An Experimental Study on Particular Physical Properties of Several Interocclusal Recording Media. Part II: Linear Dimensional Change and Accompanying Weight Change

Konstantinos X. Michalakis, DDS, CAGS, PhD;[1]
Argiris Pissiotis, DDS, CAGS, MS, PhD;[2]
Vassiliki Anastasiadou, DDS, MS, PhD;[2] and Danai Kapari, DDS, PhD[3]

Purpose: The purpose of this study was to evaluate the linear dimensional change and accompanying weight change of several elastomeric interocclusal recording media.

Materials and Methods: Ten 50 mm long, 8 mm wide, 3 mm deep Teflon molds and a stainless steel die were constructed for the purposes of this study. The die was made in order to produce standardized reference lines, which were used for the measurement of the linear change. After homogeneous mixing, each material was carried from the mixing pad or directly from the mixing tip to the Teflon mold. The mold was inverted onto the stainless steel die. The materials were allowed to set for the manufacturers' suggested setting time plus an additional 3 minutes to ensure polymerization of the material. An electronic scale (Galaxy 110, Ohaus, Pine Brook, NJ) was used for the measurement of the weight change of the specimens and a traveling micrometer microscope (Griffin Ltd., London, England) was used to measure the linear changes at 5 time intervals: 0, 1 hour, 24, 48, and 72 hours.

Results: Analysis of variance for a significance level of 5% revealed that there was a statistically significant effect of the "material" factor on the weight changes ($F = 2229.98$, $p < 0.0005$). There was also a statistically significant effect of the "time" factor on the weight changes ($F = 2{,}332.04$, $p < 0.0005$). Descriptive statistics and Tukey's Honest Significant Difference Test revealed that the elastomeric material with the greatest weight changes is polyether (Ramitec).

Analysis of variance for a significance level of 5% revealed that there is a statistically significant effect of the "material" factor on the linear changes ($F = 215.54$, $p < 0.0005$). There is also a statistically significant effect of the "time" factor on the linear changes ($F = 1{,}996.01$, $p < 0.0005$). Descriptive statistics and Tukey's Honest Significant Difference test revealed that the elastomeric material with the smallest linear changes is polyether (Ramitec).

Conclusions: Of all materials tested, Ramitec (polyether) presented the smallest linear change at all time intervals. Addition reaction silicones presented statistically significant differences in recordings of linear changes among them only at the 1st and the 24th hour. Linear changes did not seem to be associated with weight changes.

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INDEX WORDS: interocclusal recording media, bite registration materials, linear change, weight change

[1]Visiting Assistant Professor, Division of Graduate and Postgraduate Prosthodontics, Tufts University School of Dental Medicine, Boston, MA, Clinical Associate, Department of Fixed Prosthodontics, Aristotle University, Thessaloniki, Greece, and Private Practice limited to Prosthodontics, Thessaloniki, Greece.

[2]Associate Professor, Department of Removable Prosthodontics, Aristotle University, Thessaloniki, Greece.

[3]Professor and Head, Department of Removable Prosthodontics, Aristotle University, Thessaloniki, Greece.

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Correspondence to: Konstantinos X. Michalakis, DDS, CAGS, PhD, 3, Greg. Palama str., Thessaloniki 546 22, Greece. E-mail: kmichalakis@the.forthnet.gr

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PRECISE ARTICULATION of a patient's casts is a prerequisite for proper diagnosis and subsequent correct treatment. Apart from the operator's clinical ability and the technique followed, the chosen material can critically affect the accuracy of the interocclusal registration.

Wax and zinc oxide–eugenol paste have traditionally been used for maxillomandibular registration purposes. The introduction of polyether and polyvinylsiloxane interocclusal recording media has made clinicians unsure which material they should use. These elastomeric materials are chemically similar to the impression materials that have been used successfully for many years. Modifications have been made by adding plasticizers and catalysts to provide different handling characteristics; however, it remains unknown whether these modifications in the parent impression materials have altered their excellent accuracy and dimensional stability properties. Delayed articulation of a patient's casts can occur for various reasons. Therefore, the dimensional stability of interocclusal recording materials over time is of utmost importance, as it ensures a more accurate representation of the patient's maxillomandibular relationship.

