Moisture Effect on Polyether and Polyvinylsiloxane Dimensional Accuracy and Detail Reproduction

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Purpose: This investigation evaluated and compared the dimensional accuracy and surface detail reproduction of two hydrophilic polyvinylsiloxane (PVS) and two polyether (PE) impression materials when used under dry and moist conditions.

Methods: Impressions were made of stainless steel dies as described in ANSI/ADA specification no. 19, with two vertical and three horizontal lines inscribed on the die superior surface. Impressions were made under dry and moist conditions (17 impressions per condition for each material). Dimensional accuracy was measured by comparing the average length of the middle horizontal line in each impression with the same line on the metal die using a measuring microscope with an accuracy of 0.001 mm. Surface detail reproduction was evaluated by using criteria similar to ADA specification no. 19: continuous replication of at least two of the three horizontal lines.

Results: The mean percent dimensional change and SD values ranged from −0.135% (0.035) to 0.053% (0.031). A two-way analysis of variance (ANOVA) indicated that moisture did not cause significant adverse effects on the dimensional accuracy of any material ($p > 0.05$); however, significant differences were found between the materials ($p < .05$). The surface detail evaluation indicated that moisture had a significant effect on detail reproduction of PVS materials (Pearson's Chi square, $p < 0.05$). Under dry conditions, all materials produced satisfactory detail reproduction 100% of the time; however, under moist conditions, only 29% of Aquasil and Genie Ultra PVS impressions produced satisfactory detail reproduction, while 100% of Permadyne Garant and Impregum Penta Soft PE impressions still met the surface detail criteria.

Conclusions: Although moisture may not adversely affect the dimensional accuracy of either PE or hydrophilic PVS material, the evidence suggests that PE material is more likely to produce impressions with superior detail reproduction in the presence of moisture.

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INDEX WORDS: impression material, hydrophilic, surface detail, polyvinylsiloxane

A MAJOR LIMITATION of polyvinylsiloxane (PVS) impression materials has been their hydrophobicity.[1,2] The hydrophobic properties are related to the material's chemical structure, which contains hydrophobic, aliphatic hydrocarbon groups surrounding the siloxane bond.[3,4] In contrast to PVS, polyether (PE) impression material is more hydrophilic because it contains functional groups [carbonyl (C = O) and ether (C-O-C)] that attract and interact with water molecules.[3,5] To overcome PVS hydrophobicity, manufacturers have incorporated surfactants (nonylphenoxypolyethanol homologues)[6,7] and marketed these materials as hydrophilic PVS.

In addition to enhanced wetting of the set impression material by gypsum products,[8-10] the inherent hydrophilic composition of PE impression

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material and the addition of hydrophilic surfactants to PVS should facilitate the wetting of moist oral tissues and tooth surfaces with the unset impression material and thus enhance surface detail reproduction.[11] However, impression materials with hydrophilic structures may also be more prone to moisture absorption and resultant decreased dimensional accuracy.

The purpose of this investigation was to evaluate and compare the dimensional accuracy and surface detail reproduction of two hydrophilic PVS and two PE impression materials when used under dry and moist conditions.

Materials and Methods

The materials used in this study are listed in Table 1. Seventeen impressions of each material were made under each of the two conditions, dry and moist. Manufacturer's mixing instructions were followed for all procedures. On the basis of dimensional accuracy pilot data and a power analysis, it was determined that 17 specimens per group would meet the constraints of $\alpha = .05$ and power $= 0.80$.

Two standardized stainless steel dies, similar to those described in ANSI/ADA specification no. 19,[12] scored with three horizontal and two vertical lines, were used for impression making (Fig 1). The horizontal lines (0.016×20 mm) were labeled 1, 2, and 3. The dies were assigned to either dry or moist conditions. Prior to impression making, the dies were wiped with an alcohol-soaked 2×2 cotton gauze to remove any residue and allowed to air dry. Care was taken to avoid contamination of the surface of the die prior to making impressions.

