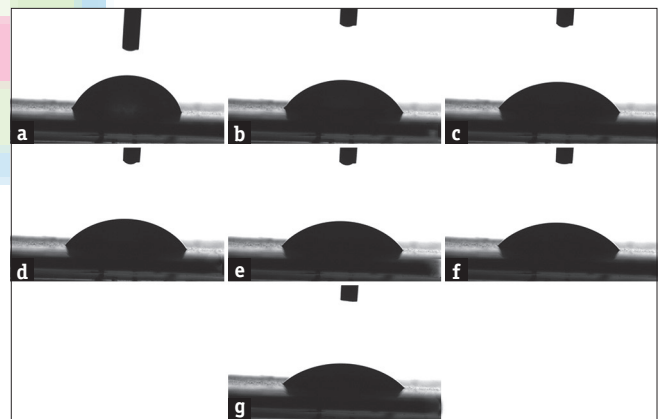
**Figure 7:** During polymerization of contact angle measurements of polyether using distilled water at each time period (a) 0 s, (b) 5 s, (c) 10 s, (d) 20 s, (e) 60 s, (f) 120 s, (g) 240 s



**Figure 8:** Post polymerization of contact angle measurements of vinyl polyether silicone using distilled water at each time period (a) 0 s, (b) 5 s, (c) 10 s, (d) 20 s, (e) 60 s, (f) 120 s, (g) 240 s



**Figure 9:** Post polymerization of contact angle measurements of VPS using distilled water at each time period (a) 0 s, (b) 5 s, (c) 10 s, (d) 20 s, (e) 60 s, (f) 120 s



**Figure 10:** Post polymerization of contact angle measurements of polyether using distilled water at each time period (a) 0 s, (b) 5 s, (c) 10 s, (d) 20 s, (e) 60 s, (f) 120 s, (g) 240 s

volume averages ( $P > 0.05$ ). There were significant differences between within groups. In the VPES group, there was a statistically significant difference between the mean volumes for T1 ( $2248.88 \pm 73.99$ ), T2 ( $2231.11 \pm 46.28$ ), T3 ( $2217.05 \pm 47.23$ ), and T4 ( $2208.12 \pm 62.8$ ) ( $P < 0.05$ ). Decreases in mean volumes for T3 and T4 were statistically significant when compared to T1 ( $P < 0.05$ ). Decreases in mean volumes for T3 and T4 were statistically significant when compared to T2 ( $P < 0.05$ ). In the VPS group, there was no statistically significant difference

between mean volumes for T1 ( $2232.89 \pm 51.75$ ), T2 ( $2235.78 \pm 52.09$ ), T3 ( $2221.78 \pm 42.38$ ), and T4 ( $2218.63 \pm 62.94$ ) ( $P > 0.05$ ). In the PE group, there was no statistically significant difference between mean volumes for T1 ( $2249 \pm 126.71$ ), T2 ( $2235.7 \pm 117.4$ ), T3 ( $2242.5 \pm 117.96$ ), and T4 ( $2235.51 \pm 123.53$ ) ( $P > 0.05$ ).

The mean values of the diametric measurements and standard deviations are presented in Table 3. The T1 ( $30.21 \pm 0.13$ ) diameter measurements

**Table 2: The mean values and standard deviations of the volumetric measurements (mm<sup>3</sup>)**

Volumetric data	Mean±SD			P <sup>a</sup>
	VPES	VPS	PE	
1 h (T1)	2248.88±73.99	2232.89±51.75	2249±126.71	0.842
1 day (T2)	2231.11±46.28	2235.78±52.09	2235.7±117.4	0.475
7 days (T3)	2217.05±47.23	2221.78±42.38	2242.5±117.96	0.705
14 days (T4)	2208.12±62.8	2218.63±62.94	2235.51±123.53	0.991
P <sup>b</sup>	0.004*	0.753	0.392	
T1-T2 P <sup>c</sup>	0.074	0.721	0.241	
T1-T3 P <sup>c</sup>	0.017*	0.139	0.386	
T1-T4 P <sup>c</sup>	0.017*	0.285	0.241	
T2-T3 P <sup>c</sup>	0.028*	0.203	0.721	
T2-T4 P <sup>c</sup>	0.047*	0.386	0.508	
T3-T4 P <sup>c</sup>	0.285	0.799	0.646	