This paper represents the second part of a study of three important physical properties of elastomeric interocclusal registration materials. The purpose of this investigation was to examine the linear change and the accompanying weight changes of one polyether and 4 polyvinylsiloxane interocclusal recording materials in comparison with a wax and a zinc oxide–eugenol paste over time.

Materials and Methods

The materials used for Part II: Linear change and accompanying weight change are listed in Table 1. All materials were stored according to manufacturers' instructions. Ten Teflon molds with a length of 50 mm, a width of 8 mm, and a depth of 3 mm were constructed for the purposes of this study (Fig 1). The molds were made of Teflon to facilitate the removal of rigid jaw relation registration materials.

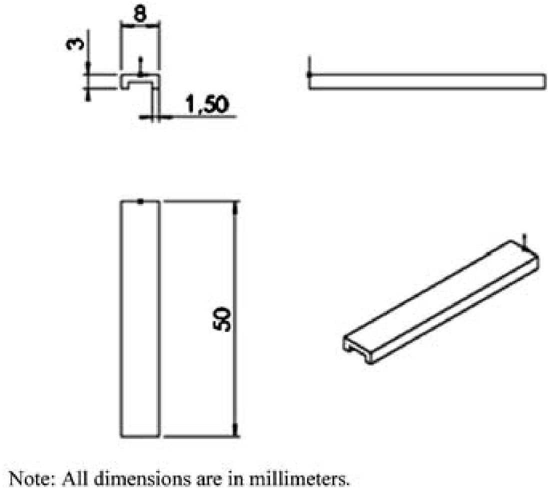


Figure 1. Teflon mold made for the measurement of linear changes.

The length of the mold was chosen in order to accommodate the total of the medial-distal dimensions of the teeth, which are approximately as follows:[1]

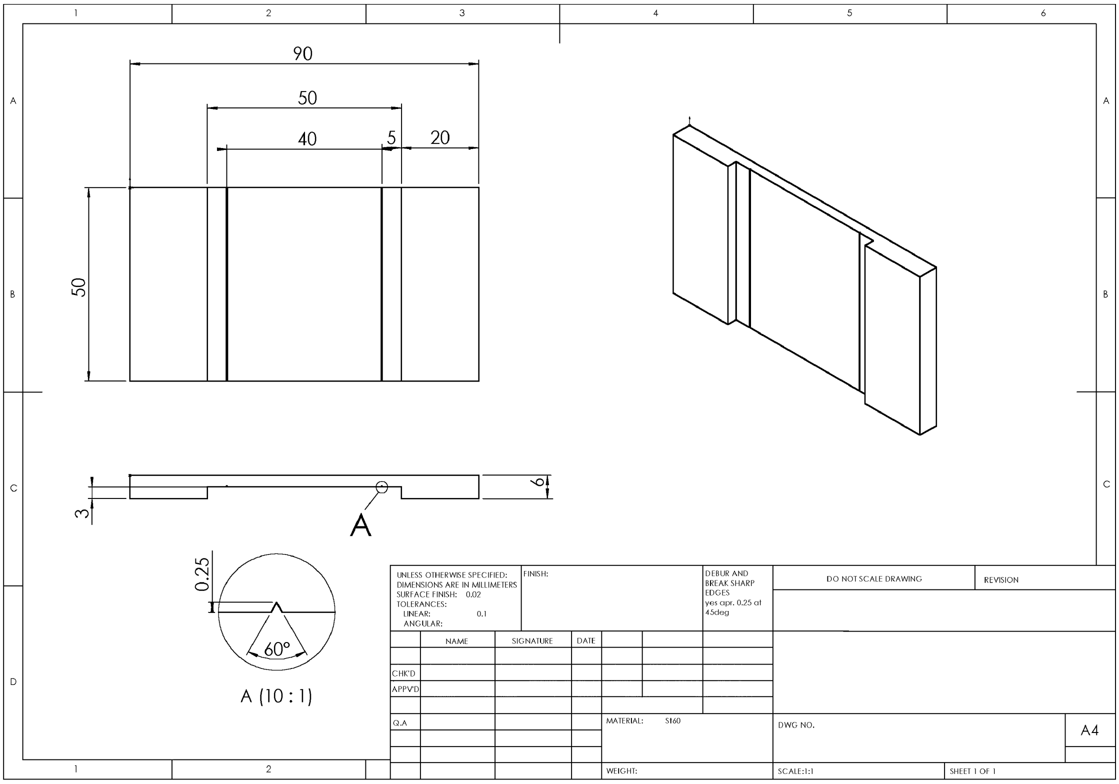
- Anterior teeth of the maxilla: 45 mm.
- Posterior teeth of the maxilla: 42 mm.
- Posterior teeth of the mandible: 45 mm.

