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IMPACT OF DIFFERENT DISINFECTION SOLUTIONS ON MECHANICAL PROPERTIES OF ORTHODONTIC IMPRESS SILICONE MATERIAL

Hrubanová A.[*], Thomková B.[**], Košková O.[***], Richtrová M.[†], Borák L.[††], Štourač P.[†††], Marcián P.[‡]

Abstract: *This study explores the influence of disinfection on silicone material used in cleft protection and orthodontic impressions. A series of uniaxial tensile tests were conducted to evaluate the mechanical properties after disinfection. Statistical analysis of stress-strain curves at various stress levels using one-way ANOVA showed no significant differences, supporting the hypothesis that disinfection does not compromise the material properties of the silicone used for the cleft protection with obturators. Additionally, the study explores the utilization of 3D printing for creating a casting mold used in the manufacturing of silicon-based products.*

Keywords: Orthodontic, silicone material, uniaxial tensile test, disinfection, ANOVA.

1. Introduction

Silicone materials are employed for cleft protection during anesthesia with obturators (Richtrova et al., 2023). The obturators are disinfected prior to insertion. The primary objective of this study is to assess the impact of various disinfectants on silicone material on its mechanical properties through uniaxial tensile testing. We hypothesize that disinfection will not induce any changes in the mechanical properties as was previously shown by (Guntupali et al., 2022) with same silicon material but different disinfectants. Consequently, a secondary goal is to evaluate the efficacy of manual mixing of two-component silicone and the utilization of 3D printing for creating a casting mold. This research aims to contribute valuable insights into the compatibility of silicone with disinfection processes and explore innovative manufacturing techniques for producing casting molds.

2. Methods

Three commonly used disinfectants, Softasept N (*B Braun Medical*; propanol and ethalon base), Octenisept (*Schulke*; Octenidine dihydrochloride and phenoxyethanol base), and Cutasept F (*Hartmann-Rico*; propanol base), were selected for this study. To assess their impact on mechanical properties, uniaxial tensile testing was conducted.

[*] Ing. Anna Hrubanová: Institute of Solid Mechanics, Mechatronics and Biomechanics, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic; CZ, anna.hrubanova@vutbr.cz, Brno PhD. Talent Scholarship Holder

[**] Ing. Barbora Thomková: Institute of Solid Mechanics, Mechatronics and Biomechanics, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic; CZ, barbora.thomkova@vutbr.cz

[***] MUDr. Olga Košková, PhD.: Department of Burns and Plastic Surgery, Faculty of Medicine, Masaryk University, Jihlavská 340/20, 625 00 Brno, Czech Republic; CZ, koskova.olga@fnbrno.cz

[†] MUDr. Michaela Richtrová: Department of Paediatric Anaesthesiology and Intensive Care Medicine, Masaryk University, Černopolní 212/9, 662 63 Brno, Czech Republic; CZ, 60032@mail.muni.cz

[††] Ing. Libor Borák, PhD.: Institute of Solid Mechanics, Mechatronics and Biomechanics, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic; CZ, xmborak01@vutbr.cz

[†††] Prof. MUDr. Petr Štourač, PhD., MBA, FESAIC.: Department of Paediatric Anaesthesiology and Intensive Care Medicine, Masaryk University, Černopolní 212/9, 662 63 Brno, Czech Republic; CZ, stourac@med.muni.cz

[‡] Ing. Petr Marcián, PhD.: Institute of Solid Mechanics, Mechatronics and Biomechanics, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic; CZ, marcian@fme.vutbr.cz

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2.1. Specimen preparation

Specimens for the experiments were created using molds prepared on a 3D printer (Prusa i3 MK3S+). The mold was constructed from a commonly used 3D printing material PLA (polylactic acid), a thermoplastic monomer derived from renewable organic sources. The mold for sample preparation was designed according to CSN 527-2 and consisted of two parts. A drainage channel was incorporated into the lower part for the eventual removal of excess material, as shown in Fig. 1a. During mold fabrication, the infill density was set at 50 %, ensuring adequate rigidity when the mold was compressed during sample production.

The samples were produced from Zhermack Elite HD+ silicone impression material. This material is commonly used for impressions of upper palates in orthodontic laboratories. The material was prepared by mixing catalyst and base in a 1-to-1 ratio, precisely weighted using precision scale Lesak HD112 (0.001 g, Lesak). The two components were then manually mixed, placed in a mold and compressed. After the material solidified within 210 seconds, the samples were extracted and inspected.

