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A Comparative Study to Determine the Wettability and Castability of Different Elastomeric Impression Materials

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ABSTRACT

Aim: The aim of this study was to determine the wettability of different hydrophilic and hydrophobic elastomeric impression materials and the gypsum castability.

Materials and methods: The wettability was evaluated by determining the contact angles of different elastomeric impression materials. The contact angle was determined by placing a drop of aqueous solution of calcium sulfate dihydrate on the flat surface of impression material and specimens were measured using a profile projector.

Gypsum castability was determined by counting the number of voids formed in the die stone cast made from the impressions of a aluminum die. The voids were counted using an diopter magnifying lens.

Results: Polyether, different viscosities of polyvinyl siloxane, and condensation silicone impression materials exhibited low contact angle values and least number of voids in the die stone cast when compared with polysulfide impression material.

Conclusion: There was significant correlation between the contact angle and voids formed in the die stone casts when fabricating die stone casts from various elastomeric impression material impressions.

Clinical significance: Accurate reproduction of prepared tooth or edentulous arch is of clinical importance in the fabrication of a fixed or removable prosthesis. Inaccuracies in the replication processes will ultimately have an adverse effect on the fit and adaptation of final restoration. The interaction is determined in part by hydrophilic and hydrophobic nature of the elastomeric impression material. Inadequate wetting of an impression results in voids in the stone casts.

Keywords: Wettability, Contact angle, Elastomeric impression materials, Castability.

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INTRODUCTION

The fabrication of an acceptable fixed or removable prosthesis is dependent upon an accurate void free cast or dies. The interaction of elastomeric impression material and the gypsum slurry is important in fabrication of a void free die. The interaction is determined in part by the hydrophilic or hydrophobic nature of the elastomeric impression material.[1] Besides being dimensionally and chemically stable in the presence of gypsum, an impression material should possess surface properties that allow it to be easily wet by a standard mix of gypsum. Inadequate wetting of an impression results in incorporation of air bubbles and voids in the casts. These voids are often located in critical areas of preparation, such as margins and retentive grooves, which makes the die stone cast unacceptable for further use.

The wettability of a surface is usually determined by measuring the magnitude of the contact angle formed between a drop of liquid and the surface in question. The contact angle is the angle between the surface of wetted solid and a tangent to the curved surface of a drop at the point of contact. The impression materials forming a contact angle less than 90° are described as hydrophilic and those forming a contact angle more than 90° are hydrophobic in nature. Small values indicate good wettability and better castability. Smaller the contact angle, lesser the voids formed during the pouring of the impression.[2] It is has been postulated that contact angles that approximate or exceed 90°, increase the probability for entrapment of air bubbles during the pouring of the impression due to less wettability.[3]

The present study, aims to determine the contact angles of various impression materials and their relationship with the surface details of the gypsum casts.

MATERIALS AND METHODS

Materials (Fig. 1) and methods used in this study have been discussed under the following headings:

Grouping of Samples

Polyether impression material – A (Fig. 2)
Polyvinyl siloxane light body impression material – B (Fig. 3)
Polyvinyl siloxane medium body impression material – C (Fig. 4)
Polyvinyl siloxane heavy body impression material – D (Fig. 5)
Polyvinyl siloxane putty consistency impression material – E (Fig. 6)
Condensation silicone impression material – F (Fig. 7)
Polysulfide impression material – G (Fig. 8)

