Dimensional accuracy and surface detail reproduction of two hydrophilic vinyl polysiloxane impression materials tested under dry, moist, and wet conditions

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Statement of problem. A major limitation of vinyl polysiloxane (VPS) impression materials is their hydrophobicity. There are 2 aspects to this problem, the wettability of the polymerized impression by dental gypsum materials and the ability of the unpolymerized material to wet intraoral tissues. To address this problem, manufacturers have added surfactants and labeled the new products as *hydrophilic vinyl polysiloxane*.

Purpose. The purpose of this investigation was to compare dimensional accuracy and surface detail reproduction of 2 hydrophilic VPS impression materials, when used under dry, moist, and wet conditions.

Material and methods. A total of 102 impressions were made of stainless steel metal dies similar to those described in American Dental Association (ADA) specification 19. The dies had 2 vertical and 3 horizontal lines inscribed on their superior surfaces. Impressions were made under dry, moist, and wet conditions. Dimensional accuracy was measured by comparing the average length of the middle horizontal line in each impression to the same line on the metal die, by use of a measuring microscope with an accuracy of 0.001 mm. A 2-way analysis of variance and least significant difference post hoc test were used to compare mean dimensional changes (α=.05). Surface detail reproduction was evaluated in 2 ways: (1) by use of criteria similar to ADA specification 19 for detail reproduction, continuous replication of at least 2 of the 3 horizontal lines, and (2) by use of a method developed for this study that categorized the impressions as satisfactory or unsatisfactory based on their surface characteristics: presence of pits, voids, or roughness. Pearson χ^2 (α=.05) was used to compare detail reproduction results.

Results. Conditions (dry, moist, and wet) did not cause significant adverse effects on the dimensional accuracy of either material. The mean dimensional change and SD were 0.005% ± 0.002% or less. With both surface detail analyses, dry, moist, and wet conditions had a significant effect on the detail reproduction of both materials ($P<.05$). Only under dry conditions did both impression materials continuously replicate at least 2 of the 3 horizontal lines 100% of the time. Under moist conditions, 82% of the Aquasil impressions and 100% of the Reprosil impressions were judged satisfactory, while under wet conditions, only 47% Aquasil and 11% Reprosil impressions were satisfactory. With the additional surface detail characterization, only under dry conditions were impressions produced with clinically acceptable surface quality (Aquasil 77% and Reprosil 100% satisfactory).

Conclusions. Dimensional accuracy of both materials tested was well within ADA standards. Best surface detail results were obtained only under dry conditions for both materials. (J Prosthet Dent 2003;90:365-72.)

CLINICAL IMPLICATIONS

Although the 2 impression materials tested in this in vitro investigation are advertised as hydrophilic, evaluation of the impressions' surface characteristics revealed that both materials performed reliably only under dry conditions. Under moist and wet conditions, both materials performed inconsistently. These results suggest that when these materials are used, moisture control remains a vital factor for predictable success.

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The widespread use of additional reaction silicone impression materials, also known as vinyl polysiloxane (VPS) materials, is attributed to their dimensional accuracy and stability.[1,2] Other advantages of VPS materials include excellent elastic recovery, ease of handling, ability to produce multiple casts from 1 impression, and good detail reproducibility.[2-5]

VPS impression materials have application in a wide variety of situations in both fixed and removable prosthodontics.[2,6-8] Accurate reproduction of the prepared tooth or edentulous arch is of critical importance in the fabrication of a fixed or removable restoration. Inaccuracies in the replication process will ultimately have an adverse effect on the fit and adaptation of the final restoration.[1,3,9] VPS impression materials are very accurate when used in clinical dental practice.[1-3,5,10,11] The dimensional accuracy of a material is usually time dependent; for example, a material may be highly dimensionally accurate soon after its initial polymerization but less accurate after storage for a period of time.[3,12] Dentists have been reported to delay pouring of impressions up to 72 hours[13]; therefore, it is important that an impression material remain dimensionally accurate for this period of time. VPS impression materials have demonstrated superior dimensional stability when compared with other elastomeric materials, primarily because they do not release any by-products.[1,3,5,12,14]

