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Effect of Cellulose Nanofibers Incorporation into RTV Maxillofacial Silicone Elastomer on Tear Strength, Shore 'A' Hardness and Surface Roughness: A Pilot Study

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ABSTRACT

The main goals of the present study to improve the function and aesthetics of the maxillofacial prosthesis, these were benefits for the patient's quality of life. Throughout determine the appropriate percentage of cellulose Nano-fibers placement that improve the silicone used in the maxillofacial area's mechanical and physical characteristics. Methods: Overallof 75 samples were created by placement of cellulose nanofiber (CNF) in various wt. percentages to VST50 (RTV) platinum silicone elastomer. Five groups, for each group which have 15 samples were created from the study samples. Four groups were made with varying percentages of CNF (0.5%, 1%, 1.5%, and 2% by weight), whereas one control batch was prepared without the inclusion of cellulose nanofibers. According to the conducted tests, each group was subsequently separated into three subgroups which included testing for tear strength, surface roughness and shore A hardness (n=5), An analysis using descriptive statistics was used to examine the data (mean, standard deviation, and bar chart representation). Results: The average value of shore A hardness, tear strength of the 0.5% by weight CNF strengthening group raising significantly as comparative to the control group. Whereas surface roughness non-significant raising. In contrast to the other parameters of the reinforcement groups, which were severely degenerated. Conclusion: It was determined that placement 0.5% by weight CNF to maxillofacial silicone substitution material can enhance its mechanical qualities.

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INTRODUCTION

Congenital anomalies and the surgical removal of tumors, trauma, or a combination of these events may be to blame for maxillofacial malformations [1,2]. They frequently call for risky and difficult operations carried out by a prosthodontics and maxillofacial surgery team, and they may have detrimental esthetic, functional, and psychological effects [3].

The manufacture of maxillofacial prostheses has historically utilized a variety of materials. These materials may include metals, wax and wood. Recently, the polymers To address the need requirement for materials that will be biocompatible, flexible, color stable, durable for long life time and easily handled, polydimethylsiloxane have been used as substitution for maxillofacial prosthesis [4].

Cellulose fiber can be obtained from a variety of plant sources and offers a sustainable, environmentally beneficial reinforcing option. A cellulose fiber that has been reduced from

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a macro to a nano scale is known as a cellulose nano fiber (CNF). This improves the fiber's aspect ratio (=length/diameter) and helps to smooth out some of its flaws. A novel option for reinforcement results from the size reduction, which produces a fiber with an extraordinarily high Young's modulus and tensile strength. [5]

The current pilot study's objectives were to determine how much cellulose nanofibers should be added to the silicone elastomeric materials used in the craniofacial region in order to increase tear strength, shore A hardness, and little effect on surface roughness.

MATERIALS AND METHODS

Cellulose nanofibers are added in concentration of (0.5%, 1%1.5% and 2%) by weight to silicone RTV elastomer VST50 and then tested. The results were compared to 0% without CNF addition (control group). one-handed Five specimens (n=5) were prepared for control and each percentage, and they were disseminated into three groups based on the tests conducted in this study (tear strength, surface roughness and shore A hardness), each group contains 25 samples and they were subdivided according to the percentage used (0%, 0.5%, 1%, 1.5% and 2%), The Shore A hardness samples were used which have the same dimension for samples of surface roughness test. To evaluate tear initiation at a stress concentration location positioned at the 90° apex, all specimens were examined using a universal testing equipment (GESTER-Techno Co. Ltd. China) at a cross-head speed of 500 mm/min. According to ISO 34-1 [6], 25 Type C specimens, which are unnicked specimens with a right angle on one side and specimens with two tab ends, are created. (Fig. 1A) Each specimen's thickness was measured using a vernier caliper and digital screen at three different locations throughout the breadth, near the right angle where the fracture is anticipated to occur, at the slit or apex and at each tab ends. In accordance with ASTM D3767, 2014, the median value of three measurements was taken. 20 silicon specimens were produced after the addition of various amounts of CNF, and 5 specimens were employed as the control group for the tear strength test (n=5). A computerized universal testing equipment had specimens set in it spaced 30 ± 0.5 mm apart then The machine software computed the maximum load and then recorded the tear strength value using the formula: [7]

$$\text{Tear strength} = F/D$$

Where illustrated as:F: a strongest force needed to cause a specimen to cut off (KN).D: an average specimen thickness (mm).