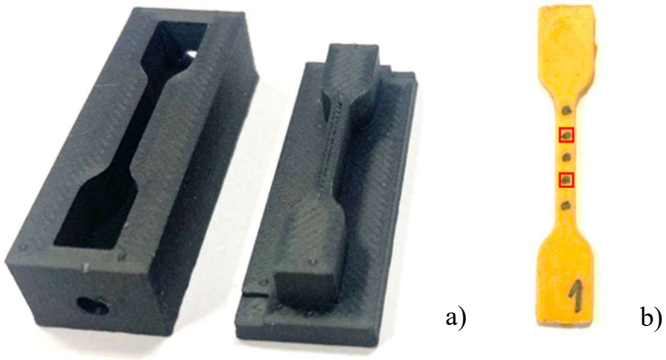

Fig. 1: 3D printed mold used for specimen preparation a), uniaxial tensile specimen with markers for deformation evaluation b); those marked in red in were employed for deformation tracking.

All specimens were prepared 24 hours before mechanical testing to mitigate the impact of specimen aging. Before testing, black markers were applied to the neck area of each specimen to track the deformation during testing (Fig. 1b). All specimens were categorized into four groups, consisting of three groups subjected to different disinfection procedures and one reference group without any disinfection.

2.2. Testing and evaluation

All tests were conducted on a customized computer-controlled testing device (Camea, s.r.o., CZ). The device is equipped with linear-stepped motor that enables mechanical displacement of clamps. In the case of uniaxial testing, a single motor was employed, and the specimen was gripped by two spring clamps with serrations to prevent slippage during testing. The force was measured by a load cell (max. 20 N) mounted on one actuator axis allowing the controlled displacement. The specimen was captured by a CCD camera with a resolution of 0.02 mm/pixel, positioned perpendicular to the testing area. To ensure a good visibility of the markers, the measured area was illuminated by two external lights. The specimen thickness was measured by a dial indicator at 3 locations on each specimen, and the mean value was used for further analysis.

Before undergoing tensile testing, each specimen (except that from the reference group) was immersed in one of the three different disinfection solutions (Softasept N, Octenisept, Cutasept F) for 60 seconds. Subsequently, the specimens were air-dried before being subjected to uniaxial tension testing. This simulated pre-operative conditions, where the surgeon immerses the prosthesis in the disinfectant for approx. 1 minute and allows it to air-dry before inserting into the patient's body. After clamping a pre-tension of 0.1 N was applied to each specimen to ensure its flatness. The testing was displacement-controlled, with a displacement speed set to 0.333 mm/s. Uniaxial specimens were loaded until failure occurred at the neck area.

The evaluation of the test was conducted in software Tibixus (Turčanová et al., 2023), which analyzes the images captured by the CCD camera. The first captured image served as a reference, and the

deformation was assessed through digital image correlation (DIC). The calculation of the first Piola-Kirchhoff (engineering) stress was carried out using Eq. (1):

$$\sigma = \frac{F_{exp}}{b\,T}, \tag{1}$$

where F_{exp} is the force measured by the load cell, b is the initial (undeformed) width of the specimen and T is the measured mean thickness.

2.3 Statistical Analysis

To compare the difference between the four groups (3 disinfectants and 1 control group), thirteen datasets were created by interpolating the strain value of stress-strain curves at thirteen stress-levels (Lisický et al., 2021), ranging from 0.1 MPa up to 1.3 MPa and sorted into four groups by the disinfectant used. At each stress level a one-way ANOVA test was conducted to determine whether there is a significant difference between the various disinfectant groups and the reference group. The significance was assumed for $p < 0.05$.

The normalization of data was used for clearer data representation using Eq. (2):

$$\varepsilon_N = \frac{\varepsilon_i - \bar{\varepsilon}}{S_\varepsilon}, \tag{2}$$

where ε_N is the normalized strain data, ε_i is the strain value before normalization, $\bar{\varepsilon}$ is the mean value and S_ε is the standard deviation.

3. Results and discussion

The resulting stress-strain curves are shown in Fig. 2.