A significant limitation of VPS impression materials is their hydrophobicity.[2,4,5,9,15-17] This hydrophobicity can be explained by the material's chemical structure, which contains hydrophobic, aliphatic hydrocarbon groups surrounding the siloxane bond.[3,18] In contrast, polyether and polysulfide impression materials are more hydrophilic than VPS because of chemical structures containing available functional groups that attract and interact with water molecules through hydrogen bonding.[18,19] The hydrophilic structures present in polyether impression material are represented by carbonyl (C=O) and ether (C-O-C) groups, whereas polysulfide impression material contains hydrophilic disulfide (-S-S-) and mercaptan groups (-S-H).[3,18]

There are 2 different aspects of the hydrophobic nature of VPS impression materials. The first aspect relates to the surface free energy of the solid, polymerized VPS, and the high contact angle that typically forms when polymerized VPS impressions are wetted with dental gypsum materials.[4,9,15,17,19] The second aspect relates to the surface free energy of the unpolymerized, liquid phase of the impression material, and the ability or lack of ability of the liquid VPS to wet oral tissues during impression-making.[2,5,16,19,20] In the literature, the term *hydrophobicity* has been used interchangeably to describe these 2 phenomena, creating confusion.[2,5]

As mentioned previously, VPS typically behaves hydrophobically when poured with gypsum slurries.[1,9,15,17] To overcome this limitation, manufacturers have incorporated intrinsic surfactants (nonylphenoxypolyethanol homologues)[4,21] and marketed these materials as hydrophilic VPS. These hydrophilic VPS impression materials have exhibited increased wettability of the polymerized impression with gypsum slurries.[9,17] However, when hydrophilic VPS impression material was used clinically in the presence of moisture in the form of water, saliva, crevicular fluid, or blood, decreased accuracy of the produced impression was reported.[5] This inaccuracy in the presence of moisture suggests that the VPS hydrophilic additives may not enhance the ability of the unpolymerized VPS to wet the oral tissues under partial or complete moisture conditions. The purpose of this study was to evaluate 2 syringe forms of hydrophilic VPS impression materials allowed to polymerize under dry, moist, and wet conditions. The dimensional accuracy and the surface detail reproduction were evaluated on impressions made with the 2 materials under the 3 conditions.

MATERIAL AND METHODS

On the basis of dimensional accuracy pilot data and a power analysis, 51 impressions for each material (17 specimens per group) would meet the constraints of α=.05 and power=.80.

Impression procedure

The materials used in this study were a hydrophilic, medium-bodied, type I VPS impression material (Reprosil, Lot No. 011003, Dentsply/Caulk, Milford, Del) and a quadrafunctional, hydrophilic, heavy-bodied, type I VPS impression material (Aquasil Monophase, lot no. 010517, Dentsply/Caulk). Seventeen impressions of each material were made under each of the 3 conditions, dry, moist, and wet. Manufacturer's mixing instructions were followed for all procedures.

Three standardized stainless steel dies (similar to those described in ADA specification 19),[22] scored with 3 horizontal and 2 vertical lines, were used for impression making. The horizontal lines were labeled 1, 2, and 3. The width of the horizontal lines was 0.016 mm. Two cross-points at the intersection of the vertical lines with line 2 were marked x and x' and served as the beginning and end points of measurements for dimensional accuracy (Fig. 1). The dies were labeled *1, 2,* and *3*, and each die was assigned to 1 of the 3 conditions, dry, moist, or wet, respectively. Before impression making, the dies were ultrasonically cleaned to remove any residue and allowed to air dry. Care was taken to avoid contamination of the surface of the die before making impressions.

Impressions were made using an automixing impression gun (Dentsply/Caulk) and prepackaged cartridges of the impression material. Latex gloves were not worn during material application because of their potential inhibitory effect on the polymerization of VPS materi-

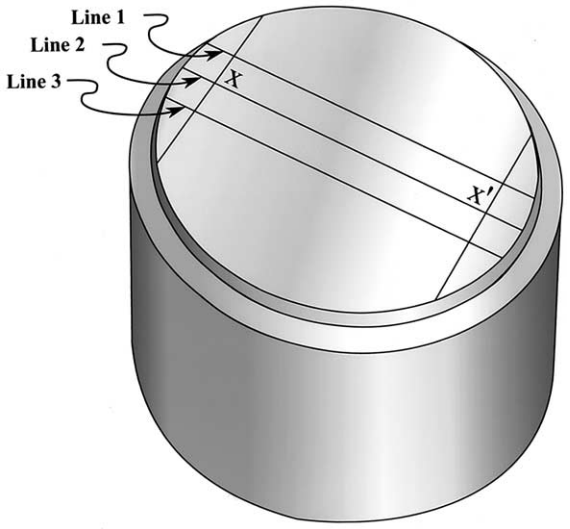

Fig. 1. Stainless steel die with 3 horizontal lines (1, 2, 3) and 2 vertical lines. Intersection of cross lines *x* and *x'* served as beginning and end points of line used for measurement of dimensional accuracy.