Fig. 1: Armamentarium used in this studies

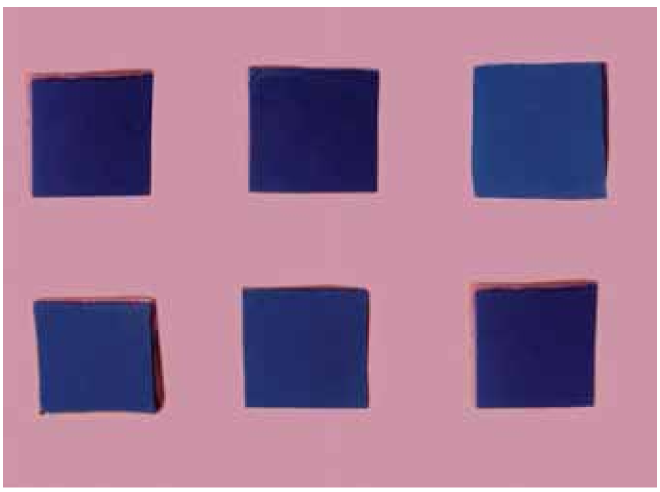


Fig. 2: Specimens of polyether impression material

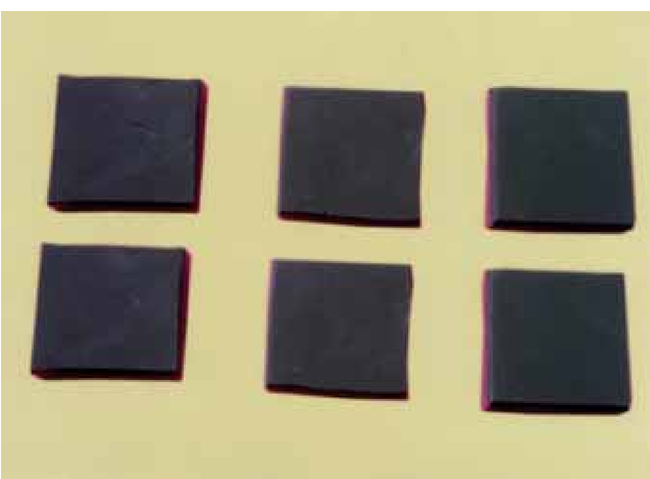


Fig. 3: Specimens of polyvinyl siloxane (light body)

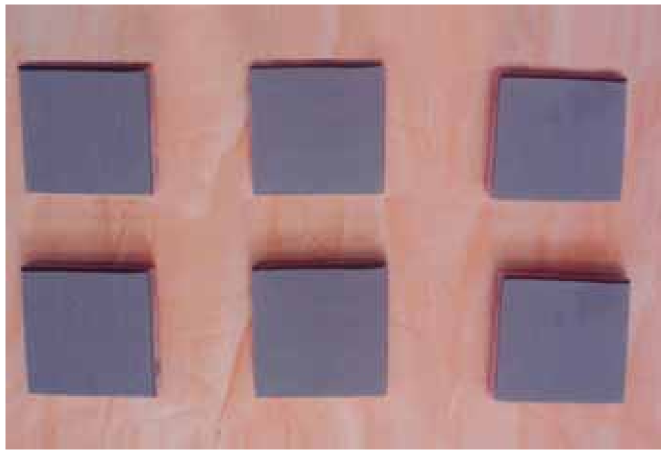


Fig. 4: Specimens of polyvinyl siloxane (medium body)

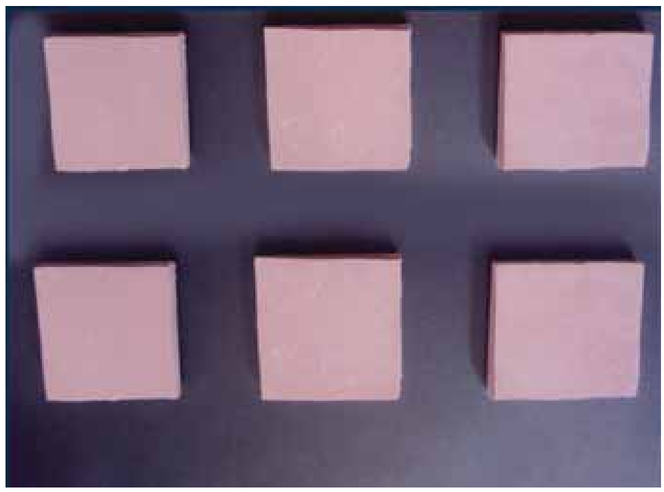


Fig. 5: Specimens of polyvinyl siloxane (heavy body)

