The effect of pouring time on the dimensional stability of casts made from conventional and extended-pour irreversible hydrocolloids by 3D modelling

Hasan Ö. Gümüş, Mehmet Dinçel, Süleyman K. Büyük, Halil İ. Kılınc, Mehmet S. Bilgin, M. Zortuk

Department of Prosthodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey
Department of Orthodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey
Department of Prosthodontics, Faculty of Dentistry, Sifa University, İzmir, Turkey

Received 2 April 2013; Final revision received 23 February 2014
Available online 28 July 2014

Abstract Background/purpose: The aim of this study was to determine the accuracy of casts made from irreversible hydrocolloid impressions with immediate and delayed pouring.

Materials and methods: A master model was mounted on a modified articulator designed to standardize impression procedures. A total of 250 impressions were taken and grouped into 25 groups (n = 10) according to irreversible hydrocolloid material (CA37, Tropicalgin, ColorChange, Hydrogum 5, and Hydrocolor 5) and storage time (0 hours, 1 hour, 24 hours, 72 hours, and 120 hours). Impressions were stored at 23 ± 1°C and 100% relative humidity and poured with gypsum at the predetermined storage time. Casts were scanned with a three-dimensional (3D) model scanner. The digital models were measured and subtracted from the measurements obtained from the master model. The absolute values of dimensional differences were statistically analyzed using two-way analysis of variance (ANOVA) and post hoc Fisher LSD test (P < 0.05).

Results: Different irreversible hydrocolloids and pouring times showed significant differences (P < 0.001). In all irreversible hydrocolloids, no statistically significant differences were found with impressions poured after 0 hours, 1 hour, and 24 hours of storage (P > 0.05). However, after 72 hours and 120 hours of storage, Tropicalgin and CA37 irreversible hydrocolloid impressions were found to be significantly different (P < 0.05). Moreover, ColorChange, Hydrogum 5, and Hydrocolor 5 irreversible hydrocolloid impressions were not statistically different up to 120 hours (P > 0.05).
Introduction

Irreversible hydrocolloids are one of the most common impression materials used in the dental office. These water-based materials are inexpensive and can be easily manipulated by following the manufacturer’s instructions to create mouth guards, impressions for removable prostheses, preliminary impressions for complete dentures, and orthodontic and research models. The greatest disadvantage of an irreversible hydrocolloid is its low dimensional stability, which can be defined as the ability of a material to maintain accuracy across time. Water absorption (imbibition) and water release (syneresis) that occurs over time may result in the production of inaccurate casts, and it is generally recommended that irreversible hydrocolloid impressions be poured immediately or within 10–12 minutes of removal from the mouth without wrapping in a damp paper towel. This is because it is not possible to predict the amount of water that may be absorbed by the impression material. However, immediate pouring of an impression may not always be possible, especially if it must be shipped to a dental laboratory.

Ideally, an impression material should be dimensionally stable over time in order to allow the operator to pour an impression at his/her convenience. A number of alternative “extended-pour” irreversible hydrocolloids are available on the market that claim to maintain dimensional stability and accuracy with delayed pouring times of up to 4 days or 5 days, if the impressions are wrapped in a damp towel or sealed in a plastic bag. This is because it is not possible to predict the amount of water that may be absorbed by the impression material. However, immediate pouring of an impression may not always be possible, especially if it must be shipped to a dental laboratory.

In recent years, different tests have been developed to analyze dimensional stability of materials. However, many studies conducted in relation to the dimensional stability of irreversible hydrocolloids have limited relevance today, as many of the materials studied are no longer commercially available. Among recent studies, interest has also focused on the effects of disinfection materials and procedures on the dimensional stability of impression material.

The aim of the present study was to investigate the dimensional stability of different irreversible hydrocolloid impressions at different storage times. Of the various irreversible hydrocolloids tested, three claim to maintain dimensional stability for up to 5 days. The study was conducted in a laboratory environment designed to simulate clinical practice and shipping under specified, standardized conditions. In order to reduce the number of variables, the impressions were not subjected to any disinfection, and irreversible hydrocolloid adhesives were not used.

