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ACCURACY OF INDIRECT STONE MODELS MADE FROM REVERSIBLE HYDROCOLLOID IMPRESSIONS

BY

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ABSTRACT

A reversible hydrocolloid impression material was evaluated by testing the fine line reproducibility, surface hardness and dimensional changes of resultant models and also the linear shrinkage of the setting material. It could fully reproduce the 20-micron wide line on the model. The model surface was harder than that from the alginate impressions. Its linear shrinkage when cooled to room temperature was as great as 0.6% and so the impression held in the trays produced models of increased outside dimension and decreased inside dimension. The outside-inside difference was exaggerated by ice water cooling of the impressions.

INTRODUCTION

Since the reversible hydrocolloid impression material was introduced into dentistry for the indirect inlay and crown technique by Sear in 1937[1)], many researchers have reported on their experimental data and clinical use of this material[2–9)]. It is still widely used in the United States, though many other impression materials have been introduced since then[10–14)]. In this study, the detail reproducibility, surface hardness and dimensional change of the stone models made using a reversible hydrocolloid impression material and the linear dimensional change of the impression material itself were determined to evaluate the impression material for indirect technique.

METHODS

Material and manipulation. A pair of reversible hydrocolloid impression materials, tray type (Surgident Poly Tube—B. N. 11678560) and syringe type (Surgident 3/8 Sticks—B. N. 59), were used.

According to the direction of the manufacturer, the tray type was melted in the liquefying bath at 100°C in a hydrocolloid conditioner for 10 minutes, stored in the storage bath at 60(±1)°C for more than 20 minutes, tempered in the tempering bath at 45(±1)°C for 10 minutes and then pressed

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upon the original models with trays. The syringe type was loaded in a plastic syringe, melted in the liquefying bath for 6 minutes, stored in the storage bath for more than 20 minutes, folded on the tray type in trays and then pressed upon the original models.

After 10 minutes, the impressions were removed from the original models and immersed in a 2 percent potassium sulfate fixing solution[4-6,15]. After 30 seconds they were taken out, shaken to remove the residual fixing solution and poured with Zostone, a dental stone of hydrocal type (water/powder ratio=0.24, setting expansion=0.38%). The stone models were taken out of the impressions after storing in a humidor at room temperature for 1 hour. The laboratory room was kept at 23±2°C and at 64~72% relative humidity throughout this experiment.

Surface detail reproducibility test. The original model designed by Fusayama (Fig. 1)[16] was used for testing the surface detail reproducibility on the stone models.

It consisted of six stainless steel blocks having triangular fissures of 60° bottom angle and with a width of 7, 10, 15, 20, 30 and 40 microns, respectively, assembled in a brass frame. Impressions were taken from the original model in a humidor at 36(±1)°C. The original model was cleansed in an ultrasonic bath and then under running water before repeating the impression.

The resultant stone models were examined under a binocular microscope (16×) using a low-angle illumination for reproducibility of the fine lines. Ten specimens were examined in each group.

Surface hardness test. A glass plate was impressed using the tray type or the syringe type folded on the tray type loaded in a perforated brass tray

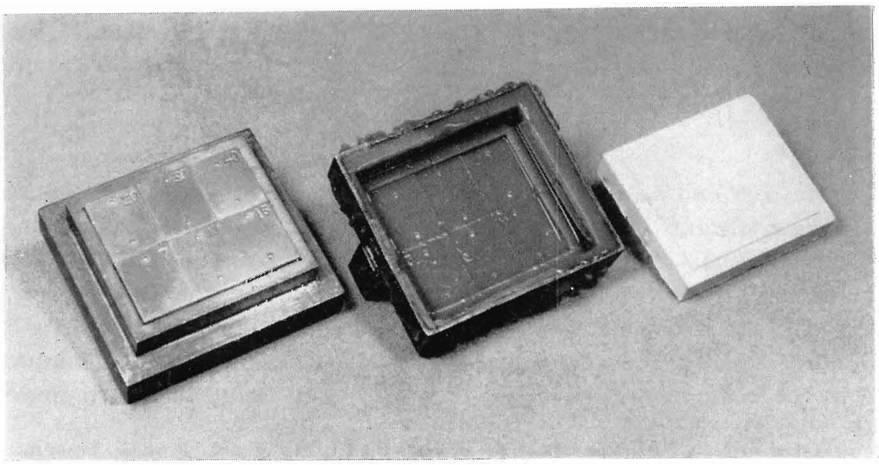

Fig. 1. The original model (left), a hydrocolloid impression (center) and a stone model (right) used for the fine line reproducibility test.

