# Microtomographic Porosity Determination in Alginate Mixed with Various Methods

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## Abstract

**Purpose:** Mechanical spatulation of alginate impression materials reportedly produces fewer voids and superior casts than hand mixing. Two current methods of alginate mechanical preparation are a vacuum mixer Vac-U-Vestor, (Whip Mix Corp, Louisville, KY) and a semiautomated method that involves hand spatulation in a rotating bowl Alginator II (Cadco, Oxnard, CA). A new alginate-mixing machine has been introduced, TurboMax (Dentsply Raintree Essex, Sarasota, FL), with a centrifugal-spinning action that reportedly incorporates the alginate powder into the water more efficiently. The purpose of this study was to determine the number, percent, and volume distribution of porosities in alginate mixed with three mechanical-mixing methods using a nondestructive, microtomographic analysis method.
**Materials and Methods:** Alginate was mixed by each of the three mechanical methods per respective manufacturer's guidelines, with the set alginate analyzed using a microtomography unit and proprietary software. A mean and standard deviation was determined per group and analyzed with Kruskal-Wallis ANOVA/Mann-Whitney tests.
**Results:** Significant differences ($p < 0.001$) were found between groups per each of the three testing parameters (number, percent, volume distribution of porosities). The vacuum mixer produced significantly less percent porosity and number of porosities than the centrifugal mixer and semiautomated hand mixer. Both the vacuum mixer and centrifugal mixer produced porosities of significantly smaller volume than the semiautomated hand mixer.
**Conclusion:** Of the three mechanical mixing methods, the vacuum mixer had the best performance overall in reducing the number, percent, and volume of porosities in the mixed alginate.

Alginate impression materials are used routinely by dental practitioners and represent the most common impression material used in dentistry.[1] Precise reproduction of the involved oral structures is necessary for successful fabrication of a dental prosthesis. The accuracy of an impression affects the precision and quality of dental appliances.[2-4] Air entrapments or porosities within the impression material may influence the accuracy of an impression and the resulting cast.

Several studies report that impression material porosity has been reduced using mechanical-mixing devices. Koski compared mixing techniques and devices with different alginate brands and showed that alginate mixed with the vacuum mixer produced fewer surface defects and had better detail reproduction with cast gypsum than either hand or centrifugal mixing.[5] Studies have shown that hand mixing of elastomeric impression materials produced more porosities than cartridge-dispensed, automated-mixing tips.[6-8] In a technique paper, Rudd et al demonstrated that mechanical preparation of alginate materials with a vacuum mixer produced fewer porosities than hand mixing but did not compare the findings statistically.[2] Inoue et al investigated the setting characteristics and the rheological properties of alginates mixed by three methods: a hand-mixing technique, a semi-automatic-mixing instrument (combination with hand), and an automatic-mixing instrument (double-rotation mechanism). The investigators found almost no porosities using the automatic-mixing instrument and concluded that in clinical use, the homogeneous mix produced by automatic mixing was preferred over hand mixing.[9]


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Manufacturers of alginate-mixing machines claim a more homogeneous mixture with fewer porosities can be produced with their equipment than with manual preparation methods.[10-12] Two popular mixing systems are the Vac-U-Vestor Combination Unit, (Whip Mix Corp., Louisville, KY) and Alginator II (Cadco, Oxnard, CA). The Vac-U-Vestor involves mechanical spatulation combined with a vacuum; the Alginator II technique is based on a semi-automated-mixing technique with a hand spatula and rotating bowl. A new alginate-mixing machine, TurboMax (Dentsply Raintree Essex, Sarasota, FL), based on a centrifugal-mixing method was recently introduced.[10] The TurboMax uses a spinning action (3000 to 3600 rpm) that reportedly incorporates the alginate powder into the water to produce a smooth paste.

In recent years, microtomography has gained popularity in dental research. Microtomography allows the nondestructive, 3D evaluation of materials with quantitative analysis and has been used in multiple studies to evaluate marginal interfaces, endodontic anatomy, and remineralization.[13-16] No studies have compared and quantified porosity formation in alginate when mixed with various mechanical mixers using microtomographic techniques. The null hypothesis investigated in this study was that there would be no difference in the number, percent, or volume of porosities in alginate mixed using three mixing techniques.

## Methods and materials

The Vac-U-Vestor Combination Unit was used to create specimens by placing 16 g of alginate powder (Jeltrate, Dentsply, York, PA) and 38 ml of distilled water (23°C) into a bowl. The powder was thoroughly mixed with hand spatulation until no dry powder or large lumps remained. The lid and bowl were pressed together, and the vacuum was connected by slipping the metal nozzle of the vacuum hose into the opening on top of the lid. Next, the slotted drive nut was inserted into the drive chuck to initiate the mixing process. The material was mixed at low speed (430 rpm) for 15 seconds. After mixing, the alginate was placed in a 60-ml syringe and injected into a 9-ml vial and allowed to set. A separate mix of alginate was used per vial.

