Tear Strength of Five Elastomeric Impression Materials at Two Setting Times and Two Tearing Rates

NATHANIEL C. LAWSON, MS*
JOHN O. BURGESS, DDS, MS†
MARK LITAKER, PHD‡

ABSTRACT

Problem/Aims: Thin sections of impression materials are susceptible to tearing in gingival crevices and interproximal spaces. This study measures the tear strength of six fast and regular set impression materials after different setting times and at different tearing rates.

Materials/Methods: Tear strength specimens were prepared of four addition silicone materials: Aquasil (Dentsply, Konstanz, Germany), Imprint 3 (3M ESPE, Seefeld, Germany), Stand Out (Kerr, Orange, CA, USA), Virtual (Ivoclar Vivadent, Schaan, Liechtenstein); one polyether material: Impregum (3M ESPE); and a new hybrid material: Senn (GC, Aichi, Japan) using a split mold. Specimens were divided into four groups ($N = 5$). Groups 1 and 2 were immediately removed from the mold and loaded in tension until failure using an Instron testing device (Instron Corp., Canton, MA, USA). Groups 3 and 4 were tested 24 hours after fabrication. Groups 1 and 3 were tested at 1 mm/minute, and groups 2 and 4 were tested at 500 mm/minute.

Results: A two-factor analysis of variance (ANOVA) and Tukey's test revealed differences among material brands ($\alpha = 0.05$) in all experimental groups. The polyether and hybrid material were in the lowest statistically significant ranking group for all experimental groups. A three-factor ANOVA determined that a 500 mm/minute tearing rate and a 24-hour set time produced higher tear strengths and that fast set materials produced greater tear strength than regular set materials.

Conclusions: Most addition silicone materials provide higher tear strengths than polyether and hybrid materials. Materials display higher tear strengths after longer set times and at faster tearing rates. Impressions should be removed from the mouth with the fastest possible speed.

CLINICAL SIGNIFICANCE

Addition silicone materials should be used in impressions requiring replication of gingival crevices or interproximal spaces to prevent tearing of thin sheets of material. Impressions should be removed from the mouth and separated from the model with the fastest possible speed.

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*DMD/PhD resident, School of Dentistry, University of Alabama at Birmingham, Birmingham, AL, USA
†Assistant dean for clinical research, School of Dentistry, University of Alabama at Birmingham, Birmingham, AL, USA
‡Associate professor, School of Dentistry, University of Alabama at Birmingham, Birmingham, AL, USA

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INTRODUCTION

Impressions should resist tearing when tensile stresses are applied during impression removal and cast separation from the set impression. Impression materials are most susceptible to tearing in gingival crevices and interproximal areas. Tearing in the impression causes defects, which affect the accuracy of the final restoration.[1] Additionally, some impression material remnants remaining in the sulcus may produce inflammation reactions.[2,3] Therefore, it is necessary for impression materials to have maximum tear strength at the time of removal.[4]

The tear strength of impression materials has been measured using several different tests, including the Trouser tear test,[5–7] which measures tear propagation, and the Die C tear test,[8,9] which measures tear initiation and propagation. ANSI/ADA specification 20 (4.3.10) describes the tear test for nonaqueous dental duplicating material and specifies the use of an ASTM standard Die C tear specimen. According to their specifications, specimens are to be fabricated and stored at 23°C. One hour following fabrication, the specimen should be tested in tension at 254 mm/minute.[10] A more clinically relevant tear strength specimen, developed by Boghosian and Lautenschlager,[11] was used in this study, which mimics thin sheets of impression material in gingival crevices and interproximal areas.

This study examined the effect of setting time on the tear strength of the materials. Two setting times were examined, immediately after setting and 24 hours following setting. Testing immediately following specimen preparation mimics oral removal, and 24-hour testing mimics cast removal. Shorter setting times for impression materials are more convenient for clinicians, particularly when a single tooth has been prepared. If the manufacturer's suggested set time is not accurate and the impression material has not completely polymerized before removal, the impression material will tear. Therefore, testing materials 24 hours after setting will also determine if setting time beyond the manufacturer's directions will affect tear strength.

