Flowing of light-bodied elastic impression materials

TROND HEGDAHL & NILS ROAR GJERDET

Department of Dental Materials, School of Dentistry, University of Bergen, Bergen, Norway

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The ability of light-bodied elastomeric and reversible hydrocolloid impression materials to spread on a surface was studied *in vitro*. The material which most readily coated the surface was a polysulfide, followed by silicone, hydrocolloid, and polyether materials. The influence of surface energy was studied by comparing the spreading of impression materials on high energy (glass) and low energy (PTFE) surfaces. Only for polysulfide and hydrocolloid materials was any effect observed: The glass was more readily coated than PTFE. As a result of an increase in temperature of the elastomeric materials a reduction in the materials' ability to wet the surface was found for silicones and polysulfide, but not for polyether. An addition-polymerized silicone product showed the strongest temperature dependence. A strong negative correlation was found between spreading ability and viscosity of elastomeric materials.

Key-words: Dental materials; elastomers; hydrocolloids

T. Hegdahl, Department of Dental Materials, School of Dentistry, University of Bergen, Årstadvei 17, 5000 Bergen, Norway

When an impression material is placed on a tooth surface, it will flow along the surface to a certain degree. By the time the setting has taken place, the material will cover an area the size of which depends on several factors. The surface energies of the material and the tooth are probably of importance. From contact angle measurements (2, 3, 4) it is. known that elastomeric impression materials differ with respect to surface energy. The significance of a contamination (water, oil) of a dentin surface for the ability of the impression material to coat the surface has been demonstrated (1). Other factors of importance for the flow of impression materials might be the roughness of the preparation, the specific gravity of the material, and the viscosity which may be both time and temperature dependent. The ability of an impression material to spread over a large area is most likely an advantageous property for the clinical use of the material.

The purpose of the present *in vitro* study was to determine the contact areas formed when constant volumes of impression materials are placed on a test surface. Furthermore, it was the intention to observe the effects of variations in surface energy of the surface, simulating the tooth, and variations in the temperature of the material at the time of contact with the test surface. Finally, the relationship between the impression materials' flow on the surface and their viscosity was examined.

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MATERIALS AND METHODS

The materials studied are presented in Table 1. They were all of the light-bodied or injection type. Since Impregum® has no particular syringe material, the Impregum thinner was added to decrease its viscosity. The amount of thinner was equal to the amount of catalyst paste. The materials were handled according to the instructions given by the manufacturers with respect to proportioning, mixing, and, for the hydrocolloid material, temperature.

Contact areas

Using a syringe with a 1.8 mm inside nozzle diameter, 0.35 ml of newly mixed elastomeric material was injected into a cylindrical steel mold in which it was kept separated from a piston by a disk of PTFE (Polytetrafluoroethylene) (Fig. 1). Ninety seconds after the end of mixing, which is within the working time for all the materials, the piston was moved at 500 mm/min (Instron Universal Testing Machine, Model 1193, England) until contact between the PTFE disk and the test surface was obtained (Fig. 2). This was done inside a temperature cabinet kept at 35°C. The test surface was either glass (Socorex Microscopic Slides, Switzerland) or PTFE, conditioned to 35°C. The PTFE surface was a polished 0.5 mm thick PTFE sheet glued onto a resin block. The roughness of the PTFE expressed by the R_a-value was 0.03 µm. The test surfaces were cleansed in water in an ultrasonic bath, then cleaned in an alkaline laboratory cleaning agent (RBS 25, Belgium), rinsed in distilled water, and dried in air.

In a first series of measurements the temperature of the elastomeric materials and the instruments for mixing and injecting, as well as the steel block and the PTFE disk, was 23°C. In the case of the reversible hydrocolloid the material was injected into the steel mold by means of the special syringe to be used with that product. The material was then immediately extruded, at a temperature of 65°C, onto the test surface of 35°C.

In order to study temperature dependence a second series was done, involv-

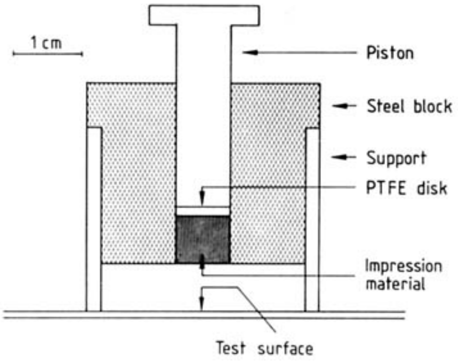

Fig. 1. The experimental arrangement immediately before extrusion of the impression material onto the test surface.

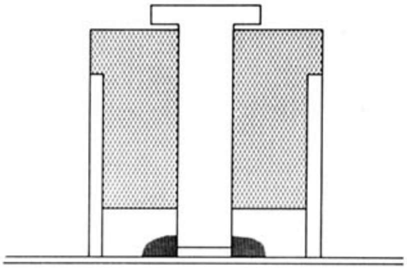

Fig. 2. The formation of a specimen of impression material on the test surface.