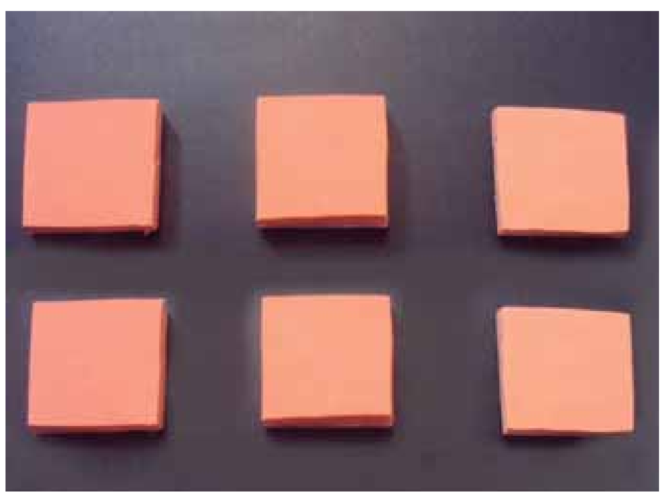


Fig. 6: Specimens of polyvinyl siloxane (putty consistency)

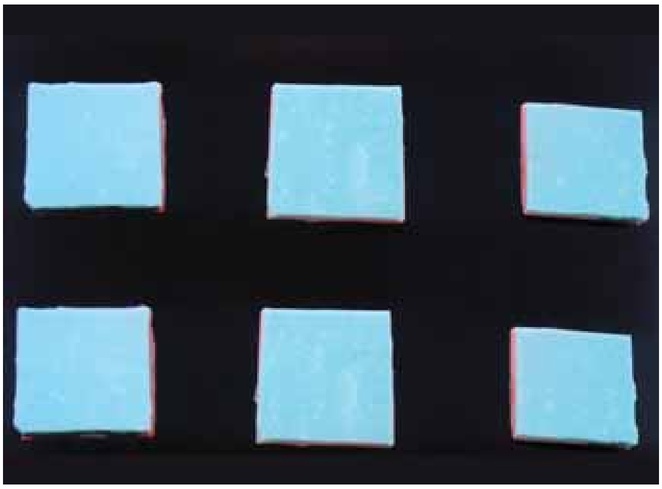


Fig. 7: Specimens of condensation silicone impression material

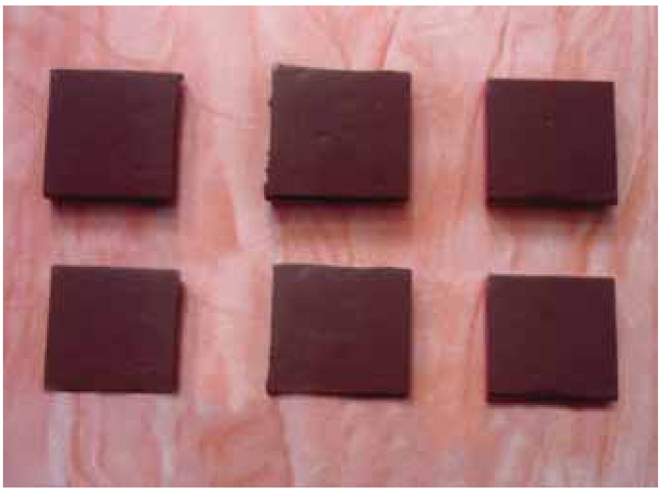


Fig. 8: Specimens of polysulfide impression material

Among the impression materials grouped above, group A, B, C, D, E, F are hydrophilic and group G is hydrophobic.

A. *Preparation of acrylic blocks:* A total of 42 wax blocks measuring approximately 5 × 38 mm thickness were prepared using modeling wax. The prepared wax blocks were invested in curing flasks using dental stone and allowed to set. Dewaxing was done by keeping the invested flasks in the boiling water for 5 minutes. After complete wax elimination, separating media (cold mold seal) was applied over the mold area. Self-cure acrylic resin was mixed in a porcelain mixing jar according to manufacturer's recommendation and was packed into the mold during the dough stage. The flasks were kept under hydraulic pressure for 3 hours to undergo complete curing. After curing, the deflasking was done and the acrylic blocks were recovered from the mold. The prepared acrylic blocks were trimmed and finished using tungsten carbide bur.

