

Chlorhexidine Gluconate Mouthwashes as a Surfactant for Addition-reaction Silicone Impressions

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Abstract - Addition-reaction silicone impression (PVS) materials are hydrophobic. Hydrophobicity of the impression material may interfere with the wetting of the tooth, resulting in void formation. The study investigates whether conditioning teeth with Chlorhexidine-gluconate based mouthwashes can reduce the hydrophobicity and the number of voids on PVS impressions. Impression material contact angle specimens on bovine tooth surfaces were measured using a Reflex Microscope. PVS impressions (President) were made of untreated bovine teeth in three groups (1, 2 and 3) and fourth group used Impregum polyether impression material. Group 1 was used as a control group, and original and mint flavoured Corsodyl (Chlorhexidine) mouthwashes were used as clinical surfactants in Groups 2 and 3, respectively. Contact angle readings were recorded on each side of every impression in each of the four groups and compared by an analysis of variance. In the second part of the study, the numbers of air voids on impression surfaces were visually recorded. The proportions of air voids in the groups were compared using a Chi-squared test. The mean angle for Group 3 with mint flavoured Corsodyl mouthwash was significantly smaller than that of any of the other groups ($P < 0.05$). The only statistically significant ($P < 0.01$) comparisons of the proportions of air voids were between Group 4 and each of the other experimental groups, with the percentage of voids being significantly greater in Group 4. Although Corsodyl mint significantly reduced the mean contact angle it did not significantly reduce the percentage of voids on impression surfaces.

KEY WORDS: Contact angle, Void, Impression, Chlorhexidine

INTRODUCTION

An accurate void-free impression is an integral part of predictable fixed prosthodontics. The wettability of dentine surfaces by impression materials depends on the hydrophilicity and viscosity of the material. Additional factors in detail reproduction include the rheological characteristics of the impression material, rate of setting and other handling characteristics of the impression materials¹.

Studies on contact angles between die stone and impression materials demonstrate a similar pattern as studies that investigate contact between tooth and impression materials. There appears to be a direct relationship between the reduction in contact angles and the reduction in the number of voids on the surface of casts^{2,3}. The addition-reaction silicone impression materials are more hydrophobic when compared to the polyether impression materials.

The use of specific clinical surfactants has been shown to improve quality of reproductions and reduced void formation with addition reaction silicones^{4,5}. It has been anecdotally reported by numerous clinicians that chlorhexidine gluconate based mouthwashes used as a clinical surfactant may improve surface wettability.

There are currently no documented studies that investigate the effect of additives to chlorhexidine gluconate mouthwashes when used as a clinical surfactant.

The purpose of this two-part in-vitro study was to:

- Investigate the effect on contact angles when conditioning teeth with Chlorhexidine gluconate based mouthwashes
- Compare the number of voids on impression surfaces in teeth conditioned with Chlorhexidine gluconate based mouthwashes and in control teeth.

MATERIAL AND METHODS

Contact Angle Determination:

Thirty two freshly extracted crowns of bovine teeth were sliced longitudinally into 160 thin sections, using a diamond saw (Table 1). Four groups of 8 specimens were randomly created for the first part of the experiment (Table 2). President addition-reaction silicone light body impression material was used for the first three experimental groups. A fine syringe tip (Table 1) was cut by 1mm with a sharp scalpel and attached to the mixing cartridge (Table 1). Impression material was initially injected onto the glass slab for monitoring setting time and then roughly equal amounts were placed onto the tooth surfaces. Each tooth slice accommodated four or five contact angle impression specimens (Fig.1). The impression material delivery was timed and specimens were dispensed within 60 seconds from start of mixing. The syringe tip was changed and the above process was repeated until 20 specimens were

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Table 1. *Manufacturers' Details*

<i>Product</i>	<i>Manufacturer</i>	<i>City / Country</i>
Rotary Diamond Saw, Model 660	Testbourne Ltd	Basingstoke, UK
Fine Syringe Tip	Coltene Whaledent	Altstätten, Switzerland
Coltene Mixing tips	Coltene Whaledent	Altstätten, Switzerland
Mixstar mixing unit	DMG Dental	Hamburg, Germany
Reflex microscope	Reflex Measurement	Somerset, UK
SPSS version 12	SPSS inc.	Chicago, Illinois
Knuth Rotors	Struers	Copenhagen, Denmark
GC Fuji IX Capsules	GC Corp	Tokyo, Japan
Parallelometer	Metalor	Neuchatel, Switzerland
Rotary handpiece	KaVo Dental AG	Brugg, Switzerland
Spiralbohrer, Twist Drill, 7800.103.015	Edenta	Edenta, Germany
Wild M21 Microscope	Wild Heerbrugg Ltd	Heerbrugg, Switzerland

