

Evaluation of Outgassing, Tear Strength, and Detail Reproduction in Alginate Substitute Materials

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Clinical Relevance

Alginate substitute materials are inexpensive polyvinyl siloxane (PVS) impression materials that exhibit better detail reproduction and tear strength than alginate. Alginate substitute materials do show slightly more outgassing and resulting cast porosity than traditional alginates, particularly when they are poured soon after mixing. To reduce cast surface porosity, a minimum pouring delay of 60 minutes is suggested.

SUMMARY

Objective: To compare three alginate substitute materials to an alginate impression mate-

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rial for cast surface porosity (outgassing), tear strength, and detail reproduction.

Materials and Methods: Detail reproduction tests were performed following American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 19. To measure tear strength, 12 samples of each material were made using a split mold, placed in a water bath until testing, and loaded in tension until failure at a rate of 500 mm/min using a universal testing machine. For cast surface porosity testing, five impressions of a Teflon mold with each material were placed in a water bath (37.8°C) for the in-mouth setting time and poured with vacuum-mixed Silky Rock die stone at 5, 10, 30, and 60 minutes from the start of mixing. The gypsum samples were analyzed with a digital microscope for surface porosity indicative of hydrogen gas release by comparing the surface obtained at each interval with four casts representing no,

little, some, and significant porosity. Data analysis was performed using parametric and Kruskal-Wallis analysis of variance (ANOVA), Tukey/Kramer *post-hoc* tests ($\alpha=0.05$), and individual Mann-Whitney U tests ($\alpha=0.0167$).

Results: All alginate substitute materials passed the detail reproduction test. Tear strength of the alginate substitute materials was significantly better than alginate and formed three statistically different groups: AlgiNot had the lowest tear strength, Algin-X Ultra had the highest tear strength, and Position Penta Quick had intermediate tear strength. Significant variation in outgassing existed between materials and pouring times ($p<0.05$). All alginate substitute materials exhibited the least outgassing and cast porosity 60 minutes after mixing.

Conclusions: Detail reproduction and tear strength of alginate substitute materials were superior to traditional alginate. The outgassing effect was minimal for most materials tested. Alginate substitute materials are superior replacements for irreversible hydrocolloid.

INTRODUCTION

Traditionally, irreversible hydrocolloid (alginate) has been the material of choice for diagnostic impressions because it is inexpensive, hydrophilic, reasonably accurate, and easy to manipulate.^{1,2} Advances in material refining processes, however, have produced low cost polyvinyl siloxane (PVS) impression materials, or "alginate substitutes," as alternatives to traditional alginate. For comparison, the alginate material cost for a full arch impression is approximately 90 cents, a full arch PVS impression is about \$20, and a full arch impression with alginate substitute materials is \$5-\$7.¹ These materials may be used for the same procedures as traditional alginate materials, such as making study and orthodontic models, fabricating provisional crown and bridge restorations, and making final impressions for removable prosthodontics.^{3,4} The proposed advantages of alginate substitute materials over traditional alginate are increased accuracy, prolonged dimensional stability, and the ability to repour an impression to obtain a second cast.

Earlier generations of alginate substitute materials were composed of alginate with silicone additives.^{5,6} These materials demonstrated little, if any, improvements in dimensional stability and were not able to accurately transfer fine details to gypsum

casts.⁵ Newer generation alginate substitutes, however, are composed of refined polyvinyl siloxane. The materials are termed alginate substitutes because advances in their refining process and proprietary changes in their chemical composition have significantly reduced the price of these PVS materials. A probable cost-saving modification in alginate substitute materials is the removal of palladium. Palladium is an expensive component of PVS added to impression materials to scavenge excess hydrogen gas. Studies have suggested that hydrogen gas release from PVS materials produced bubbles on gypsum casts. Adding palladium to PVS, therefore, decreases cast porosity.^{7,8} It is clinically relevant to measure the properties of alginate substitutes to determine the effects of compositional modifications of PVS on its physical and mechanical properties and compare these properties to those of traditional alginate impression material.

