Flow Profile of Regular and Fast-Setting Elastomeric Impression Materials Using a Shark Fin Testing Device

NATHANIEL C. LAWSON, MS*, **DENIZ CAKIR,** DDS, MS†, **LANCE RAMP,** DMD, PhD‡, **JOHN O. BURGESS,** DDS, MS§

ABSTRACT

Statement of the Problem: Light-bodied impression materials with high flow over time are needed to capture preparation margins, particularly with impressions of multiple preparations.

Purpose: The flow of five different impression materials (three vinyl polysiloxane, one polyether, and one hybrid) of two setting times (fast and regular) was compared over 30-second intervals.

Materials and Methods: Flow was measured using a shark fin testing apparatus (3M ESPE, Seefeld, Germany). A weighted metal caste was suspended above a cup of impression material. The caste was dropped into the impression material, which displaced the material and caused it to flow into a triangular notch within the caste, creating a "shark fin." The test was repeated for each specimen at 30-second increments. These shark fin molds were kept in an incubator to allow setting of the impression materials. After complete setting, the height of the "shark fin" was measured. The data were analyzed using separate two-way analysis of variance and Tukey's HSD post hoc analyses to determine significant intergroup differences ($p = 0.05$).

Results: Shark fin values differed significantly among materials and at each time interval ($p = 0.05$). Polyether impression materials produced the greatest flow when compared with the vinyl polysiloxane and hybrid materials.

Conclusion: Based on the limitations of this study and the materials used, polyether impression material had a better flow profile compared with the vinyl polysiloxane and hybrid materials.

CLINICAL SIGNIFICANCE

An impression material must be selected based on the consistency and flow properties of the material, its setting time, anatomic aspects of the preparation, and speed of the operator. Impressions with deep subgingival margins and/or multiple preparations may be better captured with a polyether impression material.

(J Esthet Restor Dent 23:171–178, 2011)

INTRODUCTION

Impression material must have low viscosity to accurately record impression details such as the interproximal spaces, deep restorative preparations, and gingival crevices. Low viscosity allows better flow of the material, which is important for accurately capturing fine details of the preparation.[1] Vinyl polysiloxane impression materials are the most widely used materials for final impressions.[2] These materials are

*DMD/PhD student, Department of Prosthodontics, University of Alabama at Birmingham, Birmingham, AL, USA
†Instructor, Department of Prosthodontics, University of Alabama at Birmingham, Birmingham, AL, USA
‡Associate professor, Department of Prosthodontics, University of Alabama at Birmingham, Birmingham, AL, USA
§Assistant dean for clinical research, Department of Prosthodontics, University of Alabama at Birmingham, Birmingham, AL, USA

 DOI 10.1111/j.1708-8240.2010.00396.x

manufactured in four different consistencies (viscosities): (extra) light-bodied, medium-bodied, heavy-bodied, and putty.[3] Light-bodied materials contain a lower volume percent of silica fillers than heavy-bodied materials. Decreased filler content in light-bodied materials increases their flow.[4]

A combination technique is employed for impression taking that involves the use of heavy-bodied material in a tray and a light or extra light consistency impression material in a syringe. In this technique, the light-bodied material captures the fine details, whereas the heavy-bodied material provides support to the light-bodied material.[3] Often, a light-bodied material will be injected around multiple preparations for the same final impression. In this scenario, the flow properties of the light-bodied impression material surrounding the first preparation might change by the time the last preparation is injected and the tray is seated. Therefore, both the flow and flow profile over time are critical properties of a light-bodied impression material.

The shark fin test device was developed for testing the flow of impression materials. Benchimol and colleagues,[5] Broome and colleagues,[6] Stipho and colleagues,[7] Klettke and colleagues,[8] and German and colleagues[9] published results with this shark fin testing apparatus. The initial design for this device simulated the flow of impression material from 1.5 N of applied force. The seating forces for elastomeric impression materials, as determined by Sotiriou and Hobkirk, reach as high as 10 N.[10] To more closely simulate clinical forces, the device was modified by the addition of a 268.20 g (~2.6 N) weight on top of the metal caste. The weight increases the pressure applied to the material to more than 4 N. The weight more closely approximates the average pressure used by a clinician while loading an impression tray into a patient's mouth.