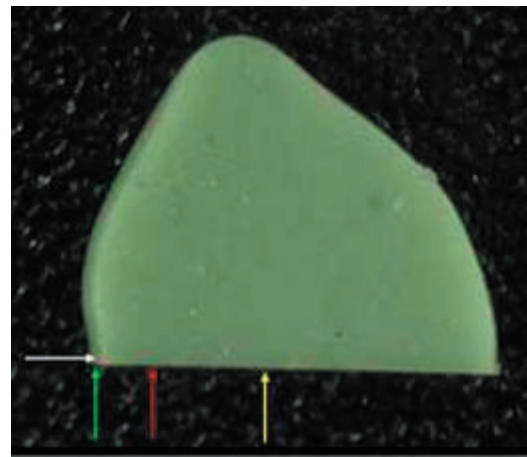
**Figure 1.** *Five impression material specimens on bovine tooth slice.*

produced. Non-treatment groups were prepared first to avoid contamination.

In the fourth group, Impregum Penta soft was used. This material is a polyether and it is delivered using a motorised mixing system (Table 1). The impression syringe was fully loaded from the motorised delivery system and contact angle specimens were delivered as described above.

Table 2 illustrates the distribution of impression materials and selected surfactants for each of the four groups. The contact angle impression specimens were allowed to set for ten minutes. They were removed and placed in labelled containers. A Reflex Microscope (Table 1) was used to measure the contact angles created by the impression materials against tooth slices.

A computer program was devised which allowed four points to be recorded along the profile of the cut impression material specimen (Fig. 2). Point B1 was the approximate central point of the base of the impression specimen (yellow arrow). B2 was a point on the base, close to the edge of the impression specimen (red arrow). Connecting points B1 and B2 allowed the line that represented the base to be drawn. B3 was the point on the edge of the impression specimen (green arrow). B4 was the point on the slope of the initial curved portion of the impression specimen (white arrow).

**Figure 2.** *Photo of sliced contact angle specimen:*

- B1: Central point of the base of the impression specimen (yellow arrow).*
- B2: Point on the base, close to the edge of the impression specimen (red arrow)*
- B3: Point on the edge of the impression specimen (green arrow)*
- B4: Slope of initial curved portion of impression specimen (white arrow).*

The program was designed to derive an angle between the extrapolated line joining points B3 to B4 and the base of the impression specimen (points B1 and B2). This was taken to represent the contact angle of the set impression material on the tooth. All measurements were recorded to the nearest seconds of angle. Profile plots of the impression specimen could also be obtained. All observations were carried out at 20X magnification. All specimens with ill-defined edges were discarded. Each specimen consisted of a left and a right side.

The mean contact angle of the duplicate readings for each side was calculated for every specimen, and the statistical analysis was performed on these means using SPSS (Table 1). A 2-way repeated measures hierarchical analysis of variance, with specimens nested in groups, was performed to investigate the effects of the groups and sides on the angles. When a significant effect was observed, this was followed by Least Significant Difference (LSD) *post hoc* tests to assess which group means differed from which,

after adjusting the P -values for multiple comparisons. For each analysis of variance, the assumptions of Normality and homogeneity of variance were checked using residuals and were found to be satisfactory. A result was regarded as statistically significant if $P < 0.05$.

Impression recording of parallel preparations:

Freshly extracted bovine maxillary anterior tooth crowns were used in the second part of the study. The buccal and palatal surfaces were flattened using a sanding turntable (Table 1) and water. The empty pulp chambers were packed with a capsulated glass ionomer cement (Table 1).

Horizontal lines were drawn across the flat buccal and palatal surfaces of the teeth. The lines were 5 millimeters apart. Markings were made at four millimetre intervals along the horizontal lines using a lead pencil. A parallelometer (Table 1) and a hand piece (Table 1) was used to create parallel preparations with a twist drill, which were 1mm deep (Table 1) on both sides of the bovine teeth (Fig. 3).

