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Short Communication

Repeated Bleach Sanitization Effects on Medical Exam Glove Mechanical Properties

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Abstract
Since the mass outbreak of COVID-19 globally, the unique challenges of the pandemic have demanded the global economy, governments, and scientific community adapt in unprecedented ways. Despite pre-existing federal stockpiles of personal protective equipment (PPE) in countries such as the United States, rising shortages and resource constraints have compounded the complexity of curbing the spread of the pandemic and treating patients. To face such shortages, healthcare workers in different parts of the world have been reusing PPE, especially personal protective gloves, and possibly sanitizing them through more cost-effective means such as a simple bleach and water solution. To preserve current and future PPE resources, this study investigates the effect of repeated diluted bleach treatment on mechanical properties of representative gloves to determine if reuse is an acceptable practice. This study aims to determine how bleach sanitization may affect material degradation of gloves when used in working environments. To this end, tensile tests were performed on elastomeric exam gloves with and without bleach sanitization treatments. Control data were prepared for both non-conditioned and humidity conditioned glove samples. Additional glove samples were subjected to ten repetitions of bleach exposure as outlined by Centers for Disease Control and Prevention US (CDC US) guidelines. Subsequently, all glove samples were tensile tested, and mechanical properties were determined. A statistically significant ($p \leq 0.05$) loss of stiffness was observed for some of the tested samples, ranging as high as a 90% loss in stiffness. This research could serve to inform medical professionals as to whether sanitization through bleach treatments is acceptable and if so, at how many repetitions this treatment could potentially compromise the glove's ability to function as intended.

Keywords: Glove, Sanitization, COVID-19, PPE, Nitrile, Latex, Reusability.

1 Introduction

By May of 2020, over 1,000 healthcare worker deaths attributable to COVID-19 were reported globally (Gouda, et al., 2021). By September of the same year, the World Health Organization reported 570,000 healthcare workers infected by COVID-19, and a total of approximately 2,500 deaths caused by the virus with the most deaths in countries such as Mexico and the United States (Erdem and Lucey, 2021). As the international struggle to combat COVID-19 continues, the importance of healthcare workers' access to personal protective equipment (PPE) cannot be understated. The immediate need for PPE caused by the coronavirus pandemic, exacerbated by unprecedented demand and market trends caused by a panicking international community, lead to intermittent shortages throughout the past year (Cohen and Rodgers, 2020). This demand for PPE has most notably included alcohol-based hand rubs, medical gowns, and medical gloves, and has induced serious, unprecedented constraints on the medical infrastructures of countries worldwide (Kampf, G, et al, 2020). In an effort to preserve medical equipment, in the case of elastomer nitrile and latex gloves, the Centers for Disease Control and Prevention US (CDC US) recommends a number of sterilization treatments to be employed by medical professionals (CDC US, 2020). These methods include simple soap and water treatments, hand sanitizer treatments, and a diluted bleach solution to sterilize latex or nitrile gloves, the latter of which the CDC cites only "limited data" to suggest that the permeability of gloves is unaffected when treated with a 10-13% bleach solution (CDC US, 2020). As nations worldwide work to combat the pandemic, countries, especially those with less resources in Asia, Africa and South America, may be attracted to a simple, cost-effective solution such as sterilizing glove PPE with a bleach-water solution (Paula Cotrin, et al., 2020).

Previous studies from other research efforts have shown that disinfection methods can be utilized to preserve the supply of gloves, where nitrile and latex gloves were safely disinfected through methods including alcohol, UV radiation, and heat treatment (Chang, Boon Peng et al., 2021). Existing research regarding the effects of bleach-treatment is limited, however a study seeking to explore the effects of glove disinfection found specifically that nitrile gloves responded to bleach treatments to a greater extent when compared to other polymer types, where mechanical properties such as the ultimate tensile strength (UTS) were observed to degrade significantly (Alcayde-García A, et al., 2020). When considering the chemical resistance of nitrile gloves, this seems to indicate a discrepancy for nitrile, which is normally considered more chemically resistant. One study indicated that this may be attributable to movement of the gloved hand when being exposed to a chemical or solvent (Phalen and Wong, 2012), although the CDC does not warn against moving the hand when sterilizing gloves with bleach in its guidelines. A better understanding of the effects that bleach sterilization could have on elastomer gloves, including nitrile, is therefore necessary so that medical providers who do elect this option for PPE sterilization are less likely to risk personal health, as the pandemic cannot be fought without preserving and protecting the health and lives of healthcare workers and their patients.