The null hypothesis was that dimensional accuracy would not differ significantly among the three "extended-pour" irreversible hydrocolloid and two conventional irreversible hydrocolloid materials, regardless of cast pouring time.

Materials and methods

Five irreversible hydrocolloid impression materials from two different manufacturers and generally used for prosthetic purposes were selected for the study (Table 1). All procedures were carried out under the same conditions.

Standardization of impressions

A device resembling Wandrekar et al’s system was developed to reproduce clinical conditions and standardize impression procedures (Fig. 1).

Self-curing acrylic (PalapressVario, Heraeus Kulzer, Hanau, Germany) was poured into a rubber mold (ANA 4-G, Frasaco, Tettnang, Germany) to create a master model of a complete upper dental arch with 16 teeth. Specific reference points for cast measurements were identified on the cusps of the canines (13, 23) and on the mesiobuccal cusps of the first molars (16, 26) by attaching a metal cone at each reference point. In order to ensure accurate and reproducible positioning of trays during impression-taking, standardized tray placement was achieved by fabricating a light-cured polymethylmethacrylate seat (Durabase LC, Duradent, Polzano, Italy) that was affixed to the lower side of the articulator (Keystone Industries GmbH, Singen, Germany) to provide a firm fit for impression trays, and impressions were taken with the articulator’s posterior stop-pin in contact with the opposite side of the articulator.

Table 1 Hydrocolloid impression materials used in the study.

<table>
<thead>
<tr>
<th>Impression material</th>
<th>Supplier Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA37</td>
<td>Cavex, Haarlem, The Netherlands Conventional</td>
</tr>
<tr>
<td>Tropicalgin</td>
<td>Zhermack Spa, Badia Polesine, Italy Conventional</td>
</tr>
<tr>
<td>ColorChange</td>
<td>Cavex, Haarlem, The Netherlands Extended-pour</td>
</tr>
<tr>
<td>Hydrogum 5</td>
<td>Zhermack Spa, Badia Polesine, Italy Extended-pour</td>
</tr>
<tr>
<td>Hydrocolor 5</td>
<td>Zhermack Spa, Badia Polesine, Italy Extended-pour</td>
</tr>
</tbody>
</table>
Impression procedures

The master model was mounted on the upper part of an articulator. Impression materials were prepared according to the manufacturers’ instructions by mixing together powder and liquid constituents with a spatula for 30 seconds. Immediately after mixing, the irreversible hydrocolloid was placed in a Size 3 prefabricated, perforated stainless steel stock tray (Inci Dental, Istanbul, Turkey). No tray adhesives were used. The tray was then transferred to the acrylic seat, and the upper side of the articulator holding the master model was lowered until the posterior pin came into contact with the opposite side of the articulator to provide a uniform impression thickness of $\frac{5}{16}$ mm (Fig. 2). Excess material was extruded through the perforations in the tray and seat. To compensate for delayed setting of the material at room temperature (in comparison to the temperature in the oral cavity), the recommended setting time was increased to 5 minutes.

The upper part of the articulator and model were separated from the impression with a snapping motion. The impression was immediately placed in a hermetic nylon bag containing a paper sheet wetted with $30 \pm 5$ g of distilled water that had been inserted 10 minutes prior to the impression, according to Schleier et al\textsuperscript{15} with the paper positioned to avoid direct contact with the tray and the irreversible hydrocolloid. Impressions were stored at $23 \pm 1^\circ C$ for a specified time (0 hours, 1 hour, 24 hours, 72 hours, and 120 hours) prior to pouring, with ”0 hours” indicating casts poured immediately after removal from the master model. Impressions were not rinsed with water or immersed in any disinfectant. Prior to each new impression, the acrylic resin master dental arch model was steam-cleaned for 10 seconds and immersed in $24^\circ C$ distilled water for 5 minutes to avoid possible distortions due to thermal expansion.