B. *Preparation of test specimens for measuring contact angle:* Seven different elastomeric impression materials (see Fig. 1) were used in this study to measure the contact angles which include polyether impression material, different viscosities of polyvinyl siloxane impression materials, condensation silicone impression material and polysulfide impression material. All the impression materials were stored in a cool, dry environment before use. Tray adhesive supplied by manufacturers for the different impression materials were applied to the acrylic blocks and allowed to dry for 5 minutes. Further the impression materials were mixed on the mixing pad according to manufacturer's instructions and were spread over the acrylic blocks and subsequently the blocks were inverted on a clean Granite surface plate (Fig. 9) to form a smooth, flat surface of the impression materials. Care was taken to avoid inclusion of air bubbles. Specimens were allowed to set on the Granite surface plate (Fig. 9) for 20 minutes. For each of the seven impression materials studied, six specimens were made in the similar manner. Each impression material was grouped alphabetically into seven groups from A to G. Each group was subdivided into six subgroups numbered from 1 to 6. All the specimens were labelled and subjected for measuring the contact angles.

C. *Measuring the contact angle of different elastomeric impression materials:* The contact angles of 42 specimens from different elastomeric impression materials were examined by placing 0.4 ml aqueous solution of calcium sulfate dihydrate over each of the above said specimens for 1 minute. Then a photograph was taken by a Nikon520S digital camera (Fig. 10) mounted on a stand with standardized distance of the specimens. The photographs obtained were placed under the Nikon profile projector (Fig. 11) to measure the contact angle.

Fig. 9: Granite surface plate

Fig. 10: Nikon digital camera

Fig. 11: Profile projector

To Determine the Surface Details of Casts using Different Hydrophilic and Hydrophobic Elastomeric Materials

A. *Fabrication of aluminum master die:* An aluminium die shown in Figure 12 having seven dimensionally identical elevations of 4 mm wide and 5 mm length each of which represents the tooth, having smooth surface, good line angles and margins was used to prepare the die stone casts specimens.

B. *Fabrication of acrylic custom tray:* A total of 42 acrylic custom trays with uniform spacer thickness of 2 mm were fabricated on the aluminum master die. The wax spacers were removed from the trays and the borders were trimmed using tungsten carbide bur. All the acrylic custom trays fabricated were marked for group identification.

C. *Making of impressions and casts from the aluminum master die:* Seven different elastomeric impression materials were used to make the impressions of the aluminum master die using acrylic custom trays. With each impression materials tested six impressions of the master die were made. A total of 42 impressions were made. Each impression was allowed to set for 20 minutes on the die. Once the impressions were removed, the die stone [(type-IV, Kalrock)(see Fig. 1)] was mixed with distilled water in the ratio of 24 ml/100 gm (W/P) in a clean scratch free rubber mixing bowl. The mix was allowed to soak for 20 seconds in the rubber bowl, then spatulated for 5 seconds using a round ended spatula and mixed under vacuum for 1 minute by using vacuum investing machine (Fig. 13), after which the impressions were poured using a mechanical vibrator (Fig. 14). The die stone casts were allowed to set for 1 hour before removal from the impressions. A total of 42 die stone casts were obtained and grouped for identification (Fig. 15).

D. *Determining the surface details of the casts:* Each silhouette of the die stone casts was evaluated for its castability by using stereoscopic micrometer (Fig. 16). The voids of the die stone casts were examined under diopter light magnifier lens (Fig. 17) occurring at the

Fig. 12: Aluminum master die

Fig. 13: Vacuum investing machine

line angles, margins and smooth surfaces. Thus, total number of voids were counted and subjected for statistical analysis.

RESULTS

A. The contact angle values of different impression materials (Table 1 and Graph 1) ranged from 52.6° for polyether impression material, 54.7° for polyvinyl siloxane light body impression material, 55.2° for polyvinyl siloxane medium body impression material, 56.4° for polyvinyl siloxane heavy body impression material, 68.7° for polyvinyl siloxane putty consistency impression material, 68.6° for condensation silicone impression material and 96.6° for polysulfide impression material. ANOVA indicated significant differences ($p < 0.001$) in mean contact angle and New Mann – Kaul's range test indicated significant pairwise contrasts. Polyether impression material showed minimum contact angle values and polysulfide impression material showed maximum contact angle values.

