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ORIGINAL ARTICLE

Comparison of the surface roughness of gypsum models constructed using various impression materials and gypsum products

Yi-Chih Chang [a], Chien-Hung Yu [b,c], Wen-Miin Liang [d], Ming-Gene Tu [b,c*], San-Yue Chen [b*]

[a] Department of Medical Laboratory Science and Biotechnology, China Medical University, Taichung, Taiwan
[b] School of Dentistry, China Medical University, Taichung, Taiwan
[c] Department of Dentistry, China Medical University Hospital, Taichung, Taiwan
[d] Graduate Institute of Biostatistics, Biostatistics Center, China Medical University, Taichung, Taiwan

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surface roughness

Abstract *Background/purpose:* This study compared the surface roughness of gypsum models constructed using various impression materials, gypsum products, and storage times before repouring.
Materials and methods: Three alginate impression materials, four commercial silicone impression materials, and three types of gypsum product (MG crystal rock, Super hard stone, and MS plaster) were used. Impression materials were mixed and poured into five plastic rings (20 mm in diameter and 2 mm high) for each group, and the surfaces of the set gypsum product models of 63 groups, which were poured immediately, and 1 hour and 24 hours later, were assessed using a surface roughness tester. One-way ANOVA and Bonferroni's comparison tests were used for the statistical analyses.
Results: The surface roughness: (1) was greater for most specimens constructed from alginate impression material (2.72 ± 0.45–7.42 ± 0.66 μm) than from silicone impression materials (1.86 ± 0.19–2.75 ± 0.44 μm); (2) differed with the type of gypsum product when using alginate impression materials (surface roughness of Super hard stone > MG crystal rock > MS plaster), but differed little for silicone impression materials; and (3) differed very little with the storage time before repouring.

* Corresponding authors. School of Dentistry, China Medical University, 91, Hsueh-Shih Road, Taichung 404, Taiwan.
E-mail addresses: mgtu@mail.cmu.edu.tw (M.-G. Tu), saychen@mail.cmu.edu.tw (S.-Y. Chen).

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Conclusion: The surface roughness of stone models was mainly determined by the type of alginate impression material, and was less affected by the type of silicone rubber impression material or gypsum product, or the storage time before repouring.
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Introduction

Most dental prostheses and orthodontic appliances are fabricated after taking an impression and making a dental model. Thereafter, dental technicians can perform a series of procedures on the model to construct individualized dentures, cast crowns, or orthodontic appliances. A crucial factor in the success of this process is having a model that is both accurate and possesses a smooth surface. The surface roughness of models affects the surface roughness of the cast restorations; therefore it may affect their fit or retention to prepared teeth.[1] Previous studies concentrated on factors affecting model accuracy, including storage temperature changes,[2,3] impression techniques,[4–6] the use of individual trays,[7–10] the types of impression material and model materials used,[11–13] and the stone pouring time.[14,15] However, only a few studies have dealt with how stone models are affected by the repouring and storage times.[16,17]

The elastic impression materials currently used in dental clinics can be categorized into two groups: (1) hydrocolloid materials, with alginate being the most widely used by clinicians;[13] and (2) rubber-based impression materials, comprising polysulfide, polyether, condensation silicone, and addition silicone. Silicone rubber appears to be the most popular type.[11,16] Alginate is cheaper than rubber-based impression materials and is derived from an edible plant, making it safer than rubber. In addition, some articles have reported that stone casts constructed from alginate impressions are as accurate as rubber-based impressions.[18,19] Our previous study also found that alginate impression materials were as accurate as elastomeric impression materials in the first poured model.[20] However, very few studies compared the effects of repouring and storage times on the surface roughness. Hence, we thought it would be interesting to assess the smoothness of repoured-stone model surfaces constructed with alginate and rubber-based impression materials after different storage times.

This study compared the effects of impression materials, storage times before repouring, and dental stones on the surface roughness of stone models.