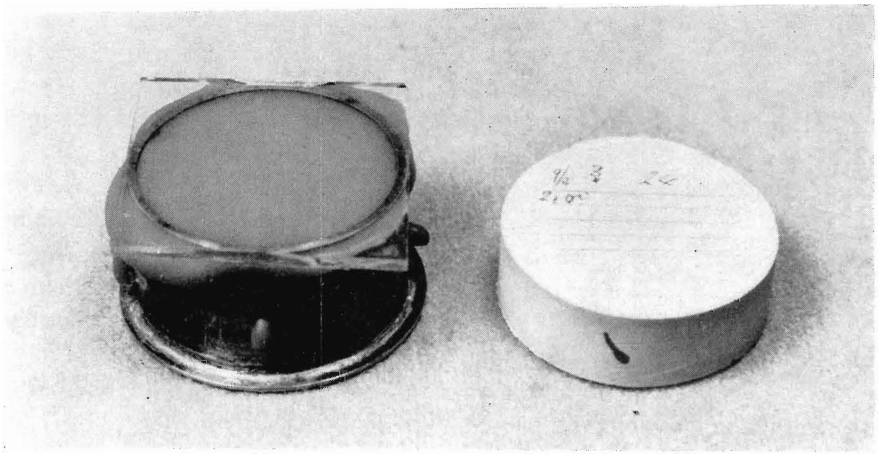

Fig. 2. An impression with a glass plate pressed upon it (left) and a stone model surface which set against the impression surface (right) used for the scratch hardness test.

23 mm in diameter and 12 mm in depth (Fig. 2) in a humidor at 36(±1)°C simulating the mouth.

After the material set the impression was removed from the glass plate and immersed in the fixing solution for 30 seconds. The stone was poured in a copper band frame of 8 mm height and 23 mm diameter placed on the

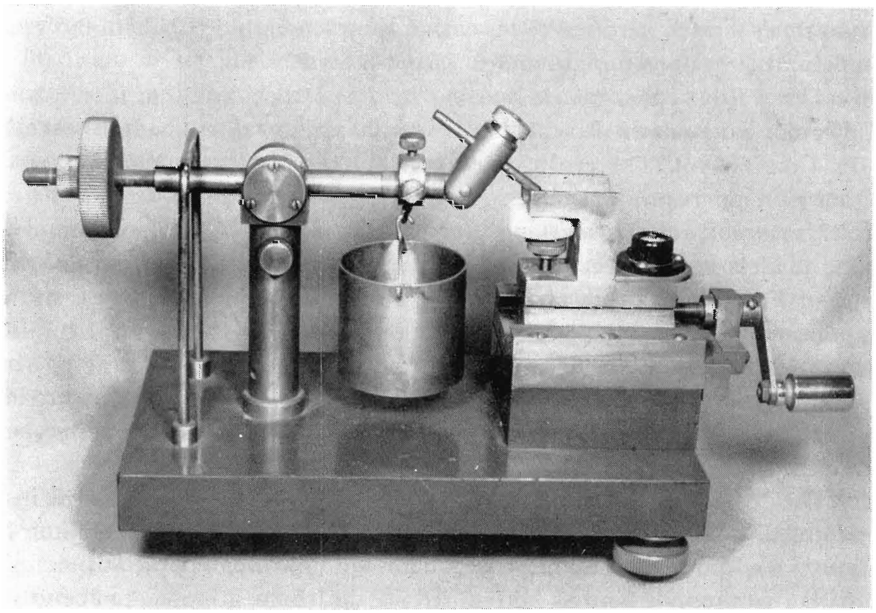

Fig. 3. Fusayama's scratch hardness tester.

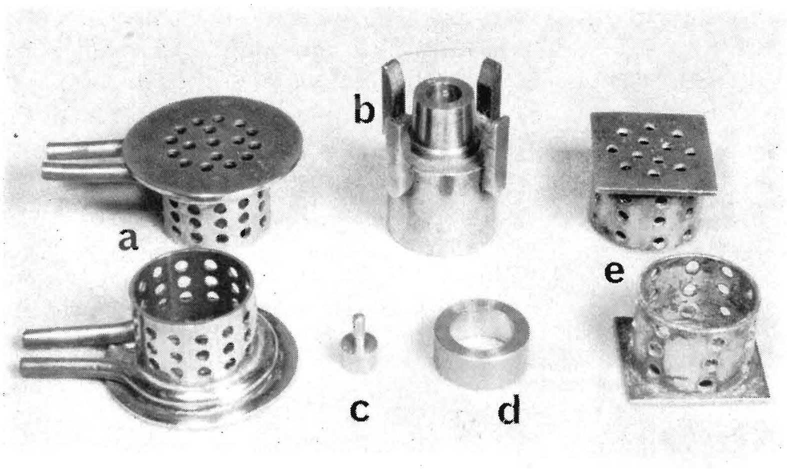

Fig. 4. The inside and outside dimensions comparative measuring apparatus used for measuring the dimensional changes of stone models: a=top and reverse views of a water cooling tray, b=the original model, c=the fitting insert, d=the fitting ring, and e=top and reverse views of a tray without water coolant.

impression surface and stored in the humidor at room temperature. The stone model was separated from the impression after 1 hour. Five specimens were prepared for each group.