als.[23] The cartridge was bled in compliance with manufacturer's recommendations to ensure proper dispensing ratios. For impressions made under dry conditions, the material was loaded into a fine-tipped impression syringe (Dentsply/Caulk) and applied to the lined areas of the dies. The impression material was pushed ahead of the syringe tip. This technique yielded the fewest voids as shown in the pilot study. Custom-made plastic molds were placed on the beveled edges of each die, to contain the material and ensure a consistent thickness of 3 mm. A polyethylene sheet (DensSilk; Reliance, Worth, Ill) and a rigid, flat, metal plate were placed on top of the molds to contain the material as described in ADA specification 19.[22] To simulate oral conditions in which the impression material would polymerize in an aqueous environment, the dies with the applied impression material were transferred into a water bath maintained at 32°C ± 2°C.

For the impressions made under moist conditions, a fine mist of water (32°C ± 2°C) from a spray bottle was applied to the surface of the die before the impression material was syringed onto the die surface. 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 as described above were followed to obtain the impressions.

For making the impressions under wet conditions, the metal die was immersed in a water bath before the application of the impression material. With the tip of the impression syringe under water, the material was injected onto the surface of the die, following the procedure as described previously.

The medium-bodied type I VPS impressions (Reprosil) were recovered from the water bath 9 minutes after the material was first applied onto the die, whereas the heavy-bodied type I impressions (Aquasil) were recovered after 8 minutes. The impressions were allowed to set for 3 minutes longer than manufacturer's recommended minimal removal time as indicated in ADA specification 19 for laboratory testing.[22]

After each impression was allowed to air dry, an alpha numeric coding system was used to ensure blind evaluation. Each impression base was marked with a number that when matched with a master sheet, corresponded to the impression material used and the condition under which the impression was made. Blinded evaluation was used for both the measurement of dimensional accuracy and the evaluation of detail reproduction. The polymerized impressions made from the 2 materials were different colors; thus although the investigators could not distinguish the conditions under which the impressions were made, they could distinguish which of the 2 materials was used.

Evaluation of dimensional accuracy and surface detail reproduction

Dimensional accuracy was evaluated 24 hours after making each impression. A single investigator measured the length of line 2 between cross points x and x' for each impression (Fig. 1). This measurement was made 3 times to the nearest 0.001 mm at original magnification ×10 using a measuring microscope (Unitron Bi5-3174; Bohemia, NY). The 3 measured lengths were averaged and compared with the measurement of line 2 on the metal die used to make the impression.

Two independent examiners also evaluated surface detail reproduction. Surface detail reproduction was evaluated immediately after the impressions were recovered from the dies. Evaluation was achieved using 2 methods. The first evaluation was an assessment of the continuity of line replication according to ADA specification 19[22] with a slight modification. Rather than only evaluate the continuity of 1 of the 3 horizontal lines in 2 out of 3 specimens, all 3 lines were assessed for each specimen. If at least 2 of the 3 horizontal lines were reproduced continuously between cross-points, this impression was considered satisfactory. All others were rated unsatisfactory. This modification was made to attain the power analysis parameters and maintain a manageable sample size.

Preliminary results from the pilot study revealed that although some impressions would be rated satisfactory for detail reproduction according to the protocol described above, they exhibited surface characteristics such as roughness, pits, and voids on other areas of the impression. In clinical situations, if these imperfections were located in critical areas, such as preparation finish lines, they would render the impression unacceptable. It was decided that an additional evaluation of the impres-