The width of 8 mm was selected to approximate the width of the occlusal table of the posterior teeth.[1] The depth of 3 mm was chosen because the occlusal reduction of the teeth for a ceramometal restoration is about 1.5 mm, providing a total of 3 mm between the antagonist arches.[2,3]

A stainless steel die was also made to produce standardized reference lines 40 mm apart (Fig 2). The standardized reference lines were produced by flow of the recording material into the two 0.25 mm deep V-shaped grooves. These notches were impressed on the interocclusal recording materials as triangular-shaped projections. The apices of these

Table 1. Interocclusal Recording Materials Included in the Study

Brand	*Material Type*	*Batch*	*Manufacturer*
Ramitec	Polyether	B404/C392	ESPE, Seefeld, Germany
3M	Polyvinylsiloxane	6BGP1U1	3M, St. Paul, MN
Stat-BR	Polyvinylsiloxane	22739/4-1166	Kerr, Romulus, MI
Blu-Mousse	Polyvinylsiloxane	S438	Parkell, Farmington, NY
Regisil 2X	Polyvinylsiloxane	980902	LD Caulk, Milford, DE
ZOE-SSW	Zinc oxide–eugenol	049436	SS White, Gloucester
Alminax	Wax	DW219204	Purton, Swindon



Note: All dimensions are in millimeters.

Figure 2. Stainless steel die made for the measurement of linear changes.

projections were used as the reference lines for the linear change measurements.

The Teflon molds, as well as the stainless steel die, were lubricated with a silicone separating medium (Rikospray Silicone 3M, St. Paul, MN) to facilitate removal of the specimens. Each of the tested materials was mixed according to the manufacturer's instructions. After homogenous mixing, the material was carried from the mixing pad or directly from the mixing tip to the Teflon mold. The mold was inverted onto the stainless steel die (Fig 3). Hand pressure was applied for 5 seconds to initially express material; this was followed by application of a 0.5 kg weight to further eliminate excess material.[4] The Teflon mold, the stainless steel die, and the weight were submerged in a 36 ± 1°C water bath (Dentek Inc, Buffalo, NY) to simulate oral conditions.[4,5] Each assembly remained in the bath for the manufacturer's suggested setting time plus an additional 3 minutes to ensure polymerization of the material.[4]

For the wax, the method was modified by softening it submerged in a 45°C water bath (Dentek Inc, Buffalo, NY). A 5 ml syringe was filled with the wax and placed in the water bath for 5 minutes. After this period the wax was injected in the Teflon mold, and the mold was inverted onto the stainless steel die. The procedure followed as previously described for the rest of the tested materials.

Upon removal from the water bath, the Teflon mold was removed from the stainless steel die and all excess material (flash) was trimmed by using a No. 6 Bard

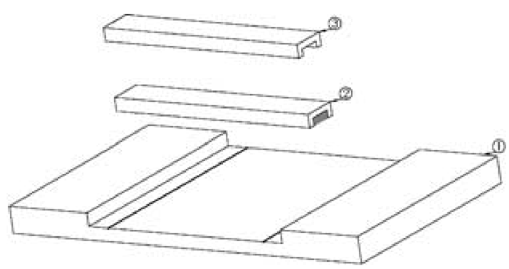


Figure 3. The Teflon mold and the corresponding stainless steel die fabricated for the measurement of the linear changes of interocclusal registration materials: 1, Stainless steel die; 2, Teflon mold filled with the interocclusal registration material; 3, Empty Teflon mold. The Teflon mold was filled with the interocclusal registration material and placed on the stainless steel die.