Materials and methods

Materials

All of the materials used in this study are listed in Table 1. This study included three alginate impression materials: Algiace Z (Sankin Kogyo, Tokyo, Japan), Cavex (Cavex, Haarlem, The Netherlands), and Jeltrate (Dentsply Asia, Hong Kong). According to promotional material, Jeltrate has a high algin content and provides quality impressions without excessive flow; Algiace Z has excellent compatibility with agar and can be used with any type of plaster; and Cavex can be used for double pours. Four commercial silicone impression materials were used: Aquasil LV (Dentsply, Chicago, IL, USA), Coltex fine (Coltene/Whaledent, Mahwah, NJ, USA), Exaflex injection type (GC America, Chicago, IL, USA), and Take 1 wash (Kerr, Romulus, MI, USA). According to the manufacturers' information, Aquasil has high strength and resistance to permanent deformation; Coltex has excellent physical properties and consistent quality; Exaflex has outstanding physical properties, optimum handing, and accuracy; and Take 1 has excellent dimensional stability, and outstanding wear strength. All of the materials are asserted to have good properties by their manufacturers, but the most popular materials were randomly chosen for the study to obtain general conditions corresponding to a clinical state. This study included three commercial gypsum products: MG crystal rock (Maruishi

Table 1 Materials used in this study.

Materials	Types of materials	Manufacturers
Impression materials		
Algiace Z	Alginate	Sankin Kogyo KK, Tokyo, Japan
Cavex	Alginate	Cavex, The Netherlands
Jeltrate	Alginate	Dentsply Asia, Hong Kong
Aquasil LV	Addition type silicone	Dentsply, Chicago, IL, USA
Coltex fine(light body)	Condensation type silicone	Coltene/Whaledent Inc., Mahwah, NJ, USA
Exaflex regular (injection type)	Addition type silicone	GC America Inc., Chicago, IL,USA
Take 1(wash type)	Addition type silicone	Kerr Co., Romulus, MI, USA
Gypsum products		
MG crystal rock	Type IV stone	Maruishi Gypsum Co., Tokyo, Japan
Super hard stone	Type IV stone	Chi Shi Co., Taipei, Taiwan
MS plaster	Type II stone	Chi Shi Co., Taipei, Taiwan

Gypsum, Tokyo, Japan; Type IV stone), Super hard stone (Chi Shi, Taipei, Taiwan; Type IV stone), and MS plaster (Chi Shi; Type II stone).

Methods

Each type of alginate impression material was mixed in the same powder:water ratio by quantifying the number of scoops of powder and the necessary amount of water in the mixing cylinder, since different powder:water ratios will change the setting time; the mechanical properties of the alginate impression materials made it more difficult to explain the results. In the present study, the scoop and cylinder provided with the Jeltrate alginate impression material was used. Each sample was mixed for 10 s in an electric mixer (Algimax AM505; Transasia Co., NY, USA), poured into five plastic rings (20 mm in diameter and 2 mm high) placed on a glass slab used for cement mixing (120 × 60 × 10 mm and weighing 400 g), and then covered and pressed with another glass slab to extrude the excess material. After 5 min, when the impression materials had set, one type of gypsum powder (40 g for pouring five specimens) at a certain powder:water ratio was mixed and poured on the set impression surface, and then allowed to set for 1 hour. The second and third gypsum models were constructed with the same impression and repoured after 1 hour and 24 hours. The silicone impression materials were mixed according to the manufacturers' instructions, and the other procedures were the same as for the alginate impression materials. Because three types (two Type IV and one Type II) of gypsum products (with different powder:-water ratios: MS plaster 10:3; Super hard stone 10:5; MG crystal rock 10:2.5) were used, all procedures were repeated for each type of gypsum product.

The impressions and gypsum models were stored in a sealed plastic box containing wet tissue paper. In total, 63 groups of samples were studied. The surfaces of the set gypsum models were assessed using a surface roughness tester (Surfcorder SE1200; Kosaka Laboratory, Tokyo, Japan) with a tracing length of 5 mm and a cutoff value of 0.8 mm. One measurement was performed on each gypsum model in a laboratory environment, and five specimens of each combination were used to determine the average roughness for the impression material in each gypsum combination group.