Five different storage times (0 hours, 1 hour, 24 hours, 72 hours, and 120 hours) were tested by five different irreversible hydrocolloid materials. A total of 25 groups were obtained. By taking 10 impressions for each group, a total of 250 impressions were fabricated. The acrylic resin master dental arch model was used as a control group for measurement.

Casting procedures

Impressions were removed from storage at the predetermined storage times, and casts were poured from high-strength Type-III dental stone (Moldano, Heraeus Kulzer, Hanau, Germany) on a vibrating platform, according to the manufacturer’s recommendations (100 g powder + 30 g distilled water). Casts were removed from impressions after the recommended setting time (1 hour after the final setting) and were stored for 48 hours prior to measurement. In total, 250 stone models (10 per group) were produced. All materials were used at least 6 months prior to their expiration date.

Digital model production and measurement

A three-dimensional (3D) model scanner (3Shape R700 3D Scanner, 3Shape A/S, Copenhagen K, Denmark) was used to digitally transform all 250 stone models, and the digital models were analyzed using 3Shape Orthoanalyzer software, version 1.0 (3Shape A/S, Copenhagen K, Denmark).

Four points (A, B, C, and D) and four linear measurements (A–B, B–C, C–D, and D–A) were used to analyze the master and digital models (Fig. 3). Measurement points were selected with reference to the metal cone crest contours. Digital models were measured to the nearest 0.01 mm (10 $\mu$m). The measurements obtained from the digital models were subtracted from the measurements obtained from the master model, and the absolute dimensional differences of the results were subjected to statistical analysis.

Statistical analysis

Data was statistically analyzed with SPSS version 12.0 (SPSS Inc., Chicago, IL, USA). Two-way analysis of variance (ANOVA) and Fisher LSD test for post hoc comparison among
different up to 120 hours (P < 0.05). The Hydrocolor 5 (Zhermack Spa) groups were not statistically significantly different (P < 0.05; Fig. 4).

Results

According to the results of two-way ANOVA, significant differences were found for both impression material and time factors (P < 0.001). The results of post hoc Fisher LSD analysis are given in Table 2. In all tested irreversible hydrocolloid materials, no statistically significant differences were found with impressions poured after 0 hours, 1 hour, and 24 hours of storage (P > 0.05). However, after 72 hours and 120 hours of storage, Tropicalgin (Zhermack, Badia Polesine, Italy) and CA37 (Cavex, Haarlem, The Netherlands) irreversible hydrocolloid impressions were found to be significantly different (P < 0.05). Moreover, ColorChange (Cavex), Hydrogum 5 (Zhermack Spa), and Hydrocolor 5 (Zhermack Spa) groups were not statistically different up to 120 hours (P > 0.05; Fig. 4).

Discussion

Irreversible hydrocolloid impression materials are generally used in the dental office. These materials are inexpensive and can be easily prepared by clinicians. In spite of their general use, they have some limitations such as dimensional changes over time. It is not surprising to find that even after setting, water exchange between the impression material and the surrounding environment causes a reduction in dimensional stability with increased storage time.

Some studies have found that the best results are achieved when casts from conventional hydrocolloid impressions are poured as soon as possible after setting, regardless of storage condition or brand. Other researchers have stated that in order to achieve the best results, dental irreversible hydrocolloid impressions should be poured after 10 minutes to avoid distortion from initial expansion and elastic deformation, but prior to 1 hour to avoid distortion from irreversible hydrocolloid contraction or expansion caused by imbibition and syneresis. The present study is not entirely in agreement with these earlier studies. While it might be expected that the dimensional stability of conventional impression material would differ from that of extended-pour impression material after 1 hour of storage, this study found that CA37 and Tropicalgin performed similarly to extended-pour irreversible hydrocolloids when poured up to 24 hours following storage, suggesting that under certain storage conditions, conventional irreversible hydrocolloids may be used for up to 24 hours without a loss of accuracy. However, this study found extended-pour irreversible hydrocolloids to be more accurate than conventional irreversible hydrocolloids when poured following 72 hours and 120 hours in storage. Thus, the null hypothesis “dimensional accuracy would not differ significantly among the three “extended-pour” irreversible hydrocolloid and two conventional irreversible hydrocolloid materials, regardless of cast-pouring time” was rejected. Due to methodological differences, it is difficult to compare the findings of this study with those of previous studies.