Another variable examined in tear strength testing is the tearing rate, the speed at which the materials are removed from the mouth or the cast from the impression. Elastomeric impression materials are viscoelastic, and the tearing rate will affect the tear strength of the material.[12] Clinically, the speed at which impressions are removed from the oral cavity and the cast will affect the tear strength of the impression material. Therefore, the impression should be removed with the fastest possible speed.[13] Klooster and colleagues performed a study loading ASTM specimens at 100, 200, and 500 mm/minute and determined that higher strain rates produced higher tear strength.[14]

This experiment measured the tear strength of five regular and fast set elastomeric impression materials with two variables: setting time (immediately after setting and 24 hours after setting) and tearing rate (1 and 500 mm/minute). The hypothesis is that setting time, tearing rate, and if the material is regular or fast set will have no effect on the tear strength of the material.

METHODS AND MATERIALS

A plexiglass mold was fabricated at the University of Alabama at Birmingham School of Dentistry to perform the tear strength testing. The mold contained a 70 (length) × 10-mm (width) indentation that was 1.9-mm deep. A 90° triangular notch was inserted along the 10-mm width of the indentation at the center of its length. The mold produced a 0.1-mm-thick space between the top of the triangular notch and the lid of the mold. The section of the specimen that was between the top of the triangular notch and the lid of the mold is most susceptible to tearing, and the thickness of the specimen in that section is referred to as the film thickness.

TABLE 1. LIGHT BODY IMPRESSION MATERIALS USED IN THIS STUDY.

Material	Manufacturer	Composition	Set Time	
Aquasil Ultra	Dentsply	Addition silicone	Reg	5:00 minutes
			Fast	3:00 minutes
			Reg	5:00 minutes *
			Fast	3:00 minutes *
Imprint 3	3M ESPE	Addition silicone	Reg	6:30 minutes
			Fast	4:40 minutes
Virtual	Ivoclar Vivadent	Addition silicone	Reg	7:05 minutes
			Fast	4:05 minutes
			Reg	7:30 minutes *
			Fast	4:15 minutes *
Impregum Soft	3M ESPE	Polyether	Reg	5:30 minutes
			Fast	4:00 minutes
Senn	GC	Hybrid (addition silicone/polyether)	Reg	7:00 minutes
			Fast	4:10 minutes

Reg = regular.
*Denotes extralight body material.

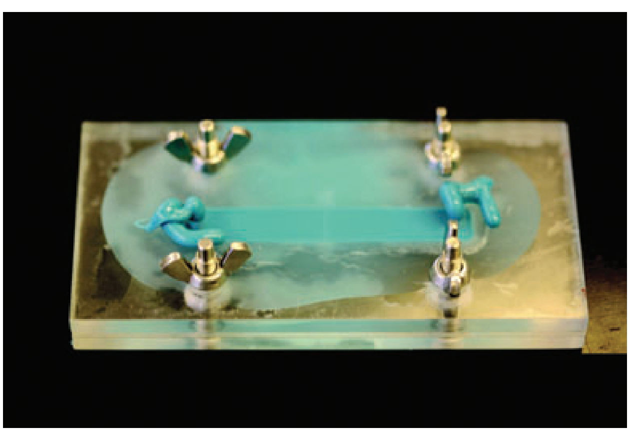

Figure 1. Tear strength mold.

Six commercially available impression materials were used for this study (listed in Table 1). The specimens were prepared by dispensing impression material into the plexiglass mold. A small amount of material was extruded and discarded to ensure proper mixing in the dispensing tip. A timer was started immediately after the impression material was first dispensed from the cartridge into the mold. The cover of the mold was applied with finger pressure and secured to the base. Excess material flowed out of the mold from two holes in the lid (Figure 1). The specimens were fabricated at 24°C and 51% humidity before being placed in the incubator (Kendro Laboratory Products, Asheville, NC, USA) at 37°C for the manufacturer's set time (listed in Table 1). After setting, the mold was removed from the incubator, and the specimen was removed from the mold. The 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.

