Effects of mixing technique on bubble formation in alginate impression material

Thomas F. McDaniel, DMD, FAGD • Robert T. Kramer, DMD, FACD, FICD • Francis Im, BS, MA • Dallin Snow, BS, MS

Previous studies have found that variations in mixing technique can influence the porosity content of alginate impression material. The aim of this study was twofold: determine whether bubble formation in alginate is influenced by the sequence of water/powder addition prior to mixing, and to compare 4 different mixing techniques. Manual spatulation, an automated spinning bowl, a centrifugal mixer, and a vacuum mixer were evaluated for the resulting porosity in the set alginate. It was found that adding powder first, versus water first, made no difference in the bubble content using the 3 automated mixing techniques ($P = 0.714$). However, porosity was significantly less for powder-first trials using manual spatulation ($P < 0.05$). It was also found that surface porosity in the resulting impressions was significantly less for centrifugal and vacuum mixing when compared to manual spatulation, while internal porosity was significantly less for centrifugal mixing compared to all other mixing techniques ($P < 0.05$). The centrifugal mixing and vacuum mixing techniques required the least amount of mixing time.

Received: March 13, 2012
Accepted: September 11, 2012

Irreversible hydrocolloid impression material, more commonly known as alginate, is widely used in dentistry for fabrication of study models, orthodontic models, bleaching trays, provisional, bite guards, etc. It remains popular for a variety of reasons. Alginate is less expensive than virtually any other dental impression material ($0.72 per alginate full-arch impression versus $11 per VPS full-arch impression, for example). Alginate is hydrophilic in nature, making it easy to use, and it is sufficiently accurate to be useful for a wide range of impression applications.¹

All impression materials are technique sensitive, requiring careful attention to mixing, loading, and seating procedures. When alginate impression materials are manually mixed using a bowl and spatula, the potential for air entrapment is great. For the manual spatulation technique, some authors specify that clinicians should add powder and water components to the mixing bowl in a particular sequence to minimize bubble formation. The effect of this variable was evaluated in the present study.

In addition, manufacturers have developed various automated alginate mixing systems touted to speed the mixing process while reducing the incorporation of air bubbles. The present study compared the differences in porosity content of alginate mixed using the manual technique and 3 different automated techniques.

Materials and methods
Type II (regular set) alginate impression material (Rite-Dent Manufacturing Corporation) was used exclusively during all phases of this study. In each case, alginate was mixed with room-temperature (78° F) distilled water. A variety of manual and automated mixing techniques were then tested.

For manual spatulation, a large Flexibole (Hygenic Corporation) and metal spatula (Miltex, Inc.) were utilized (Fig. 1). Automated spatulation was performed using the Cadco Alginator (DUX Dental) (Fig. 2), the Rite-Dent Alginate Mixing Machine (Rite-Dent Manufacturing Corporation) (Fig. 3), and the Whip Mix Vac-U-Mixer (Whip Mix Corporation) (Fig. 4). During all trials, 21 grams (3 level scoops) of alginate powder was combined with 60 ml of water, in accordance with the alginate mixing instructions. Total
mixing time in each trial varied in compliance with each manufacturer’s instructions (described below).

During manual spatulation, the alginate was mixed for 60 seconds, as recommended by the manufacturer. The final mixture was scooped from the bowl with the spatula and delivered to the impression tray.

The Cadco Alginator (hereafter referred to as the ‘spinning bowl’) is a conventional mixing bowl that is mounted on a spinning turntable. After addition of alginate powder and water to the bowl, the turntable is activated and the operator holds a spatula against the inside of the bowl, thus mixing and smearing the alginate against the wall of the bowl. The recommended mixing sequence takes 30 seconds. As the bowl continues to spin, the mixed alginate is then gathered onto the spatula and delivered to the impression tray.

The Rite-Dent Alginate Mixing Machine is a centrifugal force mixer (hereafter referred to as the ‘centrifuge’). Alginate powder and water are added to the mixing container and loaded into the machine. The lid is closed and upon activation the machine spins for 10 seconds. The mixing container is removed from the mixer and the alginate is scooped out with a spatula and delivered to the impression tray.

The Whip Mix Vac-U-Mixer (hereafter referred to as the ‘vacuum mixer’) utilizes a mixing bowl with an airtight lid. The lid has a spinning spatula that operates under vacuum conditions when connected to the Whip Mix Combination Unit (Whip Mix Corporation). After mixing for 15 seconds, the lid is removed and the alginate is scooped out with a spatula and delivered to the impression tray.

A total of 8 different mixing combinations were performed. Twenty trials were completed for each of the 4 mixing techniques, 10 by placing water in the bowl first, and 10 by placing powder in the bowl first. In each case the manufacturer’s instructions for mixing technique were otherwise followed. This series of 80 mixing trials was completed by the same clinician.

