The Wetting of Surface-Treated Silicone Impression Materials by Gypsum Mixes Containing Disinfectants and Modifiers

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Purpose: This work evaluated wettability of silicone impression surfaces by gypsum mixes containing disinfectants.

Materials and Methods: Two types of dental stone were modified by mixing with aqueous solutions of either sodium hypochlorite or povidone iodine. These materials were subjected to further modification by adding a mixture of 1% gum arabic and 0.132% calcium hydroxide to reduce the water requirement of the hemihydrate. Mix consistency tests were carried out to determine the effect of the disinfectants and the modifying additives on the mix fluidity. Contact angles of the mixed materials were measured when they were poured against a polyvinylsiloxane impression material that had undergone the following treatments (1) no treatment (control), (2) surfactant treated, (3) disinfectant treated, and (4) treated with both surfactant and disinfectant. One-way analysis of variance (ANOVA) was carried out using Dunnett's method to determine if experimental groups were significantly different from the control.

Results: Gypsum mix consistency was reduced by the presence of combined gum arabic and calcium hydroxide additives. Contact angle data showed that the additives and disinfectants incorporated into the gypsum had, in general, no beneficial effect on the wetting of an untreated silicone surface, or a surface treated with surfactant. In some instances, better wetting was obtained with disinfectant-treated surfaces, and surfaces that had been disinfected and treated with surfactant.

Conclusions: Fluidity of the mixed gypsum was affected by the modifying additives. Chemical disinfectants incorporated in gypsum have little effect on the wetting behavior of dental gypsum. Modifying dental stone powders with gum arabic and calcium hydroxide additives (before mixing at the manufacturers' recommended liquid/powder ratios), improved the wetting behavior of the mixed materials in some cases, but results were not consistent.

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POSSIBLE TRANSMISSION of pathogenic microorganisms by means of dental impressions and cast and die materials is of great concern for dental office and laboratory personnel. In previous research, the effect of disinfecting additives on dental gypsum has been studied, in terms of bulk mechanical properties[1] and surface properties.[2] Such additives can be used in conjunction with a mixture of added calcium hydroxide and gum arabic, which serves to reduce the water requirement of the gypsum.[1-4]

The interaction between mixed gypsum and impression materials is important. Certain impression materials appear to yield stone casts that contain more entrapped air bubbles than others using the same die stone.[1] Many of the earlier versions of addition silicone impression materials produced hydrogen gas on setting.

Poor wettability of impression materials, as measured by contact angle analysis, is also considered a factor contributing to negative surface defects or voids in stone casts. It has been shown

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that the greater the contact angle, the greater the probability of formation of surface defects in stone casts.[2]

Thus, some manufacturers have produced hydrophilic impression materials by the incorporation of a surfactant.[5] The wettability of elastomeric impression materials can also be increased by application of a surface tension reducing agent (topical surfactant) to the set impression before pouring.[6]

The present work was undertaken to explore the hypothesis that the wettability of a polyvinylsiloxane (PVS) impression material will be affected by (1) surfactant treatment of the impression material and (2) by the presence of disinfectants—both with and without water-reducing additives—in the gypsum mixes.

Materials and Methods

Materials

Two types of dental stone (Type III, Lab Stone, lot no. 25375; Type V, Die Keen, lot no. 46580; both from Heraeus Kulzer Inc, South Bend, IN) were mixed with an aqueous solution of chemical disinfectants, either 0.525% sodium hypochlorite (NaOCl) (Fox-Chlor, Fox Packaging Co, St. Paul, MN, lot no. 62207-6) or 0.1% povidone iodine (PI) (Betadine, The Purdue Frederick Co., Norwalk, CT, lot no. 0034-2100-01), in addition to water, which served as the control. Hemihydrate powders of these stones were subjected to further modification by adding both 1% gum arabic (lot no. 9000-01-5, Acros Organics, Fairlawn, NJ) and 0.132% calcium hydroxide (lot no. 792589, Fisher Scientific, Fairlawn, NJ) based on previous studies.[3,4] The modified materials were mixed at the manufacturers' recommended liquid-powder (L/P) ratios (0.30 and 0.21 for types III and V, respectively) and at reduced L/P ratios (0.26 and 0.19 for types III and V stone, respectively). Table 1 shows the formulations of gypsum tested. There were 14 experimental groups, designated III.1 to III.7 and V.1 to V.7 for the type III and V stones, respectively.