<sup>a</sup>Kruskal–Wallis test, <sup>b</sup>Friedman test, <sup>c</sup>Wilcoxon signed rank test, \*P<0.05. SD=Standard deviation; VPES=Vinyl polyether silicone; VPS=Vinyl polysiloxane; PE=Polyether

**Table 3: Assessment of in-group and intragroup diameter measures (µm)**

Diameter measures	Mean±SD			P <sup>a</sup>
	VPES	VPS	PE	
1 h (T1)	30.2±0.08	30.21±0.13	30.13±0.09	0.026*
1 day (T2)	30.17±0.08	30.21±0.07	30.16±0.04	0.294
7 days (T3)	30.16±0.07	30.15±0.06	30.07±0.06	0.011*
14 days (T4)	30.15±0.05	30.12±0.07	29.98±0.08	0.001*
P <sup>b</sup>	0.045*	0.033*	0.001*	
T1-T2 P <sup>c</sup>	0.646	0.508	0.415	
T1-T3 P <sup>c</sup>	0.017*	0.114	0.047*	
T1-T4 P <sup>c</sup>	0.028*	0.037*	0.005*	
T2-T3 P <sup>c</sup>	0.386	0.022*	0.005*	
T2-T4 P <sup>c</sup>	0.285	0.053	0.241	
T3-T4 P <sup>c</sup>	0.005*	0.005*	0.005*	

<sup>a</sup>Kruskal–Wallis test, <sup>b</sup>Friedman test, <sup>c</sup>Wilcoxon signed rank test, \*P<0.05. SD=Standard deviation; VPES=Vinyl polyether silicone; VPS=Vinyl polysiloxane; PE=Polyether

**Table 4: Assessment of in-group and intragroup height measures (µm)**

Height measures	Mean±SD			P <sup>a</sup>
	VPES	VPS	PE	
1 h (T1)	3.11±0.04	3.16±0.16	3.25±0.17	0.096
1 day (T2)	3.09±0.04	3.13±0.09	3.19±0.13	0.044*
7 days (T3)	3.08±0.04	3.07±0.08	3.21±0.15	0.017*
14 days (T4)	3.06±0.04	3.01±0.07	3.19±0.15	0.001*
P <sup>b</sup>	0.011*	0.001*	0.043*	
T1-T2 P <sup>c</sup>	0.021*	0.327	0.047*	
T1-T3 P <sup>c</sup>	0.008*	0.017*	0.114	
T1-T4 P <sup>c</sup>	0.012*	0.009*	0.017*	
T2-T3 P <sup>c</sup>	0.138	0.009*	0.386	
T2-T4 P <sup>c</sup>	0.037*	0.009*	0.799	
T3-T4 P <sup>c</sup>	0.037*	0.037*	0.386	

\*P < 0.05. <sup>a</sup>Kruskal–Wallis test, <sup>b</sup>Friedman test, <sup>c</sup>Wilcoxon signed rank test. SD=Standard deviation; VPES=Vinyl polyether silicone; VPS=Vinyl polysiloxane; PE=Polyether

**Table 5: Assessment of in-group and between groups contact angles during polymerization**

Contact angle	Mean±SD			P <sup>a</sup>
	VPES	VPS	PE	
0.sec	102.49±7.92	49.94±19.91	80.88±5.16	0.001*
2.sn	90.15±6.72	43±17.77	70.79±4.7	0.001*
5.sn	83.75±5.82	40.45±20.18	67.91±4.71	0.001*
20.sn	72.28±6.21	23.03±24.34	62.87±4.12	0.001*
60.sn	65.98±4.44	9.37±20.07	57.79±3.41	0.001*
120.sn	61.51±4.23	0±0	53.11±4.12	0.001*
240.sn	52.58±6.39	0±0	44.77±5.14	0.001*
P <sup>b</sup>	0.001*	0.001*	0.001*	