2 Materials and methods

2.1 Materials

Tested materials for this study included six varieties of gloves, classified by four brands, polymer type of nitrile and latex, and powdered or non-powdered. The four brands included Glovepak (Glovepak USA, Palm Desert, CA, USA), Polymed latex (Ventyv, Tampa, FL, US), SemperSure (Sempermed, Clearwater, FL, USA), and Surgi Gloves (Connect Pack LLP, Mumbai, India). For convenience, gloves are referenced by their respective glove codes as shown and explained in Table 1.

Table 1. Classification criteria for gloves and glove number used as reference in study

Polymer Type	Glove Brand	Brand Code	Powder Status	Glove Code
Nitrile (N)	Glovepak Europa	B1	Powdered (P)	N-B1-P
	SemperSure	B2	Powder-free (F)	N-B2-F
	Surgi Gloves	B3	F	N-B3-F
Latex (L)	Surgi Gloves	B3	P	L-B3-P
	Surgi Gloves	B3	F	L-B3-F
	Polymed	B4	F	L-B4-F

A 1 cm x 6 cm die (W.R. Sharples, North Attleboro, MA, USA) was used to cut samples for tensile testing. A digital micrometer of 0.001 mm resolution (Fisher Scientific, Houston, TX, USA) was used to record thicknesses of cut samples. A tensile testing apparatus consisting of a Mark-10 ESM303 test stand, G1061 grips, and a Series 5 force gauge (Copiague, NY, USA) were used for tensile testing. The bleach solution consisted of store-bought Clorox disinfecting bleach (The Clorox Company, Oakland, CA, USA), which was diluted with tap water prior to treatment of gloves.

2.2 Methods

2.2.1 Bleach treatment

A bleach-water solution was prepared consisting of one-part bleach (6.0% sodium hypochlorite) to sixteen parts water. Samples were submerged into the bleach solution for exactly one minute before being pulled into open air for approximately five seconds, which constituted a single treatment. In accordance with CDC US guidelines, all gloves were bleach-treated exactly ten times.

2.2.2 Preparation and cutting

Regardless of treatment, the steel die was used to produce 12 samples from each glove to be tested. For treated samples, samples were immediately cut via a steel die so that they could be tested within one hour of treatment. Cut samples were measured for their thicknesses with a digital micrometer. A total of five thickness measurements were made and these values were averaged to estimate the thickness of the sample cross-section.

2.2.3 Tensile testing

All investigated samples were tensile tested according to ASTM D882-10 (ASTM International, 2010). Tensile tests were concluded following the breakage or slippage of the glove specimen. Special attention was paid to failure modes, where slippage, edge breaking, or other non-desirable failure modes were associated with each tensile test conducted.

2.2.4 Statistical analysis

Stress/strain data were calculated from load and displacement data produced by tensile tests. Excel utilities were used to identify the stiffness and ultimate tensile strength of samples from tensile test data. From stress/strain data, bleach treated results were compared against control data. Significant drops in stiffness were determined either statistically significant or insignificant based on t-testing from data sets produced by each glove, where a statistically significant result produced p values less than or equal to 0.05.

3 Results and Discussion

3.1 Effect of bleach sanitization on the mechanical performance of nitrile gloves

Nitrile samples underwent ten bleach-treatments and were compared to control samples to study the overall change in stiffness. A comparison of control and treatment stiffnesses is given in Figure 1 for nitrile samples consisting of N-B1-P, N-B2-F, and N-B3-F.

Nitrile samples responded significantly by majority to bleach treatment ($p \leq 0.05$), with p values for N-B1-P and N-B2-F of 0.00 and 0.006 respectively. As seen in Figure 1, the stiffness of N-B1-P after treatment was effectively half that of its untreated value. For N-B2-F, a significant loss in stiffness was observed at nearly a 50% drop from its control value. For N-B3-F, no significant stiffness loss was observed ($p > 0.05$) with an associated p-value of 0.12. Even though the chemical nature of the reactions between the bleach and nitrile exceeds the scope of this study, this result is well-within expectations outlined in published research, where bleach solution was observed to affect the ultimate tensile strength and stiffness of powder-free nitrile elastomer gloves (Alcayde-García A, et al., 2020). In the aforementioned study, a direct application of disinfection treatments on cut glove samples demonstrated how UTS degraded based on treatment type. Results indicated that bleach treatment rendered a significant loss of UTS, second only to 3% hydrogen peroxide.