Impregum Penta impressions were made using prepackaged cartridges and the Pentamix electric mixing unit (3M ESPE). Aquasil, Genie, and Permadyne Garant impressions were made using automixing impression guns (Dentsply/Caulk or 3M ESPE) and prepackaged cartridges of each of the impression materials. Latex gloves were not worn during material application because of their potential inhibitory effect on the polymerization of PVS material.[13] The cartridges were bled in compliance with manufacturer's recommendations to ensure proper dispensing ratios.

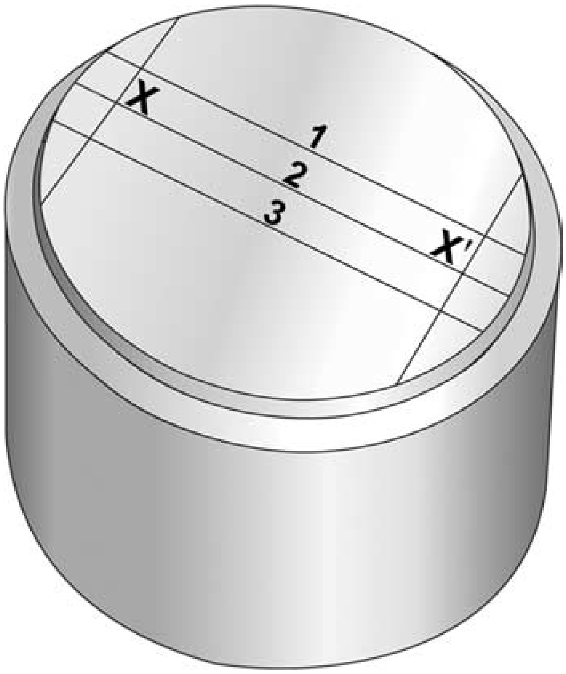

Figure 1. Stainless steel die with three horizontal lines (1, 2, 3) and two vertical lines. Intersection of cross lines X and X' served as beginning and end points of line used for the measurement of dimensional accuracy.

For impressions made under dry conditions, the impression material was applied to the lined area of the dies from a fine-tipped impression syringe (Dentsply/Caulk) for Pentamix Impregum or dispensed directly from the automixing gun with an intraoral tip for Aquasil, Genie, and Permadyne. The impression material was pushed ahead of the syringe tip in a zigzag pattern with tip buried in the material. Custom-made plastic molds were placed on the beveled edges of each die to contain the material and to ensure a consistent thickness of 3 mm. A polyethylene sheet (DensSilk, Reliance, Worth, IL) and a rigid, flat, metal plate were placed on the top of the molds to contain the material. According to ADA specification no. 19, the dies

Table 1. Impression Materials Used

Product	*Manufacturer*	*Type*	*Viscosity*	*Lot Number*
Aquasil Monophase	Dentsply/Caulk, Milford, DE	Polyvinylsiloxane	Medium	010517
Genie Ultra Hydrophilic	Sultan Chemists, Inc., Englewood, NJ	Polyvinylsiloxane	Low	24417
Impregum Penta Soft	3M ESPE, St. Paul, MN	Polyether	Medium	B144735 C145761
Permadyne Garant	3M ESPE	Polyether	Low	B140661 C141374

with the applied impression material were transferred into a water bath maintained at 32 ± 2°C to simulate polymerization in the aqueous oral environment.[12] The impressions were allowed to set for 3 minutes longer than manufacturer's recommended minimal removal time as indicated in the specification.

For impressions made under moist conditions, a fine mist of water (32 ± 2°C) was applied to the die surface before the impression material was applied. Care was taken to ensure that the entire die was covered with a uniform mist of water, avoiding any excess or beading. The same procedures described previously were then followed to obtain the impressions.

After removal from the dies, each impression was coded to ensure blind evaluation by the examiner. All the impression materials were of different colors; thus, although the investigator could not distinguish the condition under which the impression was made, the impression material could be identified.

Surface detail reproduction was evaluated immediately after the impressions were recovered from the dies. If at least two of the three horizontal lines were reproduced continuously between cross-points, the impression was considered satisfactory; all others were rated unsatisfactory.