The American National Standards Institute and American Dental Association (ANSI/ADA) have developed standard practices for measuring properties of dental impression materials. Specification No. 18 was developed for alginates, and Specification No. 19 was developed for elastomeric impression materials.^{9,10} Because alginate substitutes are composed of PVS, an elastomeric material, it is reasonable to measure their properties in accordance with Specification No. 19. Major advantages of most elastomeric impression materials over traditional alginates include increased detail reproduction¹¹ and strength.¹² Detail reproduction is described in Specification No. 19 as the ability of a material to reproduce a line of 50 microns scribed into a steel die.¹⁰ An ANSI/ADA specification exists for tear strength using a notched specimen (4.3.10 of Specification No. 20); however, a more clinically relevant thin film tear strength method has been described by Lawson and others¹³ and reviewed by the ADA.¹⁴ In addition to detail reproduction and tear strength, it is also relevant to measure the cast porosity produced from alginate substitutes due to the assumed reduction of palladium scavengers in these materials.

Some studies have already examined the properties of alginate substitutes. Because these materials are relatively new, laboratory testing is scarce and clinical studies are nonexistent. A recent article by Torassian and others¹⁵ has determined that these materials have superior dimensional stability to alginate, remaining dimensionally accurate up to a week following mixing.¹⁵ Patel and others¹⁶ examined the detail reproduction, gypsum compatibility, and linear dimensional accuracy of several alginate

substitute materials. All materials demonstrated superior properties to a control alginate group.

The aim of this study was to compare the detail reproduction, tear strength, and cast porosity of alginate substitutes to the control, alginate. The null hypothesis was that there are no significant differences between the alginate substitute materials and alginate for detail reproduction, tear strength, and cast porosity.

MATERIALS AND METHODS

Three alginate substitute materials (AlgiNot, Algin-X Ultra, and Position Penta Quick) and a traditional alginate (Jeltrate) were evaluated using three testing methodologies. The characteristics of the three alginate substitute materials and alginate (control) are described in Table 1.

Detail Reproduction

ANSI/ADA Specification No. 19 for elastomeric impression materials was used to evaluate the detail reproduction of the alginate substitute materials. Three specimens were produced for each material. The ANSI/ADA specified steel die with 20-μm, 50-μm, and 75-μm scribed lines was used for this test. Prior to testing, the die was heated to oral temperature (37.8°C) in a water bath (Hygrobath, Whip Mix, Louisville, KY, USA). A ring was then placed on top of the die, and impression material was loaded into the ring. A glass slab was placed on top of the ring and secured with a 1-kg weight. The entire assembly was transferred to a 37.8°C water bath for the manufacturers' in-mouth setting time (Table 1). The specimens were then carefully separated from the die (Figure 1) and examined with a Keyence Digital Microscope VHX600 (Keyence, Itasca, IL, USA) at 12× optical magnification. Specimens were determined to have

either passed or failed the test based on their ability to capture the entire length of the 50-μm line.

Tear Strength

A plexiglass mold as described in a previous study¹³ was employed for this test. Specimens had dimensions of 70 mm × 10 mm with a 0.1-mm thickness film in their center. Twelve tear strength specimens were prepared of each material. After a small amount of material was extruded and discarded to ensure proper mixing in the dispensing tip, the molds were filled with impression material. The cover of the mold was applied with finger pressure and secured to the base. All fabrication occurred at 24°C and 51% humidity before moving the specimens to a water bath (Hygrobath, Whip Mix) at 37.8°C for the manufacturers' set time (Table 1). After setting, the mold was removed from the incubator and the specimen removed from the mold. Any excess material from the edges of the specimen was trimmed using a razor blade, and benchmarks were drawn on the specimen 10 mm on either side of the center line with a digital caliper. The specimen was secured into a universal testing machine (Instron Corp, Canton, MA, USA) with a pneumatic clamp at the location of the previously applied benchmarks. Before the test began, the fixture was adjusted so that the specimen was neither in compression nor tension. Starting 2.5 minutes after the specimens were removed from the water bath, the specimens were loaded in tension until failure with a crosshead speed of 500 mm/min. The tear strength was calculated as tear strength = ultimate tensile strength / (10 mm × 0.1 mm).