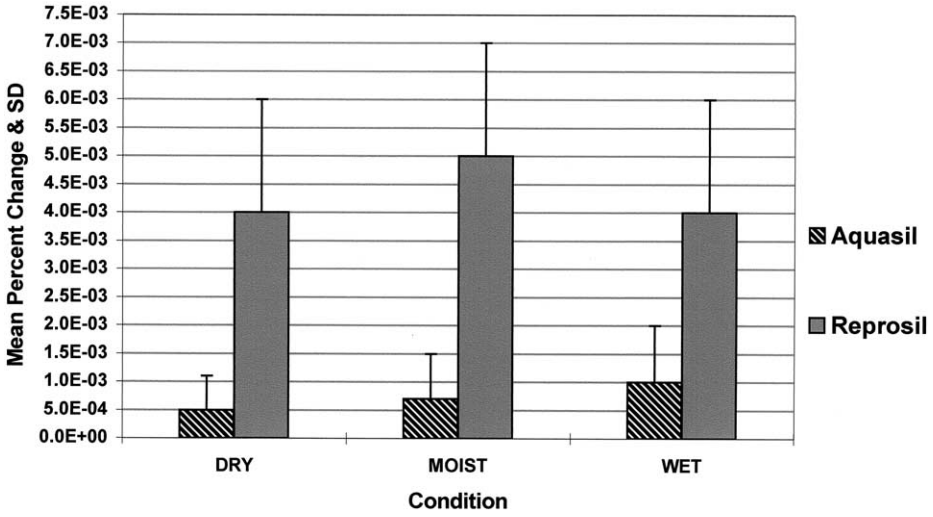

Fig. 2. Mean values and SDs of percent dimensional change between each impression material and metal die. Terms *dry, moist,* and *wet* refer to conditions under which impressions were made.

sions was necessary; consequently, a macroscopic evaluation of the impression's smooth surface was developed and included in this study. For this additional macroscopic evaluation, impressions were rated satisfactory if the entire impression surface was smooth, shiny, and free of voids or pits; and impressions were rated as unsatisfactory if the impression surface was rough or contained any pits or voids.

Statistical analysis

This study used a 2-factor completely randomized design. A 2-way analysis of variance (ANOVA) was used to compare the mean dimensional changes of the 2 materials under the 3 conditions at an $\alpha=.05$ level. The least significant difference (LSD) test was used as a post hoc test for pairwise comparisons. Pearson χ^2 ($\alpha=.05$) was used to compare detail reproduction of the 2 materials under the 3 conditions as determined by criteria similar to ADA specification 19 and the additional smooth surface characteristic evaluation.

RESULTS

The mean scores for the 3 measurements between cross points x and x' (line 2) in each impression were compared with the line 2 measurement obtained from the metal die used for the impression. The percent change from the metal die was computed. The mean percent changes and SDs between the measurement on the impressions and the standard die are displayed graphically in Figure 2.

A 2-way ANOVA was performed on the percent-change data for measured lengths for the 2 impression materials under the 3 conditions. No statistically significant interactive effect was found among conditions (dry, moist, or wet) for either material. This result indicated that the dimensional accuracy as measured by the ADA specification 19 was not affected by the conditions in either material. However, statistically significant differences ($P<.05$) were found between the 2 materials. The heavy-bodied, type I VPS (Aquasil) exhibited less percent change in dimensional accuracy compared to the medium-bodied, type I VPS (Reprosil). Mean percent change of the heavy-bodied, type I VPS (Aquasil) across conditions was 0.0008% ± 0.0009% whereas mean percent change of the medium-bodied, type I VPS (Reprosil) across conditions was 0.004% ± 0.001%. However, when these percent changes in dimensional accuracy were compared with ADA specification 19 standards, both materials exhibited acceptable dimensional accuracy, well below 0.5% dimensional change.[22]

Surface detail reproduction was first evaluated based on criteria similar to ADA specification 19 (2 of the 3 horizontal lines were reproduced continuously between cross-points).[22] Data for the 2 materials under the 3 conditions are shown in Table I. Dry, moist, and wet conditions had a significant effect on the detail reproduction for both materials (Pearson χ^2, $P<.05$). Impressions made from both materials under dry conditions were 100% satisfactory, reproducing at least 2 of 3 lines continuously. Under moist conditions, only 82.4% of the heavy-bodied, type I VPS (Aquasil) impressions were satisfactory, whereas 100% of the medium-bodied, type I VPS (Reprosil) impressions were satisfactory. Under wet conditions, 47.1% of the heavy-bodied, type I VPS (Aquasil) and 11.8% of the medium-bodied, type I VPS (Reprosil) impressions were satisfactory. It should be noted that when a pit or void was seen on a line, this line was considered discontinuous. In Figure 3, impres-