To create specimens with the TurboMax, distilled water and alginate powder were placed into the mixing cup as before. Using the stirrer stick, the alginate powder and water were mixed together for 2 seconds before capping the mixing cup and loading it into the machine. The start button was pressed to start the mixing action at 3600 rpm through completion of the 10-second cycle. The mixed alginate was placed in a syringe using the spatula and injected into a vial as before.

To create specimens with the Alginator II, distilled water and alginate powder were placed into the mixing bowl as before and blended by hand for several seconds. Holding the spatula firmly in one hand, the Alginator II was grasped with the other hand so the speed controls could be easily operated. The edge of the blade was positioned to lightly touch the inside of the bowl. With the bowl turning on "LO" speed, the spatula was moved in a straight line from the highest level of material down to the center of the bowl. Then the flat side of the spatula blade was placed against the center and side, while the bowl continued to rotate. Finally, the spatula was lifted off the side of the bowl. This procedure was repeated until the powder and water were incorporated while keeping the material in the bottom half of the bowl. The unit was stopped, and the spatula was cleaned by wiping it against the top edge of the bowl. Using "HI" speed, the procedure was repeated a minimum of five strokes to ensure thorough mixing. After mixing, the mixed alginate was placed in a syringe and injected into a vial as before.

**Table 1** Scan parameters for microtomographic imaging

| Parameter | Setting |
|---|---|
| Voltage | 59 kV |
| Current | 169 $\mu$A |
| Image pixel size | 12 $\mu$m |
| Image rotation step | 0.4 degrees |
| Exposure time | 1475 ms |
| Filtration | 0.5 mm Al |
| Frame averaging | 10 frames |

Twelve specimens were made per group. A sample size of 12 per group for three groups provided 80% power to detect an effect size of 0.54 (or 1.0 standard deviation) difference among means. The vials containing the alginate specimens were placed into a microtomography unit (Skyscan 1172, Kontich, Belgium), and scans were made according to the parameters listed in Table 1. Recorded images were then reconstructed (NRecon, version 1.4.4, Skyscan) into 3D images, which were in turn analyzed using proprietary software (CT Analyzer, version 1.6.0.0, Skyscan) for percent and total volume porosity as well as number of actual pores. A mean and standard deviation was determined per group. A Kruskal-Wallis ANOVA ($\alpha = 0.05$) with Mann-Whitney tests was used to determine differences between each group for each of the three testing parameters (number, percent, volume distribution of porosities).

## Results

Nonparametric statistics were used because exploratory graphical analysis found a nonnormal distribution and unequal variance of the data. Kruskal-Wallis ANOVA found significant differences between groups per test type ($p < 0.001$). Using the Mann-Whitney post hoc test, the Vac-U-Vestor was found to produce significantly fewer porosities than the TurboMax and Alginator II, which were not significantly different from each other (Fig 1). When examining the percent of the alginate containing pores, the Vac-U-Vester produced significantly less percent porosity than the TurboMax, which was significantly less than the Alginator II (Fig 2). The Alginator II produced alginate with porosities of significantly larger volume at all size distributions than the Vac-U-Vestor and TurboMax, which were not significantly different from each other (Table 2).

## Discussion

Irreversible hydrocolloid impression materials are some of the most common impression materials used in dentistry.[1]

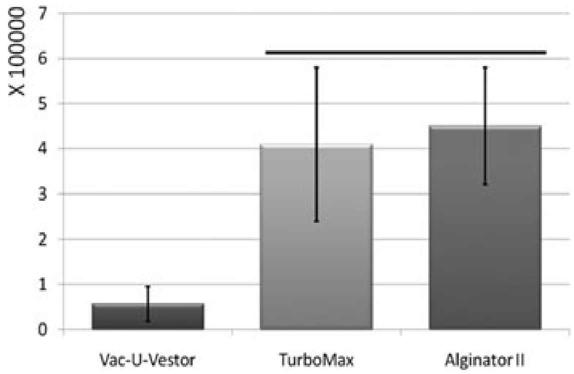


**Figure 1** Number of porosities in the alginate mixed with the three mechanical-mixing methods. Error bars indicate ±1 SD. Horizontal line indicates no significant difference ($p > 0.05$).

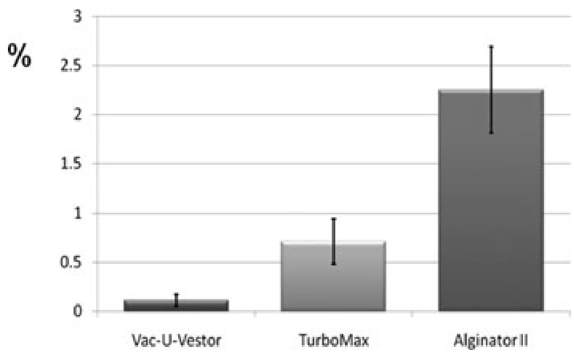


**Figure 2** Percent porosity of the total alginate mixed with the three mechanical-mixing methods. Error bars indicate ±1 SD.

