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Short Communication

Mechanical Performance of Latex and Nitrile Medical Exam Gloves Under Repeated Soap and Water Treatment

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Abstract

The human cost of the COVID-19 pandemic has taken a great toll, and led, around the globe, to a shortage in personal protective equipment (PPE) such as medical exam gloves. To face this shortage and keep themselves and patients safe, many front-line healthcare providers have been overextending the life of PPE. Though not ideal, one pragmatic solution often used is the practice of sanitization and extended use of existing PPE. The data produced by these experiments should help determine an acceptable reusability window of PPE in a working environment, by which the effective use time may be extended and justified. The effect of repeated sanitization, using soap and water, on the mechanical performance was investigated for latex and nitrile elastomeric medical exam gloves. Tensile tests were performed for various manufacturer brands commonly used in the United States (Glovepak Europa, Polymed and Sempersure) and India (Surgiglove). Tensile test samples were prepared for each studied glove and treatment combination.

Nitrile gloves were observed to be more uniformly affected by the application of soap and water sanitization than latex gloves. Glovepak Europa nitrile gloves saw significant changes ($p \leq 0.001$) in elastic modulus after 5, 10 and 20 treatments losing 31.5%, 42.7% and 49.7%, respectively. Sempersure nitrile gloves also saw significant changes ($p \leq 0.05$) in elastic modulus at 5, 10 and 20 treatments losing 44.2%, 34.3% and 45.9%, respectively. Surgiglove nitrile gloves saw a significant loss in elastic modulus of 42.0% ($p \leq 0.001$) after 10 treatments. Surgiglove powder free latex showed no significant ($p>0.05$) change after 10 or 20 repeated treatments using soap and water. Polymed powder free latex showed no significant ($p>0.05$) change after 10 treatments, but did show a significant ($p \leq 0.05$) decrease in elastic modulus by 24.2% after 5 treatments and 25.5% after 20 treatments. Surgiglove powdered latex showed a significant ($p \leq 0.05$) increase in elastic modulus by 19.9% after 5 treatments and 15.8% after 10 treatments, while showing no significant ($p>0.05$) change at 20 treatments.

Due to the consistent significant degradation after five repetitions, use of soap and water may not be an adequate sanitization procedure for nitrile gloves, since it would potentially induce premature failure. The latex gloves showed no clear pattern and the results were inconclusive.

Keywords: Reusability, PPE, Sterilization, Gloves, Tensile testing.

1 Introduction

The global SARS-CoV-2 pandemic has strained medical personal protective equipment (PPE) supplies and caused concern in the medical community [WHO 2020; CDC 2020; FDA 2020; Noguchi 2021; PBS 2020]. Malaysia, the world's largest medical exam glove manufacturer, expects production to be behind demand until 2023 [Lee 2020].

SARS-CoV-2 viral material can survive on fomites, particles and droplets that carry the virus, prolonging infectivity and offering another vector for transmission by surfaces [Van Doremalen et al. 2020]. The SARS-CoV-2 virus has been shown to remain infectious for up to 24 hours and over 96 hours on polystyrene plastic [Pastorino et al. 2020]. If the virus is in a protein solution with concentrations on the same order as respiratory fluid, it can remain infectious for over 96 hours on glass, polystyrene plastic and aluminum [Pastorino et al. 2020]. The use of protective exam gloves helps prevent the transmission of the virus from patient to patient as well as from patient to the healthcare workers (HCW). Hand hygiene has also been shown to reduce the risk of fomite transmission [CDC 2021].

Medical exam gloves are single-use, disposable items intended for short term use and, therefore, are not designed to last for longer time spans or meant to be reused [CDC 2020]. The materials in question, latex and nitrile, are both in use due to their mechanical and chemical properties [0; 0]. Little is known, however, about these materials' resilience to sanitization by soap and water, a readily available hand hygiene regimen. To reduce time spent without access to gloves, HCWs could delay disposal of the in-shortage gloves by making them safe to use for longer. Indeed, in this limited resource environment, and under crisis capacity, the Centers for Disease Control and Prevention US (CDC) recommends extending usage of medical exam gloves by cleaning them with soap and water up to 10 times [CDC 2020].