Mix Consistency

Accurately proportioned amounts of dental stones and mixing solutions were hand mixed following ADA specification no. 25. The mixed material was then placed in a disposable plastic syringe to dispense five 2 ml quantities of material onto a glass plate, followed by vibration at high speed for 5 seconds (timed with a digital stopwatch), during which the mixed material flowed to form an approximately circular disk. The vibrator was Buffalo model number 1A (Buffalo Dental Mfg. Co. Inc, Syosset, NY), used at the high setting.

After setting, the diameter of each specimen was measured 3 times, in different directions, using a digital micrometer (Mitutoyo Solar, digimatic micrometer, Model CD-S6 CP, Mitutoyo Corp., Japan), and the mean diameters were calculated. A larger diameter indicated greater fluidity of the mixed material.

Wetting Behavior

Wetting behavior of the mixed materials was assessed against four differently treated polyvinylsiloxane (Imprint II, 3M ESPE Dental Products, St. Paul, MN) impression surfaces as follows:

1. Untreated. Impression surfaces not subjected to any sort of treatment before pouring of mixed stones.

Table 1. Experimental Design*

Group	*Dental Stone*	*Additives to Stone*	*Liquid*	*Liquid/Powder Ratio*
III.1	Type III	None	Water	0.30
III.2	Type III	None	0.525% NaOCl	0.30
III.3	Type III	None	0.1% PI	0.30
III.4	Type III	1% gum arabic and 0.132% $Ca(OH)_2$	0.525% NaOCl	0.30
III.5	Type III	1% gum arabic and 0.132% $Ca(OH)_2$	0.1% PI	0.30
III.6	Type III	1% gum arabic and 0.132% $Ca(OH)_2$	0.525% NaOCl	0.26
III.7	Type III	1% gum arabic and 0.132% $Ca(OH)_2$	0.1% PI	0.26
V.1	Type V	None	Water	0.21
V.2	Type V	None	0.525% NaOCl	0.21
V.3	Type V	None	0.1% PI	0.21
V.4	Type V	1% gum arabic and 0.132% $Ca(OH)_2$	0.525% NaOCl	0.21
V.5	Type V	1% gum arabic and 0.132% $Ca(OH)_2$	0.1% PI	0.21
V.6	Type V	1% gum arabic and 0.132% $Ca(OH)_2$	0.525% NaOCl	0.19
V.7	Type V	1% gum arabic and 0.132% $Ca(OH)_2$	0.1% PI	0.19

*Each of the above 14 gypsum mixes was tested against the polyvinylsiloxane material under each of 4 conditions (1) no surface treatment of the impression material, (2) surfactant treatment, (3) treated with disinfectant, and (4) treated with disinfectant followed by the surfactant.

Table 2. Mix Consistency of Dental Stones

Type III Stone					*Type V Stone*				
Group	*Mean Disk Diameter (mm)*		*SD (n = 5)*		*Group*	*Mean Disk Diameter (mm)*		*SD (n = 5)*	
III.1	25.1		0.8		V.1	28.8		1.2	
III.2	25.4		0.9		V.2	30.4		1.6	
III.3	24.9		1.1		V.3	29.4		1.5	
III.4	33.8*		2.0		V.4	45.5*		0.8	
III.5	40.6*		1.3		V.5	45.7*		0.9	
III.6	24.2		5.2		V.6	35.1*		1.9	
III.7	26.8		1.3		V.7	35.3*		1.0	
One-Way ANOVA					One-Way ANOVA				
Source	DF	Sum of sq	Mean sq	F-ratio	Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	1153.2545	192.209	36.1597	Model	6	1557.6612	259.610	147.3758
Error	28	148.8358	5.316	*P*-value	Error	28	49.3235	1.762	*P*-value
C Total	34	1302.0903		<0.0001	C Total	34	1606.9847		<0.0001

*Significantly different from control by Dunnett's test ($p < 0.05$).

2. Surfactant treated. Impression surfaces were sprayed with topical surfactant (Delar Corporation, Lake Oswego, OR) before pouring of mixed stones.
3. Disinfectant treated. Impression surfaces were spray disinfected with 0.525% NaOCl and air dried after 10 minutes, before pouring of mixed stones.
4. Disinfected, surfactant treated. Impression surfaces were disinfected as previously described, then sprayed with topical surfactant before pouring of mixed stones.

Using a similar method to that of Lorren et al,[7] five 2 ml disks of the mixed stones were dispensed over flat impression surfaces (18 cm × 12 cm × 3 mm), followed by vibration at high speed for 2 seconds. After setting, these disks were sectioned into 2 halves and their cross-section was seen at 10× original magnification using a computer-linked stereomicroscope (Olympus PM-PB20, Japan) and a video camera (Sony CCD-IRIS/RGB, Japan). All pictures were then captured and printed, in order to facilitate the protractor measuring of contact angles represented by the cross-sectional edges of each stone disk. The mean contact angle for each disk was then determined and the results were subjected to statistical analysis.

