The Influence of Nitrile Gloves on the Setting Behavior of Polyvinyl Siloxane Putty Impression Materials

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Authors

Dr. Alex J. Delgado *
(DDS, MS)

Dr. Silvia P Amaya-Pajares §
(DDS, MS)

Yu Su *
(PhD (c))

Dr. Linda Behar-Horenstein *
(PhD)

Dr. Terence Edward Donovan ‡
(DDS)

Address for Correspondence

Dr. Alex J. Delgado *

Email: adelgado@dental.ufl.edu

* *University of Florida*

§ *Oregon Health & Science University*

‡ *University of North Carolina*

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ABSTRACT

Objective: The purpose of this study was to assess the gelation and polymerization time of three polyvinyl siloxane (PVS) putty materials and to determine if those times were affected by nitrile gloves under different conditions. Materials and Methods: Ten specimens (n=10) were obtained for each PVS putty material (Express STD, 3M ESPE; Extrude Xtra, Kerr and Exafast, GC) and tested under different conditions (gloves washed, gloves unwashed and hand contaminated). The gelation and polymerization time were measured using an oscillating rheometer and recorded for 400 s at 37°C to simulate the oral environment. Results: The mean gelation time of hand contaminated specimens was 157.50 minutes and was significantly slower than that by using nitrile washed gloves (mean=117.94, p=.004) and by using unwashed gloves (mean=99.46, p<0.001). Unwashed gloves had significantly quicker gelation times compared to washed gloves (p=.046). The gelation time was significantly delayed with Exafast compared to Extrude Xtra and Express STD across all the different types of glove conditions (p<0.043). No significant differences were observed between polymerization time with Exafast and Extrude Xtra Putty. Conclusions: Extrude Xtra putty material had significantly better performance than GC Exafast and Express. Hand contaminated specimens were affected by the gelation/polymerization time.

INTRODUCTION

Polyvinyl siloxane (PVS) putty materials are used for making impressions, bite registration, and for laboratory functions. PVS are currently used for teaching how to measure reductions in the preclinical laboratory. Previous investigations have shown that the polymerization of PVS impression materials were inhibited by latex gloves, producing distorted casts.[1,2] These impressions materials cannot be mixed on a glass slab or on mixing pads. Manufacturers recommend washing and drying hands thoroughly, and mixing by hands, or kneading with the fingertips until a uniform color is obtained. In the instructions that accompany PVS, some manufacturers suggest setting and working times as well as glove precautions. While using this technique chairside, wearing gloves, which complies with infection control guidelines, is an imperative standard of care. Studies reported that latex gloves (LG) inhibit polymerization of PVS materials, because latex products contain unreacted sulphur as byproduct of the manufacturing process. Furthermore, sulphur has been shown to contaminate the chloroplatinic acid catalyst of the PVS impression material.[1-3] In a recent study, polymerization of PVS light body impression materials was inhibited using latex and non-latex products when the PVS material was in direct contact.[3]

For many years, because of their elasticity, strength, tear or puncture resistance, and durability, latex gloves (LG) have been used in dentistry. Studies have showed that LG may result in allergic response, such as dermatitis due to concentration of polypepdites in it.[4] Many manufacturers have improved the quality of latex with pretreatment and additional centrifuging to remove as many remaining impurities and proteins as possible.[5] Some of those improvements include additives for preservation such as zinc diethyl dithiocarbamate.[6] White *et al.* reported that the accelerator zinc diethyl dithiocarbamate produced retardation in PVS materials by inactivating the platinum catalyst of the impression materials.[7]

Nitrile gloves (NG), made of synthetic monomers such as acrylonitrile, butadiene and carboxylic acid, are popular due to the relatively high incidence of allergies from latex gloves.[8] They are considered an alternative to dental gloves manufactured from natural latex, especially for individuals who experience a hypersensitivity response to LG.[9] On the other hand, among the chemicals used in the manufactures of NG is aluminum sulphate, the same that is used in the manufacturing of latex gloves.[10]