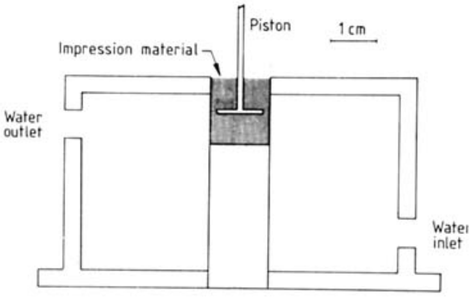

Fig. 3. Apparatus used for viscosity measurements.

Table 1. *Materials included in the study*

Material	Type	Batch No.	Manufacturer
Impregum	Polyether	Base: D–208 Catalyst: D–168 Thinner: A–211	Espe GmbH Seefeld Germany
Permlastic	Polysulfide	Base: 82349 Catalyst: 91018	Sybron/Kerr Scafati Italia
President	Addition polymerized silicone	12711	Coltène AG Altstätten Switzerland
Xantopren Blau	Condensation polymerized silicone	0956 T	Bayer Dental Leverkusen Germany
Thompson's Hydrocolloid Sticks	Reversible hydrocolloid	080377	Lactona Corp. N.J., U.S.A.

ing the elastomers only, where the temperature of the impression material when extruded onto the test suface was either 15 or 27°C. The temperature of the test surface was constantly maintained at 35°C. The material remained on the test surface for the stated setting time. For each material or condition 5 specimens were made. In each specimen the contact area was determined after measuring of 2 diameters at right angles to each other in a profile projector (Nikon Profile Projector, Model 6CT2, Japan) at a magnification of 10X.

Viscosity

The viscosity of the impression materials was assessed by measuring the force needed to cycle a piston within a cylinder filled with the impression material (Fig. 3). The material was brought into the cylinder by means of the syringes described above. The temperature of the cylinder was maintained at 35°C for the elastomers and 65°C in the case of the hydrocolloid by means of circulating water. The instrument (Fig. 3) was clamped to the load cell of the mechanical testing machine, and the piston was moved up and down with a stroke of 0.1 mm at a cross-head speed of 10 mm/min. The load was continuously recorded on a chart recorder. Full scale load on either side of the zero line was 2 N (Fig. 4). The recording started 90 s after the end of mixing. Three determinations were made for each material.

Statistics

Statistical evaluation was performed using the Wilcoxon Rank Sum Test at the 5 % level ($\alpha = 0.05$).

RESULTS

Contact areas

The contact areas obtained for materials at temperatures usally met with in clinical practice show that Impregum exhibited the lowest values while Permlastic® had the highest ones (Fig. 5). The differences between areas on glass and areas on PTFE were significant only for Permlastic and Thompson's Hydrocolloid Sticks® ($p = 0.005$) (Fig. 5).

When the temperature of the elastomeric impression materials was changed to 15 or 27°C at the time of contact with the test surface, a temperature effect was observed for some materials (Fig. 6). As the temperature was raised, the contact areas decreased. When the areas obtained for 15°C and 27°C were evaluated statistically, significant differences ($p = 0.005$) were found for the silicones and the polysulfide, but not for the polyether.

Viscosity

The elastomers exhibited viscosities which were quite different not only initially, i.e. after 90 s, but also in their subsequent change pattern (Fig. 7). Marked differences in the rate of change were seen in the course of 30 s (Fig. 8). Permlastic had the lowest initial viscosity and it increased only about 30 % from 90 to 120 s. The silicones Xantopren® and President® had slightly higher initial values, but during the same period of time they showed an increase of 150 and 230 %. The initial viscosity of Impregum was about 6 times higher than that of Permlastic, and increased only 30 % from 90 to 120 s. The hydrocolloid at 65°C had values close to the 90 s viscosity of the silicones.

DISCUSSION

The present study has shown that various elastic impression materials behave quite differently when placed on a dry surface of glass or PTFE. If the degree of coating of the test surface is governed by the surface energies, then the results for contact areas in the present experiment would be affected by the variations in the energy of the surface (glass, PTFE). The results obtained indicate such an energy dependence

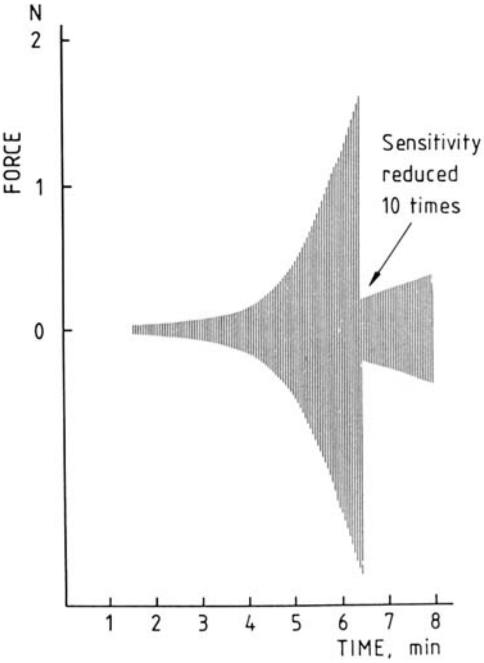

Fig. 4. Example of a recording obtained when using the equipment shown in Fig. 3.

