Effect of Mixing Methods on Mechanical Properties of Alginate Impression Materials

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Background: A commercial mechanical mixer is available to make the mixing of alginate more convenient and more consistent for the practitioner; however, there is very little information on the mechanical properties of alginate mixed with this device as compared with hand mixing.

Purpose: To compare the mechanical properties of alginate impression materials mixed with a mechanical mixer (Alginator II, Cadco) and hand mixing.

Material and Methods: Three alginate impression materials (Identic, Jeltrate, and Kromopan) were tested. Strain in compression, elastic recovery, and compressive strength were measured according to ANSI/ADA specification no. 18-1992; tear energy was measured using a pants tear test. Five specimens were prepared for each group with 12 groups for the mechanical mixer and 12 groups for hand mixing, for a total of 120 specimens. A two-way analysis of variance and Fisher's PLSD test at the 0.05 level of significance were used to analyze the data.

Results: There were statistically significant differences in properties among the materials, but mixing technique had no statistically significant effect on strain in compression and tear energy.

Conclusion: The mechanical mixer improved elastic recovery and compressive strength of the alginate impression materials tested and had no effect on strain in compression and tear energy. A mechanical mixer facilitates the mixing of alginate impression materials and improves some mechanical properties.

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INDEX WORDS: irreversible hydrocolloid, strain in compression, elastic recovery, compressive strength, tear energy, mechanical mixing, hand mixing

ALGINATE IMPRESSION material was originally developed in the 1930s and has been used in dentistry for over 50 years. [1] During World War II, due to a shortage of raw materials for reversible hydrocolloids, irreversible hydrocolloids were introduced, and their use subsequently exploded.[2] Today, alginate is the most commonly used impression material in the world.[1-3] It is popular because the material is easy to manipulate, fairly comfortable to the patient, and relatively inexpensive for the dentist.[2,4]

Although the above qualities are important, the impression material must have adequate physical properties to make and pour an accurate impression of the desired tissues (hard or soft). Some of the mechanical properties that can determine success or failure with an impression material are strain in compression, elastic recovery, and compressive strength. The requirements for these mechanical properties are described in ANSI/ADA specification no. 18-1992 for alginate impression materials.[5] Although not included in the ANSI/ADA specification, tear energy is also an important property when using alginate impression materials in areas where an impression lacks bulk or encounters a mechanical undercut.[6]

The property of strain in compression is related to the flexibility/stiffness of the material. An alginate impression must be able to be removed from the mouth without injury to the impressed tissues, must resist deformation when pouring the impression with dental gypsum, and must resist breakage when the set model material is removed from the impression.[7]

Elastic recovery is the ability of the alginate material to recover after it has been deformed during removal from the mouth. The greater the

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Table 1. Materials Used

Product	Manufacturer	Batch Number	Expiration Date	Mixing Time (sec)	Oral Setting Time (sec)	Mixing Ratio (Powder:Water)
Identic	Cadco	043165	Nov 2005	45	105	6 g:16 ml
Jeltrate dustless	Dentsply/Caulk	0310041	Apr 2005	45	105	7 g:19 ml
Kromopan	LASCOD	0153343107.105	Jul 2005	45	105	9 g:20 ml

elastic recovery, the more accurate the impression material will be.[8]

The compressive strength of alginate is important, because the material must resist compressive failure in any area where there is an undercut close to the impression tray and the material is compressed against the side of the tray and the tooth.[7]

The tear energy becomes important when areas with undercuts are impressed. The higher the tear energy, the less likely it is for the material to tear in an area with existing undercuts.[6]

Although alginate is easy to manipulate, all the manipulative factors (water/powder ratio, spatulation – too much or too little) affect the strength of the set material, and it is imperative to follow the manufacturer's directions on mixing.[9,10] The most accurate way to dispense alginate is to weigh it, because volumetric dispensing can differ from the recommended weight by 10% to 20%.[10] Using a syringe to measure the water also ensures that the correct amount of water is added to the mix.

In 1978, an alginate mixing device (Alginator I) became available. This semiautomatic mixing device produced a fine paste with few bubbles when compared to hand mixing.[11] It also lowered the viscosity of the alginate when compared to hand mixing.[11] A study performed by Kilinc et al found that the regular set alginate had better mechanical properties when mechanically mixed; however, the fast set impression material did not improve.[12]

The purpose of this study was to compare the mechanical properties and tear energy of three commercial alginate materials mixed semiautomatically with a mechanical mixer and mixed by hand. The null hypothesis was that there were no significant differences in the properties among the three alginate impression materials and the two mixing methods.

Materials and Methods

The impression materials used in this study are listed in Table 1. The materials were mixed by hand according to manufacturers' directions, or were mechanically mixed using a semiautomatic mixer (Alginator II, Cadco, Oxnard, CA).

Elastic recovery (K), strain in compression (E), and compressive strength (C) were tested according to ANSI/ADA specification no. 18.[5] For measurement of elastic recovery (K), the specimens were deformed by 20% of the original length (L) for 5 seconds on a screw-driven universal testing machine (Mini 44, Instron Corp., Canton, MA). The load was then released, and after 40 seconds the change in length (ΔL) was measured. K (%) was calculated as $100 \times (L - \Delta L)/L$.