To that end, this research would support medical providers by providing expected values of elasticity change, which can be a sign of degradation, for gloves after repeated sanitization. From this, recommended sanitization procedures for each of two glove material types can be developed to extend usage time safely. To accomplish this, tensile tests were performed on control and conditioned samples to observe the change in elasticity of the materials, thus indicating the increase in likelihood of punctures or tears in the material during usage. From these data, conclusions about recommended sanitization regimen and performance were drawn.

2 Material Molecular Characteristics and Resilience

Nitrile Butadiene Rubber (NBR), commonly known as nitrile, is a material composed of the copolymers acrylonitrile and butadiene (Figure 1), which is commonly used in medical exam gloves. Nitrile is noted for its resilience to chemicals due to the presence of acrylonitrile units within its molecular structure [0]. Even a small extension of usage time for this material would impact overall availability significantly, as it is one of the most common gloves in use today. Approximately 36% of healthcare workers are estimated to have an allergic reaction to latex and it is this population in need of nitrile gloves [Bousquet et al. 2006].

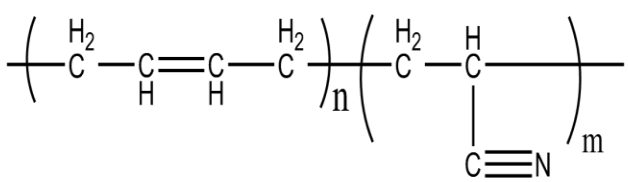

Fig. 1. Nitrile rubber with acrylonitrile unit.

Natural rubber, a type of polyisoprene (Figure 2), is processed from raw latex secreted by the rubber tree, or the *Hevea Brasiliensis* [Jayathilaka et al. 2020].

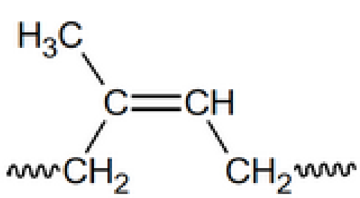

Fig. 2. Cis-1,4 polyisoprene (major component of natural rubber).

Enhancement of the natural rubber's already respectable resilience is accomplished with fillers and other additives [Hongkeab and Peerapan 2017]. Latex is not recommended for petroleum products as the nonpolar molecules may compromise the structural integrity of the glove and cause swelling [Rach and Kühn 2009]. Latex also suffers facile oxidation due to a double bond in each repeating unit causing chain degradation by oxygen, heat, ozone and weather [0]. Its extended use would significantly increase usage time due to its prevalence.

Soap operates to attract nonpolar molecules and bind them with water molecules through its polar head and nonpolar tail. Citric acid (Figure 3) is a common active ingredient in liquid soap and chelating agent, which was present in the soap used in this study. The combined effect of soap and citric acid in the presence of tap water is unknown on the polymers and gloves herein.

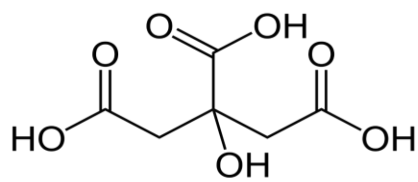

Fig. 3. Molecule of citric acid

While soap and water can remove infectious agents from surfaces, they can also interact with the polymers and potentially degrade them. Investigation into the effects of soap and water on these materials is critical to extending usage time. With an understanding of the elastic changes related to potential polymer degradation, countermeasures and effective replacement procedures may be developed. This may also lead to further study on the mechanisms associated with these chemical interactions between soap and medical exam gloves.

3 Materials and Methods

3.2 Gloves

Six styles of gloves were obtained and contained therein were three styles of nitrile gloves and three of latex, from a total of four different brands (Table 1). The liquid soap was Dial Professional Basics Hypoallergenic (Henkel Consumer Goods Inc, Stamford, CT). A 1 cm x 6 cm die cutter (W.R. Sharples, North Attleboro, MA, USA) and hammer were used to prepare samples for tensile testing. A Marathon Digital Micrometer with 0.001 mm resolution (Fisher Scientific, Houston, TX, USA) was used to measure thickness of the cross-section for all individual tensile tests, with an average of five readings used.