Four groups, each of 8 specimens, were randomly created for impression making. President addition-reaction silicone light body impression material was used for the first three experimental groups. Impregum Penta soft was used for the fourth group. Table 2 illustrates the distribution of impression materials and selected surfactants for each of the four groups.

For each group, the teeth were embedded into a plastic box containing the impression material. The material was allowed to set for fifteen minutes before separation. The experiment was repeated with the opposite side of the same teeth. A total of 176, 185, 189 and 195 impressions of drill holes were recorded for Groups 1, 2, 3 and 4, respectively.

The impression specimens were examined using a low powered microscope (Table 1) ($\times 6$ magnification). Table 5 shows the number of extensions with 0, 1 and 2 voids for each of the 4 groups. Figure 5 demonstrates voids of different sizes in a typical Impregum impression. All internal and external line angles of the preparations were included in the acceptance criterion for voids. Any voids not involving the external line angles of the preparations were excluded.

Chi-squared analysis, with a significance level of 0.05, was utilized to compare the percentages of impressions with voids in the four groups (i.e., the number of impressions with one and two voids were combined in each group for the purpose of statistical analysis). Because statistical significance was achieved, this was followed by pairwise Chi-squared comparisons to assess differences between groups, using a significance level of 0.01 to adjust for multiple comparisons. The assumption relating to the Chi-squared test was satisfied in each instance in that at least 80% of the relevant expected frequencies were 5 or greater.



Figure 3.



Figure 4. Impression created from 4 bovine teeth in plastic box.



Figure 5. Different size voids in typical Impregum impression.

Table 2. Table to demonstrate 4 experimental groups for contact angle and void measurements

Group	Material	Type	Manufacturer	Conditioning treatment
1	President Jet, Fast, Light body Low Viscosity	Addition reaction silicone	Coltene, Switzerland	None (Control)
2	President Jet, Fast, Light body Low Viscosity	Addition reaction silicone	Coltene, Switzerland	Corsodyl Original
3	President Jet, Fast, Light body Low Viscosity	Addition reaction silicone	Coltene, Switzerland	Corsodyl Mint
4	Impregum Penta Soft Medium Consistency	Polyether Pentamatic	ESPE Germany	None (Control)

Table 3. Summary table of results for the contact angles (degrees)

Side	Group	N	Mean	Std. Deviation	Std. Error of Mean	Median	Minimum	Maximum
Left	1	8	69.60	14.23	5.03	70.79	46.72	86.89
	2	8	64.80	12.27	4.34	66.59	48.48	82.05
	3	8	58.80	10.69	3.78	56.47	45.76	72.61
	4	8	60.94	14.47	5.11	63.72	37.05	77.14
	Total	32	63.54	13.05	2.31	65.35	37.05	86.89
Right	1	8	61.31	12.80	4.52	62.13	41.74	75.41
	2	8	58.11	13.75	4.86	62.00	35.04	72.48
	3	8	43.03	18.03	6.38	53.86	7.00	56.04
	4	8	62.94	16.61	5.87	63.39	39.92	86.23
	Total	32	56.35	16.72	2.96	54.95	7.00	86.23
Total	1	16	65.46	13.76	3.44	68.29	41.74	86.89
	2	16	61.45	13.06	3.26	64.26	35.04	82.05
	3	16	50.91	16.48	4.12	54.33	7.00	72.61
	4	16	61.94	15.08	3.77	63.72	37.05	86.23
	Total	64	59.94	15.31	1.91	58.67	7.00	86.89

Table 4. Post hoc comparisons (LSD) comparing the group means of the contact angles

Group (i)	Group (j)	Difference in contact angle means (i - j) (degrees)	95% CI for difference in contact angle means (degrees)	P-value
1	2	4.01	-6.58 to 14.58	0.45
	3	15.54	3.96 to 25.13	0.009
	4	3.51	-7.07 to 14.10	0.50
2	3	10.54	-0.04 to 21.12	0.051
	4	-0.49	-11.07 to 10.10	0.93
3	4	-11.03	-21.61 to -0.45	0.04

Table 5. Contingency table showing number of impressions by group and number of voids