Our study findings support previous studies that the extended-pour irreversible hydrocolloid impressions are dimensionally stable up to 5 days. However, most of these earlier studies have limited relevance today, because many of the materials examined are no longer available on the market. By comparison, the hydrocolloids tested in our study are widely available on the current market.

Measurements were taken both from impressions or from poured casts in the literature. There may be an

Table 2 Changes in measurements of casts poured into five irreversible hydrocolloids from two different manufacturers at five different storage periods.

<table>
<thead>
<tr>
<th>Irreversible hydrocolloid</th>
<th>0 hours</th>
<th>1 hour</th>
<th>24 hours</th>
<th>72 hours</th>
<th>120 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA37 (Cavex, Haarlem, The Netherlands)</td>
<td>0.172 ± 0.09</td>
<td>0.158 ± 0.14</td>
<td>0.166 ± 0.15</td>
<td>0.310 ± 0.19</td>
<td>0.386 ± 0.18</td>
</tr>
<tr>
<td>Tropicalgin (Zhermack, Badia Polesine, Italy)</td>
<td>0.104 ± 0.08</td>
<td>0.111 ± 0.10</td>
<td>0.107 ± 0.05</td>
<td>0.313 ± 0.10</td>
<td>0.286 ± 0.12</td>
</tr>
<tr>
<td>ColorChange (Cavex)</td>
<td>0.131 ± 0.09</td>
<td>0.152 ± 0.08</td>
<td>0.181 ± 0.15</td>
<td>0.154 ± 0.10</td>
<td>0.184 ± 0.10</td>
</tr>
<tr>
<td>Hydrogum 5 (Zhermack)</td>
<td>0.176 ± 0.09</td>
<td>0.146 ± 0.13</td>
<td>0.164 ± 0.13</td>
<td>0.117 ± 0.07</td>
<td>0.174 ± 0.09</td>
</tr>
<tr>
<td>Hydrocolor 5 (Zhermack)</td>
<td>0.135 ± 0.10</td>
<td>0.134 ± 0.11</td>
<td>0.161 ± 0.12</td>
<td>0.177 ± 0.08</td>
<td>0.129 ± 0.12</td>
</tr>
</tbody>
</table>

※ Statistically significant difference between same material and different time (P < 0.05).
* Statistically significant difference between same time and different material (P < 0.05).
interaction between gypsum and irreversible hydrocolloid material. A study conducted by Wandrekar et al. in which impressions were made using a technique similar to the one in our study used a travelling microscope to measure the distance between reference points marked on impressions and scanning electron microscopy and energy dispersive X-ray analysis to examine impression material. The authors found that manufacturers added different portions of basic elements such as titanium, fluorine, and zinc to impression material and suggested that these materials could interact with gypsum to improve the dimensional stability of the impressions taken. Hence, in our study, we chose to scan casts rather than impressions themselves and made measurements on these 3D images, because pouring irreversible hydrocolloids with gypsum is a standard clinical procedure.

Water-based impression materials have been found to provide maximum accuracy with a cross-sectional thickness of 4–6 mm. In our study, this thickness was achieved with the use of a properly sized stock tray, acrylic seat, and posterior stop-pin. Wandrekar et al. were able to achieve a standardized thickness with a system similar to the one used in our study. However, Wandrekar et al. did not standardize the horizontal position of the impression tray, whereas our device was designed to fix the position of the tray both horizontally and vertically.