Statistical analysis

A three-factor repeated analysis of variance (ANOVA) with interaction terms was used to assess the effects of different materials, gypsum products, and time periods on the surface roughness of the final products. Since there were significant interactions between these factors, the data were further analyzed, stratified by material group and time. In the stratified analysis, a one-way ANOVA model or one-way repeated ANOVA model was used to assess the effect of material type, gypsum product, and time period. When the *F* test of the ANOVA model was significant, Bonferroni's comparison that considered the per-group Type I error rate was performed to examine the difference between the two groups. In addition, seven materials were classified into two groups: alginate impression group (Algiace Z, Cavex, and Jeltrate) and silicone rubber group (Aquasil LV, Coltex fine, Exaflex injection type, and Take 1 wash), and compared by a two-sample *t* test. All analyses were performed using SAS 9.2 (SAS, Cary NC, USA), and a probability value of $P < 0.05$ was considered statistically significant.

Results

Roughness of different gypsum model surfaces using different impression materials

Surface roughness values of gypsum models constructed using different impression materials and gypsum products with different storage times before repouring are listed in Table 2. The surface roughness clearly differed between models constructed using alginate impression materials (2.72 ± 0.45—7.42 ± 0.66 μm) and silicone rubber materials (1.86 ± 0.19—2.75 ± 0.44 μm). One-way ANOVA *F* tests revealed significant differences in the surface roughness among different materials (all $P < 0.05$); results of pairwise comparisons for each subgroup are listed in Table 2.

Roughness of different gypsum model surfaces poured after taking impressions for different storage times before repouring

A stratified analysis was performed to examine the effect of the storage time before repouring on the surface roughness of each type of gypsum product. Results revealed that the storage time before repouring had less effect on the surface roughness than the materials themselves did (Table 2). A stratified analysis was also used to examine the effect of the type of gypsum product on the surface roughness for each time period. Variations in roughness among the gypsum products were greater for the alginate group than for the rubber-based group for all three time periods. Differences in roughness values between the alginate and rubber-based group were 2.84 ± 0.25 μm ($P < 0.0001$) in the 5-minute group, 3.00 ± 0.18 μm ($P < 0.0001$) in the 1-hour group, and 3.03 ± 0.23 μm ($P < 0.0001$) in the 24-hour group (based on a one-way mixed-effect model).

Different surface roughness values were determined for different types of gypsum products for models in the alginate group, with MS plaster models (2.72 ± 0.45—4.96 ± 0.72 μm) exhibiting a better result than Super hard stone (5.21 ± 0.89—7.42 ± 0.66 μm) or MG crystal rock (4.21 ± 0.68—6.64 ± 0.70 μm), but there was little difference among the silicone rubber group (1.86 ± 0.19—2.75 ± 0.44 μm for MS plaster, 1.73 ± 0.38—2.44 ± 0.49 μm for Super hard stone, and 1.52 ± 0.33—2.44 ± 0.63 μm for MG crystal rock; Table 2).

Discussion

According to our results, alginate impression groups were 2—3-times rougher than when using silicone rubber materials; there was little difference in the roughness within the alginate group or the rubber-based group (Table 2). Since the surface of a dental model product is always in contact

Table 2 The surface roughness of gypsum models made by different impression materials and gypsum products (μm) at different storage times.