Intuitively, proper preparation of alginate can be considered critical for some procedures in which a dental appliance is to be fabricated upon the cast made directly from the impression [e.g., removable partial denture (RPD) frameworks, orthodontic appliances, nightguards, obstructive sleep apnea devices]. An efficiently mixed alginate will tend to avoid entrapment of air in potentially critical parts of the impression, providing an appliance requiring less adjustment.

This study compared the effectiveness of three alginate preparation methods, using porosity as the measure with which each method could be compared. The use of microtomography in this evaluation allowed a nondestructive, novel quantitative assay of total porosity formed by the different preparation methods. Previous studies relied on rather subjective methods of porosity determination by manually counting the number of voids on the surface[5] or subsurface of sectioned impression material using a light microscope.[6–8] The microtomographic method avoids the disadvantage of lost information inherent to destructive methods and has the advantage of standard parameters during image acquisition and analysis. Microtomography works in exactly the same way as the X-ray tomography systems (CAT scans) used in medicine but with much finer resolution. Internal structures are reconstructed as a set of flat cross sections that are then used to analyze the 2D and 3D morphological parameters of the object.[15] Microtomography has been used successfully in recent studies to evaluate marginal interfaces, endodontic anatomy, and remineralization.[13–16] This study introduces the additional use of microtomography in the efficient and objective evaluation of impression materials.

**Table 2** Percent porosity volume distribution and standard deviation of the alginate mixed with the three mechanical-mixing methods. Groups with the same letter per row are not significantly different ($p > 0.05$)

| | Percent porosity | | |
|---|---|---|---|
| Porosity volume range | Vac-U-Vestor | TurboMax | Alginator II |
| 0.024–0.073 mm$^3$ | 97.4 (5.0) a | 95.0 (3.2) a | 56.3 (16.1) b |
| 0.073–0.121 mm$^3$ | 2.5 (5.0) a | 4.7 (2.9) a | 37.2 (11.1) b |
| 0.121–0.169 mm$^3$ | 0.0 | 0.4 (0.4) a | 6.4 (6.8) b |

The null hypothesis was rejected in this study. A difference was found in the number, percent, and volume of porosities in alginate mixed using the three techniques. The Vac-U-Vestor mixed the alginate under a vacuum and produced set alginate with the lowest number and percentage of porosities. The Vac-U-Vestor was similar to the TurboMax in producing porosities of smaller size compared to the Alginator II. The TurboMax uses a centrifugal-spinning action, which significantly reduced percent porosity formation, but not number of porosities compared to the semiautomated hand spatulation using the Alginator II. Figure 3 displays images of the internal surface of a representative specimen from each of the three mixing techniques. The images visually portray the quantitative data calculated using the microtomographic software. The image of the alginate produced by the Vac-U-Vestor displays the least void formation, followed closely by the alginate mixed with the TurboMax. The Alginator II produced a set mix of alginate with obvious void formation. For clinical procedures requiring greater accuracy, such as RPD frameworks, the mixing method producing the least porosity may be advantageous.

Although the use of microtomographic techniques in this study allowed for an objective comparison, other factors, such as ease of use and clinical indication, should be considered when comparing the overall performance of mixing techniques. Based on clinical-user evaluations reported by Clinical Research Associates, the Vac-U-Vestor provided a dense mix, but the unit was not portable and moderately expensive. The TurboMax was found to be heavy to transport and expensive; however, the evaluators found the convenience and consistency of the mix outweighed the higher cost. The Alginator II was judged to be a low-cost, portable alternative for routine applications not requiring a porosity-free mixture; however, more experience was necessary for the operator to become proficient with the mixing technique.[17]

Alginate materials prepared with a method that produces less porosity may have improved properties such as recovery from deformation, strain in compression, compressive strength, surface detail reproduction, and dimensional stability. Future investigations should investigate the effect of porosity on these parameters.

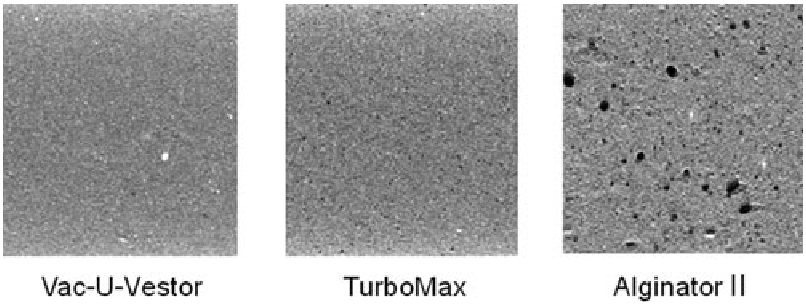


**Figure 3** Images of the internal surface of a representative specimen per mixing method at 5 × magnification.

## Conclusions

Of the three mechanical mixing methods, the vacuum mixer had the best performance overall in reducing the number, percent, and volume of porosities in the mixed alginate.

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