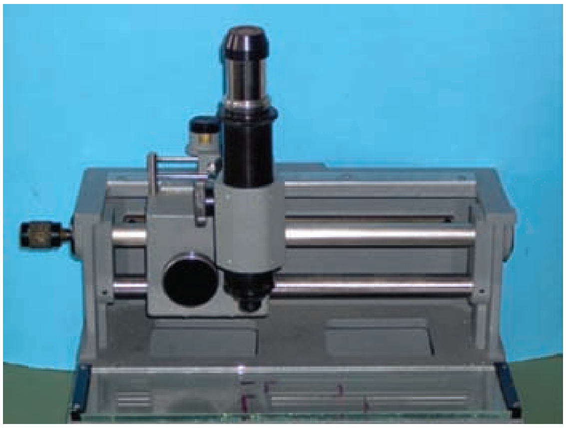


Figure 4. The traveling micrometer microscope, which was used to measure the linear changes of the interocclusal registration materials.

Parker knife. The material was separated from the Teflon mold, the wax was allowed to bench cool for 5 minutes, and it was removed from the mold.[6] Each specimen had a total length of 50 mm, a width of 8 mm, and a height of 3 mm with two parallel triangular-shaped projections on the surface. The apices of these projections were 40 mm apart, and they were used for the measurements, as previously described. Specimens with external or visible internal defects (bubbles) were discarded. The specimens were dried by use of an absorbing paper until there was no moisture on the sample.

An electronic scale (Galaxy 110, Ohaus, Pine Brook, NJ) with an accuracy of ±0.0001 g was used for the measurement of the weight changes of the specimens. A traveling micrometer microscope (Griffin Ltd., London, England) with an accuracy of ±0.001 mm was used to measure the linear changes (Fig 4). The weight changes were based on the difference of the weight between the time of the measurement and the initial weight of each sample. The linear changes were based on changes in the separation between the reference lines. Ten samples for each material were measured at 5 time intervals: 0, 1 hour, 24, 48, and 72 hours.[7,8] Measurements and data collection were always performed by the same operator.

Temperature and relative humidity were recorded each day throughout the experiment (21 ± 1°C, 50 ± 10%).

Results

Weight Changes

The results of the descriptive statistics for the measurements of the weight changes are depicted in Table 2. The analysis of variance for a significance level of 5% (Table 3) revealed the following:

Table 2. Descriptive Statistics of Weight Changes of Interocclusal Recording Media (All Data Were Multiplied by a Factor of 1000 to Avoid Too Many Decimal Digits. Positive Values Indicate Weight Loss, Negative Ones Indicate a Weight Gain)

	Material	*Mean*	*SD*	*N*
1 hour	Ramitec	3.40	0.51	10
	3M	−1.60	0.51	10
	Stat-BR	2.50	0.52	10
	Blu-Mousse	2.40	0.51	10
	Regisil 2X	1.70	0.48	10
	ZOE-SSW	3.50	0.52	10
	Alminax	0.30	0.48	10
24 hours	Ramitec	6.10	0.87	10
	3M	−5.70	0.67	10
	Stat-BR	5.20	0.78	10
	Blu-Mousse	3.40	0.69	10
	Regisil 2X	5.00	0.94	10
	ZOE-SSW	23.20	1.22	10
	Alminax	1.00	0.66	10
48 hours	Ramitec	17.10	1.10	10
	3M	−10.00	1.24	10
	Stat-BR	9.20	1.22	10
	Blu-Mousse	6.10	0.99	10
	Regisil 2X	8.60	1.26	10
	ZOE-SSW	30.90	1.37	10
	Alminax	1.50	0.52	10
72 hours	Ramitec	21.80	1.31	10
	3M	−14.60	1.26	10
	Stat-BR	13.30	1.25	10
	Blu-Mousse	10.60	1.26	10
	Regisil 2X	14.00	1.24	10
	ZOE-SSW	40.00	1.15	10
	Alminax	1.70	0.48	10

1. There was a statistically significant effect of the "material" factor on the weight changes ($F = 2{,}229.08$, $p < 0.0005$).
2. There was a statistically significant effect of the "time" factor on the weight changes ($F = 2{,}332.17$, $p < 0.0005$).
3. There was a statistically significant interaction of the "material" and "time" factors on the weight changes ($F = 699.00$, $p < 0.0005$).