At 3 and 24 hours after pouring, the model surface was scratched by Fusayama's scratch hardness tester with a tungsten carbide blade of 60° edge angle and 30° contact angle under a 5-gram load[17] (Fig. 3).

The width of the scratch line was read at 5 spots at 2 mm intervals by the ocular micrometer attached to a microhardness tester (made by Akashi Mfg. Co., Tokyo). The result of each group was shown by the average of 25 measurements on 5 specimens.

Measurement of dimensional change of stone models. The accuracy of stone models for indirect models were investigated by using the improved type of Fusayama's inside and outside dimensions comparative measuring apparatus[11] (Fig. 4). The original die of this apparatus was an invar column with a 10-mm top diameter and 1/10 taper having a cylindrical cavity with a 6-mm opening diameter and 1/10 taper. The apparatus had an invar ring and insert to fit the original die with the top surfaces becoming flush when assembled.

The tray type or the syringe type folded on the tray type loaded in a perforated tube tray was pressed upon the original die, removed after 10 minutes and poured with the stone under the following conditions:

(1) Impressed, poured and stored in the room at room temperature and at 64 to 72 percent relative humidity.

(2) Impressed, poured and stored in a humidor at room temperature and at 100 percent relative humidity.

(3) Impressed and poured in a thermostatic box at 36(±1)°C and at 40 or slightly less percent relative humidity and stored in the room.

(4) Impressed in a humidor placed in a thermostatic box at 36°C to simulate the mouth and poured and stored in a humidor at room temperature.

(5) Impressed, poured and stored in a thermostatic box at 36°C and at relative humidity of 40 percent or slightly less using materials and implements kept at 36°C.

(6) Impressed, poured and stored in a humidor placed in the thermostatic box at 36°C using materials and implements kept at 36°C.

(7) Impressed in a humidor at 36°C using materials and implements kept at room temperature, cooled for 2 minutes with 5°C water circulated through a tube attached to the tray by means of a gear pump at a rate of 450 to 500 ml/min., and after removal poured and stored in a humidor at room temperature.

(8) Manipulated similarly to (7), except cooling for 5 minutes with 20(±1.5)°C water.

Stone models, 10 for each group, were thus made separating from the impressions 1 hour after pouring and their outside and inside dimensional changes were determined after 24 hours by reading the discrepancies between the top surfaces of a stone model and the ring and insert placed on it using a dial gauge calibrated by 5 microns (Fig. 5). A vertical protrusion or intrusion of 100 microns of the ring or insert from the top surface of a stone model indicated a horizontal expansion or shrinkage of 10 microns of the model (1/10 percent of the outside diameter or 1/6 percent of the inside diameter) because of the taper of 1/10.

Measurement of gelation shrinkage of impression material. A trough type tray (Fig. 6 and 7) was designed for measuring the linear gelation shrinkage of the impression material itself. A screen was fixed near the end of this trough to hold one end of the impression material in measurement and a thermistor tip was inserted in it to measure the internal temperature in the material. An acrylic movable screen to follow the shrinkage of the impression material was placed 102 mm distant from the fixed screen. The movable screen was backed up by a supporter to prevent it from falling before gelation.

The trough was lined with petroleum jelly of a thickness of 0.5 to 1.0 mm, stored in a thermostatic humidor (a modified infant incubator) regulated at 36(±1)°C and 100 percent relative humidity (Fig. 8) and poured with the impression material of 35 g melted by the technique instructed by the manufacturer. A triangular tin foil was placed 2 mm distant from the