Statistical Analysis

One-way analysis of variance (ANOVA) was used for both consistency and wetting behavior data. Dunnett's method was used to determine which group(s) of mixed stones differed significantly from the control.

Results

A significant difference was detected for the mix consistency of each of type III and type V stone mixes ($p < 0.0001$ for both, Table 2). Type III stone materials modified with gum arabic and calcium hydroxide additives and mixed at the manufacturer's recommended L/P ratio showed a significantly lower consistency than the control mix (Dunnett's values = 4.71 and 11.54). Again, the gum arabic and calcium hydroxide-modified type V stone materials mixed at either the manufacturers' recommended or reduced L/P, all showed a significantly lower consistency than the control.

The contact angle data are presented in Tables 3–6 for the 4 differently treated silicone surfaces. Type III disinfected stones showed no difference in contact angle between the mixes and the control when all were poured against untreated impression surfaces (Table 3), while the unmodified type V stone mixed either with NaOCl or P.I. (Groups V.2 and V.3) showed higher contact angles when measured against the untreated impression surfaces. Contact angles of both types of stone (whether modified or not), differed from the control when measured against the surfactant-treated, disinfectant-treated, and disinfected surfactant-treated impression surfaces. The only clear exception is for the unmodified materials mixed with NaOCl (Tables 4–6).

Discussion

The clinical implication of this work is that it would be beneficial to have gypsum products with incorporated disinfectants as a passive means of control of cross-infection. This work has explored

Table 3. Wetting Behavior of Stones Against Untreated Silicone Impression Surfaces

Type III Stone			Type V Stone		
Group	*Contact Angle (Degrees)*	*SD (n = 5)*	*Group*	*Contact Angle (Degrees)*	*SD (n = 5)*
III.1	67.0	1.6	V.1	60.8	2.4
III.2	70.4	2.6	V.2	71.0*	2.0
III.3	67.6	1.1	V.3	65.4*	1.7
III.4	64.6	2.9	V.4	62.0	2.9
III.5	65.2	2.9	V.5	64.2	1.9
III.6	64.4	1.1	V.6	62.4	1.5
III.7	66.4	2.3	V.7	63.8	1.5

One-Way ANOVA (Type III Stone)

Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	131.94286	21.9905	4.5678
Error	28	134.80000	4.8143	*P*-value
C Total	34	266.74286		0.0024

One-Way ANOVA (Type V Stone)

Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	337.37143	56.2286	13.4795
Error	28	116.80000	4.1714	*P*-value
C Total	34	454.17143		<0.0001

*Significantly different from control by Dunnett's test ($p < 0.05$).

this possibility by determining the ability of disinfected mixes to wet a polyvinylsiloxane material given different chemical treatments.

The consistency test was conducted to discover the effect of consistency on the wetting behavior of the mixed, disinfected stones against impression surfaces. Materials with low viscosity (consistency) will flow and spread readily over impression surfaces with gentle vibration, while others with high consistency could show reduced flow rates. A disk diameter test was selected because it is a simple, reliable, and easily controlled method, and it has been used in previous studies.[4] In this study, aqueous solutions of chemical disinfectants had no significant effect on the consistency of the mixed dental materials; however, these consistencies were reduced by the addition of gum arabic and calcium hydroxide to the hemihydrate powders before mixing at the manufacturers' recommended L/P ratios. This reduction was the result of excess liquid content of the mixed materials, in agreement with the results of Alsadi et al.[4]

Surface defects on stone casts could affect the accuracy of cast restorations. Numerous factors can contribute to surface defects or void formation in stone dies, including production of hydrogen gas by many addition-cured silicone impression materials and poor wettability of impression materials. The greater the contact angle, the greater the probability of surface defects in stone casts.[8] It has been shown that the ability of liquid to wet a solid surface is dependent on the surface tension of the liquid as well as the surface energy of the substrate,[9,10] which is markedly affected by the application of a surface tension reducing agent.[6]

Table 4. Wetting Behavior of Stones Against Surfactant-Treated Silicone Impression Surfaces