According to ISO 48-4, 2018 [8], 25 specimens was manufactured for hardness test shore A. The dimensions of a hardness test should be 25 mm length, 25 mm width, 6 mm thickness, and the outside surface should be marked with five points, one in the center and the others 6 mm away in each direction around. the center point, according to ISO 48-4 (2018) specification. as in (Fig. 1B) Measurements of Shore A hardness were made by using durometer set on a mechanical platform. To execute the hardness test into the sample's surface at five previously defined locations, a durometer stylus with a blunt indenter of 1.25 mm diameter and a digital scale (0 to 100) is punctured. According to the instructions. The device was tightly clamped over the sample's surface by hand using a mechanical stand and a 1Kg load for 1-3 seconds. The mean of five readings was then recorded.

The sample size for surface roughness tests is 25 mm length, 25 mm width, 6 mm thickness, and the sample size for surface roughness tests is the

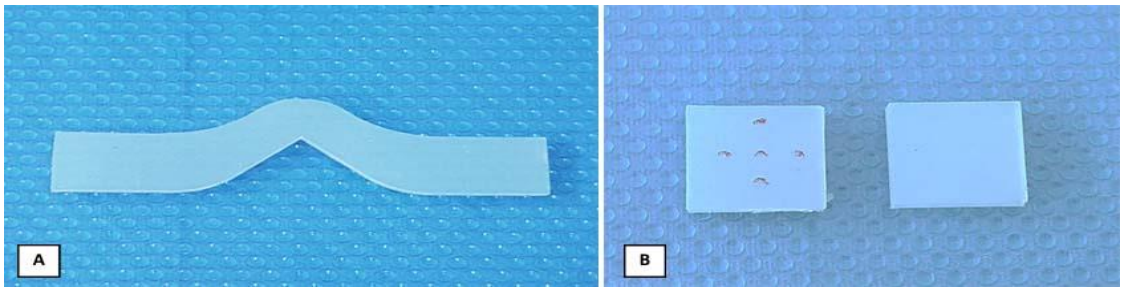

Fig. 1. (A) Tear strength test sample, (B) Specimens used for testing hardness with 5 points marketing.

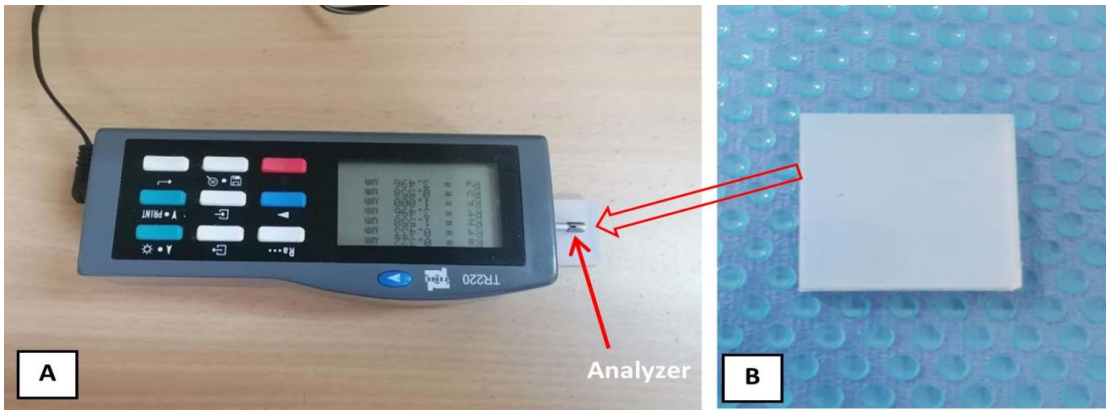

Fig. 2. A: Surface roughness tester (profilometer) B; Specimens used for testing surface roughness.