Materials storage time	(1) Algiace	(2) Cavex	(3) Jeltrate	(4) Aquasil	(5) Coltexfine	(6) Exaflex	(7) Take 1Wash	Bonferroni's test
MG crystal rock	Mean ± SD							
5 min	5.01 ± 0.97	4.76 ± 1.28	4.60 ± 0.31	1.89 ± 0.50	2.44 ± 0.63	1.91 ± 0.42	2.01 ± 0.59	1,2,3 > 4,5,6,7
1 h	5.46 ± 1.45	5.11 ± 0.53	4.35 ± 1.34	1.52 ± 0.33	2.03 ± 0.28	1.86 ± 0.23	1.95 ± 0.21	1,2,3 > 4,5,6,7
1 d	5.87 ± 0.40	6.64 ± 0.70	4.21 ± 0.68	2.08 ± 0.07	2.10 ± 0.14	2.31 ± 0.61	1.96 ± 0.34	1,2,3 > 4,5,6,7 2 > 1,3
t test	NS	1 < 3	NS	NS	NS	NS	NS	
Super hard stone	Mean ± SD							
5 min	7.420.66	7.33 ± 1.22	6.26 ± 1.34	2.44 ± 0.49	1.90 ± 0.26	2.1 ± 0.11	2.04 ± 0.46	1,2,3 > 4,5,6,7
1 h	5.62 ± 0.87	7.25 ± 0.60	5.21 ± 0.89	2.29 ± 0.49	1.78 ± 0.49	2.22 ± 0.13	1.82 ± 0.30	1,2,3 > 4,5,6,7 2 > 1,3
1 d	6.96 ± 0.97	6.38 ± 0.66	6.35 ± 1.48	1.86 ± 0.13	1.73 ± 0.38	2.05 ± 0.23	1.96 ± 0.34	1,2,3 > 4,5,6,7
t test	1 > 2	NS	NS	1 > 3	NS	NS	NS	
MS plaster	Mean ± SD							
5 min	3.18 ± 0.68	3.65 ± 0.68	2.72 ± 0.45	2.16 ± 0.52	2.28 ± 0.51	2.46 ± 0.16	2.10 ± 0.36	1 > 7 2 > 4,5,6,7
1 h	4.54 ± 0.63	4.96 ± 0.72	3.26 ± 0.19	2.46 ± 0.28	2.34 ± 0.28	2.70 ± 0.35	2.07 ± 0.17	1,2 > 3,4,5,6,7 3 > 5,7
1 d	2.82 ± 0.53	3.64 ± 0.50	3.29 ± 0.78	1.86 ± 0.19	2.11 ± 0.08	2.37 ± 0.24	2.75 ± 0.44	1,2 > 4,5,6 3 > 4,5
t test	2 > 1,3	2 > 1,3	NS	NS	NS	NS	1,2 < 3	

Bonferroni's test was performed for pair-wise comparisons after *F* test in one-way ANOVA, which was used to test the effect of materials on the surface roughness for each subgroup stratified by gypsum products and storage time; P-values for all *F* tests were <0.05. The *t* tests were performed to do all pair-wise comparisons of roughness among different time points from one-way within-effect mixed model after Bonferroni's adjustment. 1 < 3 indicated the mean of Algiace (1) was significantly less than that of Jeltrate (3). 1,2,3 > 4,5,6,7 indicates 1 > 4, 1 > 5, 1 > 6, 1 > 7 ; 2 > 4, 2 > 5, 2 > 6, 2 > 7 ;3 > 4, 3 > 5, 3 > 6 and 3 > 7. NS = not significant.

with a light body type or washing-type material of rubber-based impression materials, in principle, to mimic a clinical situation, we only chose low-viscous materials of the rubber-based group in this study. In order to evaluate the effects of different water:powder ratios of gypsum products on the roughness of the stone model, two brands of Type IV stone, and one brand of Type II stone were chosen. In laboratory work on crown and bridge fabrication, it is necessary to construct an accessory cast following the first pouring cast, and sometimes a smooth recording model is made and given to the patient, so the effect of different storage times on repouring was also investigated.

Irrespective of the types of impression material or gypsum product used, surfaces of the models were smoother in the rubber-based group than in the alginate impression group (Table 2). In 1988, Johnson et al compared the surface roughness of gypsum models constructed using two irreversible hydrocolloid impression materials with those of one polyether and one addition silicone, and claimed that irreversible hydrocolloid impressions produced approximately 3-times the roughness than those using elastomeric impression materials.[21] Results of the present study are consistent with their findings, but they did not consider the effects of re-pouring or different storage times on repouring.