The specimens were divided into four groups with $N = 5$ for each group. Immediately following specimen preparation, the specimens from groups 1 and 2 were

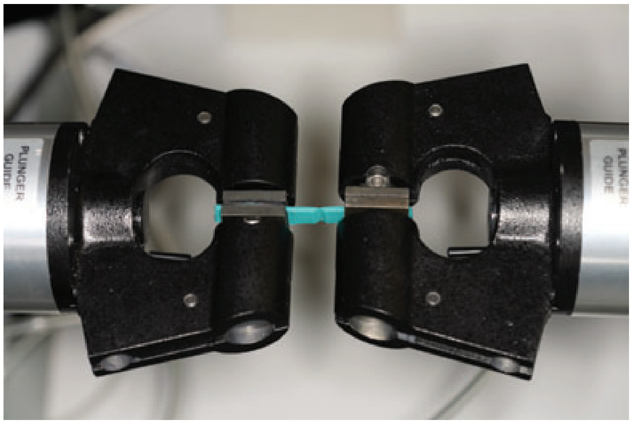

Figure 2. Tear strength specimen in the Instron testing device.

secured into the Instron universal testing machine (Instron Corp., Canton, MA, USA). The specimen was gripped on both sides by a pneumatic clamp at the location of the previously applied benchmarks (Figure 2). Before the test began, the jig was adjusted so that the specimen was neither in compression nor tension. Starting 2.5 minutes after the specimens were removed from the incubator, the specimens were loaded in tension until failure with a crosshead speed of 500 mm/minute (group 1) and 1 mm/minute (group 2).

Groups 3 and 4 were stored at 24°C for an additional 24 hours after preparation. Tear strength testing was performed identically to group 1 and 2 at 500 mm/minute (group 3) and 1 mm/minute (group 4). The area of the tear was nominally 1 mm.[2] The tear strength was calculated as tear strength = ultimate tensile strength/(10 mm × 0.1 mm).

The data from every group were subjected to a two-way analysis of variance (ANOVA) and Tukey's HSD test ($\alpha = 0.05$). A three-way ANOVA was used to compare the regular and fast set materials ($\alpha = 0.05$). The groups (1–4) were compared using a three-way ANOVA and Tukey's HSD test ($\alpha = 0.05$).

RESULTS

The tear strength of each regular setting material for each group is graphed in Figure 3, and the tear strength of each fast setting material for each group is graphed in Figure 4. Means and SDs of tear strength values of each group are provided in Table 2. The two-way ANOVA revealed a significant difference between brands of materials in each experimental group (1–4). Tukey's HSD test ranked materials into statistically different categories. In all groups, the polyether and hybrid materials were ranked in the statistically significant category with the lowest tear strength. A three-way ANOVA revealed that fast set materials provided a greater tear strength than regular set materials ($\alpha = 0.004$).

The three-way ANOVA test showed a significant difference between overall materials tested after different setting times and at different tearing rates. Tukey's comparison revealed that longer setting time and a faster tearing rate produced statistically higher tear strengths. Individual materials were tested to see if there was a statistically different tear strength for longer setting times and increased tearing rates for *each* material. Longer setting times produced significantly greater tear strength for all materials except for Imprint 3 LB Fast, Aquasil LB, and Virtual XL Fast. Fast tearing rates produced significantly greater tear strength for all materials except for Imprint 3 LB, Virtual XLB, Senn LB Reg and Fast, and Impregum Reg and Fast.