Table I. Percentage of satisfactory and unsatisfactory impressions according to criteria based on ADA specification 19 for acceptable surface detail reproduction

Impression materials	Condition (n = 17)	Satisfactory (%)	Unsatisfactory (%)
Aquasil	Dry	100	0
	Moist	82.4	17.6
	Wet	47.1	52.9
Reprosil	Dry	100	0
	Moist	100	0
	Wet	11.8	88.2

Table II. Percentage of satisfactory and unsatisfactory impressions assessed with additional smooth surface evaluation

Impression materials	Condition (n = 17)	Satisfactory (%)	Unsatisfactory (%)
Aquasil	Dry	76.5	23.5
	Moist	17.6	82.3
	Wet	0	100
Reprosil	Dry	100	0
	Moist	70.6	29.4
	Wet	0	100

Satisfactory: Impression surface was smooth, shiny, and free of voids or pits.
Unsatisfactory: Impression surface was rough or exhibited voids or pits.

sions in *3a* and *3b* are examples of satisfactory impressions for detail reproduction, with at least 2 of 3 horizontal lines continuously reproduced. It is important to note that although the impression in Figure *3b* exhibited imperfections, the imperfections were not directly associated with the horizontal lines and were therefore not accounted for in the ADA specification.

For the additional macroscopic evaluation of the impressions' smooth surfaces, the produced impressions were rated as satisfactory or unsatisfactory, based on the presence or absence of voids or pits on the entire surface of the impression (Table II). Pearson χ^2 revealed that the 3 conditions had a statistically significant effect on each material ($P<.05$). Under dry conditions, 76.5% of the heavy-bodied, type I VPS (Aquasil) impressions were smooth and shiny, whereas 100% of the medium-bodied, type I VPS (Reprosil) impressions were smooth and shiny (Fig. 3). Under moist conditions, only 17.6% of the heavy-bodied, type I VPS (Aquasil) impressions were smooth and shiny, whereas 70.6% of the medium-bodied, type I VPS (Reprosil) impressions were smooth and shiny. Under wet conditions, both materials failed to produce acceptable impressions, because all impressions were pitted and voided. Figure *3b* and *3c* present impressions rated as unsatisfactory because there was evidence of some pitting in the impression's smooth surface.