In each trial, the mixed alginate was used to make an impression of a mandibular typodont with melamine teeth and urethane gingiva (Model D95SDP-200 GUB, Kilgore International, Inc.) using a large maxillary disposable tray (Vista Dental Products). This tray was chosen for its proper fit and consistent, repeatable seating position on the typodont (Fig. 5).

In each trial, the mixed alginate was scooped with a spatula from the mixing container in large increments and the impression tray was loaded with a scrape and press technique. With no further manipulation of the alginate material, the impression trays were then seated on the dry typodont to the predetermined stop and allowed to sit undisturbed. Once set, the impressions were pulled with a snap removal from the typodont.

Following each of the 80 trials, photographs were immediately made of a designated 1 cm² area of the smooth floor-of-mouth region to assess surface porosities (Fig. 6). Each impression was then sectioned in half using a sharp paring knife. Sectioning occurred in a buccolingual dimension through the first molars (Fig. 7). The 1 cm² segment centered at the arch midline of the posterior cut section was then photographed to assess internal porosities (Fig. 8).

Photography was made using high dynamic range imaging (HDR) (Fig. 9). Software supporting HDR has become widely available. This technique can solve
many of the exposure problems inherent with conventional photography, and has the potential to improve images beyond traditional practices. HDR combines multiple exposures of the same subject into a single image file, thus greatly enhancing the dynamic range of the resulting images. Files can then be automatically processed to reduce unwanted shadows and glare. This increases local detail and preserves information that would otherwise be lost, a process called tone mapping. The enhanced dynamic range of HDR rendered porosities in the alginate impressions more readily detectable.

All photographs were analyzed for bubbles using ImageJ processing software (public domain, http://rsbweb.nih.gov/ij/). ImageJ was programmed to analyze two fixed 1 cm² areas (surface and internal) of each impression sample and to select all voids >100 μm in diameter for inclusion in the calculations (Fig. 6 and 8).

**Results**

Using the Shapiro-Wilk test, it was determined that the data demonstrated a non-normal distribution ($P < 0.05$). Therefore, nonparametric testing (Mann-Whitney U and Kruskal-Wallis) was applied during the analysis of void areas. When examining the total void area and comparing water-first with powder-first trials, results showed that the sequence of water-powder addition makes no statistical difference in the alginate porosity when using the 3 automated mixing techniques ($P = 0.714$). For manual spatulation, it was found that powder-first trials exhibited significantly less surface porosity, while internal porosity was unaffected by water/powder sequence ($P < 0.05$).

Because of the non-normal distribution of the data, the median area is a better measure of central tendency than the mean area. Also, since the addition of powder-first or water-first had no statistical significance on the overall outcome, the 20 samples from each technique were combined to analyze the different mixing techniques in a pairwise comparison.

The centrifuge and vacuum mixer both produced statistically less total surface void space/cm² (0 μm² and 0 μm², respectively) compared to manual spatulation (152,265 μm²) ($P < 0.05$) (Chart 1).

![Fig. 8. Internal void photographs. A. manual spatulation. B. spinning bowl. C. centrifuge. D. vacuum mixer.](image_url)

![Fig. 9. HDR imaging of alginate samples.](image_url)

**Chart 1. Comparison of median area of total surface void space by mixing technique.**

<table>
<thead>
<tr>
<th>Mixing Technique</th>
<th>Median Area (μm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual spatulation</td>
<td>200,000</td>
</tr>
<tr>
<td>Spinning bowl</td>
<td>150,000</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>100,000</td>
</tr>
<tr>
<td>Vacuum mixer</td>
<td>50,000</td>
</tr>
</tbody>
</table>

**Chart 2. Comparison of median area of internal surface void space by mixing technique.**

<table>
<thead>
<tr>
<th>Mixing Technique</th>
<th>Median Area (μm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual spatulation</td>
<td>800,000</td>
</tr>
<tr>
<td>Spinning bowl</td>
<td>600,000</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>400,000</td>
</tr>
<tr>
<td>Vacuum mixer</td>
<td>200,000</td>
</tr>
</tbody>
</table>
When comparing the total internal (cross-sectional) void space, the centrifuge produced less void space/cm² (0 μm²) compared to all other techniques; manual spatulation = 585,024 μm²; spinning bowl = 407,971 μm²; and vacuum mixer = 213,114 μm² (P < 0.05) (Chart 2).

Finally, the total number of images for each mixing technique which yielded no voids >100 μm in diameter was tallied (Table). It was found that both the water-first group and the powder-first group exhibited 28/80 trials each with no voids >100 mm in diameter, thus strengthening the case that water-first versus powder-first did not influence the results overall. Further analyzing the images, manual spatulation yielded images with no void spaces 5% of the time (2/40). The centrifuge yielded the greatest number of trials exhibiting no voids (33/40; 82.5%). The spinning bowl and the vacuum mixer yielded images with no void spaces 22.5% (9/40) and 30% (12/40) of the time, respectively. Chi-square analysis on this data proved a significant effect of mixing technique on zero void frequency in favor of the centrifuge (P = 0.0015).