Fig. 14: Mechanical vibrator

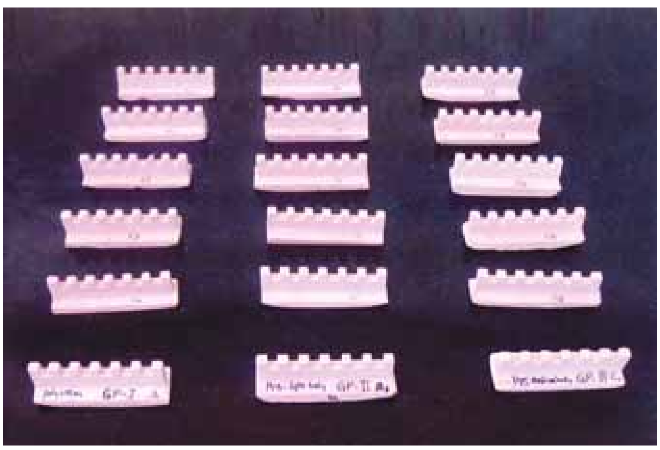


Fig. 15: Die stone casts of different study groups

Fig. 16: Stereoscopic micrometer

Fig. 17: Diopter magnifying glass

B. The mean die stone percent castability values (Table 2 and Graph 2) ranged from 94.5% for polyether impression material, 93.5% for polyvinyl siloxane light body impression material, 92.5% for polyvinyl siloxane medium body impression material, 92% for polyvinyl siloxane heavy body impression material, 90.3% for polyvinyl siloxane putty consistency impression material, 87% for condensation silicone impression material and 81.1% for polysulfide impression material. Statistically significant differences were found among materials ($p > 0.05$) but New Mann-Kaul's range tests indicated strong pairwise contrasts for seven impression materials. No significant difference could be demonstrated between the polyether, different viscosities of polyvinyl siloxane impression materials and condensation silicone impression materials. The polysulfide impression material demonstrated an ability to produce cast with least castability compared to polyether, polyvinyl siloxane impression materials and condensation silicone impression material which produced casts with good castability.

C. The mean voids for the seven impression materials (Table 3 and Graph 3) ranged from 17.0 for polyether impression material, 22.3 for polyvinyl siloxane light body impression material, 23.3 for polyvinyl siloxane medium body impression material, 25.8 for polyvinyl

Table 1: Contact angle of different elastomeric impression materials (in degrees)

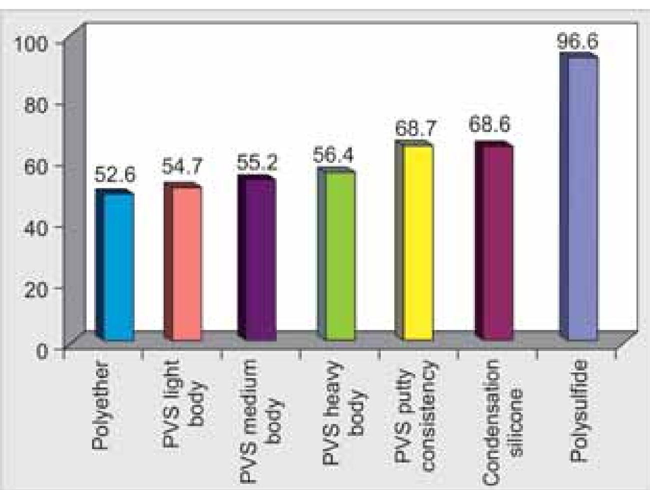
Sample No.	Polyether	PVS light body	PVS medium body	PVS heavy body	PVS putty consistency	Condensation silicone	Polysulfide
A	53.4	54.3	54.3	56.9	68.9	69.3	95.4
B	52.1	54.8	56.4	57.1	67.5	67.4	97.3
C	52.8	53.9	55.1	55.4	69.3	68.1	96.7
D	51.2	55.1	54.5	55.8	69.8	69.9	95.7
E	53.4	55.4	55.8	56.1	69.7	68.7	97.8
F	52.7	54.7	54.9	57.3	67.1	68.3	96.4
Mean	52.6	54.7	55.2	56.4	68.7	68.6	96.6
SD	0.8	0.5	0.8	0.8	1.1	0.9	0.9
Min	51.2	53.9	54.3	55.4	67.1	67.4	95.4
Max	53.4	55.4	56.4	57.3	69.8	69.9	97.8