Descriptive statistics and Tukey's Honest Significant Difference Test (Table 4) revealed that the elastomeric material with the greatest weight changes was polyether (Ramitec). All elastomers displayed smaller weight changes than zinc oxide–eugenol paste (SS White), but greater than wax (Alminax). Only 3M polyvinylsiloxane displayed weight gain. All other materials displayed a linear weight loss (Fig 5). Regisil polyvinylsiloxane

Table 3. Analysis of Variance for the Evaluation of Weight Changes in Relation to Time ($p = 0.05$; Mixed Factorial or Split-Plot Design)

Source	*SS*	*df*	*MS*	*F*	*Sig*	η^2	*OP*
Between the groups							
Material	23585.84	6	3930.97	2229.08	0.000	0.99	1.00
Error	111.10	63	1.76				
Within the groups							
Time							
Greenhouse-Geisser	4431.12	2.43	1818.18	2332.17	0.000	0.97	1.00
Time × material							
Greenhouse-Geisser	7968.67	14.62	544.95	699.00	0.000	0.98	1.00
Error (time)							
Greenhouse-Geisser		119.70	153.53	0.78			

appeared to have a small weight loss in the first hour, while it displayed greater changes during the next hours. On the other hand, Blu-Mousse polyvinylsiloxane displayed more weight loss than Regisil in the beginning, but presented less weight changes afterwards. According to Tukey's HSD Test, in the first hour, Stat-BR (polyvinylsiloxane) belonged to the same group with Blu-Mousse, while for the next testing hours it formed a group with Regisil. As previously mentioned, Ramitec polyether presented the greatest weight loss of all elastomers tested, with the greatest weight change taking place between 24 and 48 hours.

Linear Changes

The results of the descriptive statistics for the measurements of linear changes are depicted in Table 5 and Figure 6. The analysis of variance for a significance level of 5% (Table 6) revealed the following:

1. There is a statistically significant effect of the "material" factor on the linear changes ($F = 215.54$, $p < 0.0005$).
2. There is a statistically significant effect of the "time" factor on the linear changes ($F =$ 1,996.01, $p < 0.0005$).
3. There is a statistically significant interaction of the "material" and "time" factors on the linear changes ($F = 19.50$, $p < 0.0005$).

Descriptive statistics and Tukey's HSD Test (Table 7) revealed that Ramitec polyether was the elastomeric material with the smallest linear changes. Addition reaction silicone materials displayed significant differences only at the 1st and 24th hours. Regisil and Blu-Mousse displayed smaller linear changes than 3M and Stat-BR in the beginning, but they did not present statistically significant differences afterward. Alminax and zinc oxide–eugenol paste displayed the greatest linear changes.

Discussion

Dimensional stability is a very important property for interocclusal recording media, because it is important to avoid any discrepancies between the maxillomandibular registration and mounting of the casts.[9]

Only linear dimensional changes of interocclusal recording materials over time were measured in this study. These measurements provide only an indication regarding their dimensional stability. Weight changes of the materials were also measured in order to establish any existence of correlation to their linear changes.

In general, the polyvinylsiloxanes displayed a weight loss throughout the testing period. The only exception was 3M, which presented a weight gain. Weight loss of addition silicones could be due to hydrogen loss, as stated by Braden and Elliot,[10] and Zhang and Lacy.[11] Most manufacturers add platinum or palladium as a scavenger in polyvinylsiloxane impression materials.[12] To date, however, there is no published paper to support that there is also a scavenger in interocclusal registration materials, since there is no need for these materials to be poured with stone. The weight gain observed in 3M was probably caused by the absorption of moisture from the environment. 3M was not the only

Table 4. Multiple Comparisons of Means by Using Tukey's Honest Significant Difference for the Evaluation of Weight Changes ($p = 0.05$)