DISCUSSION

The specimens fabricated for this study are different than tear strength specimens used in previous studies. Our specimens measure the maximum tensile yield

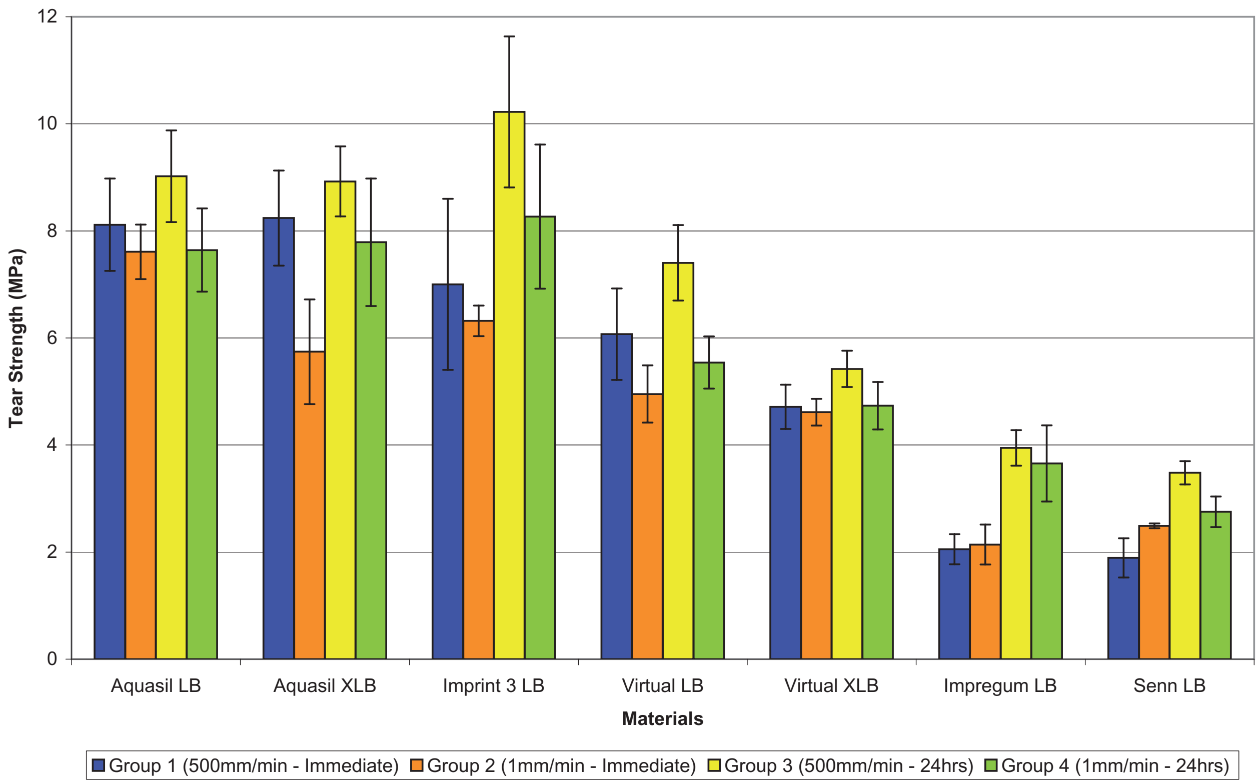

Figure 3. Tear strength (mean ± SD) for regular set materials.

stress of a thin film of impression material. This test was developed by Boghosian and Lautenschlager to produce clinically relevant results.[11] The thin film of impression material models the thin sheets of material in interproximal and subgingival areas subject to clinical tearing. Impression material has been shown to penetrate a crevice as thin as 0.05 mm in vitro.[15] Our study used specimens with a film thickness of 0.1 mm (instead of 0.2 mm[11] or 0.4 mm[16]) to mimic the very thin regions of impression material produced clinically.

Boghosian and Lautenschlager's tear strength study evaluated 10 impression materials. Comparing the numerical results of our study to Boghosian and Lautenschlager's data reveals that our tear strength values are almost twice as great as their reported data. The most important difference between our study and theirs is that our specimens had a 0.1-mm film thickness and theirs had a 0.2-mm film thickness.[11] This observation suggests that thicker film thickness produces a lower tear strength (which is measured as force/area).