Few researchers have studied the setting time and viscosity changes of impression materials as function of gelation time and polymerization setting time.[11,12] The gelation time is the interval during which the viscosities of the material change by the addition of catalyzers to a base. The polymerization setting time of PVS materials occurs with a series of cross-linkage between products with no release of by-products before the reaction is completed. The viscoelasticity is studied using a dynamic mechanical analysis whereby oscillatory forces (stress) are applied to the PVS and the resulting displacement (strain) is measured. The machine applies torque to the PVS specimen and measures deformation or strain, which can simulate similar temperatures and mimick what the material are exposed to, thus demonstrating how temperatures affect the reaction.[12] An oscillating rheometer offers a convenient way to evaluate the properties of these materials during polymerization time. The rigidity of a material does not mean that the chemical reaction of the polymerization is completed. When a material reaches a gelation point, this means that a cross linkage of polymer chains has reached a solid state. However, the polymerization is not completed and there is still some reaction happening before the material set is complete.

The purpose of this study was to assess the gelation time and polymerization setting time of three types of PVS putty materials and to determine if those times were affected by the use of nitrile gloves used under different conditions. The authors assumed the null hypothesis and that there would be no difference in the gelation time and polymerization setting time of the material tested under any condition with nitrile gloves.

MATERIALS AND METHODS

Three contemporary PVS putty impression materials were tested under different conditions using a nitrile glove, all the materials used are listed in Table 1. Ten specimens (n=10) were obtained for each PVS putty material and tested in each condition. All the specimens were evaluated for the gelation and the polymerization setting time using an oscillating rheometer (Stresstech, ATS RheoSystem, Bordentown, NJ, USA). This machine determines the gelation time of a material using viscosity-time data obtained at constant temperature. Specimens were weighted at 1.10 g. (base and catalyzer) using an analytical laboratory balance scale (ML204, Mettler Toledo International Inc., Columbus, OH, USA). Each specimen was mixed according to manufacture recommendations under different conditions. Under the washed condition, gloves were washed with a copious amount of room temperature water and soap, rinsed thoroughly with water and dried with disposable paper towel. A different new pair of gloves was used each time that putty materials were mixed.

Table 1. Materials used.

Gloves
Nitrile gloves. KC300 powder-free exam glove, Kimberly-Clark Inc. USA
PVS material
Extrude Xtra. Kerr Corporation, Romulus, MI, USA Express STD. 3M ESPE Co, St. Paul, MN, USA Exafast. GC America Inc, Alsip, IL, USA
Conditions
Washed gloves Unwashed gloves Hands contaminated

After a single specimen of PVS putty material was mixed, it was placed in the oscillating rheometer chamber *(Figure 1)*. The gelation and polymerization setting time were recorded for a period of 400 seconds (6 minutes and 40 seconds). All specimens were tested at 37°C to simulate the temperature of the oral environment; each cycle was approximate to 300 pascals (Pa). Data was collected every 9 seconds for a total of the time mentioned above. The oscillating rheometer was attached to a computer that calculated the rheological parameters of G' (shear storage), representative of the in-phase (elastic) component of oscillatory flow and G" (shear loss moduli) that is the out-phase (viscous) component. Those parameters measure the relative importance of viscous to elastic contributions for the PVS material at a given frequency. The storage and loss modulus in viscoelastic materials measured the stored energy, representing the elastic portion, and the energy dissipated as heat, representing the viscous portion. Each specimen was evaluated using a plot scatter graphic that expressed the gelation point and the polymerization setting time *(Figure 2 and 3)*.

Figure 1: Sample in the rheometer chamber after 400 seconds test.

STATISTICAL ANALYSIS

To test the number of successful polymerizations, all the raw data were transformed to dichotomous scales. Specifically, 1 indicates polymerization occurred and 0 indicates inhibition occurred. The chi-square test assessed whether the success of polymerization was determined by the type of gloves, and by conditions ($p<0.05$). Mann-Whitney U test ($p<0.05$) was performed to assess whether the gelation time for nitrile gloves differed between three conditions. Table 4 and 6.