		N	*Subset*					
1 hour								
	Material		1	2	3	4	5	
	3M	10	−1.60					
	Alminax	10		0.30				
	Regisil 2X	10			1.70			
	Blu-Mousse	10				2.40		
	Stat-BR	10				2.50		
	Ramitec	10					3.40	
	ZOE-SSW	10					3.50	
24 hours								
	Material		1	2	3	4	5	
	3M	10	−5.70					
	Alminax	10		1.00				
	Blu-Mousse	10			3.40			
	Regisil 2X	10				5.00		
	Stat-BR	10				5.20		
	Ramitec	10				6.10		
	ZOE-SSW	10					23.20	
48 hours								
	Material		1	2	3	4	5	6
	3M	10	−10.00					
	Alminax	10		1.50				
	Blu-Mousse	10			6.10			
	Regisil 2X	10				8.60		
	Stat-BR	10				9.20		
	Ramitec	10					17.10	
	ZOE-SSW	10						30.90
72 hours								
	Material		1	2	3	4	5	6
	3M	10	−14.60					
	Alminax	10		1.70				
	Blu-Mousse	10			10.60			
	Stat-BR	10				13.30		
	Regisil 2X	10				14.00		
	Ramitec	10					21.80	
	ZOE-SSW	10						40.00

Note: Negative values indicate weight gain. Positive values indicate weight loss.

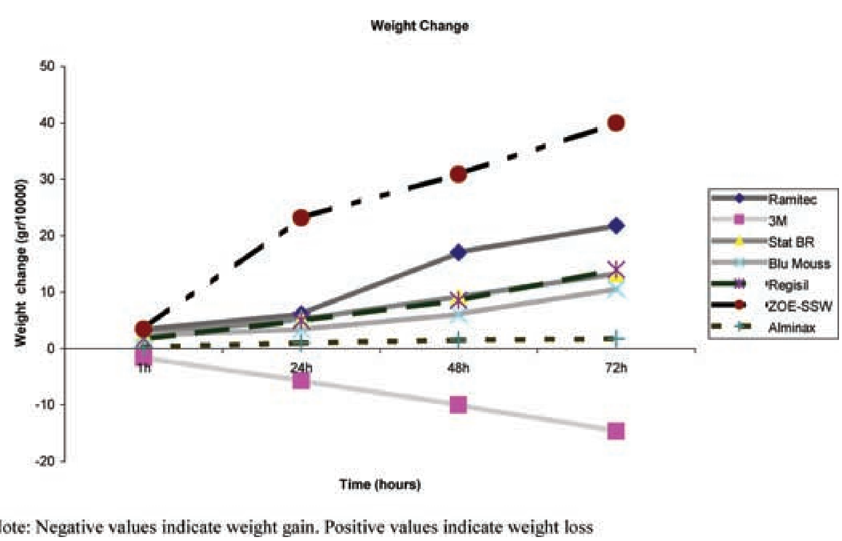


Figure 5. Weight change of interocclusal recording media over a 72 hour period.

Table 5. Descriptive Statistics of Linear Changes of Interocclusal Recording Media (All Data Were Multiplied by a Factor of 10 in Order to Avoid Too Many Decimal Digits)

	Material	*Mean*	*SD*	*N*
1 hour	Ramitec	0.80	0.42	10
	3M	2.40	0.51	10
	Stat-BR	2.30	0.48	10
	Blu-Mousse	1.60	0.51	10
	Regisil 2X	1.50	0.52	10
	ZOE-SSW	3.50	0.52	10
	Alminax	4.50	0.52	10
24 hours	Ramitec	2.20	0.42	10
	3M	4.00	0.47	10
	Stat-BR	4.50	0.70	10
	Blu-Mousse	3.20	0.42	10
	Regisil 2X	3.40	0.69	10
	ZOE-SSW	6.20	0.78	10
	Alminax	9.30	0.67	10
48 hours	Ramitec	4.10	0.73	10
	3M	5.60	0.69	10
	Stat-BR	6.20	0.78	10
	Blu-Mousse	5.60	0.69	10
	Regisil 2X	5.80	0.63	10
	ZOE-SSW	9.10	0.73	10
	Alminax	10.60	0.51	10
72 hours	Ramitec	5.60	0.51	10
	3M	7.20	0.63	10
	Stat-BR	7.90	0.73	10
	Blu-Mousse	7.30	0.67	10
	Regisil 2X	7.20	0.63	10
	ZOE-SSW	11.60	0.51	10
	Alminax	11.70	0.48	10