Cast Porosity Test

A custom milled Teflon mold (Figure 2) was used to prepare specimens of each impression material. The

Table 1: Materials Used in This Study						
Brand Name	Type	LOT/Exp	Manufacturer	Setting Speed	Working Time	Setting Time
Jeltrate (control)	Traditional alginate	1006091 2012-12	DENTSPLY/Caulk (Konstanz, Germany)	Fast set	1:30	2:30
AlgiNot	Alginate substitute	01142 2012-05	Kerr (Orange, CA, USA)	Fast set	1:00	2:30
Algin-X Ultra	Alginate substitute	100414 2012-04	DENTSPLY/Caulk (Konstanz, Germany)	Fast set	1:00	2:30
Position Penta Quick	Alginate substitute	401166 2012-05	3M ESPE (St Paul, MN, USA)	Fast set	1:10	2:40

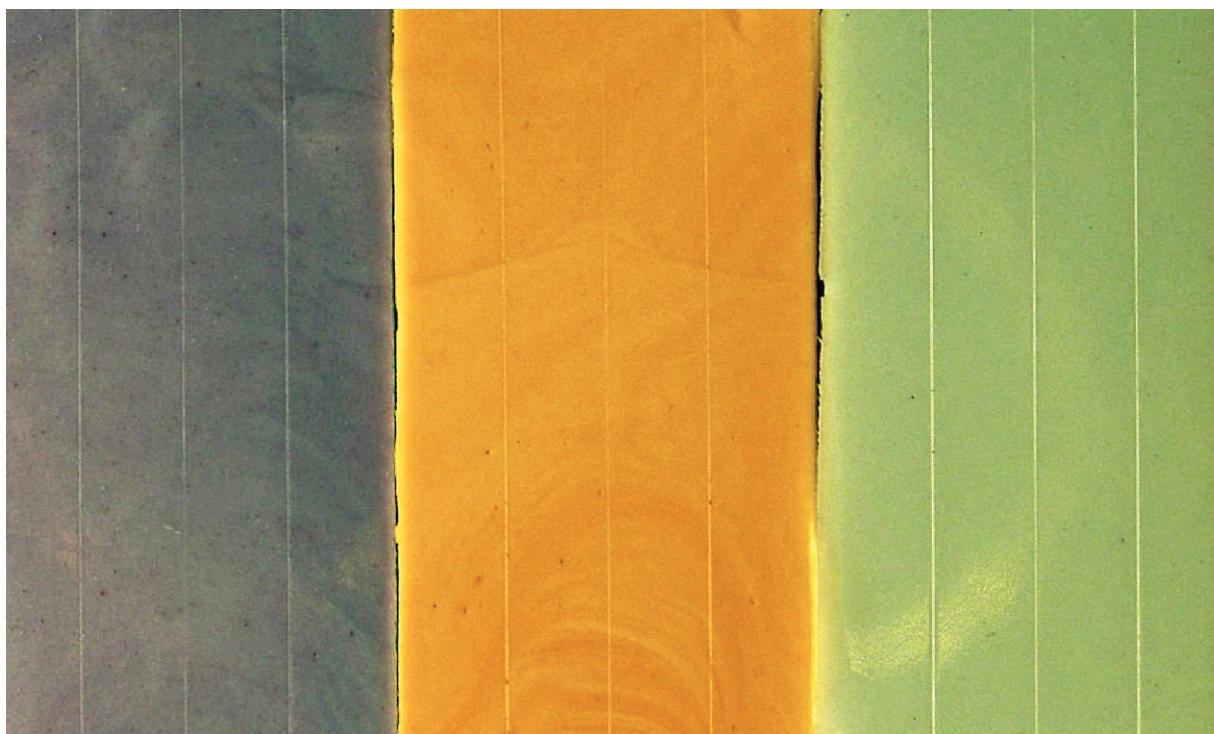


Figure 1. Detail reproduction specimens. (Left to right: Position Penta Quick, AlgiNot, Algin-X Ultra)

mold was designed so that its impression could retain dental stone independently and provide a uniform surface area to analyze porosities on the stone. Five impressions of the mold were taken with each

impression material at each time period. A glass slab was placed over the mold, and the filled molds were placed into a water bath (37.8°C) for the in-mouth setting time (Table 1). Each impression specimen was