<sup>a</sup>Kruskal–Wallis test, <sup>b</sup>Friedman test, \*P<0.05. SD=Standard deviation; VPES=Vinyl polyether silicone; VPS=Vinyl polysiloxane; PE=Polyether

**Table 6: Assessment of in-group and between groups contact angles after 24 h**

Contact angles after 24 h	Mean±SD			P <sup>a</sup>
	VPES	VPS	PE	
0.sec	109.51±13.92	35.36±11.63	75.63±4.75	0.001*
2.sn	104.77±15.48	26.28±17.37	67.85±8.32	0.001*
5.sn	84.48±17.55	10.81±13.48	65.56±8.68	0.001*
20.sn	56.83±4.45	2.93±4.88	63.22±8.96	0.001*
60.sn	49.32±3.89	0.56±1.77	59.26±8.49	0.001*
120.sn	44.33±2.31	0±0	54.51±4.01	0.001*
240.sn	38.71±2.21	0±0	48.3±3.05	0.001*
P <sup>b</sup>	0.001*	0.001*	0.001*	

<sup>a</sup>Kruskal–Wallis test, <sup>b</sup>Friedman test, \*P < 0.05. SD=Standard deviation; VPES=Vinyl polyether silicone; VPS=Vinyl polysiloxane; PE=Polyether

of the VPS were statistically significantly higher than those (30.13 ± 0.09) of the PE (P < 0.017). In addition, the T3 (30.07 ± 0.06) and T4 (29.98 ± 0.08) diameter measurements of the PE were statistically significantly lower than those of the VPES and VPS (P < 0.017).

Mean values and standard deviations for height measurements are presented in Table 4. The T2 (3.09 ± 0.04) height measurements of the VPES were statistically significantly lower than those of the PE (3.19 ± 0.13) (P < 0.017). Finally, the T3 (3.21 ± 0.15) and T4 (3.19 ± 0.15) height measurements of the PE were statistically significantly higher than those of the VPES and VPS (P < 0.017).

The mean contact angle values and standard deviations for the impression material during polymerization are presented in Table 5 and Figures 5–7. The mean contact angle values and standard deviations for the impression material after polymerization are presented in Table 6 and Figures 8–10.



## DISCUSSION

Different clinical conditions require the use of different impression material. The selection of the impression material appropriate for the prevailing conditions is of utmost importance. The characteristics of the materials must be known precisely to make an accurate selection. There is no impression material with ideal properties. However, with the development of nanotechnology, studies are conducted to produce the most suitable impression material possible. Physical and chemical properties such as dimensional stability, tearing resistance, and biocompatibility of the materials have been tried to be improved by the studies made. In this study, dimensional changes and wettability of three impression material, namely, VPES, VPS, and PE were determined and then compared to each other. Even though a new hybrid impression material named VPES has been introduced by combining the best features of VPS and PE impression materials, the wettability of VPES did not surpass the one of VPS.

The first analysis of the specimen from the  $\mu$ -CT scanner takes 1 h to be completed. When the dimensional changes of the impression material were evaluated for 14 days, it was observed that there was no difference between them. Furthermore, it was determined that there was a difference between the contact angle measurements conducted in 7 different time periods and for 240 s.

Doshi *et al.*<sup>[17]</sup> examined the linear dimensional change, which when compared to condensation silicones (Zetaplus; Zhermack) and PE impression materials (Impregum F; 3M ESPE), showed better results with silicone admixtures (Exaflex; GC). Nassar and Chow.<sup>[8]</sup> assessed the two-dimensional surface detail of VPS and VPES, using a light microscope; where it was found that the VPES impression material demonstrated lower dimensional change when compared to the VPS impression material. However, this research determined that the VPES and VPS impression material exhibited similar and minimal dimensional changes.