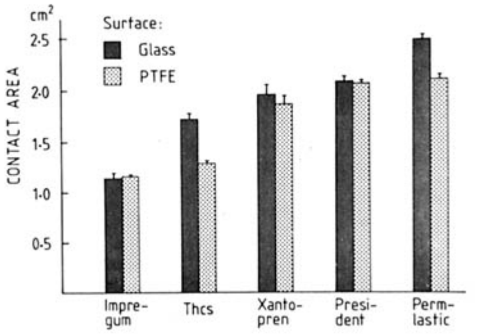

Fig. 5. Areas of impression materials formed on glass and PTFE test surfaces. Temperature of elastomeric materials 23°C and of hydrocolloid 65°C at time of contact. Vertical lines on top of columns give the standard deviation. Thcs: Thompson's Hydrocolloid Sticks.

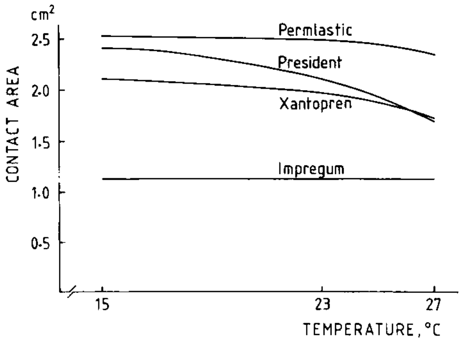

Fig. 6. The influence of temperature on the contact areas of elastomers.

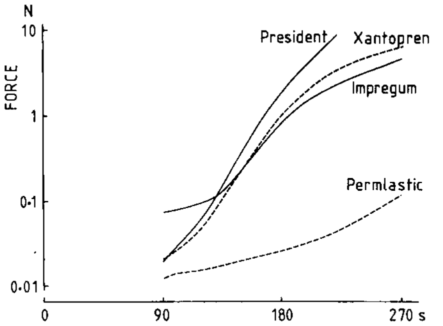

Fig. 7. Force indicating viscosity. Time measured from the end of mixing. Force is given in a logarithmic scale.

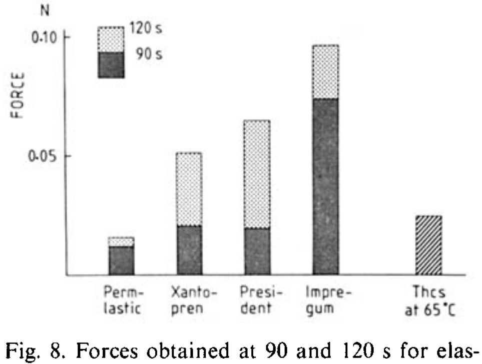

Fig. 8. Forces obtained at 90 and 120 s for elastomers and at 65°C for hydrocolloid (Thcs). Time measured from the end of mixing.

only for the polysulfide and the hydrocolloid. In addition the results would be expected to depend on the surface tension of the impression materials themselves. It has been shown already (2) that the contact angles formed by gypsum slurries on elastomeric impression materials differ, thereby reflecting differences in surface tension of the impression materials. The order of decreasing surface energy is polyether – polysulfide – silicone (2). If the formation of contact areas is well correlated with the energy of the impression materials, the areas measured in the present study would be expected to increase in the same order. This was not quite the case, although the finding of larger areas for the silicones and the polysulfide than for the polyether material is in accordance with such an energy dependence. It appears, therefore, that the coating ability of elastomeric impression materials is only partly depending on surface energy when the energies range as in the present experiment. Landt & Glantz (1) found, however, that the spreading of impression material could be strongly affected by a contamination of the surface. In particular, the presence of water enhanced the spreading of hydrocolloid and diminished that of elastomers.

As a result of an increase in temperature of the elastomers at the time of contact with the test surface a reduction in contact areas was encountered for the polysulfide and the silicones, but not for the polyether material. The reason for the area reduction is most likely the accelerated polymerization rate and, hence, the higher increase in viscosity accompanying the temperature rise. The effect of this factor would then be governed by the dependence of setting time on temperature. In the past the setting times of silicones have been less dependent on temperature than those of polysulfides (6). The present results indicate that such a difference does not exist for the products included in this study. The addition-polymerized silicone President in particular appears to be highly influenced by temperature during setting. According to previous findings (5) the reaction of Impregum is less sensitive to temperature changes than that of polysulfides. This seems to be confirmed by the present results.

When the contact areas for elastomers are compared with the viscosity data, a connection can be seen: the lower the viscosity at 90 s, the smaller the contact area. The Spearman's Rank Correlation Coefficient calculated for contact areas formed by elastomers of 23°C on glass versus viscosity at 90 s was $r_s = -1$.

The results of the present study suggest that the coating ability of elastomers depends on viscosity more than on any other of the factors examined. This applies under the experimental conditions used, i.e. for test surfaces which are clean except for water which always adheres to surfaces under atmospheric conditions. An initially low and slowly increasing viscosity appears to be favorable.

The hydrocolloid material had a coating ability which was inferior to that of polysulfide and silicone under the present conditions. As has been demonstrated earlier (1), however, this type of material has an asset in cases where water is more abundantly present.

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