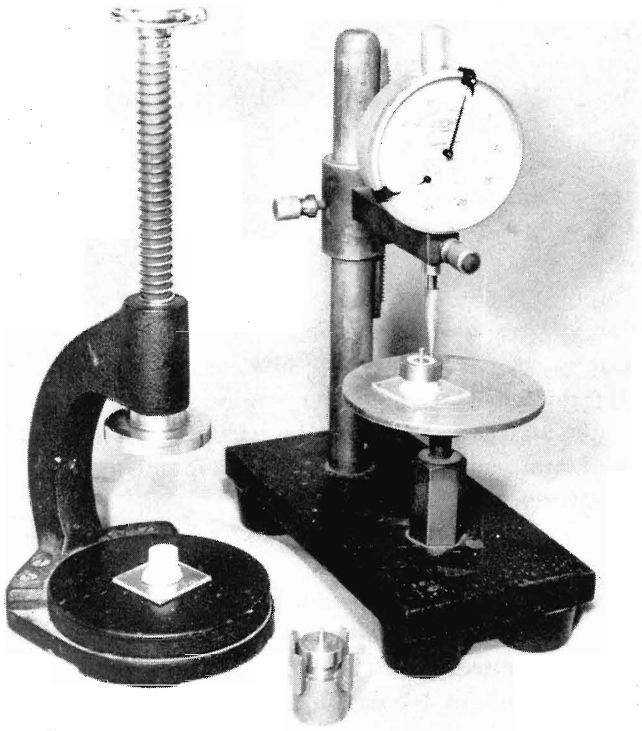

Fig. 5. Measuring the dimensional changes of a stone model: a stone model was put on a temporary cement mix and pressed by a horizontal presser (left). The ring and insert were fit on the stone model placed on a stage and the discrepancies between their top surfaces and the model top surface were read by using a dial-gauge (right).

movable screen, namely 100 mm distant from the fixed screen, as a mark for reading the shrinkage of the impression material. The tin foil was 10 mm high and 4 mm wide and bent in the middle to use one-half of it as a base to be placed on the material surface. The movement of the tip of the tin foil was read by a comparator microscope graduated in 2 microns. (manufactured by Shimazu Mfg. Co., Kyoto).

After pouring the impression material in the trough, the thermostatic humidor was switched off and left to cool to room temperature and the shrinkage and the temperature change were read. The experiment was repeated 5 times for each group.

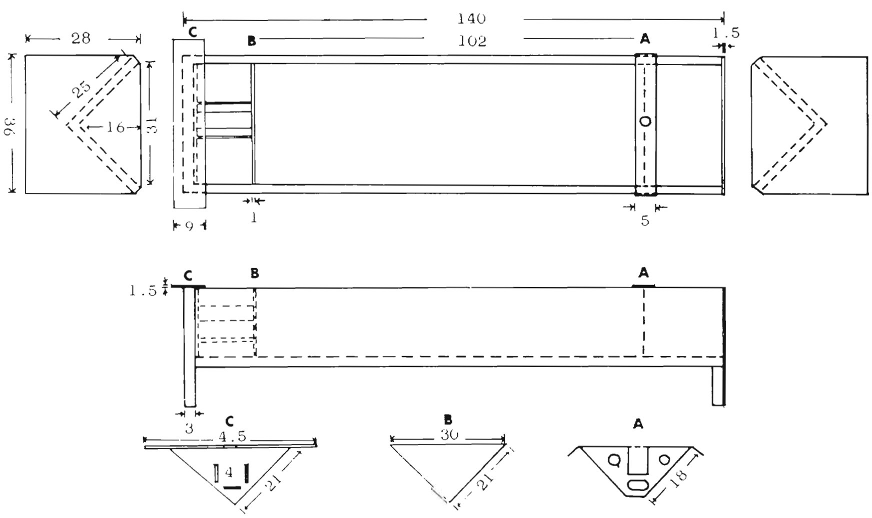

Fig. 6. Design of the trough for measuring linear gelation shrinkage of hydrocolloid impression material (in milimeter): Top=side and top views, middle=vertical section, and bottom=fixed screen (A), movable screen (B) and screen supporter (C) made of plastic.

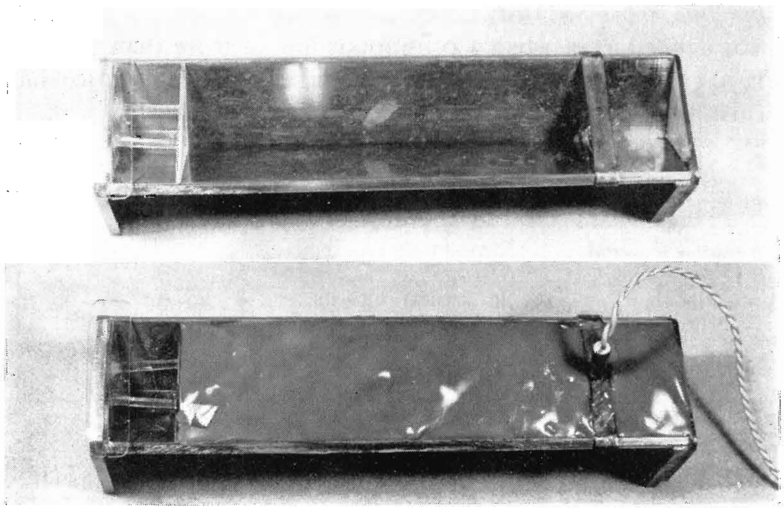

Fig. 7. The trough for measuring linear gelation shrinkage of the impression material ready to be used (top) and that being used with the impression material loaded and a thermister set (bottom).