There were some variations in the data obtained for the alginate impression materials. In general, the gypsum model constructed using Jeltrate showed the lowest roughness, followed by Cavex and Algiace Z (with little difference between these two), as indicated in Table 2. Data variations were lower in the rubber-based group, and it was difficult to determine which impression and gypsum-cast combination produced the best result for different storage times before repouring, especially in the rubber-based group. In 2003, Johnson et al. compared the surface roughness of eight rubber-based impression materials (two polyether and six polyvinylsiloxane).[22] They found that, among the six polyvinylsiloxane impression materials, five had no statistically significant difference in surface roughness ($P < 0.5$). In our study, we also found that there was little difference among rubber-based impression materials. In 2004, Murata et al compared the surface roughness of three types (two Type III and one Type IV) of dental stone casts constructed using six alginate impression materials, and found large differences in the surface roughness among the alginate/stone cast combinations. Type III dental stone casts in combination with any of the alginate impression materials produced smoother surfaces than the Type IV dental stone, and they concluded that Type III dental stone was more suitable for alginate impression materials than were Type IV materials. However, in their study, they also found that Type IV dental stone casts made from one alginate impression material had a smoother surface than some Type III dental stone casts.[23] In our study, we also found clear differences in the surface roughness of dental casts made with different types of gypsum products. However, we also evaluated the surface roughness of cast models made in the same conditions but with rubber-based impression materials, and found smaller differences among the cast models (Table 2). This result allowed us to infer that the surface roughness was mainly affected by alginate materials.

In 1990, Drennon and Johnson compared the surface roughness of stone models constructed in three main ways: three types of impression material (one polyether, one polysulfide, and one silicone), three types of disinfectant, and four brands of Type IV stone.[24] Although statistically significant differences were revealed among the three main methods, the data for the stone models constructed with the addition silicone material alone indicated trends in similar surface roughness to those different brands of stone models constructed after immersion in all of the disinfectants. Those previous studies[23,24] and the present study (Table 2) show that the surface roughness was mainly affected by alginate impression materials and less by the type of gypsum product. In the alginate impression materials group, the roughness was greatest in the model constructed from Super hard stone (Type IV), followed by MG crystal rock (Type IV) and dental plaster (Type II). Despite using the same water:powder ratio (w/w) when mixing different brands of alginate material, we obtained different surface roughness values from the same brands of the gypsum-constructed model. By contrast, mixing three different brands of gypsum products in different water:-powder ratios produced prominent differences in the surface roughness for a single impression material. The water:powder ratio (w/w) used for mixing the gypsum products was in the order of dental plaster (5:10) > Super hard stone (3:10) > MG crystal roc (2.5:10), but the roughness did not vary in this order.

The data obtained for the rubber-based group indicated little differences in roughness when using various impression materials and gypsum products. The present study indicates that the surface roughness is difficult to predict simply from the known combination of alginate impression materials and gypsum water:powder ratios.

In the present study, the surface roughness data on repouring after different storage times differed little in each group, especially in the elastomeric group.

In 1950, Sweeney and Taylor evaluated dimensional changes of dental stone and plaster over different storage time periods and temperatures, and found that none of the set models exhibited significant dimensional changes during storage under normal laboratory conditions, but an increase in storage temperature led to water loss and shrinkage.[25] In 2009, Alcan et al investigated the effect of delayed pouring on dimensional changes of stone models poured using three different alginates of stone models immediately and after 1 day, 2 days, 3 days, and 4 days of storage.[26] They concluded that storing alginate impressions in sealed plastic bags for up to 4 days caused statistically significant differences in model deformation, although the magnitude of these deformations did not appear to be clinically significant. In 2010, Walker et al evaluated dimensional changes among three alginates, two extended-storage alginates and one conventional alginate, during storage for 30 minutes, 48 hours, and 100 hours.[27] They found that conventional alginate exhibited dimensional changes that did not significantly differ from those of the other samples for up to 48 hours. They suggested that delayed pouring of dental gypsum did not adversely affect the dimensional accuracy of the generated casts. In 2010, Imbery et al compared the accuracy and dimensional stability of extended-storage alginate and conventional

alginate impression materials.[28] They also concluded that when properly stored for up to 5 days, both types of alginate material produced accurate impressions for diagnostic casts and fabrication of acrylic appliances. Previous studies did not evaluate the surface roughness of stone models, but they indicated that the surface changed little during storage when using alginate impression materials. The present study also showed small differences between different pouring time periods even for repoured casts.

Within the limitations of the present study, we concluded that although using alginate impression materials to construct a gypsum model can achieve an accuracy similar to that using silicone impression materials, it cannot produce the same level of surface roughness as rubber-based impression materials. This means that alginate impression materials cannot yet completely replace silicone rubber-based impression materials.

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