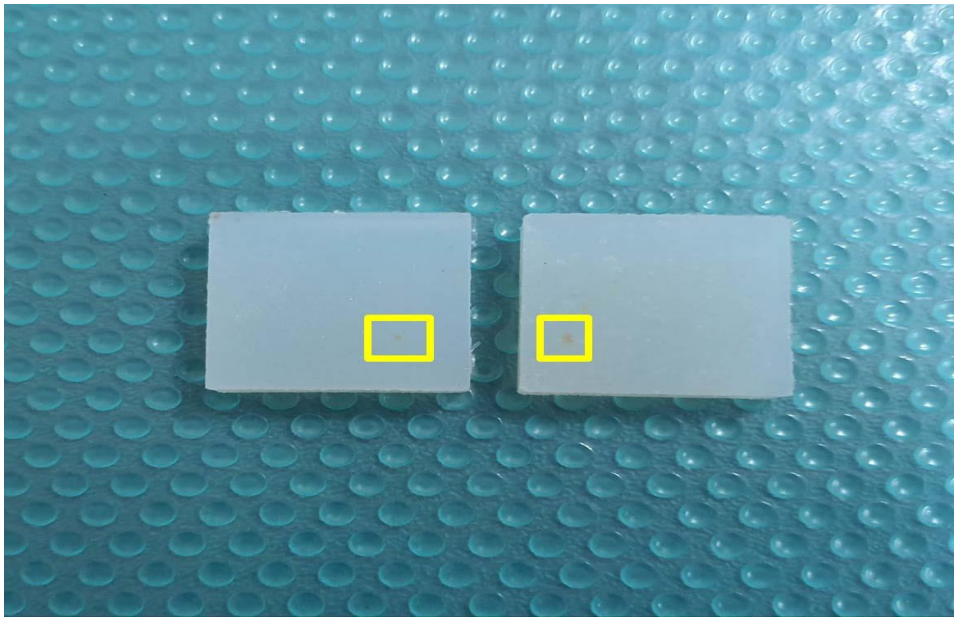

Fig. 3. Specimen of mixing percentage 2% showed small particles agglomerate.

same dimensions for shore-A hardness sample. According to ISO 48-4, 2018, Profilometer tester device used for making reading, it has stylus that moved over the surface of the sample and 3 reading is recorded for each sample, then the average value of the reading is considered as roughness results in (µm) as shown in (Fig. 2).

When mixed the percentage 2% of cellulose Nano fibers with silicone VST50 room temperature vulcanized agglomerate and appear as small particles present in the specimens, therefor we discarded the percentage 2% from the pilot study. as in (Fig. 3), and FESEM image of 1.5% group revealed to appear of aggregation of CNF due to their surface activity character as in (Fig. 4).

RESULTS AND DISCUSSION

Tear Strength Test

Results are listed in (Table 1) and Fig. 5. The 0.5 % CNF shows the highest mean among other groups.

Further comparison made by using ANOVA table with Tukey HSD Multiple Comparisons which revealed that high significant differences observed among all groups. When comparing the groups by Tukey HSD multiple comparison, control group