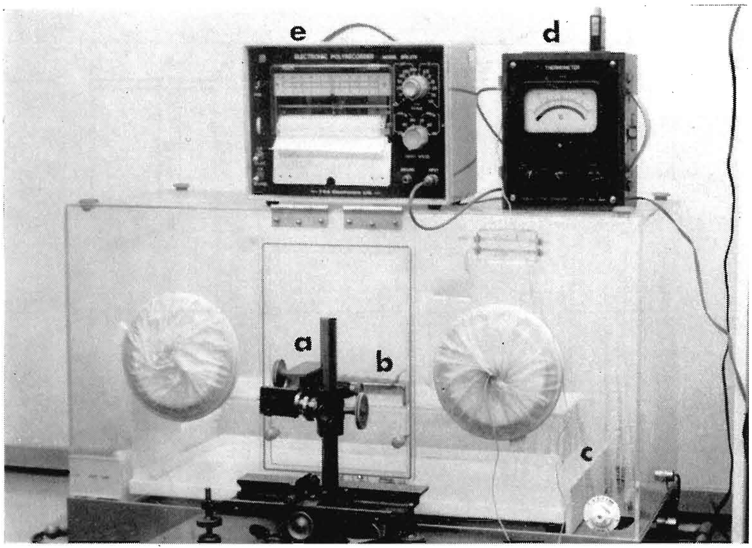

Fig. 8. The equipment for reading the gelation shrinkage: a=comparator microscope, b=trough with specimen, c=thermostatic humidor, d=thermister and e=autographic recorder.

Results

Fine line reproducibility. For comparing the results, the reproducibility was defined as + when a continuous line of more than 80 percent of the original line was reproduced, as ± when reproduced only partially and as − when not reproduced at all (Table 1).

Table 1. Fine line reproducibility of hydrocolloid impressions on stone models

Impression material		Tray type						Syringe type folded on tray type					
Line width (μ)		40	30	20	15	10	7	40	30	20	15	10	7
	1	+	+	+	−	−	−	+	+	+	±	−	−
	2	+	+	±	−	−	−	+	+	+	+	−	−
	3	+	+	+	−	−	−	+	+	+	−	−	−
	4	+	+	±	−	−	−	+	+	+	+	−	−
Reproduction	5	+	+	±	−	−	−	+	+	+	+	±	−
	6	+	+	−	−	−	−	+	+	+	+	−	−
	7	+	+	±	−	−	−	+	+	+	±	−	−
	8	+	+	+	−	−	−	+	+	+	±	−	−
	9	+	+	+	+	−	−	+	+	+	±	−	−
	10	+	+	+	−	−	−	+	+	+	±	−	−

The tray type material always reproduced a line of 30 or more microns, a 20-micron line partly, a 15-micron line in only one case but never the 10- and 7-micron lines. The syringe type material folded on the tray type always reproduced a line of 20 or more microns, a 15-micron line sometimes, a 10-micron line partially in one cast but never a 7-micron line.

Surface hardness of stone models. The surface hardness of the stone models was compared by the width of the scratched lines in microns (Table 2). No statistically significant difference in the stone model hardness was observed between the tray type and the syringe type folded on the tray type. The hardness was higher at 24 hours than at 3 hours.

Dimensional changes of stone models. The inside temperature of the material impressing the original model of the inside and outside dimensions comparative measuring apparatus dropped faster in atmosphere at room temperature than at mouth temperature, and still faster when water-cooled (Fig. 9). Little difference in the cooling curve was observed between

Table 2. Scratch hardness of stone model surfaces

Impression material	Scratch line width (μ)	
	After 3 hours	After 24 hours
Tray type	42.71 (1.25)	36.55 (0.53)
Syringe type folded on the tray type	42.60 (1.82)	35.05 (1.38)

Figures in parenthesis show the standard deviations.

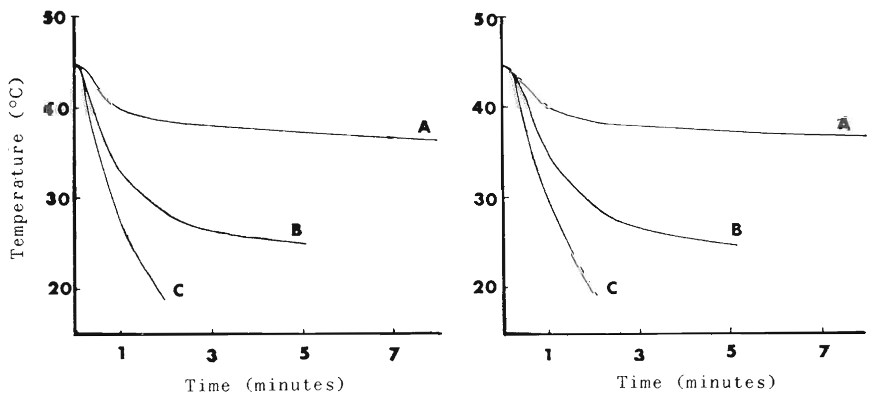

Fig. 9. Temperature changes of the impression material pressed upon the inside and outside dimensions comparative measuring molds: left=with the tray type material and right=with the syringe type folded on the tray type. A=without coolant, B=cooled with room temperature water, and C=cooled with ice water (5°C).

the tray type and the combination of the two types.