interocclusal recording medium that displayed weight gain, since Millstein and Hsu[13] reported similar findings for Correct Bite (Jeneric/Pentron, Wallingforg, CT). There is a possibility of moisture absorption from the environment because of the nonionic molecules that enhance the surface energy and give the "hydrophilic" properties to this material, as mentioned in studies of Pratten and Craig[14] and Nordling and Reisbick.[15]

Ramitec presented the greatest weight changes of the elastomeric materials tested. This could be due to the absorption of moisture from the water bath during the polymerization process, and the loss of moisture due to evaporation later on. This is the most probable explanation of this phenomenon, since polyether has the tendency to absorb water, and is the most hydrophilic of all elastomeric materials. It seems that when polyether is in an environment of 100% humidity (water bath), it absorbs moisture, which is later lost by evaporation if the storage environment is less humid. This has been proved by Braden et al,[16] who showed that after polymerization, polyether expels to the environment more water than it absorbs from it. This water rejection is responsible for the weight loss of the polyether.

For all time intervals, the smallest weight changes were reported for wax. This can be explained by the fact that the softening and hardening of the wax is a physical process.

Zinc oxide–eugenol presented the greatest weight loss of all the materials tested. This could be explained by the fact that the chemical reaction, which leads to the production of zinc oxide–eugenol, is a typical reaction between an acid and a base that gives a salt and water;[17] the water evaporates and results in weight loss.

Ramitec (polyether) presented the smallest linear changes of all materials tested, at all time intervals. There is a statistically significant difference between the linear changes of polyether and

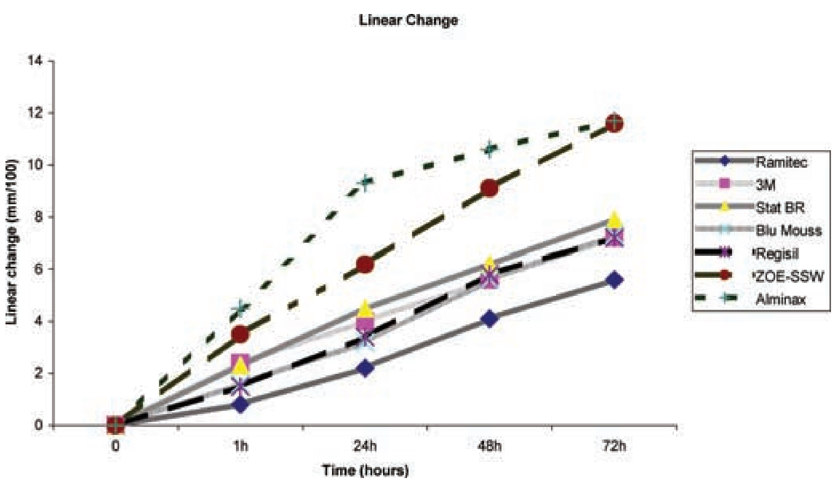


Figure 6. Linear dimensional change of interocclusal recording media over a 72 hour period.

Table 6. Analysis of Variance for the Evaluation of Linear Changes in Relation to Time ($p = 0.05$; Mixed Factorial or Split-Plot Design)

Source	*SS*	*df*	*MS*	*F*	*Sig*	η^2	*OP*
Between the groups							
Material	1000.23	6	166.70	215.54	0.000	0.95	1.00
Error	48.72	63	0.77				
Within the groups							
Time							
Greenhouse-Geisser	1405.92	2.78	504.96	1996.01	0.000	0.96	1.00
Time × material							
Greenhouse-Geisser	82.45	16.70	4.93	19.50	0.000	0.65	1.00
Error (time)							
Greenhouse-Geisser	44.37	175.40	0.25				

those of addition reaction silicones. The results of this study seem to be in accordance with those of Eames et al,[18] Ciesco et al,[19] and Federick and Caputo,[20] who studied the corresponding impression materials. There is also an agreement between the results of this study and that of Millstein and Hsu,[13] in which the polyether interocclusal registration material (Ramitec) presented the smallest linear changes from most of the polyvinylsiloxanes tested on the horizontal plane.