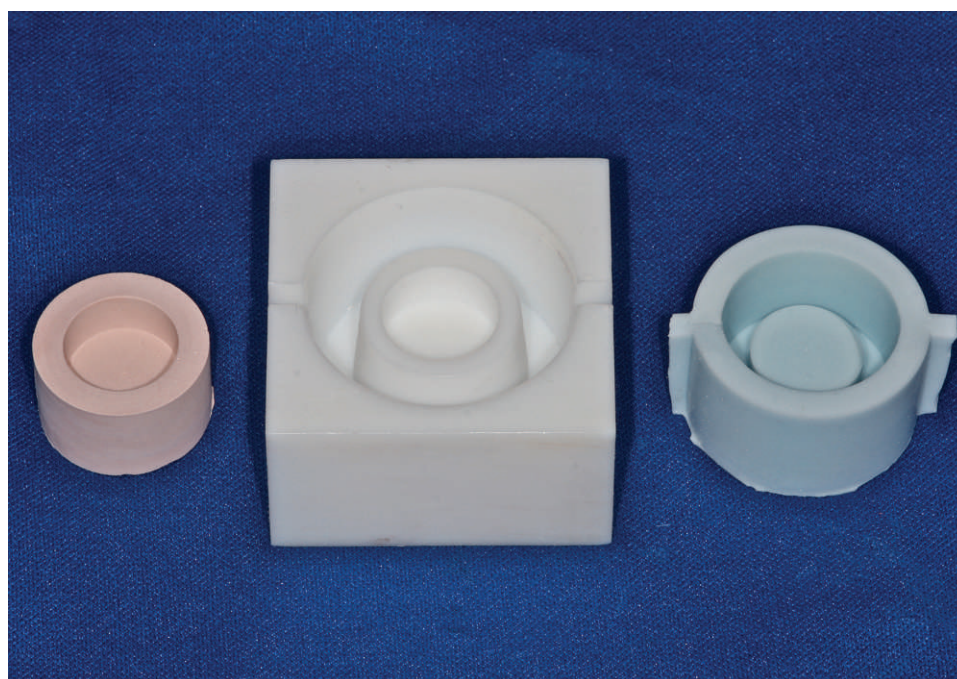


Figure 2. Teflon mold used for cast porosity testing. (Left to right: cast, mold, impression)

then filled with vacuum-mixed (–100 kPa) Silky Rock die stone (32 mL:140 g) (Whip Mix) at the appropriate interval (5, 10, 30, or 60 minutes after mixing the impression material). After setting, the surface of the stone casts that were in contact with impression material was analyzed using a Keyence Digital Microscope VHX600 at 5× magnification for surface porosity indicative of hydrogen gas release. The samples were each scored (1–4) against four representative samples with varying degrees of porosity/outgassing (Figure 3). The scores were given based upon the following criteria: 1: smooth, uniform surface; 2: slight outgassing, but uniform surface; 3: more outgassing, at irregular intervals; and 4: most outgassing at irregular intervals. The scores were averaged and used for statistical analysis.

Statistical Analysis

Tear strength data were analyzed by one-way analysis of variance (ANOVA), and significant differences between groups were examined with Tukey analysis ($\alpha=0.05$). Results of the cast porosity testing were compared using a Kruskal-Wallis ANOVA ($\alpha=0.05$) at each time interval. Alginate substitute materials were compared to each other and Jeltrate at each time point with the Mann-Whitney U test with a Bonferroni-adjusted alpha level of 0.0167. Each material was then compared for

change in porosity over time with a Kruskal-Wallis ANOVA ($\alpha=0.05$).

RESULTS

All alginate substitute impression materials exceeded the requirements of the ANSI/ADA Specification No. 19 detail reproduction test by reproducing not only the 50- μ m line, but also the 20- μ m line. The alginate control did not reproduce the 50- μ m line, failing the detail reproduction test (Table 2).

During tear strength measurement, the alginate failed (tore) before testing. For this reason, alginate was excluded from the statistical analysis and assumed to have a significantly lower tear strength than all tested alginate substitute materials. The one-way ANOVA showed significant differences between the alginate substitute materials and the Tukey/Kramer test differentiated them into three statistically separate groups ($p<0.05$). Algin-X Ultra had the highest tear strength with a mean value of 5.48 ± 0.64 MPa. Position Penta Quick was intermediate, measuring 3.53 ± 0.56 MPa; and the lowest group was AlgiNot FS at 2.44 ± 0.19 MPa (Table 2).