Dimensional accuracy was evaluated 24 hours after making each impression. The length of Line 2 was measured between cross-points X and X' for each impression (Fig 1). This measurement was made thrice to the nearest 0.001 mm at 10× magnification (measuring microscope, Unitron Bi5-3174, Bohemia, NY). The three measurements were averaged and compared to the Line 2 measurement from the metal die used to make the impression. The percent change from the metal die was computed using the following equation:

$$[(\text{mean impression measurement} - \text{standard die measurement}/\text{standard die measurement}) \times 100].$$

A Pearson's Chi square ($\alpha = 0.05$) was used to compare surface detail reproduction, and a 2-factor analysis of variance (ANOVA, $\alpha = 0.05$) was used to compare the mean percent dimensional changes, with a least significant difference (LSD) post hoc test.

Results

The mean percent changes and standard deviations between the measurement on the impressions and the standard die are presented in Figure 2. Mean percent changes for Aquasil PVS, Genie PVS, and Permadyne PE are presented as negative values, meaning the impressions were smaller than the standard die; Impregum PE positive mean percent change values signify that the impressions were larger than the standard die.

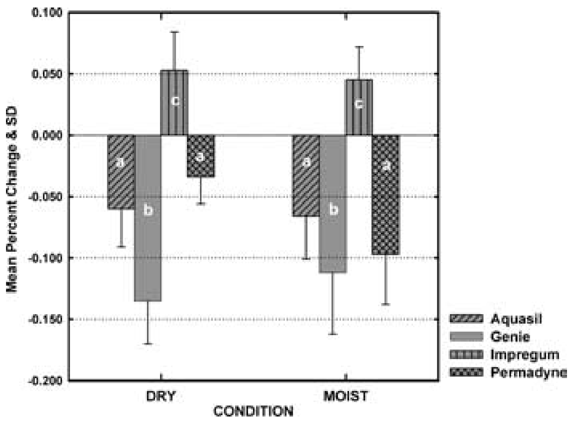

Figure 2. Means and standard deviations of percent dimensional change between each impression material and metal die. Dry and moist refer to conditions under which impressions were made. No significant effect from moisture ($p > 0.05$) occurred. Significant difference ($p < 0.05$) based on material groups are indicated by letters a–c. However, all measurements were within the ADA specification, ≤0.5% dimensional change.

A 2-factor ANOVA indicated that moisture did not cause significant adverse effects on the dimensional accuracy of any material; however, significant differences were found between materials ($p < 0.05$). The LSD post hoc test indicated that Impregum PE and Genie PVS were significantly different from each other and from Aquasil PVS and Permadyne PE. The mean percent change of Impregum PE and Genie PVS across conditions was +0.049% (0.029) and −0.133% (0.043), respectively, and the mean percent change of Aquasil PVS and Permadyne PE across conditions was −0.063% (0.033%) and −0.065% (0.031%), respectively. In spite of the significant differences between materials, all materials exhibited acceptable dimensional accuracy well below the ADA specification standard of ≤0.5% dimensional change.

Data for surface detail reproduction based on the criteria similar to ADA specification no. 19 (two of the three horizontal lines reproduced continuously between cross-points) are shown in Table 2. Dry and moist conditions had a significant effect on the detail reproduction for only the PVS materials (Pearson's Chi square, $p < 0.05$). Impressions made from all materials under dry conditions were 100% satisfactory. Under moist

Table 2. Percentage of Satisfactory and Unsatisfactory Impressions According to ADA Specification No. 19 for Surface Detail Reproduction

Impression Materials	*Condition N = 17*	*Satisfactory (%)*	*Unsatisfactory (%)*
Aquasil	Dry	100	0
(PVS)	Moist	29	71*
Genie	Dry	100	0
(PVS)	Moist	29	71*
Permadyne	Dry	100	0
(PE)	Moist	100	0
Impregum	Dry	100	0
(PE)	Moist	100	0

*Moisture had a significant adverse effect on detail reproduction of PVS materials (Pearson's Chi square, $p < 0.05$).

conditions, 100% of the PE impressions were also satisfactory, but only 29% of the PVS impressions were satisfactory. Impressions in Figure 3 represent a satisfactory and unsatisfactory impression for detail reproduction.