Type III Stone			Type V Stone		
Group	*Contact Angles (Degrees)*	*SD (n = 5)*	*Group*	*Contact Angles (Degrees)*	*SD (n = 5)*
III.1	48.6	2.7	V.1	57.0	2.3
III.2	66.4*	1.5	V.2	63.8*	2.6
III.3	60.2*	1.5	V.3	57.6	2.5
III.4	55.6*	2.1	V.4	56.2	1.8
III.5	47.8	2.8	V.5	47.6*	1.5
III.6	57.0*	1.6	V.6	55.4	2.1
III.7	56.0*	1.9	V.7	55.4	1.7

One-Way ANOVA (Type III Stone)

Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	1244.6857	207.448	48.7293
Error	28	119.2000	4.257	*P*-value
C Total	34	1363.8857		<0.0001

One-Way ANOVA (Type V Stone)

Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	677.88571	112.981	25.4298
Error	28	124.40000	4.443	*P*-value
C Total	34	802.28571		<0.0001

*Significantly different from control by Dunnett's test ($p < 0.05$).

Table 5. Wetting Behavior of Stones Against Disinfectant-Treated Silicone Impression Surfaces

Type III Stone			*Type V Stone*		
Group	*Contact Angle (Degrees)*	*SD (n = 5)*	*Group*	*Contact Angle (Degrees)*	*SD(n = 5)*
III.1	76.4	1.1	V.1	73.2	1.9
III.2	77.8	0.8	V.2	74.0	2.3
III.3	69.4*	2.9	V.3	64.0*	1.6
III.4	62.2*	3.3	V.4	65.2*	3.1
III.5	65.6*	2.3	V.5	64.4*	2.4
III.6	66.6*	2.3	V.6	65.6*	1.1
III.7	66.6*	3.0	V.7	65.4*	1.7

One-Way ANOVA					One-Way ANOVA				
Source	DF	Sum of sq	Mean sq	F-ratio	Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	1006.5714	167.762	28.7123	Model	6	549.20000	91.5333	20.4707
Error	28	163.6000	5.843	*P*-value	Error	28	125.20000	4.4714	*P*-value
C Total	34	1170.1714		<0.0001	C Total	34	674.40000		<0.0001

*Significantly different from control by Dunnett's test ($p < 0.05$).

Table 6. Wetting Behavior of Stones Against Disinfected, Surfactant-Treated Silicone Impression Surfaces

Type III Stone			*Type V Stone*		
Group	*Contact Angle (Degrees)*	*SD (n = 5)*	*Group*	*Contact Angle (Degrees)*	*SD (n = 5)*
III.1	65.4	3.4	V.1	61.8	2.8
III.2	65.6	2.2	V.2	65.6	3.0
III.3	64.4	2.1	V.3	57.2*	1.9
III.4	53.0*	1.2	V.4	51.2*	2.6
III.5	52.2*	2.2	V.5	56.4*	1.1
III.6	54.4*	3.5	V.6	53.6*	2.4
III.7	53.8*	1.3	V.7	55.2*	0.8

One-Way ANOVA					One-Way ANOVA				
Source	DF	Sum of sq	Mean sq	F-ratio	Source	DF	Sum of sq	Mean sq	F-ratio
Model	6	1208.0000	201.333	34.7126	Model	6	726.34286	121.057	24.0739
Error	28	162.4000	5.800	*P*-value	Error	28	140.80000	5.029	*P*-value
C Total	34	1370.4000		<0.0001	C Total	34	867.14286		<0.0001

*Significantly different from control by Dunnett's test ($p < 0.05$).

The contact angle is considered the best indicator of the wetting behavior of liquids against different substrates. Using the method recommended by Lorren et al[7] also seems to be realistic, because it reflects the exact situation of pouring and measures the contact angle of the mixed stone itself, not a gypsum slurry, against the impression surface.

Not all disinfectants used in this study reduced the wetting behavior of dental stones, although most of the disinfected materials showed higher contact angles against different types of impression surface treatments. Therefore, the mixed materials spread less easily over impression surfaces. The 0.1% povidone iodine had possibly the lowest surface tension among the disinfectants considered, and that was reflected in the contact angles of stones mixed with this solution. Addition of gum arabic and calcium hydroxide reduced the liquid required for mixing and reduced the consistency of stones mixed at the manufacturers' recommended L/P ratios. This reduction in consistency helped the flow of the mixed materials over the impression surfaces. With reduction of the L/P mixing ratios, the effect of reduced consistency was mitigated, that is, the contact angle then returned to higher measurements.

Conclusions

1. Fluidity of mixed gypsum could be affected in the presence of modifying additives.
2. Chemical disinfectants have little effect on the wetting behavior of dental gypsum.

3. Modifying dental stone powders with gum arabic and calcium hydroxide additives before mixing at the manufacturers' recommended L/P ratios improves the wetting behavior of the mixed materials.

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