For the strain in compression test, the load was added onto the specimen gradually over a period of 10 seconds to produce a stress of 0.1 N/mm^2. The load was maintained for 30 seconds and the change in length (ΔL) was measured. E (%) was calculated as $100 \times \Delta L/L$, where L was the original length, and ΔL was the change in length. Specimens were tested in a screw-driven universal testing machine (Mini 44).

Compressive strength was measured by application of a load at 100 N/min until fracture occurred. The force at fracture (F) was recorded to the nearest 0.1 N. Specimens were tested in a screw-driven universal testing machine (Model 4465, Instron Corp.). The compressive strength was calculated as $C = 4F/\pi d^2$, where F was the load at fracture (N), and d was the diameter of the test specimen in mm.

Tear energy (T) was measured using specimens with dimensions of 75 mm × 25 mm × 1 mm as specified by Webber and Ryge.[13] Using a sharp razor blade, a 50 mm slit was made, producing trouser leg-shaped specimens (12.5 mm wide). The thickness below the slit was measured in three locations with a dial micrometer. Specimens were tested in a screw-driven universal testing machine (Mini 44). The legs of the specimen were placed vertically in opposite directions. The grip separation speed was 20 mm/min. Tear energy (J/m^2) was calculated as $9800 \times F(\lambda_T + 1)/h$, where F was the force required to tear the material (kg), λ_T (observed extension ratio) was equal to the

Table 2. Elastic Recovery (K), Strain in Compression (E), Compressive Strength (C), and Tear Energy (T) of the Tested Impression Materials

	Elastic Recovery (K), %		Strain in Compression (E), %		Compressive Strength (C), MPa		Tear Energy (T), J/m^2	
	Machine mix	Hand mix	Machine mix	Hand mix	Machine mix	Hand mix	Machine mix	Hand mix
Identic	96.48 (0.11)*	96.42 (0.04)	13.9 (0.3)	14.0 (0.3)	0.80 (0.01)	0.76 (0.01)	164 (17)	140 (13)
Jeltrate	96.36 (0.17)	96.05 (0.13)	13.8 (0.3)	14.1 (0.3)	0.91 (0.02)	0.86 (0.02)	177 (17)	178 (20)
Kromopan	95.90 (0.37)	95.72 (0.11)	13.4 (0.3)	13.6 (0.6)	0.72 (0.07)	0.71 (0.03)	159 (5)	168 (12)

*SD (N = 5).

specimen length at the end of test divided by the original length of the specimen (dimensionless), and h was the specimen thickness (mm).[13]

Five specimens were made for each of 24 groups for a total of 120 specimens. Data were analyzed by 2-way analysis of variance (StatView 5.0, SAS Institute, Cary, NC). Fisher's protected least significance difference intervals (Fisher's PLSD) were calculated (StatView 5.0) at the 0.05 level of significance to compare the influence of material and mixing method. If the mean difference between two groups was larger than the corresponding Fisher's PLSD interval, then the two groups were considered significantly different.

Results

Table 2 lists means and standard deviations of the tested properties. Figure 1 illustrates the influence of material and technique on the tested properties. Analysis of variance (Table 3) showed that material and technique had statistically significant influences on the elastic recovery and compressive strength. The material had a statistically significant influence on the strain in compression while material and the interaction of material and technique influenced tear energy significantly. Fisher's PLSD intervals for comparisons of means among products and between mixing techniques (machine mix vs hand mix) were: 0.17% and 0.14% for elastic recovery, 0.4% and no significant difference between mixing techniques for strain in compression, 0.03 and 0.03 MPa for compressive strength, and 14 and 11 J/m^2 for tear energy, respectively.

For strain in compression, Kromopan had a significantly lower value than Identic and Jeltrate. All materials tested had elastic recovery greater than