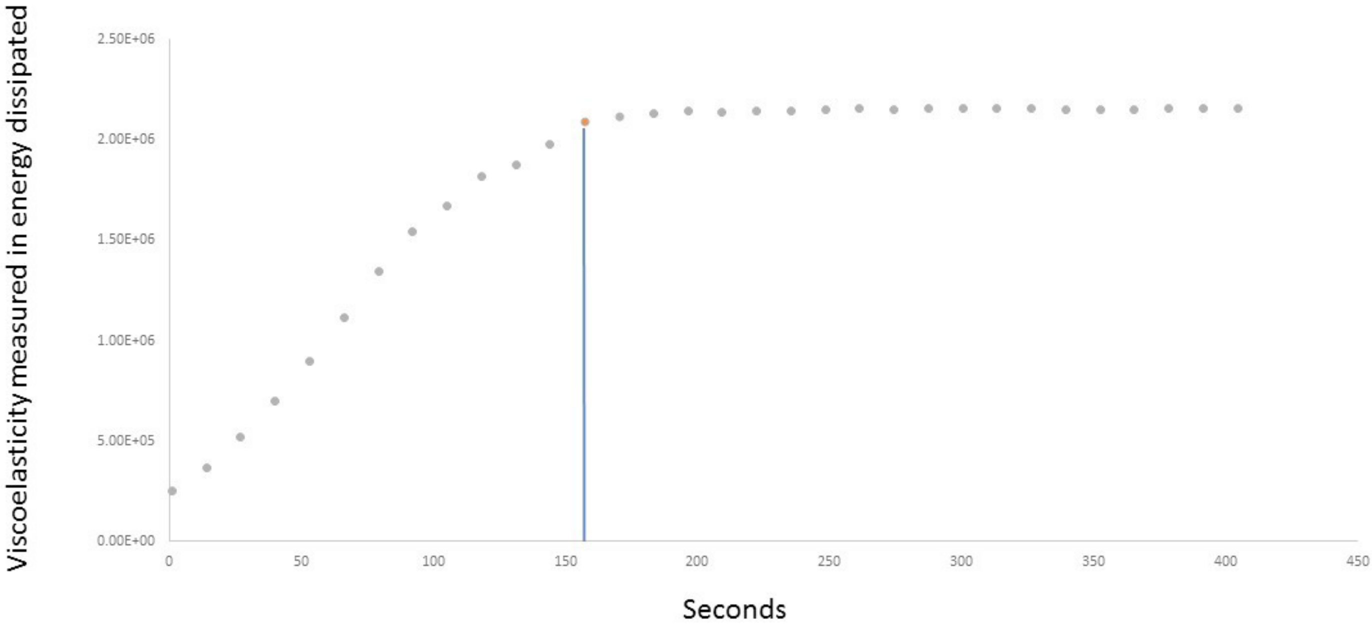

Figure 2: Sample demonstrating a lineal complete polymerization after 400 seconds according to the scatter graph.
Blue line: Gelation point