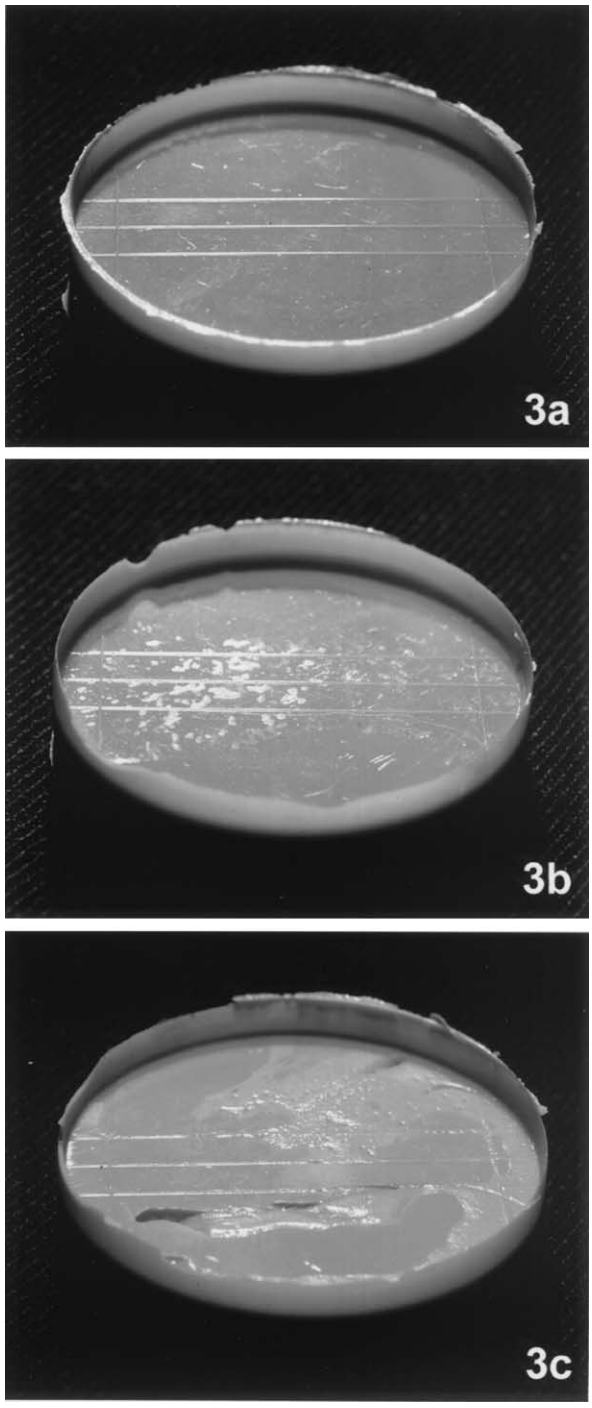

Fig. 3. Representative impressions made with Reprosil material under dry **(3a)**, moist **(3b)**, and wet **(3c)** conditions. Specimen in **3a** was rated satisfactory for detail reproduction according to both criteria based on ADA specification 19 and macroscopic evaluation. Specimen in **3c** was rated unsatisfactory for both evaluation techniques. Specimen in **3b** was acceptable according to criteria based on ADA specification 19 and unacceptable for macroscopic surface evaluation.

DISCUSSION

VPS impression materials have demonstrated very good dimensional accuracy, exhibiting the ability to closely reproduce the dimensions of the impressed surfaces.[1-3,5,10,11] In addition, hydrophilic VPS has exhibited comparable dimensional accuracy to conventional VPS, when allowed to polymerize in a dry field.[24] When ADA specification 19 protocol was used to measure dimensional accuracy, the evidence from this investigation indicated that the dimensional accuracy of 2 hydrophilic VPS impression materials was not adversely affected by the presence of moisture. ADA specification 19 criteria state that elastomeric impression materials should not display more than 0.5% dimensional change after 24 hours of polymerization of the material.[22] Both materials used in this study were well within these standards, displaying mean dimensional changes of 0.005% (±0.002%) or less.

In addition to the measurement of dimensional accuracy, this study also examined detailed reproduction of the hydrophilic VPS impression materials. Clinically, several impression material investigations have concentrated on replication of the finish line of a wet tooth preparation or gingival sulcus reproduction in the presence of crevicular moisture.[16,20,25] These studies have reported conflicting results regarding the ability of VPS impression materials to obtain complete impressions in the presence of moisture. One investigation reported that hydrophilic VPS impression materials when used on wet or moist dentin surfaces did not always produce acceptable impressions.[25] Others have found that even though there appeared to be differences in the contact angle formed between different VPS impression materials and moist tooth surfaces, the hydrophilic VPS always obtained complete impressions.[16,17] The results of this investigation disagree with the latter finding. The 2 impression materials used in this study did not always yield satisfactory impressions under moist or wet conditions.

To evaluate the detail reproduction of the impressions made under dry, moist, and wet conditions with 2 materials, the impressions were evaluated according to criteria similar to ADA specification 19. ADA specification 19 states that an elastomeric impression material should be able to continuously replicate 1 of the 0.02-mm-width horizontal lines in 2 of 3 specimens.[22] In this investigation, with similar lines (0.016-mm width) scribed on the surface of the metal dies, detail reproduction was measured on the basis of continuous replication of at least 2 of the 3 horizontal lines on each specimen, a slight modification to the specification. This modification was made to obtain the power analysis parameters and maintain a manageable sample size. The medium-bodied, type I VPS (Reprosil) could meet this criterion 100% of the time only under dry or moist conditions. In contrast, the heavy-bodied, type I VPS (Aquasil) material met the specification 100% of the time only under dry conditions. Both materials performed unsatisfactorily under completely wet conditions. As mentioned previously, other studies have proposed that both hydrophilic and hydrophobic VPS materials provide adequate detail reproduction.[16,20] However, both of those studies used their own evaluation technique and did not use ADA specification 19 criteria for acceptable detail reproduction.