Table 1. Description of the glove types investigated

Glove Brand	Polymer Type	Source Country	Code
Glovepak Europa	Nitrile	USA	GEN
Sempersure	Nitrile	USA	SMN
Surgiglove	Nitrile	India	SGN
Surgiglove Powder-Free	Latex	India	SPF
Polymed Powder-Free	Latex	USA	PPF
Surgiglove Powdered	Latex	India	SPL

3.3 Treatments

Gloves were treated according to CDC guidance. The glove to be treated was worn on one hand with a supplementary glove worn on the other for a sufficiently analogous friction profile. The glove was sanitized by delivering one pump, approximately 2 mL, of the liquid soap into the palm while wetting the other. The palms were rubbed against each other to spread and foam the soap, followed by a similar motion from each palm to the back of each hand, ensuring coverage between the fingers. Knuckles were sanitized simultaneously with similar rubbing as well as the base of the thumb. Lastly the fingertips were rubbed against the opposite palm before rinsing the soap from each specimen with water, drying completely, and repeating. The water used in this experiment was normal tap water (Harris County, TX, USA) with no water softening filter.

3.4 Tensile testing

Six tensile test samples of 1 cm by 6 cm were cut from each treated glove according to ASTM D6287 standards using a die cutter [ASTM 2017]. These samples were measured for thickness according to ASTM D6988 standards [ASTM 2013].

Each sample was stretched longitudinally until failure to determine the elastic modulus of the material. Each sample was tested within 1 hour of its last application of soap and water to capture the immediate effect on the material's mechanical properties. The samples were placed in the Mark-10 G1061 tensiometer wedge grips gently so as not to cause unnecessary stress concentrations, which would impact the results. The samples were then placed under a tensile load using a Mark-10 ESM303 tensiometer test stand (Copiague, NY, USA). The force experienced by the sample, measured by a Mark-10 Series 5 force gauge, and the extension distance, given by the test stand, were measured simultaneously to collect the data necessary to create a stress strain curve. These data were further analyzed to obtain the mechanical properties for each sample tested.

It must be noted that supply issues constrained testing for some gloves. Thus, the Surgiglove nitrile control tests consisted of 23 samples from four specimens.

Expected values for elastic modulus were determined using 24 samples for each control group, 23 for the Surgiglove nitrile. Six samples were tested for each glove-treatment combination. The test was conducted, and the data were analyzed to ASTM D882 standards [ASTM 2018]. Thirty-nine gloves were used and 233 tensile tests were conducted to investigate the effect of soap and water treatment on the mechanical performance of studied gloves.

3.5 Statistical Analysis

Control glove samples were statistically validated to ensure no significant variation existed within the style being tested and that pre-conditioning was not required. This provided a foundation to use unconditioned and/or conditioned control samples for comparison, and to evaluate whether the treatments had a statistically significant effect on the material's mechanical properties.

Two tailed heteroscedastic T-tests were conducted on each treated sample set to determine whether the treatment significantly affected the elastic moduli. A p-value equal to or below 0.05 were considered statistically significant, while those above 0.05 were considered not significant.

4 Results and Discussion

4.2 Effect of repeated soap and water treatment on nitrile gloves

The elastic modulus results for the nitrile gloves are presented in Figure 4. Analysis of elastic modulus variability indicated no statistically significant difference between individual gloves of the same type for all nitrile glove styles tested. Control samples demonstrated elastic moduli of: 2.4 ± 0.3 MPa for the Glovepak Europa Nitrile (GEN), 1.8 ± 0.2 MPa for the Sempersure Nitrile (SMN), and 2.0 ± 0.4 MPa for Surgiglove nitrile (SGN).