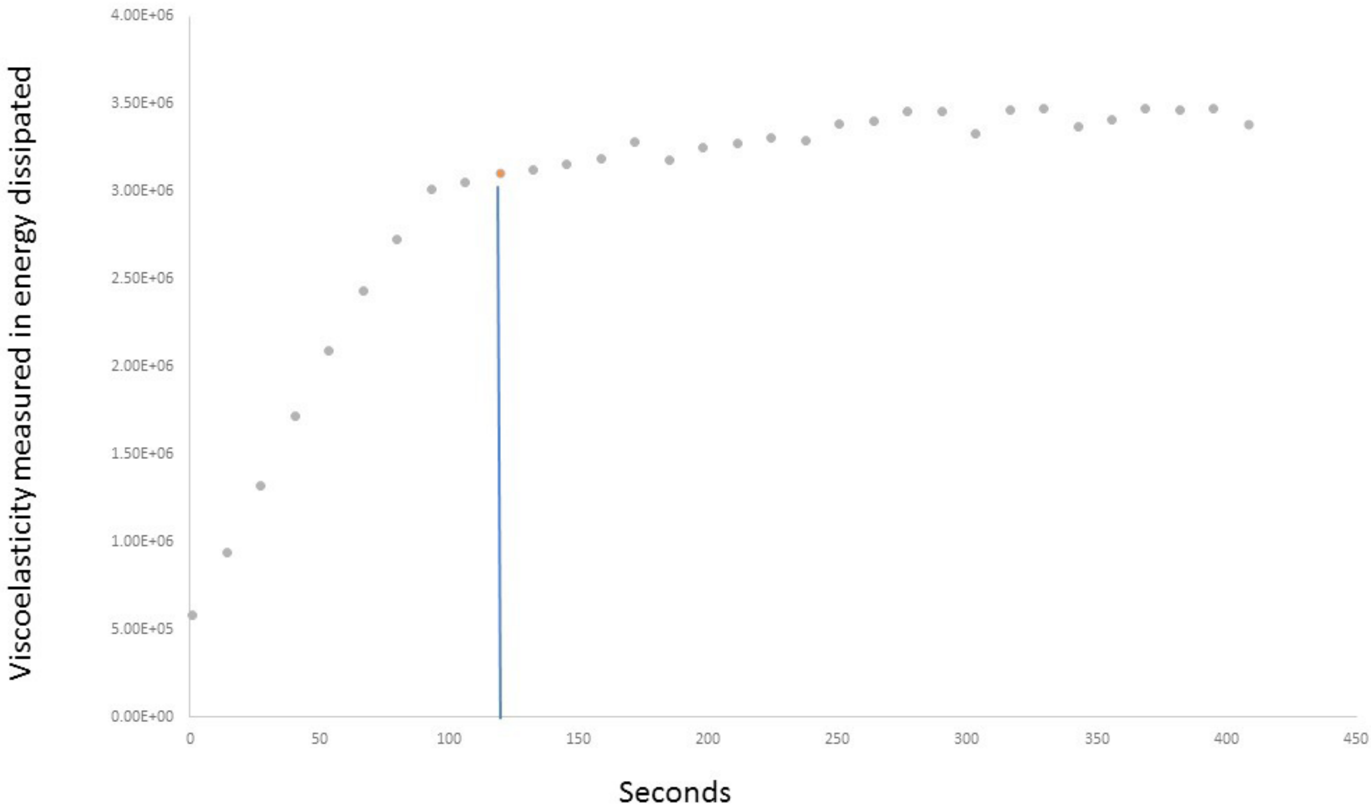

Figure 3: Scatter graph showing a non-continuous line of polymerization after reaching the gelation point.
Blue Line: Gelation point

RESULTS

GELATION TIME

The gelation time means expressed are in Table 3. There was a significant difference in the mean gelation time when GC Exafast was used. The mean gelation time using Hands contaminated (mean=157.50) is significantly slower than that by using nitrile washed gloves (mean=117.94, p=.004) and by using unwashed gloves (mean=99.46, p<0.001). Nitrile unwashed gloves (mean=99.46) had significantly quicker gelation times compared to washed gloves (mean=117.94, p=.046). However, for Express STD (3M) and Extrude Xtra Putty (Kerr), gelation time did not differ significantly by the different type of conditions. The results also indicated that the gelation time was significantly delayed with GC Exafast compared to Kerr and 3M across all the different type of glove conditions *(Table 5 and 6)*. Specifically, for washed gloves, the mean Gelation time with GC Exafast (mean=117.94) was significantly slower than that with Express STD (mean=92.46, p=0.029) and with Extrude Xtra Putty (mean=69.45, p<0.001); Similarly, for hand contaminated specimens, the mean Gelation with GC Exafast (mean=157.5) was significantly higher than that with Express STD (mean=89.84, p<.001) and with Extrude Xtra Putty (mean=97.4, p<.001). For unwashed gloves, the mean Gelation time with GC Exafast (mean=99.46) was significantly slower than that with Extrude Xtra Putty (mean=81.87, p<0.043).

POLYMERIZATION SETTING TIME

Significant mean difference in the polymerization setting time was observed between the conditions tested *(Table 2)*. Express STD (3M) showed a significant difference by washed and unwashed gloves. No significant differences were observed between polymerization time with Exafast (GC) and Extrude Xtra Putty (Kerr). For each type of gloves (washed, unwashed, hands contaminated), there was also no significant relationship between polymerization success by three different conditions.

Table 2. Polymerization time by condition of gloves

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.667[a]	2	.036
Likelihood Ratio	6.682	2	.035
Linear-by-Linear Association	3.683	1	.055
N of Valid Cases	30		

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

Table 3. Descriptive statistics for gelation time with GC Exafast (/seconds)

Gloves	N	Mean (/s)	Std. Deviation
Washed gloves	10	117.94	28.62
Unwashed gloves	10	99.46	10.88
Hand Contaminated	10	157.5	23.56

Table 4. Test Statistics (Mann-Whitney U)

Group	P value
Washed vs Unwashed	.046
Washed vs Hand contaminated	.004
Unwashed vs Hand contaminated	.001

Notes. The significant level is at 0.05.