Preliminary results from the pilot study revealed that in some impressions, there were areas of pits, voids, and roughness not associated with the 3 horizontal lines used for the ADA detail reproduction evaluation. If such pits or voids were located in the preparation margin, the impression would be unacceptable. Therefore an additional macroscopic evaluation of detail reproduction of the smooth surface of the impressions was also included in the present study. The results of this additional evaluation were not consistent with the results of detail reproduction based on the continuous replication of lines. This suggests that an additional evaluation of the smoothness of the entire surface of the impression may be beneficial. The additional evaluation used in this investigation suggested that a dry field is necessary to routinely produce clinically acceptable impressions. Both materials produced the greatest number of smooth and shiny impressions under the dry condition, and both materials failed to produce any smooth and shiny impressions under the wet condition.

The 2 impression materials tested in this in vitro investigation are marketed as hydrophilic. The manufacturer of these 2 materials purports that the materials can wet oral tissues and produce accurate impressions under partial or complete moisture. The term *hydrophilicity* has often been used to describe 2 different properties. One aspect is the adequate wettability of the polymerized, solid impression material with gypsum slurries.[1,9,15,17] This study concentrated on the ability of the unpolymerized, liquid impression material to wet the impressed surface in the presence of moisture, attempting to simulate impression-making under aqueous oral conditions.

The results of this investigation appear to reinforce the ideas suggested by others[2,5] that the so-called hydrophilic VPS materials remain hydrophobic in the unpolymerized, liquid state and will not adequately wet surfaces covered with moisture. Although the additive surfactants have improved the polymerized VPS material's wettability with dental gypsum materials,[9,17] it appears that the impression material still cannot accurately reproduce detail in the presence of moisture. These results suggest that the clinician using these materials should maintain strict moisture control during impression making.

The results of this in vitro investigation should be viewed cautiously because laboratory testing cannot exactly model clinical situations.[26] In this investigation impressions were made of standardized stainless steel

dies. Although the metal dies are calibrated surfaces for precise comparisons, they do not resemble the behavior of the oral tissues. For example, metal dies do not absorb liquids. In addition, the intrinsic surface-free energy of a metal die will be much higher than the surface-free energy of the proteinaceous surfaces of prepared teeth and oral soft tissues. This surface energy of the impressed surface will also affect how well the impression material will wet that surface.[27] Another limitation of this in vitro study is that water instead of saliva was used as the source of moisture. It is well known that properties of saliva[28] are quite different than those of water, and these differences could potentially have affected the behavior of the impression materials. However, in this laboratory study an attempt was made to reduce the variables associated with fluid composition, thus the ability of the impression material to reproduce surface detail was assessed in the presence or absence of water.

The fundamental focus of this work was to evaluate the ability of the VPS material to perform against wet surfaces. This investigation is a first step in understanding the limitations of hydrophilic VPS impression materials when used to record the surface detail of wet oral substrates. Although the moist surface method used in the investigation may appear more clinically relevant, the wet surface method, in which the dies were placed in water before the impression was made, was included to account for a very wet substrate, a worst case scenario. This was intended to produce a surface that was completely coated with water. This is in contrast to oral tissues where there is water at the surface, as well as water within the bulk of the tissue. Water within the bulk tissue can diffuse to the surface during the recording of an impression. It would be very difficult to duplicate this type of moisture contamination in the laboratory, but it does indicate that there are other sources of water present in the mouth that could interfere with the recording of impressions.

The experimental method used in this study should be considered as a preliminary testing of the accuracy and behavior of the hydrophilic impression materials. Further investigation is necessary to assess how the material's properties are affected by the presence of saliva or moisture in the oral cavity.

CONCLUSIONS

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

1. Dimensional accuracy for both hydrophilic VPS impression materials was not significantly affected by the dry, moist, or wet environments.

2. There was a statistically significant difference in the dimensional accuracy between the 2 materials. However, dimensional changes for both materials were well below ADA standards of maximal shrinkage value of 0.5%.

3. Both materials tested satisfactorily with respect to detail reproduction under dry and moist conditions, but not under wet conditions when evaluated according to criteria similar to ADA specification No.19.

4. Further evaluation of the impressions' smooth surfaces revealed that both materials performed satisfactorily under dry conditions but performed inconsistently under moist and wet conditions.