An ideal impression material will have adequate working time but a fast intraoral setting time. The clinician needs time to inject the impression material into the gingival sulcus, place the impression material into the tray, and position it in the mouth; however, the desirable material should set rapidly to reduce intraoral setting time. Ideally, the impression material would exhibit high flow initially but quickly transition to zero flow. The initial high flow would let the material flow into crevices, whereas a rapid reduction in flow will reduce distortion during the polymerization phase.[11] Generally, impression materials are available with a regular and fast-setting time. Fast-set materials have less retarder. Their polymerization is less delayed, resulting in a shorter working time than regular set materials. Fast-set materials would be expected to flow for a shorter period of time than regular set materials.[12]

This study examined the flow of three vinyl polysiloxane, one polyether, and one hybrid silicone/polyether materials with both regular and fast-setting times. The hybrid material is composed of dimethylpolysiloxane (silicone monomer), silicone dioxide (silicone monomer), and a proprietary polyether compound that forms a polymer containing both siloxane and polyether groups.[13] The null hypothesis was that there will be no difference in flow between vinyl polysiloxane, polyether, and hybrid silicone/polyether impression materials.

MATERIALS AND METHODS

Flow was measured using a stainless steel device designed and manufactured by 3M ESPE (Seefeld, Germany), termed the shark fin testing apparatus. The apparatus consisted of a 7.5-mL cup (A), a cylindrical caste with a triangular notch transversing the interior axially (B), a housing to suspend the caste over the cup (C), a pin to attach the caste to the housing (D), and a weight to apply a force for the caste to drop into the cup (E) (Figures 1 and 2).

Five impression materials were tested and listed in Table 1. Each impression material was injected into the cup, which was kept at oral temperature (37°C) in an incubator (Kendro Laboratory Products, Asheville, NC, USA). A timer was started immediately after injecting the material. All excess material was wiped away with a spatula, making the material flush with the rim of the cup. At 30-second intervals, the pin was released, dropping the caste into the impression material.

 DOI 10.1111/j.1708-8240.2010.00396.x

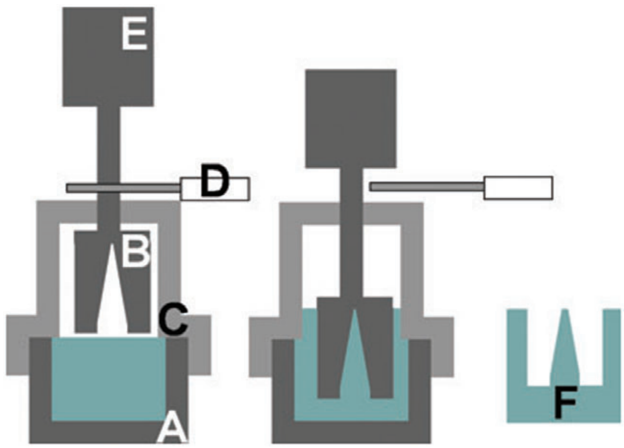

FIGURE 1. Illustration of shark fin testing device.

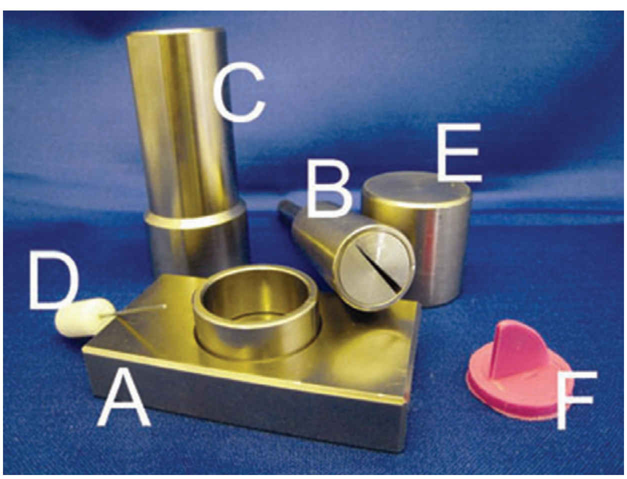

FIGURE 2. Shark fin testing device.

Specimens of each material ($N = 5$) were prepared by dropping the caste after 30, 60, 90, 120, 150, 180, and 210 seconds after injecting the impression material. Material flowed into a triangular notch in the caste creating a "shark fin" (Figure 1F). The mold was then placed in an incubator at 37°C for a time period specified by the manufacturer to allow the impression material to set completely. After the setting time, the mold was removed and disassembled. Excess material was cut away to reveal the shark fin. The shark fin height was defined as the vertical distance from the tallest part of the fin to the juncture where the fin intersected the flat surface of the specimen. The height of the shark fin was measured to the nearest hundredth of a millimeter using a digital caliper (DC150; Duratool, Tali City, Taiwan).