Table 5. Descriptive statistics for gelation time (/seconds) by condition and different types of gloves

	Express STD (3M)		Extrude Xtra Putty(Kerr)		GC Exafast	
Gloves Type	Mean	Std.Deviation	Mean	Std.Deviation	Mean	Std.Deviation
Washed gloves	92.46	50.17	69.45	16.14	117.94	28.62
Unwashed gloves	85.95	23.83	81.87	27.74	99.46	10.88
Hands contaminated	89.84	31.65	91.40	38.07	157.50	23.56

Table 6. Test Statistics (Mann-Whitney U)

	Express STD (3M) vs Extrude Xtra Putty(Kerr)	Extrude Xtra Putty(Kerr) vs GC Exafast	GC Exafast vs Express STD (3M)
Washed	0.796	0.001	0.029
Unwashed	0.939	0.052	0.043
Hand contaminated	0.796	0.001	0.001

Notes. The significant level is at 0.05.

DISCUSSION

Extrude Xtra (Kerr) performed significantly better than the other two putty materials regarding complete polymerization and gelation time. The composition of PVS impression materials has changed over time. These variations have made the materials less sensitive to sulphur contamination. Possible reasons for improved PVS performance are speculative; it may be due to the increase in the concentration of platinum in the chloroplatinic acid catalyst that has overcome the issue of chelation of platinum in the impression materials by sulphur products in the latex, or because the non-ionic surfactants in the impression materials act as a separate medium which protects the catalyst from sulphur.[3]

Specimens handled with washed gloves exhibited less complete polymerization ostensibly because washing the gloves did not remove the accelerator zinc diethyl dithiocarbamate, which is primarily located in the surface of the gloves and cannot be washed out.[19] For this reason, some authors have suggested using dithiocarbamate-free gloves to avoid this problem.[6]

Nitrile gloves have become very popular in recent years because of the relative incidence of allergic reactions to latex gloves. Most of the studies, associated with nitrile gloves have been related, to dermatitis or skin reaction, puncture or tear resistance, but not to the reaction to dental materials. The authors surmised that it was important to address this issue, because these materials are mixed by hand. Many of the chemicals used in manufacturing nitrile gloves (including aluminum sulphate) are the same as those used in the manufacture of latex gloves. Niessen *et al*. first reported the inhibition of polymerization of PVS materials in 1986.[13] After that discovery, several studies supported or mentioned that the natural latex itself, or a contaminant in the glove such as sulphur or sulphur derivative would delay or inhibit the PVS setting time.[11,14] Other publications have reported the same finding and indicated that sulphur containing components involved in the manufacturing of natural latex gloves interfere with the catalyst of the PVS materials.[1,2,6,15,16,17]

The oscilating rheometer is a convenient method for measuring the rheological properties of elastomers and helps assess the gelation time and the polymerization setting time of these materials.[11] This machine can determine viscosity changes from soft to rigid consistency.[18] In an oscillatory test, the behavior of all material is expected to be a function of the angular frequency. This is of particular interest because it is time dependent on the properties that occur at a constant frequency, which is characteristic of the deformation rates mirroring the manner in which the material will be subjected in normal practice.[12]

In the present study, a significant mean difference of the gelation time was observed between different conditions and different materials. This finding concurs with those reported in previous studies of latex gloves.[1,2,15] We can assume that the sulfur used in the manufacturing of the nitrile gloves also affects the material reaction.

It was observed that the materials reached a gelation point quicker than the setting time. Therefore, the authors suggest waiting more than 6 minutes after the material hardens to ensure that full polymerization has been reached. It is important that the clinician understand the difference between gelation time and polymerization time. According to manufactures, the recommended time for each PVS putty material varies. For Extrude Xtra Putty (Kerr), 6:00 minutes is the recommended setting time, for Express STD (3M ESPE), it is 5:00 minutes and for Exaflex (GC), it is 4:00 minutes. The results in this study suggest that more time is recommended specifically for Exaflex and Espress STD.

CONCLUSION

Extrude Xtra putty material had significantly better performance than GC Exafast and Express STD regarding complete polymerization and gelation time.

Hand contaminated specimens affected the gelation time by delaying the polymerization time of all the putty materials.

Most of the materials had not fully polymerized after 400 seconds.

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