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REFERENCES

1. Craig RG, Powers JM. Restorative dental materials. 11th ed. St Louis: Mosby; 2002. p. 348-68.
2. Mandikos MN. Polyvinylsiloxane impression materials: an update on clinical use. Aust Dent J 1998;43:428-34.
3. Anusavice KJ. Phillips' science of dental materials. 11th ed. Philadelphia: Elsevier Science; 2003. p. 205-31.
4. Craig RG, O'Brien WJ, Power JM. Dental materials: properties and manipulation. 6th ed. St. Louis: Mosby; 1995. p.136-77.
5. Chee WW, Donovan TE. Polyvinylsiloxane impression materials: a review of properties and techniques. J Prosthet Dent 1992;68:728-32.
6. Felton DA, Cooper LF, Scurria MS. Predictable impression procedures for complete dentures. Dent Clin North Am 1996;40:39-51.
7. Loh PL. An alternative for making master impressions for complete dentures. J Am Dent Assoc 1997;128:1436-7.
8. Chaffee NR, Cooper LF, Felton DA. A technique for border molding edentulous impressions using vinyl polysiloxane material. J Prosthodont 1999;8:129-34.
9. Chong YH, Soh G, Setchell DJ, Wickens JL. Relationship between contact angles of die stone on elastomeric impression materials and voids in stone casts. Dent Mater 1990;6:162-6.
10. Lin CC, Ziebert GJ, Donegan SJ, Dhuru VB. Accuracy of impression materials for complete-arch fixed partial dentures. J Prosthet Dent 1988; 59:288-91.
11. Johnson GH, Craig RG. Accuracy of addition silicones as a function of technique. J Prosthet Dent 1986;55:197-203.
12. Williams PT, Jackson DG, Bergman W. An evaluation of the time-dependent dimensional stability of eleven elastomeric impression materials. J Prosthet Dent 1984;52:120-5.
13. Shillingburg HT Jr, Hatch RA, Keenan MP, Hemphill MW. Impression materials and techniques used for cast restorations in eight states. J Am Dent Assoc 1980;100:696-9.
14. Craig RG, Urquiola NJ, Liu CC. Comparison of commercial elastomeric impression materials. Oper Dent 1990;15:94-104.
15. Derrien G, Le Menn G. Evaluation of detail reproduction for three die materials by using scanning electron microscopy and two-dimensional profilometry. J Prosthet Dent 1995;74:1-7.
16. Boening KW, Walter MH, Schuette U. Clinical significance of surface activation of silicone impression materials. J Dent 1998;26:447-52.
17. Pratten DH, Craig RG. Wettability of a hydrophilic addition silicone impression material. J Prosthet Dent 1989;61:197-202.
18. McMurry JE. Fundamentals of organic chemistry. 5th ed. Pacific Grove, CA: Brooks/Cole Publishing; 2002. p. 39-47, 257-68.
19. Van Krevelen DW. Properties of polymers: their correlation and chemical structure: their numerical and prediction and additive group contributions. 3rd ed. Amsterdam: Elsevier; 1997. p. 7-16, 227-336.
20. Takahashi H, Finger WJ. Dentin surface reproduction with hydrophilic and hydrophobic impression materials. Dent Mater 1991;7:197-201.
21. Chai JY, Yeung TC. Wettability of nonaqueous elastomeric impression materials. Int J Prosthodont 1991;4:555-60.
22. American National Standard/American Dental Association. Specification no. 19 for non-aqueous, elastomeric dental impressions. J Am Dent Assoc 1977;94:733-41; addendum 1982;105:686.
23. Kahn RL, Donovan TE, Chee WW. Interaction of gloves and rubber dam with a poly(vinyl siloxane) impression material: a screening test. Int J Prosthodont 1989;2:342-6.

24. Panichuttra R, Jones RM, Goodacre C, Munoz CA, Moore BK. Hydrophilic poly(vinyl siloxane) impression materials: dimensional accuracy, wettability, and effect on gypsum hardness. Int J Prosthodont 1991;4: 240-8.
25. Peutzfeldt A, Asmussen E. Impression materials: effect of hydrophilicity and viscosity on ability to displace water from dentin surfaces. Scand J Dent Res 1988;96:253-9.
26. Wassell RW, Abuasi HA. Laboratory assessment of impression accuracy by clinical simulation. J Dent 1992;20:108-14.
27. Black J. Biological performance of materials. 3rd ed. New York: Marcel Dekker; 1999. p. 67-78.
28. Tenovuo JO. Human saliva: clinical chemistry and microbiology. Vol. 1. Boca Raton, FL: CRC Press; 1989. p. 6-25.

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