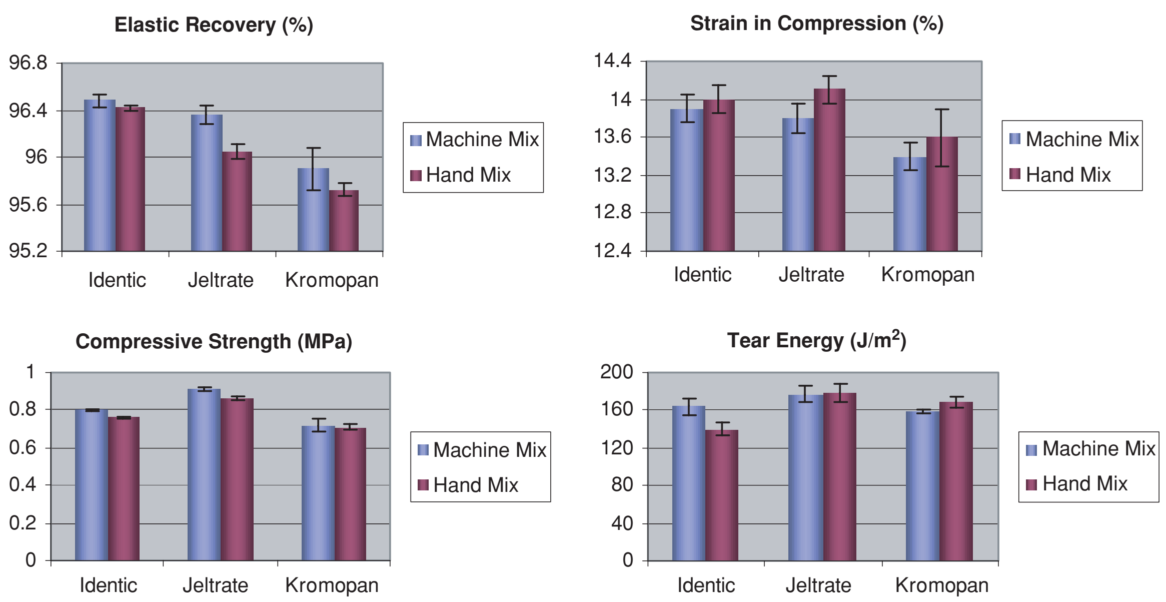

Figure 1. Effect of material and mixing technique on the mechanical properties of alginate impression materials.

Table 3. Summary of Two-Way ANOVA

	Elastic Recovery		Strain in Compression		Compressive Strength		Tear Energy	
	F-value	*p-value*	*F-value*	*p-value*	*F-value*	*p-value*	*F-value*	*p-value*
Material	30.2	< 0.0001	3.8	0.04	64.7	< 0.0001	7.8	0.003
Technique	7.3	0.01	2.7	0.12	7.9	0.01	0.8	0.37
Interaction	1.1	0.33	0.2	0.84	1.2	0.33	3.5	0.046

95%. There was a significant difference among the three materials and between machine and hand mixing for both elastic recovery and compressive strength. Hand-mixed Identic had the lowest tear energy, whereas tear energy for Jeltrate was significantly higher than that for Identic or Kromopan.

Discussion

The null hypothesis that there were no significant differences in the properties among the three alginate impression materials and the two mixing methods was rejected since material and technique had significant influence on the properties tested.

When an impression is removed from the mouth, the material must withstand the forces produced. This same impression must have the ability to be accurately poured in the appropriate model material. The accuracy of an impression material is related to strain in compression, elastic recovery, compressive strength, and tear energy.

All three materials had values of strain in compression well within the limits (not less than 5% or more than 20%) of the ANSI/ADA specification no. 18. There was no difference in strain in compression between hand mixing and mechanical mixing. Differences among the materials were so small that clinically they should behave similarly. In 1971, Walter measured strain in compression of 14% for Identic and 13% for Kromopan, similar to values observed in this study.[14]

The elastic recovery of the three alginates was above the minimum (95%) called for in ANSI/ADA specification no. 18-1992. In fact, Identic and Jeltrate had elastic recovery very close to the specification (96.5%) by ISO 4823 for elastomeric impression materials.[15] Among products, Kromopan had the lowest recovery and was statistically significantly and different from Identic and Jeltrate. Identic did not show a difference between hand and mechanical mixing; however, Jeltrate and Kromopan both showed a statistically significant improvement with mechanical mixing over hand mixing.

ANSI/ADA specification no. 18 requires a compressive strength of at least 0.35 MPa. Jeltrate, Identic, and Kromopan had significantly higher values than the standard. There were statistically significant differences among the compressive strength of the materials (Jeltrate > Identic > Kromopan). There was also an improvement in compressive strength with mechanical mixing for Identic and Jeltrate but not for Kromopan.

Tear energy was measured using thin (1 mm) specimens. The three alginates showed no significant difference among them. Cohen et al used the ASTM-D1004-94a test (15.77 mm thick "V" specimens) and observed similar results for the same products.[16] The tear energy in the present study also fell in the same range (100–300 J/m^2) as the study by Vrilhoef and Battistuzzi in 1986.[6] There was a statistically significant improvement in tear energy with mechanical mixing for Identic.

The Alginator II used in this study is an updated model from the Alginator I. Functionally they are very similar, with improvements in the LCD display/ timer, the digital switches, and the motor. The manufacturer states that Alginator II will give easy consistent mixes, save time and cleanup, and smooth bubble-free mixes.[17] It was observed in this study that mechanical mixing did improve the consistency of the alginate after mixing, the ease in which the material was incorporated into the mix, the bubble-free texture, and the ease of use, when compared with hand mixing. Mechanical mixing would make diagnostic, removable partial denture, and preliminary denture impressions much easier to accomplish.

Conclusions

Mechanical mixing improved elastic recovery and compressive strength of all three alginate impression materials and the tear energy of Identic, but had no effect on strain in compression (all three) or tear energy of Jeltrate and Kromopan.

The tested alginates, (Identic, Jeltrate, and Kromopan), performed well above the standards required in ANSI/ADA specification no. 18-1992 for alginate impression materials.

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