A study by Whiteman and Nathanson examined Aquasil, Imprint 3, and Impregum using the ADA specification 19 tear test.[9] The numerical results from their study cannot be directly compared with this study because the two tests measure different properties (tear initiation and propagation versus thin-sheet tensile strength). In Whiteman and Nathanson's study, Impregum and Aquasil LB showed a statistically greater tear strength than Imprint 3 LB Quick. This conclusion contradicts our results, which show that Imprint 3 LB Quick and

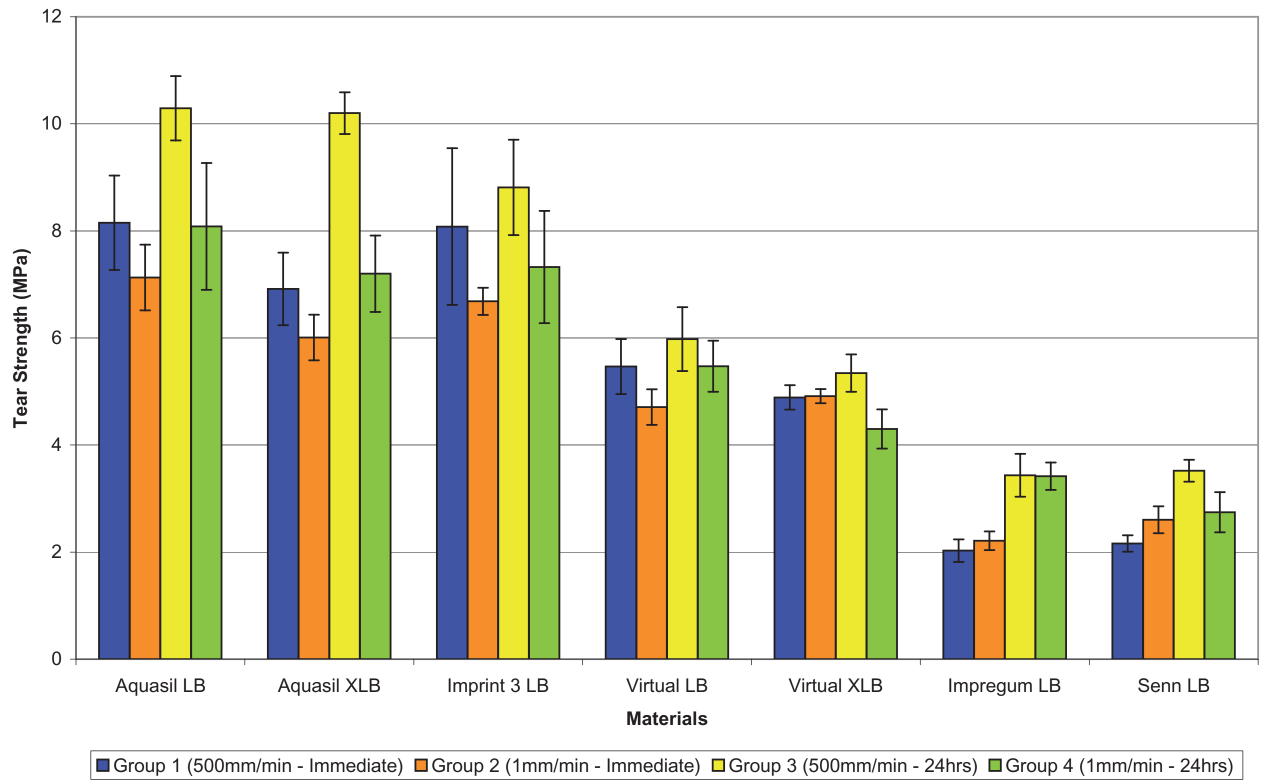

Figure 4. Tear strength (mean ± SD) for fast set materials.

TABLE 2. TEAR STRENGTH OF REGULAR SET AND FAST SET IMPRESSION MATERIALS (MEAN ± SD).