Analysis of variance showed that there were statistically significant differences among the

Table 7. Multiple Comparisons of Means by Using Tukey's Honest Significant Difference for the Evaluation of Linear Changes ($p = 0.05$)

	Material	*N*	*Subset*				
1 hour							
			1	2	3	4	5
	Ramitec	10	0.80				
	Regisil 2X	10		1.50			
	Blu-Mousse	10		1.60			
	Stat-BR	10			2.30		
	3M	10			2.40		
	ZOE-SSW	10				3.50	
	Alminax	10					4.50
24 hours							
			1	2	3	4	5
	Ramitec	10	2.20				
	Blu-Mousse	10		3.20			
	Regisil 2X	10		3.40			
	3M	10		4.00	4.00		
	Stat-BR	10			4.50		
	ZOE-SSW	10				6.20	
	Alminax	10					9.30
48 hours							
			1	2	3	4	
	Ramitec	10	4.10				
	3M	10		5.60			
	Blu-Mousse	10		5.60			
	Regisil 2X	10		5.80			
	Stat-BR	10		6.20			
	ZOE-SSW	10			9.10		
	Alminax	10				10.60	
72 hours							
			1	2	3		
	Ramitec	10	5.60				
	3M	10		7.20			
	Regisil 2X	10		7.20			
	Blu-Mousse	10		7.30			
	Stat-BR	10		7.90			
	ZOE-SSW	10			11.60		
	Alminax	10			11.70		

materials tested. Tukey's HSD Test revealed that polyvinylsiloxanes presented statistically significant differences only at the 1st and the 24th hour measurements.

Zinc oxide–eugenol presented statistically significant differences when compared to addition silicones and polyether, at all time intervals. The linear changes of zinc oxide–eugenol were always bigger than the linear changes of the elastomers.

Wax presented the greatest linear changes of all the materials tested, at all time intervals. This is explained by both the great coefficient of thermal expansion of wax[21] and the distortion of this material due to the release of internal stresses.[22-26]

From the results it can be concluded that wax and zinc oxide–eugenol are not reliable as interocclusal registration materials, because of the great linear changes these materials present even from the first hour. If the clinician chooses one of these two materials due to their lower cost, he should be aware of the possible mounting inaccuracies that may develop if they are not used immediately after the interocclusal registration procedure. Perhaps in clinical practice, impression making and construction of casts should be done in an appointment prior to making interocclusal records. On the other hand, polyether and polyvinylsiloxanes do not seem to be so time sensitive, and as a result are more appropriate for the registration of maxillomandibular relationships.

Statistical analysis of the results did not reveal any correlation between linear changes and weight changes. For example, Ramitec (polyether) was the material with the greatest weight changes among the elastomers, but it also was the one that had the smallest linear changes of all interocclusal registration media tested. Similarly, Blu-Mousse was one of the polyvinylsiloxanes that displayed small linear changes but big weight changes, when compared to the other materials of this group.

The results of this study agree with the results of Millstein and Hsu[13] who studied linear and weight changes of certain interocclusal recording media. In that study the above-mentioned factors were studied 48 hours after the construction of the samples, and the authors concluded that there was no correlation between them.

Conclusions

One polyether and 4 polyvinylsiloxane interocclusal recording materials were tested in comparison with a wax and a zinc oxide–eugenol paste for linear and weight changes at 0, 1 hour, 24, 48, and 72 hours in a controlled laboratory environment. The results are as follows:

1. Ramitec (polyether) presented the smallest linear changes of all materials tested, at all time intervals.
2. Addition reaction silicones presented statistically significant differences in recordings of linear changes among them, at the 1st and the 24th hour. However, they did not present statistically significant differences after the 48th hour. Addition silicones, as a group, presented smaller linear changes when compared to wax and zinc oxide–eugenol paste.
3. Linear changes did not seem to be correlated with weight changes.

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