The dimensional changes of the stone models in comparison with the original dies were compared in percentage (Table 3, 4). The outside measurement was always greater than the inside measurement and the outside diameter of the stone model was always much greater and the inside diameter was smaller or slightly greater than that of the original die. The difference between the inside and outside measurements was the greatest when impressed and poured at room temperature, next greatest when impressed at mouth temperature and poured at room temperature and smallest when impressed and poured at mouth temperature. The mean of the inside and outside measurements changed little in different groups. Although the difference was thus very slight, the mean was the smallest when impressed and poured at room temperature and largest when impressed and poured at mouth temperature.

Table 3. Dimensional changes of stone models made from tray type impression material

Relative humidity		100%			68±4%		
Temperature of original model		23°C	36°C	36°C	23°C	36°C	36°C
Temperature during pouring		23°C	23°C	36°C	23°C	23°C	36°C
Dimensional change (%)	Outside measurement	+0.52 (0.02)	+0.45 (0.05)	+0.27 (0.05)	+0.54 (0.02)	+0.48 (0.06)	+0.36 (0.04)
	Inside measurement	−0.18 (0.02)	−0.02 (0.01)	+0.18 (0.06)	−0.18 (0.03)	−0.07 (0.04)	+0.04 (0.02)
	Outside-inside difference	0.70	0.47	0.09	0.72	0.55	0.32
	Outside-inside mean	+0.17	+0.22	+0.23	+0.18	+0.21	+0.20

Figures in parenthesis show the standard deviations.

Table 4. Dimensional changes of stone models from syringe type folded on tray type impression material

Relative humidity		100%			68±4%		
Temperature of original model		23°C	36°C	36°C	23°C	36°C	36°C
Temperature during pouring		23°C	23°C	36°C	23°C	23°C	36°C
Dimensional change (%)	Outside measurement	+0.51 (0.04)	+0.48 (0.03)	+0.25 (0.08)	+0.53 (0.03)	+0.45 (0.04)	+0.34 (0.03)
	Inside measurement	−0.30 (0.03)	−0.24 (0.06)	+0.07 (0.02)	−0.39 (0.04)	−0.25 (0.05)	−0.17 (0.05)
	Outside-inside difference	0.81	0.72	0.18	0.92	0.70	0.51
	Outside-inside mean	+0.11	+0.12	+0.16	+0.07	+0.10	+0.09

Figures in parenthesis show the standard deviations.

The humidity affected little the general measurements though the difference between the inside and outside measurements, when poured at

Table 5. Dimensional changes of stone models made from water-cooled impressions

Impression material		Tray type			Syringe type folded on tray type		
Relative humidity		100%			100%		
Temperature of original model		36°C	36°C	36°C	36°C	36°C	36°C
Temperature of cooling water			20°C	5°C		20°C	5°C
Temperature during pouring		23°C	23°C	23°C	23°C	23°C	23°C
Dimensional change (%)	Outside measurement	+0.45 (0.05)	+0.41 (0.04)	+0.44 (0.04)	+0.48 (0.03)	+0.43 (0.04)	+0.43 (0.07)
	Inside measurement	−0.02 (0.01)	−0.10 (0.03)	−0.24 (0.06)	−0.24 (0.05)	−0.22 (0.06)	−0.40 (0.05)
	Outside-inside difference	0.47	0.51	0.68	0.72	0.65	0.83
	Outside-inside mean	+0.22	+0.16	+0.10	+0.12	+0.11	+0.02

Figures in parenthesis show the standard deviations.

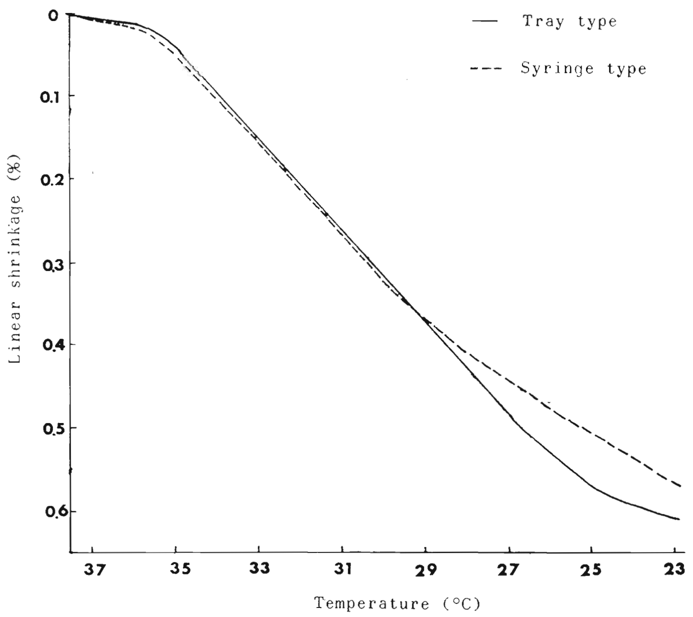

Fig. 10. The free linear thermal shrinkage of the setting hydrocolloid impression material.

mouth temperature, was greater at lower humidity.