Material		Group 1 (MPa)	Group 2 (MPa)	Group 3 (MPa)	Group 4 (MPa)
Aquasil LB	Reg	8.12 ± 0.86	7.61 ± 0.51	9.02 ± 0.86	7.64 ± 0.78
	Fast	8.15 ± 0.88	7.13 ± 0.61	10.29 ± 0.60	8.08 ± 1.19
Aquasil XLB	Reg	8.24 ± 0.89	5.74 ± 0.98	8.92 ± 0.66	7.79 ± 1.19
	Fast	6.92 ± 0.68	6.01 ± 0.43	10.20 ± 0.39	7.20 ± 0.71
Imprint 3 LB	Reg	7.00 ± 1.60	6.32 ± 0.29	10.22 ± 1.41	8.27 ± 1.35
	Fast	8.08 ± 1.46	6.68 ± 0.25	8.81 ± 0.89	7.32 ± 1.05
Virtual LB	Reg	6.07 ± 0.85	4.95 ± 0.53	7.40 ± 0.70	5.54 ± 0.49
	Fast	5.47 ± 0.28	4.71 ± 0.35	5.98 ± 1.19	5.47 ± 0.27
Virtual XLB	Reg	4.71 ± 0.41	4.61 ± 0.25	5.42 ± 0.34	4.74 ± 0.44
	Fast	4.89 ± 0.39	4.91 ± 0.35	5.34 ± 0.93	4.30 ± 0.46
Impregum LB	Reg	2.05 ± 0.28	2.14 ± 0.37	3.95 ± 0.33	3.66 ± 0.71
	Fast	2.03 ± 0.21	2.21 ± 0.17	3.43 ± 0.40	3.42 ± 0.26
Senn LB	Reg	1.89 ± 0.37	2.49 ± 0.04	3.48 ± 0.22	2.75 ± 0.29
	Fast	2.16 ± 0.15	2.60 ± 0.25	3.52 ± 0.20	2.75 ± 0.38

Reg = regular.

Aquasil LB have no statistical difference from each other, but both have statistically greater tear strength than Impregum.

The ANSI/ADA standard specifies that tear strength specimens should be tested 1 hour following polymerization.[10] Clinically, impressions are subjected to tearing forces immediately after the manufacturer's setting time. This study reveals that there are significant differences between testing immediately after the setting time and 24 hours following the setting time. Testing immediately following the setting time is a clinically relevant method.

As noted in the results, several materials did not show significant differences between a 1 mm/minute tearing rate and a 500 mm/minute tearing rate. Impregum and Senn both showed greater tear strength values at a 1 mm/minute tearing rate than 500 mm/minute immediately after setting. An explanation for this behavior is that these impression materials are undergoing further polymerization in the additional amount of time it takes to deform these materials at 1 mm/minute.

A limitation of this study is that the exact cross-sectional area of the specimen during tearing could not be accurately determined. As the specimens were deformed, they experienced necking, and the cross-sectional area decreased. The cross-sectional area at the time of tearing is needed to calculate tear strength. The most feasible method to measure the change in cross-sectional area would be to record the specimen thickness with a video extensometer. We could not find an extensometer capable of accurately measuring such small changes in length.

CONCLUSION

In conclusion, addition silicone materials have greater tear strength than polyether and polyether/addition silicone hybrid materials. Materials undergo continued cross-linking past the manufacturer's suggested set time, which is indicated by the increased tear strength that these materials experience after 24 hours of additional setting. Materials also have higher tear strength at increased tearing rates. Clinically, impressions should be removed from the mouth and separated from the model at the fastest possible speed.

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Reprint requests: Dr. John O. Burgess, DDS, MS, School of Dentistry, University of Alabama at Birmingham, Birmingham, SDB 605, 1530 3rd Ave. South Birmingham, AL 35295-0007, USA. Tel.: 205-934-5022; Fax: 205-934-2340; email: jburgess@uab.edu

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