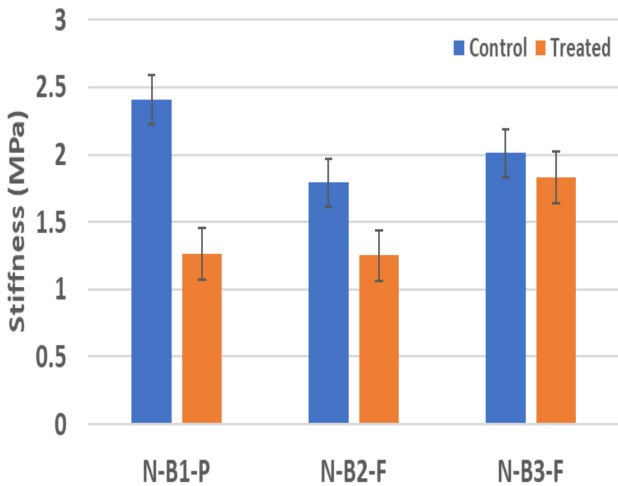

Fig. 1. Effects of diluted bleach on nitrile gloves' stiffnesses

3.2 Effect of bleach sanitization on the mechanical performance of latex gloves

As with nitrile samples, latex samples were bleach treated ten times to study the overall change in stiffness. A comparison of stiffness for zero and ten treatments is given in Figure 2 for latex samples consisting of L-B3-P, L-B3-F, and L-B4-F.

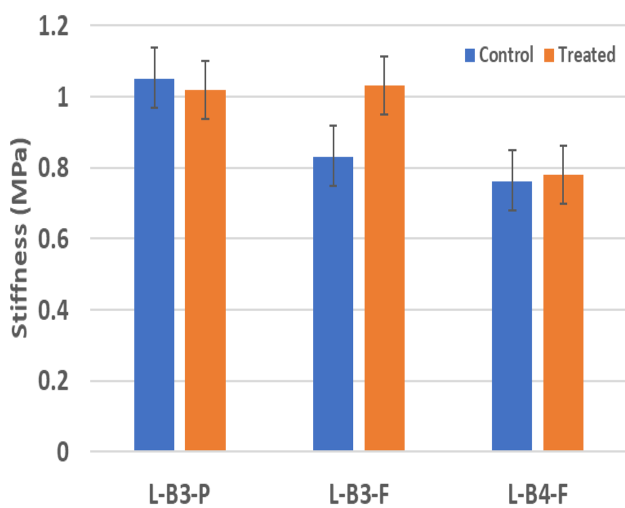

Fig. 2. Effects of diluted bleach on latex gloves' stiffnesses.

Remarkably, latex samples proved entirely unresponsive to testing ($p > 0.05$) with p values for L-B3-P and L-B4-F of 0.52 and 0.78 respectively. While it appears in the case of L-B3-F that the stiffness has increased, the value was insignificant through t-testing ($p > 0.05$) with a p-value approximately equal to 0.054, thus suggesting that bleach sanitization rendered no effect on the latex gloves used for this experiment. It is currently unknown as to why latex is more resilient to this manner of testing, though the data seem to support the notion that latex would be a more suitable glove material to use when sanitizing with a bleach-solution. A further exploration of the extent of latex's resistance to bleach treatment would make for an excellent future study.

3.3 Failure modes and ultimate tensile strength

Special attention was also given to the failure mode for all samples tested. For the UTS to be evaluated, an ideal break along the middle of the sample was necessary for accurate results. An ideal example of such a break is shown in Figure 3a. In many cases, however, "slippage" of the specimen or edge-breaking, whereby the specimen would either slip from the grip of the tensile testing machine or break evenly along the edge respectively, are shown in Figures 3b and 3c.