The data were analyzed using two-way analysis of variance (ANOVA), and significant intergroup differences were determined with Tukey–Kramer post hoc analysis (alpha = 0.05).

RESULTS

The mean shark fin height of each material is graphed at each time interval in Figure 3. A qualitative examination of Figure 3 reveals that the polyether material produced high shark fin values initially, maintained high shark fin values for 2 minutes, and abruptly produced short shark fin specimens. After the 30-second interval, all regular set materials produced higher shark fin values than the corresponding fast-set material except Impregum. This qualitative analysis was quantitatively confirmed with statistical analysis.

A two-way ANOVA table revealed that shark fin values differed significantly among materials and at each time interval ($p = 0.05$) (Table 2). A detailed comparison of shark fin values was then performed using the Tukey–Kramer post hoc test between (1) time points for each material and (2) materials at each time interval.

First, the flow of each material was compared over time. Individual Tukey–Kramer post hoc analyses for each material showed significant differences in shark fin heights between time points ($p < 0.05$). All regular and fast-set polyvinyl siloxane and hybrid materials showed a significant decrease in shark fin heights beginning at the 30-second time interval. The regular and fast polyether material did not show significant decreases in shark fin heights until the 2-minute and 90-second time points, respectively.

Next, all materials were compared at each time point. A Tukey–Kramer analysis differentiated materials into significantly different groups at each time interval ($p < 0.05$) (Table 3). At the first time interval (30 seconds), the hybrid, polyether, and several vinyl polysiloxanes were all grouped in the statistical group with the greatest flow. Between the 1- and 2-minute time intervals, the polyether was in the group

 DOI 10.1111/j.1708-8240.2010.00396.x

TABLE 1. Impression materials used in this study

Product	Manufacturer	Type	Viscosity	Manufacturer's setting time	Lot
Aquasil Ultra	Dentsply Caulk (Milford, DE, USA)	Vinyl poly-siloxane	Light bodied	Regular, 5:00 minutes	060404
				Fast, 3:00 minutes	0603221
Imprint 3	3M ESPE (Seefeld, Germany)	Vinyl poly-siloxane	Light bodied	Regular, 6:30 minutes	245958
				Fast, 4:40 minutes	245962
Virtual	Ivoclar-Vivadent (Amherst, NY, USA)	Vinyl poly-siloxane	Light bodied	Regular, 7:05 minutes	JL4093
				Fast, 4:05 minutes	JL4002
Impregum	3M ESPE	Polyether	Light bodied	Regular, 5:30 minutes	250614
				Fast, 4:00 minutes	247883
Senn	GC America (Alsip, IL, USA)	Hybrid	Light bodied	Regular, 7:00 minutes	0412201
				Fast, 4:10 minutes	0508101

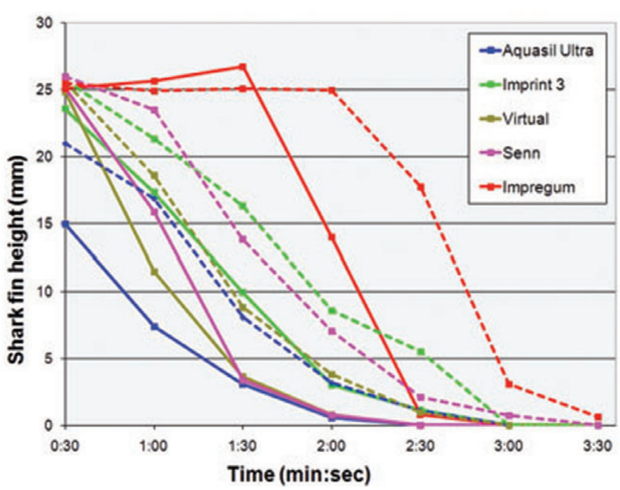

FIGURE 3. Shark fin height of light-bodied materials versus time (regular-set materials are represented with a dashed line and fast-set materials are represented with a solid line).

significantly greater than all vinyl polysiloxane materials. At the 2:30 interval, the regular set polyether material was in the group with the greatest flow. By 3:30 minutes, all materials stopped flowing, excluding the regular set polyether, and after 4 minutes, all materials stopped flowing.

DISCUSSION

The results of this study suggest that the null hypothesis should be rejected. The shark fin test measured significantly different values of flow for different materials. The ability of the device to discriminate between materials validates its utility.