Table 2: Castability of different elastomeric impression materials with stone cast (in percentage)

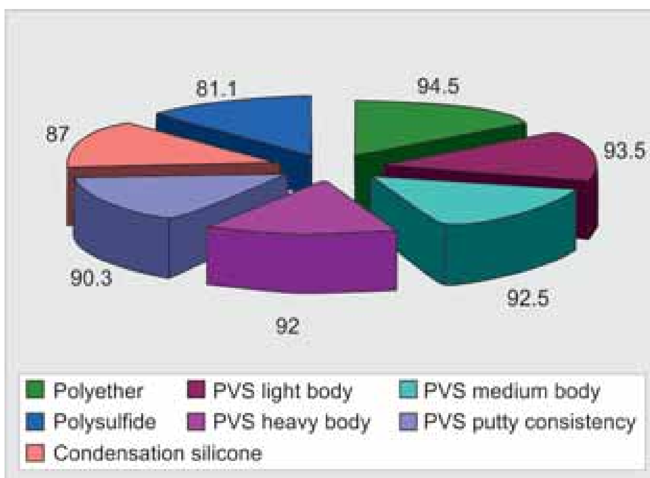
Sample No.	Polyether	PVS light body	PVS medium body	PVS heavy body	PVS putty consistency	Condensation silicone	Polysulfide
A	95	92	93	92	89	90	81.1
B	94	93	94	91	92	88	80.7
C	96	94	92	93	91	81	81
D	94	94	91	91	91	85	82
E	95	93	91	92	90	89	81.8
F	93	95	94	93	89	89	80
Mean	94.5	93.5	92.5	92.0	90.3	87.0	81.1
SD	1.0	1.0	1.4	0.9	1.2	3.4	0.7
Min	93	92	91	91	89	81	80
Max	96	95	94	93	92	90	82

Table 3: Shows voids in different stone casts of different elastomeric impression materials

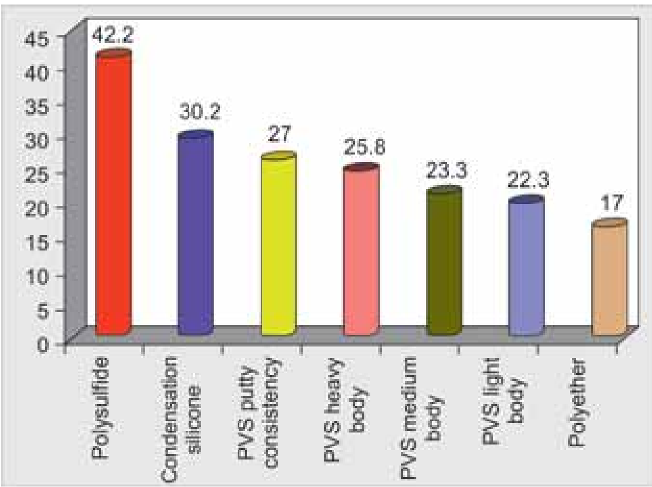
Sample No.	Polyether	PVS light body	PVS medium body	PVS heavy body	PVS putty consistency	Condensation silicone	Polysulfide
A	16	29	21	29	30	31	39
B	19	26	27	30	31	30	44
C	17	19	23	24	29	27	47
D	11	21	19	22	27	29	43
E	18	20	29	31	24	33	41
F	21	19	21	19	21	31	39
Mean	17.0	22.3	23.3	25.8	27.0	30.2	42.2
SD	3.4	4.2	3.9	4.9	3.8	2.0	3.1
Min	11	19	19	19	21	27	39
Max	21	29	29	31	31	33	47



Graph 1: Contact angle of different elastomeric impression materials (in degrees)



Graph 2: Castability of different elastomeric impression materials with die stone (in percentage)



Graph 3: Average number of voids in stone casts obtained from different elastomeric impression materials

siloxane heavy body impression material, 27.0 for polyvinyl siloxane putty consistency impression material, 30.2 for condensation silicone impression material and 42.2 for polysulfide impression material. Mann-Whitney test indicated pairwise comparisons. Polyether, different viscosities of polyvinyl siloxane impression materials and condensation silicone impression materials showed less number of voids. Polysulfide impression material showed greater number of voids.