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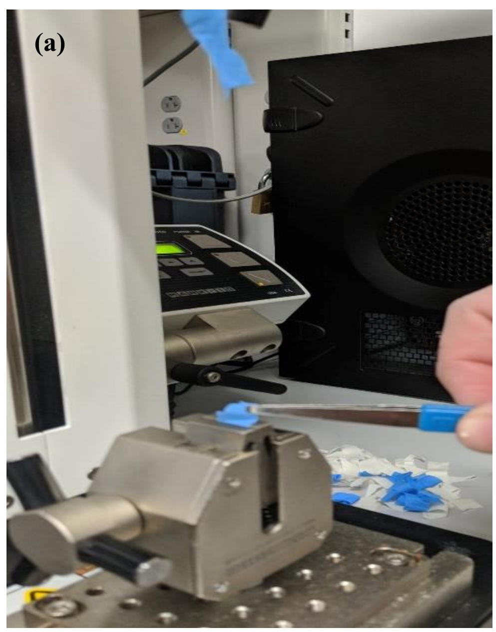
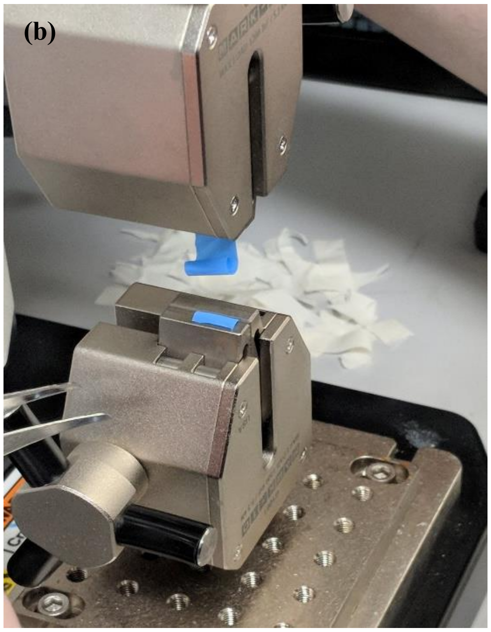
When calculating average UTS values, it was observed that these averages corresponded to high coefficients of variation especially for treated samples. These high coefficients of variation in turn corresponded to a high percentage of undesirable failure modes such as edge breaks or slippage from the tensile testing machine. The ultimate tensile strengths, coefficients of variation, and percentage of undesirable failure modes for nitrile and latex samples are given in Tables 2.





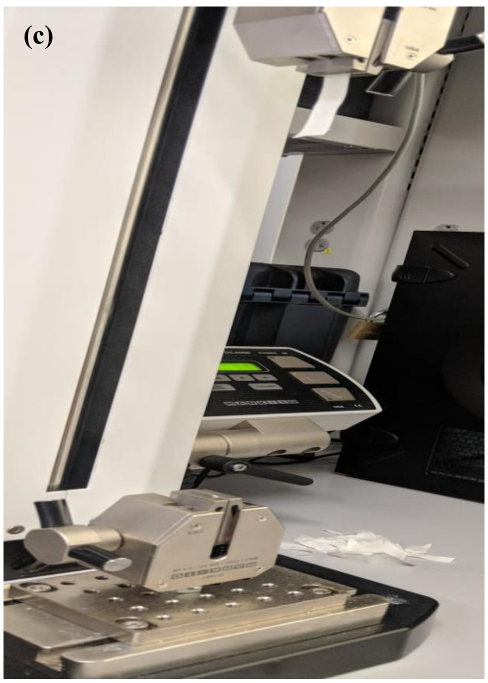


Fig. 3. Sample failure modes showing: (a) an ideal horizontal break along the length of the sample, (b) an unideal break at the edge of the grip, (c) slippage of the sample from the grip.

Coefficients of variation for nitrile samples are higher than for latex samples, suggesting the unreliability of UTS values, and may possibly correlate to the 33% occurrence of undesirable failure rates. Interestingly, latex samples have significantly lower coefficients of variation, however much higher edge/slippage failure modes on average. This, however, can be explained in that most latex samples during tensile testing proved too ductile for the samples to break, which would result in slippage of the sample from the tensile test machine grip. In either case, it was concluded that for the scope of these experiments, UTS values could not be considered reliable. Furthermore, use of a standard dog-bone sample configuration would have reduced the issues seen here, however due to the limited supply of gloves for testing this was a limitation of this current study.

Table 2 Analysis of UTS and failure modes of treated nitrile and latex samples

Glove Code	Ultimate Tensile Strength (UTS) [in MPa]	UTS Coefficient of Variation [%]	Edge/Slippage Failure [%]
N-B1-P	16.80	26.03	33
N-B2-F	22.28	22.66	33
N-B3-F	13.20	44.74	33
L-B3-P	15.12	22.58	100
L-B3-F	15.95	10.98	100
L-B4-F	14.69	20.57	50

3.4 Summary of stiffness loss across samples

The stiffnesses of samples throughout this study experienced either degradation or were unaffected by bleach treatment. A graphical representation of this loss as a percentage is offered in Figure 4.