Group	Number of voids			Total
	0	1	2	
1	164 (93.2%)	10	2	176
2	176 (95.1%)	9	0	185
3	180 (95.2%)	9	0	189
4	145 (76.3%)	39	6	190

Table 6. Chi-squared tests comparing percentage of impressions with voids

Comparison	Chi-squared test statistic (Yates corrected)	P-value	95% confidence interval for difference in percentage with voids
Gp1 & Gp2	0.32	0.57	2.9% to 6.9%
Gp1 & Gp3	0.38	0.54	2.9% to 6.9%
Gp1 & Gp4	18.51	<0.001	16.4% to 31.6%
Gp2 & Gp3	0.04	0.85	4.2% to 4.4%
Gp2 & Gp4	25.43	<0.001	18.7% to 33.3%
Gp3 & Gp4	26.24	<0.001	18.7% to 33.3%

RESULTS

The data files generated by the Reflex Microscope contained co-ordinates of 256 observed points and 64 contact angle values. Table 3 provides summary statistics for the contact angles for the four groups. The 2-way hierarchical analysis of variance indicated that there was no significant difference between the mean angles in the two sides ($P = 0.06$) but there was a statistically significant difference in the mean angles between the groups ($P = 0.04$). As there was no evidence of a group times side interaction ($P = 0.41$), any differences between the two groups were assumed to be constant for each side. *Post hoc* multiple comparisons (Table 4) indicated that the mean contact angle for Group 3 was significantly smaller ($P = 0.009$) than that of Group 2 (with Corsodyl Original) and was significantly greater ($P = 0.04$) than that of Group 4 (Polyether Pentamatic with no conditioning treatment): there were no other significant differences between group means ($P > 0.05$).

Table 5, relating to the second part of the study, shows the total number of impressions recorded for each experimental group and the number of voids created in each group during impression making. There was a statistically significant difference in the percentage of impressions with voids between at least two of the four experimental groups ($\chi^2 = 52.1$, degrees of freedom = 3, $P < .001$). The results of pairwise Chi-squared tests to establish which groups differed are shown in Table 6. Using a significance level of 0.01 to adjust for multiple testing, the only statistically significant comparisons were between Group 4 (the Impregum Penta soft group) and each of the other experimental groups, with the percentage of voids being significantly greater in Group 4 in each case. Neither of the chlorhexidine gluconate conditioning treatments appeared to reduce the percentage of voids formed in the impressions by a statistically significant amount.

DISCUSSION

Bovine teeth were used in this experiment because they are much larger than human teeth and similar in structure. Their large size allows larger surface areas to conduct the experiment.

A low viscosity impression material was used as this flowed with greater ease on tooth samples than the more viscous materials. In a study on the effect of hydrophilicity and viscosity on the ability to displace water from dentine surfaces,⁶ it was noted that if the material had a contact angle of over 70° then the viscosity of the impression material played a more important role in displacing

water from the dentine surface. If the contact angle was less than 70° then hydrophilicity played an important role in dentine wetting. As contact angles for this experiment were around 70° , using low viscosity material reduced the influence of impression material viscosity on wetting of tooth surfaces.

Group 1 was the control group. Groups 2-4 were the experimental groups. Both Corsodyl original and Corsodyl mint were used as they have different constituents. The literature conclusively shows that flavoured chlorhexidine gluconate mouthwashes reduce the effectiveness of the product as an antibacterial agent⁷⁻⁹. Bioavailability tests showed that only about 25% of the chlorhexidine gluconate in flavoured mouthwashes was in the active form^{8,9}. So if the chemical chlorhexidine gluconate itself was solely responsible for contact angle reduction, then one would have expected lower contact angles with Corsodyl original.

Previous studies show that intrinsic surfactants may affect the mechanical properties of addition-reaction silicone impression materials³ and topical surfactants are more effective than intrinsic surfactants¹⁰. The results indicate that contact angles created by President addition-reaction silicone impression material were significantly reduced by Corsodyl mint and not Corsodyl original. This finding suggests that Corsodyl mint is a better clinical wetting agent than Corsodyl original. The result may be explained in that additional additives or surfactants present in Corsodyl mint, for example peppermint oil, allow it to be more suitable as a clinical wetting agent than Corsodyl original. The results also suggest that the chemical chlorhexidine gluconate is not the cause of contact angle reduction in-vitro.