DISCUSSION

Accurate reproduction of the prepared tooth or edentulous arch is of clinical importance in the fabrication of fixed or removable restoration. It is dependent upon an accurate void free cast or die. Inaccuracies in the replication processes will ultimately have an adverse effect on the fit and adaptation of final restoration.[9] The interaction of elastomeric impression material and gypsum slurry is important in fabrication of a voids free die which will be determined by hydrophilic and hydrophobic nature of the impression material.[8]

The hydrophobicity can be explained by the material's chemical structure, which consists of hydrophobic, aliphatic hydrocarbon which do not mediate with water molecules surrounding the material. In contrast few materials are hydrophilic in nature because of their chemical structures containing functional group that attracts and interacts with water molecules through hydrogen bonding.[9]

Actual contact angle values variations resulted due to number of factors from sample preparation to measurement techniques. When die stone slurries were used to wet specimens for contact angle measurements, the size of the slurry drop (water/powder ratio) presumably affects the rheology of the slurry and cause variations in the contact angle analysis.[4] To eliminate the effect of these variables, equal sized drops of saturated calcium sulfate dihydrate solution was used in this investigation.[4] The time of contact angle measurement in this study was arbitrarily selected to be 1 minute. The advancing contact angle was used to facilitate accurate and consistent measurements. Advancing contact angle is that observed when a liquid boundary advances over a solid surface.[6]

The present study shows least contact angle values, larger castability, and less voids with respect to polyether, different viscosities of polyvinyl siloxane impression materials. Increased contact angle values, less castability and more voids were found in polysulfide impression material. A strong correlation was observed between contact angle and percent castability of die stone measurements. Indications showed contact angle measurements are good predictor of the ability of the impression material to produce voids in casts. A low value of contact angle for an impression material showed a small volume of voids.

The newer addition silicone putty consistency and condensation silicone impression materials used in this study were hydrophilic by incorporation of the surfactants that change the surface properties at the solid liquid interface. Mechanism of action probably involves surfactant solution in the wetting liquid that lowers the surface tension of the liquid and increases the surface energy of the elastomers to promote wetting property.[5] The various viscosities of different elastomeric impression materials did not show significant difference in the contact angle values.

In the present study, the wettability of different elastomeric impressions materials were determined by measuring their contact angle values using a profile projector. The contact angles of the impression materials used in this study were evaluated. All the impression materials studied showed they were of hydrophilic in nature except polysulfide impression material which was hydrophobic in nature. The hydrophobic impression materials were incorporated with surfactants by manufactures to increase their wettability and decrease the bubble entrapment in the poured casts. These findings were in agreement with the findings of Barry K Norling and H Reribick[3] which concluded that incorporation of surfactants into impression materials increased the wettability and produced voids free casts.

In the present study, the accurate and finer detail casts were produced from polyether impression material and next accurate from the silicone impression materials followed by different viscosities of polyvinyl siloxane impression materials, condensation silicone impression material and polysulfide impression material respectively. These findings were in accordance with the findings of Soh G, Chang HY (1990)[7] who studied the wettability of two hydrophilic addition silicones and two hydrophobic silicone impression materials.

CONCLUSION

After the statistical analysis of the results obtained in the present *in vitro* study, the following conclusions were made.

1. The polyether, different viscosities of polyvinyl siloxane impression materials and condensation silicone impression material showed greater wettability, which exhibited lower contact angles than the polysulfide impression materials.
2. The percent castability of die stone was significantly higher in polyether, different viscosities of polyvinyl siloxane impression materials and condensation silicone impression material when compared to polysulfide impression material.
3. The voids were significantly less in the casts made with polyether impression material followed by different viscosities of polyvinyl siloxane impression materials and condensation impression materials and more voids were present in casts made with polysulfide impression materials.

CLINICAL SIGNIFICANCE

To achieve an impression with accurate details of the teeth and oral structures, the nature of impression material to be used is important. The compatibility of the gypsum products with impression materials is also one of prime factor to produce an accurate cast. Contact angle is one of the factors, which plays a significant role in determining the nature of the impression material and to obtain an accurate cast.

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