Discussion

PVS and PE impression materials have exhibited good dimensional accuracy when allowed to polymerize in a dry field.[11,14] The results of this investigation also suggest that the presence of moisture does not adversely affect the dimensional accuracy of the hydrophilic PVS and PE impression materials used in this study. ADA specification no. 19 criteria state that elastomeric impression materials should not display more than 0.5% dimensional change after 24 hours of polymerization of the material.[12] Even when impressions were made under moist conditions, all materials in this investigation were well within this standard.

Although all dimensional changes were within the ADA specification standard, it is important to note that all of the Impregum PE impressions, whether made under dry or moist conditions, were larger than the standard die; in contrast, the other impression materials produced impressions smaller than the standard die. Previous investigators have reported polyether impression material dimensional expansion as a result of the polyether absorbing moisture.[15,16] In this investigation, Impregum PE impression material expansion occurred under both dry and moist conditions. In

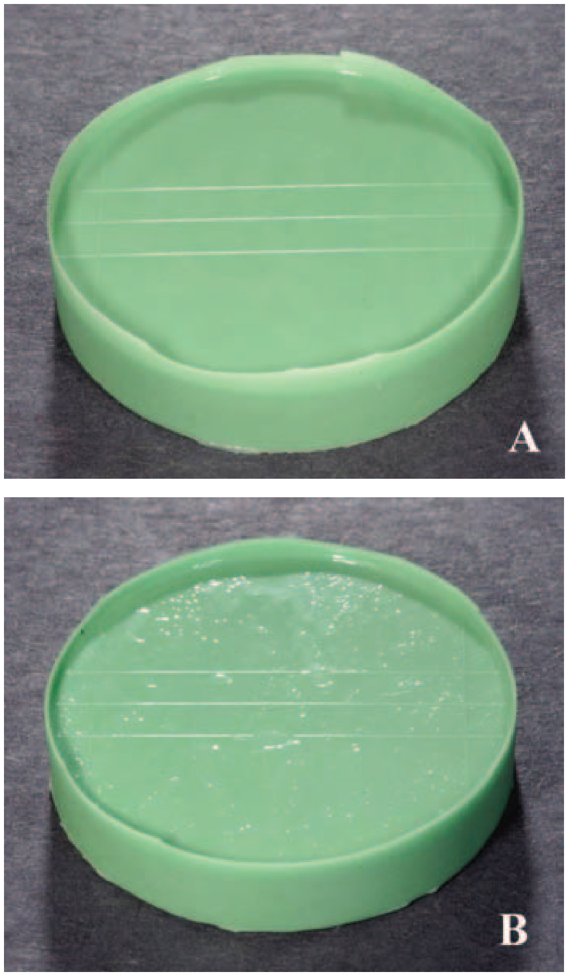

Figure 3. Representative satisfactory (two out of three horizontal lines reproduced continuously between cross-points) (*A*) and unsatisfactory (*B*) impressions.

contrast, Permadyne PE material did not show expansion even under moist conditions. Thus, in this investigation, expansion of polyether material appeared to be material dependent, suggesting that although both polyether materials are made by the same manufacturer there are significant differences in their formulations. Regardless of the exhibited expansion, however, Impregum PE impression material dimensional accuracy was still within clinically acceptable standards.

In addition to the measurement of impression material dimensional accuracy, this study also examined surface detail reproduction. To evaluate the detail reproduction of the impressions made under dry and moist conditions, the assessment was made according to the criteria similar to ADA specification no. 19. The specification states that an elastomeric impression material should be able to continuously replicate 1 of the 0.02 mm width horizontal lines in two out of three specimens.[12] In this investigation, with similar lines (0.016 mm width) scribed on the surface of the metal dies, detail reproduction was based on continuous replication of at least two of the three horizontal lines on each specimen, a slight modification to the specification. This modification was made in order to obtain the power analysis parameters and maintain a manageable sample size.