Porosity values for casts made using three alginate substitute materials were analyzed at each time interval and a significant difference in cast porosity

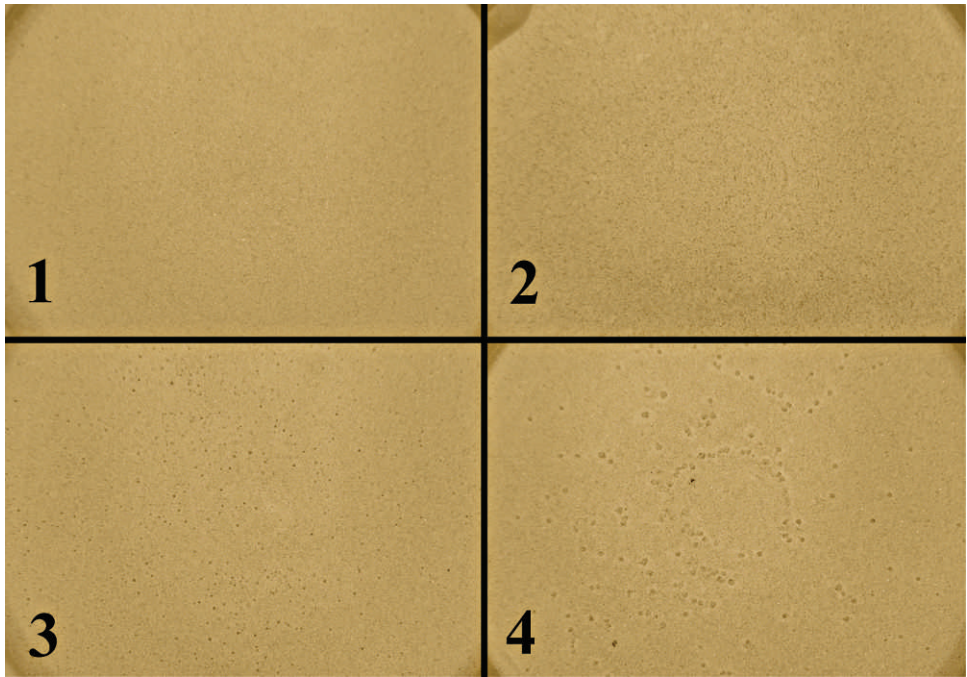


Figure 3. Porosity/outgassing reference samples. (1: smooth, uniform surface; 2: slight outgassing, but uniform surface; 3: more outgassing, at irregular intervals; and 4: most outgassing at irregular intervals)

Table 2: *Tested Properties of Alginate Substitute and Traditional Alginate Materials*

Material	Detail Reproduction	Average Cast Porosity Score				Tear Strength (Mean \pm SD), MPa
		5 min	10 min	30 min	60 min	
Jeltrate (control)	Failed	1 \pm 0	1 \pm 0	1 \pm 0	1 \pm 0	0
AlgiNot	Passed	1.8 \pm 0.4	1.4 \pm 0.5	1 \pm 0	1 \pm 0	3.53 \pm 0.56
Algin-X Ultra	Passed	2.2 \pm 0.4	2.2 \pm 0.4	2.4 \pm 0.5	1.8 \pm 0.4	5.48 \pm 0.64
Position Penta Quick	Passed	1.4 \pm 0.5	1.6 \pm 0.5	1.6 \pm 0.5	1.2 \pm 0.4	2.44 \pm 0.19

among these groups was noted at 30 minutes ($p=0.0074$) and 60 minutes ($p=0.0263$). Cast porosity at 30-minute and 60-minute periods was then analyzed with the Mann-Whitney U test for independent samples with a Bonferroni-adjusted alpha level of 0.0167. At 30 and 60 minutes, Algin-X Ultra demonstrated significantly higher cast porosity than AlgiNot ($p=0.0046$ and $p=0.0143$, respectively).

Each alginate substitute was then compared to an alginate control using the Mann-Whitney U test for independent samples at each of the four time intervals (alpha=0.0167). Cast porosity in Algin-X Ultra samples was significantly elevated from casts poured in alginate at each time interval. In AlgiNot specimens, cast porosity was significantly higher than alginate only in the first time interval. Position Penta Quick demonstrated no significant difference from alginate at any time interval.

Each material was observed to produce less mean porosity at the 60-minute interval. When each material was analyzed using Kruskal-Wallis ANOVA for change in porosity over time, AlgiNot was seen to exhibit a significantly lower value from the initial time period. Algin-X Ultra and Position Penta Quick were not significantly reduced.