Acceptable methods of measuring the dimensional accuracy of casts include measuring with microscopes, micrometers, dial gauges, calipers, and digital modeling, and there is no general agreement as to which measuring device is best. Although manual measuring techniques offer a number of advantages in that they are easy to use, inexpensive, and readily available, they have the disadvantages of being time-consuming, subject to operator fatigue and error, and capable of making linear measurements in only a few locations. The use of digital models to measure dimensional stability is a relatively new technique that has an accuracy of up to 10 μm, and the models have been found to be as reliable as traditional stone models. Techniques involving the use of optical microscopes, although offering much greater precision than digital models (up to 1 μm), are not representative of common clinical applications. Moreover, dimensional inconsistencies of only a few μm are clinically insignificant, because the crystalline structure of the gypsum products used in casting cannot reproduce such levels of detail.

The digital modeling used in this study was found to have good reproducibility of measurements. This is in line with one previous study that found the use of robotics and automation in digital modeling reduced operator error and provided greater precision in 3-D measurements. However, several studies have found significant differences in linear measurements made from digital and plaster models; however, the magnitude of difference was not considered clinically relevant. Currently, the purchase and maintenance of a 3-D optical digitizer represents a significant expense, and additional dedicated software is required for data analysis, although this may change with increasing demand and improvements in technology.

The standardized impression technique developed for this study may be helpful in obtaining comparable results among different impression materials. It has been reported that under specific conditions, irreversible hydrocolloids designed for fixed prosthodontic restorations could produce accurate results similar to the ones obtained from reversible hydrocolloids and condensation and addition silicones. Hence, this technique may be used in future studies.

The dimensional stability of impression materials has been studied widely in the literature. Most studies follow protocols described by the American Dental Association, designed to replicate a clinical scenario, by using a cylindrical metal block to perform measurements over two horizontal coordinates separated by < 5 mm in length. However, some researchers have recognized that this standard may not be sufficient to account for changes over three coordinates or over larger surface areas. The use of a definitive cast in an arch-form configuration with unprepared teeth has been suggested as the best method for simulating the oral environment, as well as the stress involved in clinical dental casting. Impression material must be capable of flowing readily into undercut areas in the mouth, setting in that position, and "rebounding" to its original shape after the set impression has been removed from the mouth, in a process referred to as "elastic recovery". For these reasons, our study utilized a full-arch master model with undercuts and unprepared teeth.
Hand versus mechanical mixing has not been reported to result in any major differences in the physical properties of irreversible hydrocolloids. In our study, all of the irreversible hydrocolloids were hand-mixed by the same examiner.

Accuracy and setting time may be affected by the mineral content in tap water; therefore, this study used distilled water for mixing irreversible hydrocolloids.

Some researchers have suggested that additives used in chromatic irreversible hydrocolloids may influence their dimensional stability. The present study included one stable (Hydrogum 5) and one chromatic (Hydrocolor 5) irreversible hydrocolloid produced by the same manufacturer (Zhermack Spa), and no statistically differences were found in their dimensional stability.

The present study had a number of limitations, namely, in order to reduce the number of variables, the effects of disinfectant solutions on the dimensional stability of irreversible hydrocolloids were not evaluated. Moreover, due to the difficulty in applying adhesive material at a uniform thickness, no adhesive material was applied to the trays.

Within the limits of this study, the following conclusions can be drawn: (1) the dimensional stability of irreversible hydrocolloid impressions are influenced by storage time prior to pouring; (2) all of the conventional and extended-pour impression materials tested in this study can be poured up to 24 hours with accuracy, providing they have been stored appropriately; and (3) extended-pour impression materials (ColorChange, Hydrogum 5, and Hydrocolor 5) can be poured up to 120 hours, if stored appropriately.

Conflicts of interest
The authors have no conflicts of interest relevant to this article.

References