The tray and syringe types used in combination as compared with the tray type did not change the outside measurement but decreased the inside measurement and therefore slightly decreased the mean of both measurements.

The use of water cooling changed little the outside measurement but decreased the inside measurement and therefore made the difference between both measurements greater and the mean of both slightly smaller (Table 5). Such an effect of cooling was more remarkable with ice water than with room temperature water and also with the combination of the two types than with the tray type.

Linear cooling shrinkage of impression material itself. Both the tray and syringe type materials began to gelatinize and shrink at 37°C and shrank at a rate of approximately 0.1 percent per 2°C from 35°C down to room temperature of 23°C, resulting in a total shrinkage of approximately 0.6 percent (Fig. 10).

Discussion

Fine line reproducibility and surface hardness of stone models. The American Dental Association Specification revised in 1967 required a hydrocolloid impression material to reproduce the 75-micron width line on stone models. The lines as fine as 15 to 20 microns were reproduced in this study. This result was comparable to those from the alginate impression materials, Palginex and Technicol, reported by Sato and others[18]. The stone model surfaces made from the hydrocolloid impression materials, however, looked slightly smoother to the naked eye than those made from the alginate impression materials. The surface hardness of the stone models was also much higher with the hydrocolloid impressions than with the alginate impressions tested by Otani[17] and Sato et al.[18].

Dimensional accuracy. The dimension of an indirect stone model changes as the function of the dimensional changes of the impression material and the stone[19]. A stone model becomes larger than the original model due to the setting expansion of the stone. When an elastic impression material held in a tray shrinks, the outside measurement of the model becomes larger because the impression walls are pulled to the tray walls, and the inside measurement becomes smaller because the impression walls are pulled to the center, with the mean of both measurements being comparable to the setting expansion of the stone. On the contrary, when an impression material expands, the outside measurement becomes smaller and the inside measurement becomes larger. Therefore, whether the balance of the outside measurement minus the inside measurement is plus or minus indicates whether the impression material has shrank or expanded, respectively, and the degree of the shrinkage or expansion can be compared referring to the magnitude of the difference. The hydrocolloid impression material used in this study always shrank on gelation making the resultant models larger in their outside measurement and smaller in their inside measurement, which was favorable for facilitating the fit of restrations. When held by a clinical tray, however, too great a shrinkage cannot be considered acceptable because the mold is distorted by an irregular shrinkage of the impression material unevenly held by the tray walls.

Two possible causes for the shrinkage of hydrocolloid impression material are considered to be cooling and drying[7,8,15].

a) Effect of cooling shrinkage

The stone model made by impressing at mouth temperature and pouring at room temperature showed a much greater difference between the inside and outside measurements than that made by impressing and pouring at mouth temperature, because the cooling shrinkage occurred over a longer range.

The outside-inside difference of the stone model was greater when impressed at room temperature than when impressed at mouth temperature. Although not clear enough, this may be possibly accounted for as follows: When the impression material was pressed on the original model at a higher temperature, the whole mass homogeneously gelatinized rather at the same time and then shrank by cooling. On the other hand, when pressed on the model at a lower temperature, the layer in immediate contact with the model produced a gelatinized film by rapid cooling and was separated from the model by the following shrinkage of the underlying material, thus adding the effect of the part of the shrinkage before and during gelation to the mold dimension.

The outside-inside difference of the model was greater with the tray and syringe types in combination than with the tray type. In this case, the temperature of the combination was much higher by the addition of the syringe type which had been tempered at 65°C (instead of at 45°C as with the tray type), resulting in a greater temperature difference compared with the original model, which increased the above-mentioned phenomenon.

The outside-inside mean did not change remarkably with such variables, because it was essentially a function of the setting expansion of the poured stone. The mean was, however, approximately 0.2 percent smaller than the stone expansion of 0.38 percent, probably because the stone expansion was restricted by the impression material resulting in smaller outside measurement of the models.