The results of qualitative and quantitative analyses show that polyether impression material demonstrated a better overall flow profile when compared with the vinyl polysiloxane and hybrid materials. The polyether material experienced high initial flow (at the 30-second interval), maintained high flow (for the first 90 seconds for the fast set and 2 minutes for the regular set), and ceased to flow by 4 minutes.

Previous studies that have examined the flow of impression materials using the shark fin testing device have achieved similar results. Benchimol and colleagues,[5] Broome and colleagues,[6] Klettke and colleagues,[8] and German and colleagues[9] concluded that Impregum, the polyether impression material, provided significantly greater flow than the vinyl polysiloxane materials tested. As expected, a comparison of the shark fin height data to previous studies reveals that shark fin heights in this study of identical materials are considerably higher because of the addition of the 350-g weight. At the 30-second interval, many of the materials in this study produced similar shark fin values. Because of the additional weight used in this study, it is possible the caste dropped to the bottom of the cup and produced a maximum shark fin value. As a result, it was

 DOI 10.1111/j.1708-8240.2010.00396.x

TABLE 2. Analysis of variance

	DF	SS	MS	*F*	*p*	Lambda	Power
Material	9	5,005.005	556.112	1,090.921	<0.0001	9,818.286	1
Time	6	24,663.589	4,110.598	8,063.733	<0.0001	48,382.4	1
Material × time	54	4,363.922	80.813	158.531	<0.0001	8,560.677	1
Residual	273	139.165	0.51				

TABLE 3. Shark fin heights of light-bodied impression materials: mean (SD)

	Shark fin height after 0:30 (mm)	Shark fin height after 1:00 (mm)	Shark fin height after 1:30 (mm)	Shark fin height after 2:00 (mm)	Shark fin height after 2:30 (mm)	Shark fin height after 3:00 (mm)	Shark fin height after 3:30 (mm)
Aquasil Ultra							
Regular	20.98 (0.53)[d]	16.87 (0.49)[d]	8.06 (0.45)[f]	3.18 (0.40)[d]	1.08 (0.06)[cd]	0.00 (0.00)	0.00 (0.00)
Fast	14.98 (0.41)[e]	7.37 (0.35)[f]	3.08 (0.15)[g]	0.56 (0.10)[e]	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Imprint 3							
Regular	25.69 (0.59)[ab]	21.34 (4.70)[bc]	16.34 (0.51)[c]	8.56 (1.27)[c]	5.51 (0.30)[b]	0.00 (0.00)	0.00 (0.00)
Fast	23.57 (0.54)[c]	17.33 (0.84)[d]	9.93 (1.12)[e]	3.03 (0.86)[d]	1.14 (0.37)[cd]	0.00 (0.00)	0.00 (0.00)
Virtual							
Regular	25.60 (0.48)[ab]	18.56 (0.82)[cd]	8.77 (0.46)[ef]	3.81 (1.08)[d]	0.96 (0.32)[d]	0.00 (0.00)	0.00 (0.00)
Fast	24.84 (0.45)[b]	11.44 (0.95)[e]	3.63 (0.41)[g]	0.79 (0.14)[e]	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Senn							
Regular	25.97 (0.12)[a]	23.48 (0.99)[ab]	13.86 (0.50)[d]	7.04 (0.83)[c]	2.10 (0.18)[c]	0.76 (0.02)[b]	0.00 (0.00)
Fast	25.13 (0.49)[ab]	15.86 (0.22)[d]	3.32 (0.63)[g]	0.73 (0.13)[e]	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Impregum							
Regular	25.47 (0.29)[ab]	24.92 (0.79)[a]	25.05 (0.64)[b]	24.96 (0.90)[a]	17.73 (1.14)[a]	3.08 (0.27)[a]	0.61 (0.23)[a]
Fast	25.09 (0.56)[ab]	25.61 (0.39)[a]	26.71 (0.81)[a]	14.02 (1.03)[b]	0.80 (0.12)[d]	0.00 (0.00)	0.00 (0.00)

Values in each column with similar superscripts are not statistically different.

more difficult to find statistical differences among materials at the early time intervals. For example, Benchimol and colleagues[5] found a 14.2-mm fin height difference between Aquasil and Impregum at a 25-second interval; however, the current study found only a 4.5-mm fin height difference after a 30-second time interval.