Several PVS impression material investigations reported conflicting results regarding the ability of PVS impression materials to obtain complete impressions in the presence of moisture.[1,17,18] In one investigation, hydrophilic PVS impression materials used on wet or moist dentin surfaces did not always produce acceptable impressions.[17] Others have reported that hydrophilic PVS materials, some with contact angles $>90°$ (indicating hydrophobicity), always produced acceptable impressions in the presence of moisture.[1,18] The results of the present investigation tend to disagree with the latter results; the PVS materials used in this investigation performed well only under dry conditions.

In contrast, the PE materials in this investigation performed extremely well under moist conditions and produced satisfactory impressions 100% of the time. Previous investigations also reported that PE impression material produced the best detail reproduction of moist surfaces when compared with other materials, such as PVS, polysulfide, and zinc oxide eugenol impression materials.[19,20] These previous reports and the results of this investigation would suggest that the hydrophilic structure of the PE material correlates with excellent detail reproduction even in the presence of moisture.

All the impression materials tested in this in vitro investigation are marketed as hydrophilic; however, the term hydrophilicity is related to two different aspects of the material. One aspect is related to the surface free energy and associated wettability of the polymerized, solid impression material with gypsum slurries.[5,7,21,22] The second aspect involves the surface free energy of the unpolymerized, liquid impression material and the ability to wet the impressed surface.[1,2,5,9,18] This investigation concentrated on the impression materials' ability to wet the impressed surface in the presence of moisture, a modification of ADA specification no. 19 to better replicate impression making in the oral aqueous environment. While the additive surfactants have improved the polymerized PVS material's wettability with dental gypsum materials,[8-10] the evidence from this investigation appears to support the observations of others[2,9] that purported hydrophilic PVS materials remain hydrophobic in the unpolymerized, liquid state and do not adequately impress in the presence of moisture. Conversely, PE materials were able to satisfactorily impress moist die surfaces, reflective of the intrinsic hydrophilic structure of unpolymerized PE.

Because laboratory testing cannot exactly simulate in vivo conditions, the results of any in vitro investigation must be viewed with caution.[23] In the current investigation, impressions were made of standardized stainless steel dies. Metal dies provide calibrated surfaces for precise measurements and comparisons; however, they cannot model the behavior of the oral tissues. For example, the surface free energy of a metal die will be much higher than the surface free energy of prepared teeth and oral soft tissues. Even though the surface free energy and chemical structure of the unpolymerized impression material is critical to the material's ability to wet the impressed surface, the energy of the impressed surface will also influence surface wettability.[24] It is also important to note that the investigation protocol did not include impression trays and tray adhesive; however, when using a tray with adhesive, depending on the bond strength of the adhesive and the stiffness of the tray material, impression shrinkage or expansion would translate into either oversized or undersized dies, respectively. Another limitation of this investigation was that water, rather than saliva or saliva mixed with blood, was used as the source of moisture. The properties of saliva[25] and blood[26] are quite different from the properties of water, and these differences could potentially affect the behavior of the impression material. In spite of these potential limitations, water is a major component of both saliva (~99%) and blood (~50%).[25,26] Therefore, the fundamental focus of this investigation was to evaluate impression material performance in the presence/absence of water and reduce the variables associated with fluid composition.

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Moisture did not cause a significant adverse effect on the dimensional accuracy of the four impression materials (Aquasil PVS, Genie PVS, Impregum PE, and Permadyne PE).
2. There was a statistically significant difference in the dimensional accuracy between the four materials; however, the dimensional change of all the materials was within the ADA specification (<0.5%).
3. Using the criteria similar to ADA specification no. 19 to test detail reproduction, Aquasil and Genie PVS impression materials tested satisfactorily only under dry conditions, while the polyether materials (Impregum and Permadyne) met the criteria 100% of the time under both dry and moist conditions.
4. Although moisture control remains an important factor for successful impressions, the results of this investigation suggest that polyether impression material performs better than PVS in the presence of moisture and may be the material of choice when moisture control is less than ideal.

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