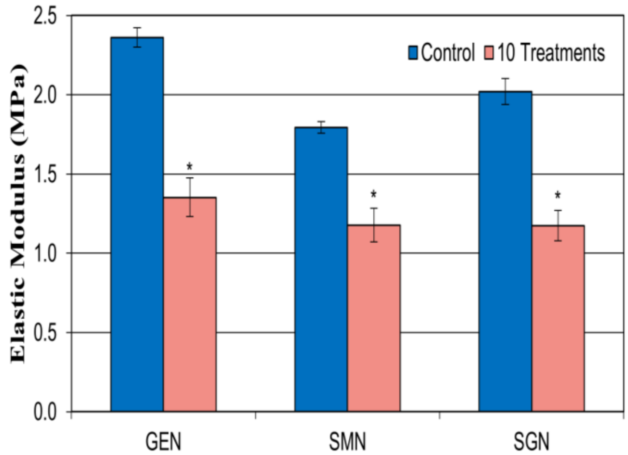

Fig. 4. Effect of 10 treatments of soap and water on nitrile gloves' elastic modulus.

Under crisis capacity, the CDC recommends cleaning medical exam gloves with soap and water no more than 10 times (CDC 2020). However, for every nitrile glove tested and every treatment regimen performed, significant degradation was observed in the elastic modulus of the material (Figure 4). GEN gloves saw a significant ($p \leq 0.001$) degradation with 42.7% loss of elasticity after 10 treatments. The SMN glove, after 10 treatments, saw a significant ($p \leq 0.05$) loss of 34.3% in elastic modulus. Lastly the SGN glove, after 10 treatments, saw a significant ($p \leq 0.001$) 42.0% loss of elasticity. Ten treatments of soap and water sanitization resulted in a significant reduction in the elastic modulus of all the nitrile gloves tested as compared to control.

With 10 treatments causing a decrease in elastic moduli by no less than 34.3%, additional tests were conducted to determine when much of the degradation occurred and whether it had a limit. Further testing was conducted at 5 and 20 treatments (Figure 5).

This data would inform whether nitrile is suitable for soap and water treatment at all and indicate the location of an inflection point, if any. For the GEN, 5 treatments showed a significant ($p \leq 0.001$) loss of 31.5% in elastic modulus and 20 treatments significantly ($p \leq 0.001$) decreased the elastic modulus by 49.7%. The SMN 5-treatment regimen saw a significant loss of 44.2% elasticity ($p \leq 0.001$); the 20-treatment regimen saw a significant loss in elastic modulus of 45.9% ($p \leq 0.001$). For those gloves tested further, the tests seemed to indicate an asymptotic limit in elastic modulus at roughly ½ their untreated moduli.

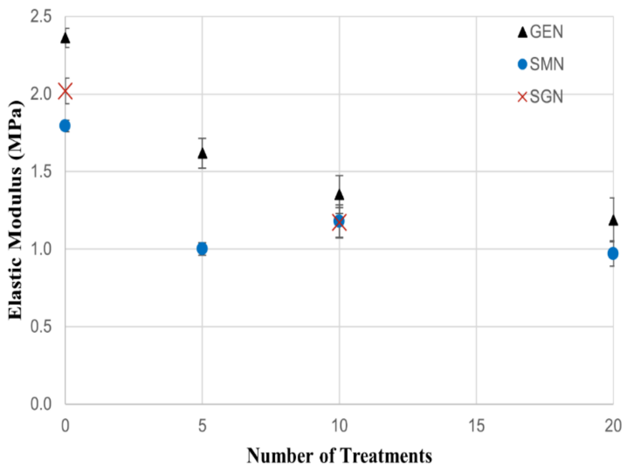

Fig. 5. Effect of the number of soap and water treatments on nitrile gloves' elastic modulus.

4.3 Effect of repeated soap and water treatment on latex gloves

The elastic modulus results for latex gloves are provided in Figure 6. Analysis of elasticity indicated no statistically significant difference between individual gloves of the same type for all latex glove styles tested. Three styles of latex glove were subjects of this study. The modulus for the Surgiglove powder free latex (SPF) was 0.9 ± 0.1 MPa. Polymed powder free latex (PPF) showed an elastic modulus of 0.8 ± 0.2 MPa. Surgiglove powdered latex (SPL) demonstrated an elastic modulus of 1.1 ± 0.3 MPa.