Balkenhol and colleagues performed a correlation analysis between the shark fin test and relevant rheological properties of a vinyl polysiloxane, polyether, and hybrid impression material. A rotational rheometer was used to measure storage modulus and phase angle, two parameters that measure chain linking in polymers. Surprisingly, not all materials showed a correlation between shark fin height and storage modulus or phase angle. Balkenhol and colleagues suggested that measuring shear viscosity, a parameter influenced by the interaction of monomer molecules, might better explain the results of the shark fin test.[14] German and colleagues concluded that shark fin heights correlate strongly with tan delta of the impression material immediately upon mixing.[9] Tan delta is a property that gives the relative ratio of the viscous to the elastic component of a material's behavior. A material with a high tan delta value will have a viscous consistency and improved flow properties. McCabe and colleagues reported that polyether materials had a comparatively long period of high tan delta values, whereas vinyl polysiloxane materials show low tan delta value initially that reduce over time.[15]

The current study measured flow of impression materials on a dry surface. Clinically, impressions are taken in an environment exposed to saliva. Future research could examine the ability of impression material to flow on a wet surface. This study could be performed by modifying the shark fin testing method; the notched caste could be coated in water or artificial saliva before it is dropped into the impression material.

CONCLUSION

Polyether impression materials provide significantly greater flow than vinyl polysiloxane and hybrid polyether/silicone materials. It is important to consider a flow profile when choosing an impression material. Theoretically, a material with greater flow can better capture deep and subgingival preparations and compensate for a slower operator and multiple preparations.

DISCLOSURE AND ACKNOWLEDGEMENTS

The authors would like to acknowledge the manufacturers for donating all of the impression materials. These materials were received from the US divisions. The authors do not have any financial interest in the companies whose materials are included in this article.

REFERENCES

1. Lowe RA. Mastering the art of impression making. Inside Dent 2006;2:38–9.
2. Chen SY, Liang WM, Chen FN. Factors affecting the accuracy of elastometric impression materials. J Dent 2004;32:603–9.
3. Anusavice KJ. Phillips' science of dental materials. 11th ed. St. Louis (MO): Saunders; 2003, pp. 219–20.
4. Hosotani M, Katakura N, Kawakami M, et al. The effect of filler content on properties of polyaddition-type silicone impression material. J Jpn Soc Dent Mater Devices 1990;9:326–35.
5. Benchimol J, Perry R, Kugel G, Halls M. Flow of eight impression materials with 2 mm slit after 25 seconds. J Dent Res 2005;84A:3083.
6. Broome JC, Burgess JO, Lawson NC. Flow of fast and regular set elastomeric impression materials. J Dent Res 2006;85C:0324.
7. Stipho S, Maiolo C, Sharma S, et al. Flow of impression materials using REALITY-method with 1.0 mm slit-size. J Dent Res 2006;85A:0413.
8. Klettke T, Ranftl D, Kuppermann B. Comparison of different types of impression materials. J Dent Res 2006;85B:2465.
9. German MJ, Carrick TE, McCabe JF. Surface detail reproduction of elastomeric impression materials related to rheological properties. Dent Mater 2008;24:951–6.
10. Sotiriou M, Hobkirk JA. An in vivo investigation of seating and removal forces associated with recording impressions in dentate patients. J Prosthet Dent 1995;74:455–62.
11. Burgess JO. Impression materials basics. Inside Dent 2005;1:30–3.
12. Klettke T, Hampe R. Prolongation of working time with polyether retarder. J Dent Res 2007;86B:0122.
13. SENN Light Body. MSDS No. 002328; Alsip, IL: GC America Inc., September 15, 2005.
14. Balkenhol M, Wöstmann B, Kanehira M, Finger WJ. Shark fin test and impression quality: a correlation analysis. J Dent 2007;35:409–15.
15. McCabe JF, Arikawa H. Rheological properties of elastomeric impression materials before and during setting. J Dent Res 1998;77:1874–80.

Reprint requests: Nathaniel C. Lawson, MS, Department of Prosthodontics, University of Alabama at Birmingham, SDB Box 77, 1530 3rd Avenue South, Birmingham, AL 35295-0007, USA; Fax: 205-934-2340; email: nlawson@uab.edu

Presented at the American Association for Dental Research annual meeting in New Orleans, LA, in March 2007.
This article is accompanied by commentary, Flow Profile of Regular and Fast-Setting Elastomeric Impression Materials Using a Shark Fin Testing Device, Huma Hamid, DDS
DOI 10.1111/j.1708-8240.2010.00397.x

 DOI 10.1111/j.1708-8240.2010.00396.x