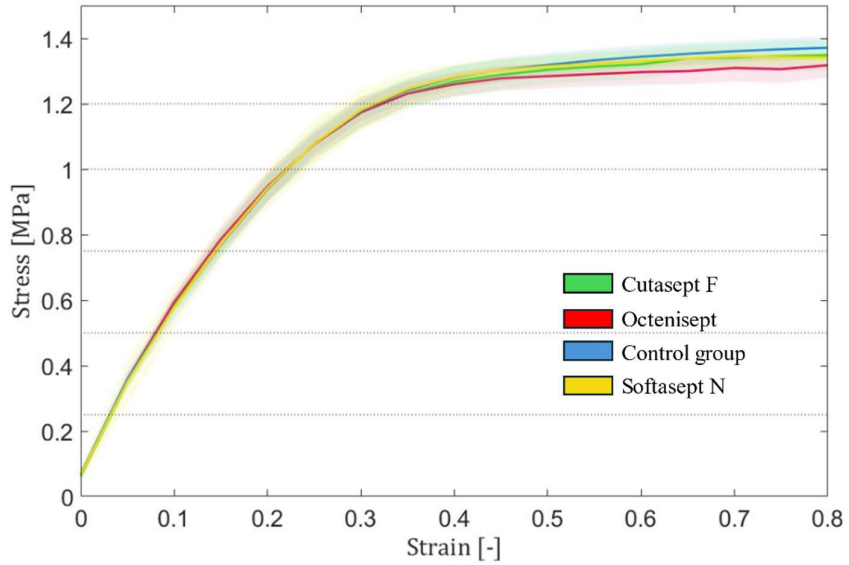

Fig. 2: Average stress-strain curve (solid line) with standard deviation of the uniaxial tensile tests for each of the 4 groups. The specimens cured with Softasept N are displayed in yellow, the specimens cured with Octenisept are shown in red, the ones cured with Cutasept F are green and the group shown in blue is the reference group which wasn't immersed in any disinfectant.

The results indicate no significant difference between the four groups, as the mean values for each group fall within the interquartile range of the others (Fig. 3). To validate this hypothesis, a one-way ANOVA test was conducted. The resulting p-values are summarized in Tab. 1. All the p-values are above the significance level of 0.05, meaning that the null hypothesis about the equality of mean cannot be rejected.

This suggests that there indeed is not a statistically significant difference between the disinfectant and that the effect of plunging the silicon into any of these three disinfectants does not change its material properties.

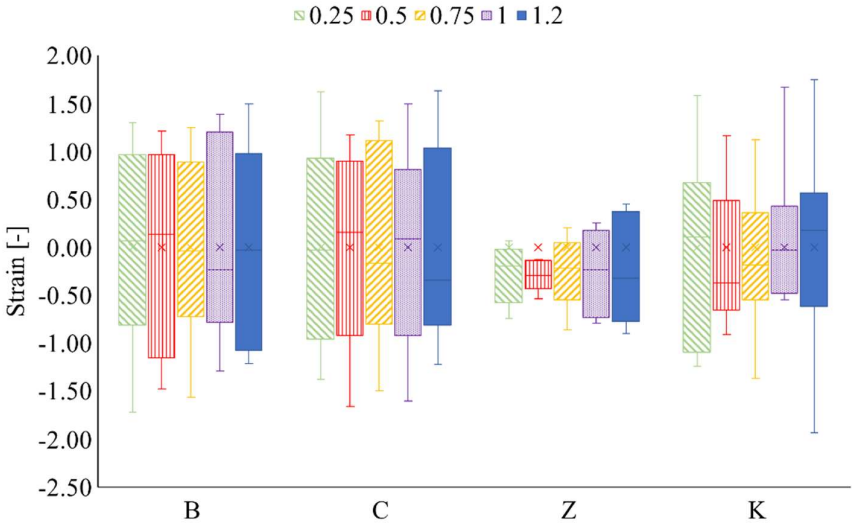

Fig. 3: Box plot of normalized strain data for different stress levels (used stress levels are shown in Fig. 2) Each disinfectant group is marked by letter (B – Cutasept F; C – Octenisept; Z – SoftaseptN; K – reference group), each stress level is differentiated by color and pattern.

Stress-level [MPa]	P-value	Stress-level [MPa]	P-value	Stress-level [MPa]	P-value
0.1	0.941	0.6	0.137	1	0.672
0.2	0.335	0.7	0.821	1.1	0.502
0.3	0.941	0.8	0.754	1.2	0.326
0.4	0.86	0.9	0.697	1.3	0.438
0.5	0.87				

Tab. 1: Resulting p-values of one way ANOVA test for different stress levels.

4. Conclusion

The aim of this study was to assess the effect of three disinfectants on the mechanical properties of Zhermack Elite HD+, a silicone material commonly used for orthodontic impressions. A series of uniaxial tensile tests were conducted, and the resulting stress-strain curves were compared using one-way ANOVA at various stress levels. The results revealed no statistically significant differences in the tensile responses, suggesting that the immersion of the material in the disinfectant should not alter its material properties.

Acknowledgement

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References

Richtrova, M. et al. (2023) Use of computer-aided design and 3D printing for airway management in paediatric patients with a cleft facial defect: a pilot study. *British Journal of Anaesthesia*, 130, 65, e469–e471.

Turcanová, M. et al. (2023) Biaxial stretch can overcome discrepancy between global and local orientations of wavy collagen fibres. *Journal of Biomechanics*, 161, 111868.

Lisický O. et al. (2021) Interpretation of experimental data is substantial for constitutive characterization of arterial tissue. *ASME J. Biomech Eng.*, 143(10): 104501.

Guntupali Y. et al. (2022) Effect of disinfectants on the tear strength of addition silicone impression material – An in vitro study. *J. Adv. Pharm. Technol. Res.*, 458–461.