**Discussion**

In clinical practice, alginate impressions are commonly made using manually-spatulated material. Regarding the sequence of powder/water addition to the mixing bowl during manual spatulation, there is disagreement about whether water or powder should come first, or whether it matters. Texts on dental materials commonly specify that water should be added first.3,4 The instructions for the alginate used in this study did not indicate which component should be added to the bowl first. In contrast, instructions for Jeltrate alginate (DENTSPLY International) specify that powder should be added first to the bowl. Given these discrepancies, it is useful to investigate whether this issue of water/powder sequence causes measurable differences in visible porosities in the set alginate. The results of this study, especially those involving zero void frequency, suggest that the water/powder sequence makes no difference when all mixing techniques are evaluated together, except for manual spatulation, where surface voids were reduced by adding powder to the mixing bowl first.

Previous studies have demonstrated that automated mixing devices often result in denser alginate mixtures with less porosity when compared to manual spatulation. This was particularly indicated in vacuum mixing techniques.5,6 In the case of the automated alginate mixing devices, some manufacturers state in their respective instructions how the powder and water should be added. The manufacturers of both the spinning bowl and the centrifuge specify that powder should be added to the mixing bowl first. Instructions do not specify a water-powder sequence for the vacuum mixer.

**Conclusions**

The effects of adding alginate powder and water to the mixing bowl in a particular sequence yielded no significant differences relative to bubble formation when using any of the 3 automated mixing techniques tested in the present study. For manual spatulation, it was found that powder-first trials exhibited significantly less surface porosity, while internal porosity was unaffected by the water/powder sequence. Additionally, there was less porosity found on the surface of the alginate impressions in comparison to the internal (cross-sectional) environment across all mixing techniques.

Finally, there were differences noted when comparing the various mixing techniques. Manual spatulation tended to incorporate the most air within the alginate. The centrifugal mixer yielded the most consistent results, and impressions made with the centrifuge were significantly less porous internally compared with all other mixing techniques. The centrifuge and the vacuum mixer were statistically superior to the other techniques regarding presence of surface porosity. In addition, the centrifuge and vacuum techniques required the least amount of mixing time (10 seconds and 15 seconds, respectively). In busy practices that fabricate a large volume of alginate impressions, this time savings could prove substantial.

Additional investigation is warranted to determine whether these differences in impression porosity are sufficient to impart clinically significant variation in the resulting casts and models.

**Author information**

Dr. McDaniel is an associate professor and Dr. Kramer is an assistant professor, College of Dental Medicine, Midwestern University, Glendale, Arizona, where F. Im and D. Snow are dental students.

**Acknowledgments**

The authors wish to thank Dr. Beth Townsend, PhD, assistant professor of Anatomy, Arizona College of Osteopathic Medicine-Midwestern University, for her assistance with the imaging aspects of this study. The authors also wish to thank Dr. Kim Cooper, PhD, professor of Biomedical Sciences, Midwestern University, for his assistance with statistical analysis.

---

| Table. Percentage of trials exhibiting zero voids >100 μm. |
|------------------|-------------------|-------------------|
| Independent variable | Number of zero void trials (n = 40) | Percentage of zero void trials |
| Centrifuge        | 33                | 82.5              |
| Manual spatulation | 2                 | 5.0               |
| Spinning bowl     | 9                 | 22.5              |
| Vacuum mixer      | 12                | 30.0              |
| Powder-first      | 28                | 35.0              |
| Water-first       | 28                | 35.0              |
| Surface           | 37                | 46.3              |
| Cross-section     | 19                | 23.8              |

**Chart 2**

Regarding the sequence of powder/water addition to the mixing bowl during manual spatulation, there is disagreement about whether water or powder should come first, or whether it matters. Texts on dental materials commonly specify that water should be added first.3,4 The instructions for the alginate used in this study did not indicate which component should be added to the bowl first. In contrast, instructions for Jeltrate alginate (DENTSPLY International) specify that powder should be added first to the bowl. Given these discrepancies, it is useful to investigate whether this issue of water/powder sequence causes measurable differences in visible porosities in the set alginate. The results of this study, especially those involving zero void frequency, suggest that the water/powder sequence makes no difference when all mixing techniques are evaluated together, except for manual spatulation, where surface voids were reduced by adding powder to the mixing bowl first.
References

Manufacturers
DENTSPLY International, York, PA
800.877.0020, www.dentsply.com

DUX Dental, Oxnard, CA
800.833.8267, www.duxdental.com

Hygenic Corporation, Akron, OH
800.321.2135, www.hygeniccambria.com

Kilgore International, Inc., Coldwater, MI
800.892.9999, www.kilgoreinternational.com

Miltex, Inc., York, PA
800.654.2873, www.miltex.com

Rite-Dent Manufacturing Corporation, Hialeah, FL
305.693.8626, www.rite-dent.com

Vista Dental Products, Racine, WI
877.418.4782, www.vista-dental.com

Whip Mix Corporation, Louisville, KY
800.626.5651, whimpix.com