Nassar *et al.*<sup>[18]</sup> evaluated the dimensional changes in VPES (EXA 'lence 370), VPS (Imprint 3) and PE (Impregum penta soft) elastomeric impression material for 14 days, using a digital micrometer. It was found that the minimal dimensional change occurred in VPS impression material after 2 weeks. This study found that the VPES and VPS impression material displayed equivalent minimal polymer shrinkage during the 14 days it was observed. The second finding, which states that the PE impression material exhibited higher shrinkage on the 7<sup>th</sup> and 14<sup>th</sup> days, supported the

above-mentioned evaluation Nassar *et al.*<sup>[18]</sup> made. Mehta *et al.*<sup>[19]</sup> investigated the time-dependent dimensional change in monophasic VPS (Aquasil; Caulk/Dentsply) and regular/medium body VPS (Reprosil; Caulk/Dentsply). The results of which were similar to this research finding, where the VPS impression material did not exhibit any dimensional change until the 7<sup>th</sup> day.

In comparison to the previous research references mentioned above, this research conducted quantitative 3D image analysis with  $\mu$ -CT. Furthermore, with  $\mu$ -CT, the whole specimen could be examined without damage to the specimen and the analysis could be repeated.<sup>[20]</sup>

When the 2D and the 3D measurements were compared, the finding of this study showed difference in the values of dimensional stability. While using a few reference points to perform a 2D analysis of the dimensional stability values, more differences were discovered; however, when the specimen was analyzed as a whole those differences were not detected. The finding of this study confirmed that, rather than calculating dimensional stability with 2D analysis, 3D analysis of  $\mu$ -CT technique shows more definitive measurement results. If all of the previous research done in 2D were to be repeated with 3D analysis of the  $\mu$ -CT technique, different results may be obtained.

Kugel *et al.*<sup>[15]</sup> compared contact angles for polyvinyl siloxane with hydrophilic properties and PE impression material using Drop Shape Analysis System (DSA10). PE Impregum impression material demonstrated a lower contact angle value. German *et al.*<sup>[21]</sup> found that the initial increase in elastomeric impression material viscosity was observed at 90 s. In the present study, time periods were determined to be more frequent during the initial 120 s and 240 s in total (0, 2, 5, 20, 60, 120, and 240 s), to compare the wettability of elastomeric impression material.

Menees *et al.*<sup>[22]</sup> compared the wettability of the measuring materials by measuring the contact angle of the elastomeric material at five different time intervals. They found that the contact angles of modified polyvinyl silicone impression material and hybrid impression material (Identicum) were small and their wettability was high. In the present study, contact angles for VPS (Monopren Transfer, Kettenbach), VPES (EXA'ye 370 Monophase, GC America), and PE (Impregum Penta Soft, 3M ESPE) were measured for 240 s in 7 different time periods and their wettability was compared. VPS demonstrated a lower contact angle when compared to PE during polymerization.

Mondon and Ziegler.<sup>[23]</sup> compared the wettability of PE and VPS (Impregum Penta Soft and Aquasil) with

different chemical compositions using time-based contact angle measurements. It was observed that Impregum Penta Soft had lower contact angle when compared to Aquasil silicone and it had higher wettability. In the present study, the contact angles of the elastomeric impression material were lower in the VPS group when compared to the VPES and PE groups. The mean contact angles in the PE group were lower than the VPES group. The best wettability was observed with VPS followed by PE, while the least wettability was observed with VPES.

While this study evaluates the dimensional change and wettability of elastomeric impression materials, the dimensional stability and wettability of the nonelastomeric and elastomeric polysulfide used in dentistry have not been investigated. The dimensional change of elastomeric impression material was compared using the  $\mu$ -CT method; however, the main mold was not used as the control group. After the findings of this study were concluded, it can be suggested that further research is needed using digital impression techniques. Furthermore, saliva could be used instead of distilled water during the examination of the wettability of elastomeric impression material.

## CONCLUSIONS

The following results were obtained in the present *in vitro* study:

- VPS, VPES, and PE impression material exhibited similar dimensional stability values. However, it was found that VPS (Monopren transfer) impression material was the best in dimensional stability and wettability
- PE impression material displayed a larger change in diameter measurements conducted with  $\mu$ -CT
- Contact angle averages for the VPS group were significantly lower when compared to mean VPES and PE group figures. Contact angle averages for the PE group were significantly lower when compared to that of the VPES group
- The contact angle values for the utilized impression material were smaller than 90°, VPES, VPS, and PE demonstrated good wettability properties.

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## Conflicts of interest

There are no conflicts of interest.

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