DISCUSSION

The results of this study indicate that alginate substitute materials have greater detail reproduction and tear strength than alginates, but some have an increase in cast porosity at certain pouring times. Therefore, the null hypothesis is rejected for all of the tests performed. Further analysis into each property will be discussed below.

All alginate substitute materials were able to accurately capture the 20- μ m and 50- μ m line, whereas the control alginate material was not able

to reproduce the 50- μ m line. The results of this test are within expected outcomes because PVS materials are considered to produce the greatest detail of all impression materials,¹⁷ and a recent study of alginate substitutes found similar results.¹⁶ Detail reproduction is a factor of the pressure exerted on an impression material and the material's wettability and rheological properties.¹⁸ Equal pressure was exerted on all materials in this study, so differences between materials should be related to differences in their wetting and rheological properties. Wettability is the ability of a liquid to spread on the surface of a solid,¹⁹ and it is related to the material's contact angle.²⁰ Alginates are recognized as having better wettability than PVS.⁸ Rheological properties, on the other hand, refer to the material's viscosity and ability to flow. German and others²¹ determined that surface detail reproduction was related to a material's tan delta (a measure of viscosity) and flow. Although the flow properties of alginates and PVS have not been directly compared, PVS has demonstrated exceptional flow properties.^{22,23} The high level of detail reproduction produced by alginate substitutes in this study can therefore be credited to the flow properties of PVS.

The tear strength test demonstrates the ability of alginate substitute materials to reproduce thin intrasulcular and interproximal areas.²⁴ The control, alginate, failed before testing, supporting the clinical observation of torn alginate fragments remaining in interproximal areas of the mouth after making an impression. In the present study, the tear strength results may be compared to a similar study using the same split molds (0.1-mm thick) and testing conditions.¹³ In that study, tear strengths of traditional PVS materials ranged from 4.71 MPa to 8.24 MPa, and the tear strength of the polyether material (Impregum) was 2.05 MPa. The tear strengths of the

alginate substitute materials in this study ranged from 2.44 MPa to 5.48 MPa. Comparing the data from the current study to the previous study, alginate substitutes produced lower tear strength values than traditional PVS materials, possibly due to modifications made to PVS to produce these cheaper alternatives. However, all alginate substitute materials tested in this study exhibited greater tear strength than Impregum, a polyether material used for fixed prosthodontics.

In this study, some alginate substitute materials showed significantly more cast porosity than a traditional alginate, particularly when poured soon after they were mixed. A study by McCrosson and others⁷ measured hydrogen gas released from setting PVS materials by gas chromatography and compared it to the porosity observed on casts poured from the same materials. Similar to the present study, cast porosity was quantified by scoring casts by the number of defects on their surface. Scores ranged from 0 to 6, generally differentiated by differences of 25 defects. The study found a relationship between hydrogen gas release and cast porosity and recommended waiting the manufacturer's recommended pouring time (30–360 minutes) before pouring PVS materials. The results of the present study suggest that alginate substitute materials will produce similar cast porosity as alginate after waiting five minutes for Position Penta Quick and 10 minutes for AlgiNot. Algin-X Ultra had slight outgassing even after 60 minutes; however, it produced less cast porosity after 60 minutes than at earlier times. Clinically, it is important to determine the degree of cast surface integrity required when selecting an appropriate material and pouring time.

One of the major limitations of this study was that detail reproduction was only measured on a dry surface. As PVS materials are generally hydrophobic,²⁵ the measurement of surface detail on a wet or moist surface has shown to reduce its detail reproduction.^{26,27} Additional properties of alginate substitutes, such as contact angle, elastic deformation, and recovery and flow measurement must be compared to traditional PVS materials in order to completely characterize these materials. Ultimately, clinical testing of these materials must be performed to determine the range of their clinical applications.

CONCLUSIONS

In conclusion, alginate substitute materials are superior to alginate in tear strength. The alginate substitute material with the highest tear strength

was Algin-X Ultra. All three alginate substitute materials passed the detail reproduction test, while the control, alginate, did not.

These materials did exhibit more outgassing than the control, particularly when poured five minutes after mixing. Position Penta Quick was the only alginate substitute material that produced cast porosity similar to that of the control at all time points. All alginate substitute materials produced the least outgassing if poured 60 minutes after mixing.

Conflict of Interest Declaration

The Authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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