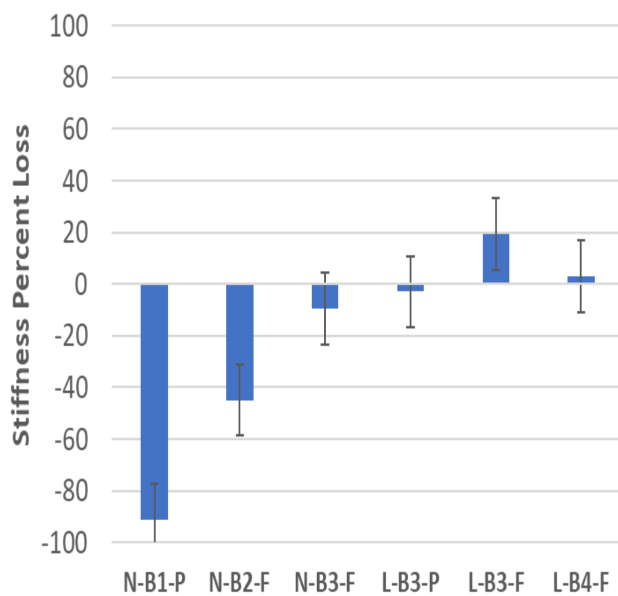


Fig. 4. Stiffness percent loss across all tested glove types.

As indicated by this data, nitrile-based gloves are significantly more susceptible to loss of mechanical properties through bleach treatment. This insight would predicate future studies regarding bleach treatment and loss of mechanical properties of elastomer gloves. A relative "acceptable" number of treatments could exist where nitrile does not respond to bleach, presumably less than the number of treatments used here. Conversely, a threshold could exist for latex gloves whereby after enough treatments, degradation of mechanical properties may occur.

4 Conclusion

The stark contrast in performance of nitrile versus latex in bleach testing begs for further investigation. As the world pushes forward to control the spread of the pandemic, it is paramount that medical professionals have as comprehensive an understanding as possible with regard to their medical equipment and PPE. The scope of this research was to study the effects of bleach sanitization treatment on the mechanical properties of nitrile and latex surgical gloves. Tensile testing data show that nearly all nitrile gloves tested experienced statistically significant losses in stiffness through bleach sanitization. Latex gloves, however, appear to be largely unaffected by repeated bleach sterilization. In all cases where latex gloves were subjected to bleach sterilization and tensile testing, latex gloves proved unresponsive to any significant change in loss of mechanical properties.

Moving forward, future studies to further knowledge in the degradation of elastomer gloves through bleach treatment may include higher or lower treatment repetitions for nitrile and latex samples to observe mechanical degradation. Furthermore, a more in-depth study of powdered versus non-powdered and their effects of resisting bleach treatment may be required. It would be the hope of such research that deeper insight into the mechanics of the degradation of glove PPE could be leveraged by medical professionals to safely use and preserve available PPE in medical environments and to protect the lives of healthcare workers worldwide.

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References

Gouda, Divakara, et al. (2021) An Overview of Health Care Worker Reported Deaths During the COVID-19 Pandemic. American Board of Family Medicine.

Erdem, Hakan, and Daniel R Lucey. (2021) Healthcare Worker Infections and Deaths Due to COVID-19: A Survey from 37 Nations and a Call for WHO to Post National Data on Their Website. International Journal of Infectious Diseases.

Cohen, Jennifer, and Yana van der Meulen Rodgers. (2020) Contributing Factors to Personal Protective Equipment Shortages during the COVID-19 Pandemic. Preventive Medicine, Elsevier Inc.

Kampf, G, et al. (2020) COVID-19-Associated Shortage of Alcohol-Based Hand Rubs, Face Masks, Medical Gloves, and Gowns: Proposal for a Risk-Adapted Approach to Ensure Patient and Healthcare Worker Safety. The Journal of Hospital Infection.

Centers for Disease Control and Prevention (2020) Strategies for Optimizing the Supply of Disposable Medical Gloves. Centers for Disease Control and Prevention.

Paula Cotrin, et al. (2020) Healthcare Workers in Brazil during the COVID-19 Pandemic: A Cross-Sectional Online Survey. SAGE Journals.

Chang, Boon Peng et al. (2021) Can Medical-Grade Gloves Provide Protection after Repeated Disinfection?" ACS Applied Polymer Materials.

Alcayde-García A, et al. (2020) Disinfection of Gloved Hands during the COVID-19 Pandemic. The Journal of Hospital Infection, U.S. National Library of Medicine.

Phalen, Robert N, and Wong, Weng Kee. (2012) "Chemical Resistance of Disposable Nitrile Gloves Exposed to Simulated Movement." Journal of Occupational and Environmental Hygiene, U.S. National Library of Medicine.

ASTM International. (2010) ASTM D882-10, Standard Test Method for Tensile Properties of Thin Plastic Sheeting. (2010) ASTM International - Standards Worldwide.