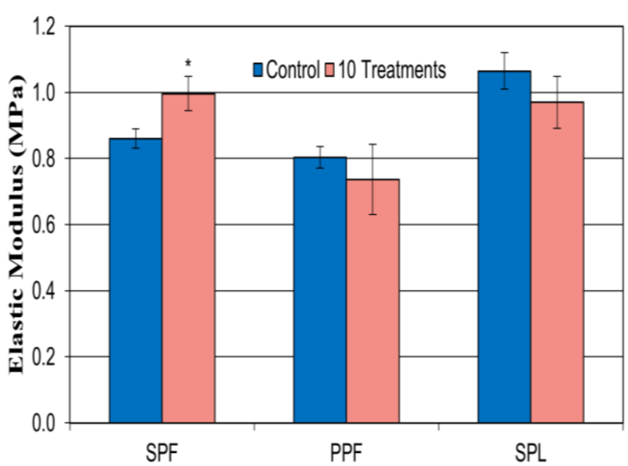

Fig. 6. Effect of 10 treatments of soap and water on latex gloves' elastic modulus.

The tested latex gloves showed significantly less changes due to treatment than the nitrile gloves. The SPF gloves showed a statistically significant ($p \leq 0.05$) increase in modulus for the 10 treatment specimens of 15.8%. The PPF latex 10-treatment specimens resulted in an insignificant ($p > 0.05$) change. The SPL 10 treatment specimens showed no significant ($p > 0.05$) change either.

The SPF gloves showed a statistically significant ($p \leq 0.05$) 19.9% increase in elastic modulus after 5 treatments. The SPF specimen subjected to 20 treatments, however, showed no such significance ($p > 0.05$). The PPF latex specimen subjected to 5 treatments showed a significant ($p \leq 0.05$) 24.2% decrease in elastic modulus. Also significant ($p \leq 0.05$), the PPF 20-treatment specimen showed a decrease of 25.5% in elasticity compared to controls. The SPL 20-treatment specimen showed no significant ($p > 0.05$) change.

Latex gloves showed a notably different reaction to treatments than the nitrile gloves. The SPF gloves showed an increase in stiffness while the SPL from the same company showed no change. The latex gloves display no clear pattern or common reaction to the treatments leaving no clear conclusions to be drawn (Figure 7), other than no significant changes in elasticity beyond approximately 26% were observed for all treatment regimens.

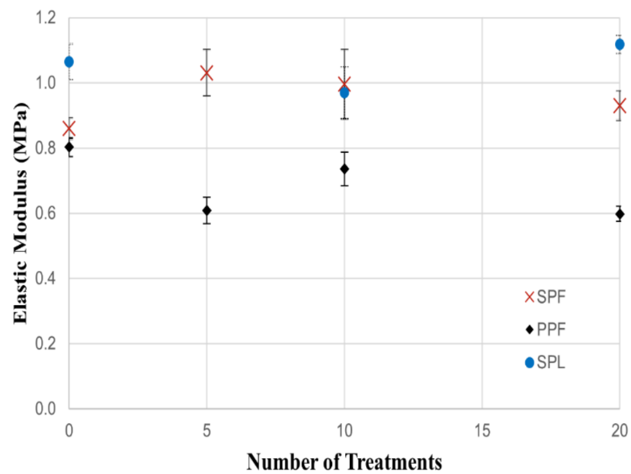

Fig. 7. Effect of the number of soap and water treatments on latex gloves' elastic modulus.

5 Conclusion

The Covid-19 Pandemic has seen shortages in critical PPE and concern in the medical community. Healthcare providers need to know how to extend the useable life of their equipment so that they do not spread the disease or fall victim to it themselves.

Nitrile gloves saw significant reductions in elasticity, indicating possible degradation, with all tests of soap and water treatment leading to a general recommendation against their sanitization by this method. Latex performed notably different, with one brand slightly increasing in elasticity while the other two showed no significant change after 10 repeated treatments. Material type was found to be the determining factor in the property degradation between the gloves tested. Latex gloves hold more promise for repeated sanitation by soap and water than nitrile gloves.

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