When a colder mold at room temperature was impressed, the decrease of inside measurement was more remarkable than the increase of the outside measurement resulting in a smaller outside-inside mean. It was probably because the cooling effect of the mold was more remarkable on the inside portion than on the outside portion of the impressions.

b) Linear shrinkage of the impression material

The free linear shrinkage of the hydrocolloid impression material when cooled down to room temperature was 0.6 percent when determined using the V-formed trough coated with petroleum jelly in this study. Hampson[9] reported that the shrinkage of a hydrocolloid impression material was 0.09 percent when determined on a mercury bath, and Skinner et al.[2] reported that it was 0.047 to 0.278 percent when determined on a trough lined with tin foil. Thus the measurements reported by different investigators deviated widely. Two possible causes which can produce an error in such a measurement are considered to be the flow of the impression material just before gelation and the resistance of the tray walls, and both tend to make the measurements of shrinkage smaller. The value of 0.6 percent obtained in this study was the greatest and therefore was considered to include the smallest errors.

c) Effect of water cooling

No significant difference in the dimensional changes of the stone models was observed between the case when the impressions were cooled by leaving at room temperature and that when cooled by using room temperature water. When cooled with ice water (5°C), however, the inside measurement of the stone model was remarkably smaller resulting in a greater difference in the outside-inside difference. The reason is obscure but the following explanation might be possible. With ice water cooling, the impression material adjacent to the tray walls rapidly gelatinized and shrank, being tightly held by the tray walls, and so the shrinkage tended to concentrate in the central portion which gelatinized far later. Anyhow, the use of ice water should be avoided to minimize the error.

d) Effect of humidity

It was reported that a hydrocolloid impression material contained about 14 percent agar, 84 percent water, 2 percent potassium sulfate and a small amount of borax and fillers[15]. Water is thus the main component of this type of material. It is, therefore, considered natural that the impression material shrinks by drying and increases the difference between the inside and outside measurements of the models. In this study, however, when the impressions were poured at room temperature, the outside-inside difference varied little by the change in relative humidity from 100 to 72 percent, although, when poured at mouth temperature, it apparently increased at a lower humidity. This indicates that the drying shrinkage of the impression material was negligible at a lower temperature, but it was facilitated at a higher temperature.

Clinical consideration. In respect of the clinical use the hydrocolloid impression material is compared with the other impression materials as described below.

The fine line reproducibility on the stone models of the hydrocolloid impression material was correspondent to the best result so far obtained with the alginate impression materials[18] and the stone surface from it looked even smoother under a naked eye. The stone model surface was also slightly harder than that from the alginate impression materials. These are the advantages of the hydrocolloid indirect technique.

The hydrocolloid impression material always shrinks on gelation, making the outside measurement of the stone models greater and the inside measurement smaller, which facilitates the fit of restrations on the preparations. The shrinkage is, however, much greater than that of the alginate impression material and the outside-inside difference of the model produced under regular clinical conditions (0.65 percent) is greater than that with the alginate impression material (0.3 percent)[11,19]. This means that the distortion due to the tray holding tends to be greater.

The main disadvantage of the reversible hydrocolloid indirect technique is the complexity in equipment and technique such as the use of a conditioner and water coolant. Further simplification may be necessary for this technique to be used more widely.

Summary

For analytical evaluation of the reversible hydrocolloid indirect technique, the stone models made from a commercial impression material were tested for detail reproducibility, surface hardness and dimensional changes. The free linear dimensional change on setting of the impression material itself was also determined. The findings were as follows:

1. The tray type of the material always reproduced on the stone models a 30-micron line, a 20-micron line partly, a 15-micron line in one case but never a 10-micron line or a smaller one. The syringe type material folded on the tray type always reproduced a 20-micron line, a 15-micron line partly but never a 10-micron line or a smaller one.

2. The surface hardness of the resultant stone models was quite hard showing wide scratch lines of approximately 43 and 36 microns respectively, at 3 and 24 hours after setting, when determined by the scratch hardness tester. No statistically significant difference in the scratch line width was observed between the results from the tray type material and from the syringe type folded on the tray type.

3. Although the stone models made from the hydrocolloid impression material were slightly larger as a whole than the original model due to the

setting expansion of the stone, the shrinkage of the impression material made the outside measurement greater and the inside measurement smaller. The difference between the inside and outside measurements in percent change was the greatest when impressed and poured at room temperature, next greatest when impressed at mouth temperature and poured at room temperature, and the smallest when impressed and poured at mouth temperature. Cooling of the impression with room temperature water did not significantly alter the measurements but the use of ice water made the outside-inside difference greater. The change of relative humidity from 100 to 72 percent during the impression and pouring did not significantly alter the measurements of the resultant models at room temperature but increased the outside-inside difference at mouth temperature.

4. The linear shrinkage of the impression material itself on gelation being cooled down to room temperature (23°C) was approximately 0.6 percent when determined on a trough lined with petroleum jelly.

5. These results indicate that the hydrocolloid impression material can produce indirect stone models clinically accurate enough, and further simplification of the equipment and technique would establish its clinical value for wider use.

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