Another finding in this experiment was that the mean contact angle created by Impregum (Group 4) against bovine teeth was not significantly different from that of President (Group 1). In studies with plaster setting on impression material it has been shown that Polyether impression material produces lower contact angles than addition-reaction silicones^{11, 12, 13}.

Although Corsodyl mint does appear to reduce contact angles on average, it did not significantly reduce the percentage of voids at the line angles. Other factors including convergence angle, and flow of the impression material may have contributed to the percentage of voids produced. Impregum polyether impression material produced a significantly greater percentage of impressions with voids than each of the other experimental groups. If relative hydrophilicity is the major factor in tooth preparation wetting, one would have expected fewer air voids with Impregum than the other experimental groups because

of its hydrophilic nature. Impregum is thixotropic so the adaptation to the test cavities could well be dependent on the direction, timing and nature of the load during placement. This property may have been the cause for more voids in this experimental group. Millar et al found that monophasic addition-reaction silicone impression material also carried an increased risk of surface void formation, when compared to two-phased addition-reaction silicone impression material¹⁴. This study by Millar et al supports our assumptions that the poor flow characteristics of Impregum may have been the cause of increased number of voids in the impressions.

As all the voids included the line angles this study confirms findings by Chong et al² that voids are more likely to appear in acute line angles of impressions. However, the present study found a smaller percentage of impressions with voids on acute line angles when Impregum was used compared to President addition-reaction silicone impression material. These findings are in agreement with the study by Takahashi and Finger¹ who stated that hydrophilicity of dental impression materials might not necessarily be the key to enhanced surface detail reproduction of dentine. They believed that other material properties were as important for adequate detail reproduction of moist dentine surfaces.

The results from the second part of the study do not support the findings in the first part. This finding was in disagreement with the study by Lorren et al in which there was a positive correlation between the number of air voids on the cast and the size of the contact angle¹¹. However, the study by Lorren et al was investigating contact angles and void formation between impression materials and setting plaster and not setting impression materials against tooth. This study is also in disagreement with their observation that polyether impression materials produced the lowest contact angles and the least number of voids on casts compared to other elastomeric impression materials. Although interesting, it may be unwise to draw comparisons to previous studies based on plaster.

The results of this in-vitro study do not support the use of Corsodyl original mouthwash as a clinical surfactant with President addition-reaction silicone impression material. Only in-vivo testing will show if this statement translates to the clinical situation. The contact angle study implies that there may be a benefit with Corsodyl mint. The evaluation of void production does not distinguish between any of the addition-reaction silicone impression methods studied. The results suggest that the contact angle of impression material on prepared teeth does provide an indication of the relative wettability of the tooth and impression material but it does not necessarily reflect on the occurrence of air voids in impressions formed on teeth. There may be other factors involved. This study does not support the use of all chlorhexidine gluconate mouthwashes as clinical surfactants with President addition-reaction silicone impression material to reduce the number of voids on impressions. The findings of this study suggest that the clinical mode of action of chlorhexidine gluconate is not as a clinical surfactant but as cleansing agent or dispersaloid. Clinically it may help to remove the organic bio-film formed on teeth as well as oil from hand pieces to allow better contact and spread between President addition-reaction silicone impression material and tooth. Peppermint oil in

Corsodyl mint may be responsible for the increased tooth to impression contact and spread.

This study was undertaken because of anecdotal reports of improved surface detail reproduction of addition-reaction silicone impressions after direct application of Corsodyl, as part of the impression making process. The results of this in-vitro study are inconclusive, and greater understanding may be achieved through evaluating other elastomeric impression materials, introducing clinically relevant contaminants such as saliva^{6,7} and hand piece oil as variables, and clinical evaluation of a large number of impressions made to an agreed protocol.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

1. Corsodyl mint significantly reduces the mean contact angle created between President addition-reaction silicone impression materials and bovine tooth.
2. The mean contact angles created in the other three groups were not significantly different from each other.
3. The Corsodyl mint group had a significantly lower mean contact angle than those in the other groups.
4. There were a significantly greater percentage of impressions with voids in the Impregum group when compared to each of the other experimental groups.
5. Neither of the chlorhexidine gluconate conditioning treatments appeared to reduce the percentage of voids formed in the impressions by a statistically significant amount.
6. All voids formed included the line angles.

ADDRESS FOR CORRESPONDENCE

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