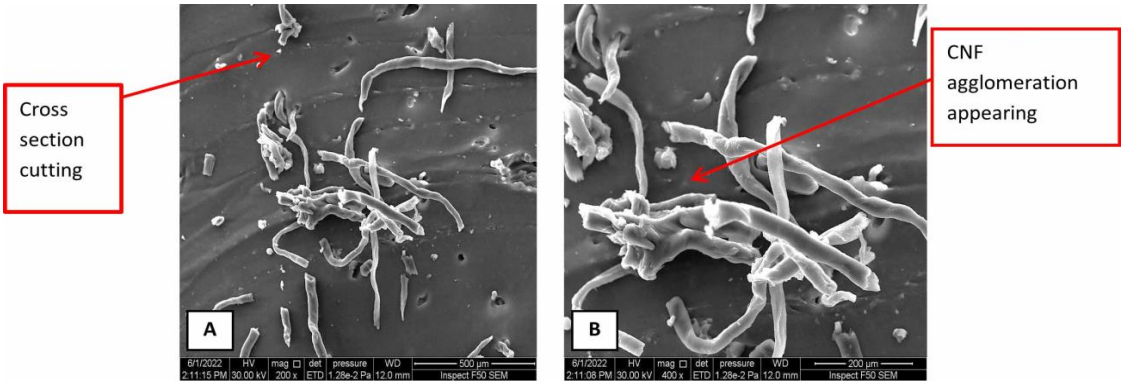

Fig. 4. FESEM image of 1.5% CNF adding to silicon matrix specimens (cross section); in pilot study A, 200X magnification. B, 400X magnification.

shows highly significant differences when compare with 0.5% and 1% by wt. CNF groups, also 1.5% by wt. of CNF group shows significant differences results, in addition to that 0.5% by wt. CNF group shows highly significant differences results when compared with1% and 1.5% groups, in addition to that 1% group shows non-significant differences results when compared with1.5% group. As (Table 2).

Shore A Hardness

Results are listed in (Table 3) and Fig. 6. The 1.5% group shows the highest mean value of Shore A Hardness among other groups. while the 0.5% group shows the lowest mean value among other experimental groups.

Table 1. Results of Tear strength test and ANOVA table of pilot study (KN/m).

Tear strength results in (N/mm)					F test	P value
Cellulose Nanofiber percentage	0%	0.5%	1%	1.5%		
Mean	20.9560	32.8000	25.3000	23.8800	59.133	.000
SD	0.40562	2.25389	0.84261	1.63003		

*The mean difference is significant at the 0.05 level.

Table 2. Multiple comparison of Tukey HSD for tear strength test.

(I) Groups		Mean Difference (I-J)	Sig.
Control	0.5%	-11.84400*	0.000
	1%	-4.34400*	0.001
	1.5%	-2.92400*	0.028
0.5%	Control	11.84400*	0.000
	1%	7.50000*	0.000
	1.5%	8.92000*	0.000
1%	Control	4.34400*	0.001
	0.5%	-7.50000*	0.000
	1.5%	1.42000	0.444
1.5%	Control	2.92400*	0.028
	0.5%	-8.92000*	0.000
	1%	-1.42000	0.444

*. The mean difference is significant at the 0.05 level.

Table 3. Shore A hardness results and ANOVA table of pilot study.

Shore A hardness results					F test	P value
Cellulose Nanofiber percentage	0%	0.5%	1%	1.5%		
Mean	29.8800	33.0600	35.2000	36.4800	87.530	0.000
SD	0.76942	0.78613	0.80000	0.22804		

he mean difference is significant at the 0.05 level.

By using ANOVA table with Tukey HSD Multiple Comparisons which revealed that high significant differences observed among all groups. When comparing the groups by Tukey HSD multiple comparison, control group shows highly significant differences when compare with 0.5%,1% and 1.5% by wt. CNF groups, in addition to that 0.5% by wt. CNF group shows highly significant differences results when compared with1% and 1.5% groups, in addition to that 1% group shows significant differences results when compared with1.5% group. As (Table 4)

Surface Roughness

Results are listed in (Table 5) and Fig. 7. The 1.5% group shows the highest mean value of Surface Roughness among other groups, while the 0.5% group shows the lowest mean value among other experimental groups.

Further comparison made by using ANOVA table with Tukey HSD Multiple Comparisons which revealed that high significant differences observed among all groups.When comparing the groups by Tukey HSD multiple comparison, control group shows non-significant differences when compare with 0.5% group, while shows significant differences with 1% group and highly significant differences with 1.5% by wt. CNF groups, in addition to that 0.5% by wt. CNF group shows non-significant differences with 1% groups and highly significant differences results when compared with1.5% group, in addition to that 1% group shows significant differences results when compared with1.5% group. As (Table 6)

Silicone generally exposed to deterioration in their physical and mechanical properties, color

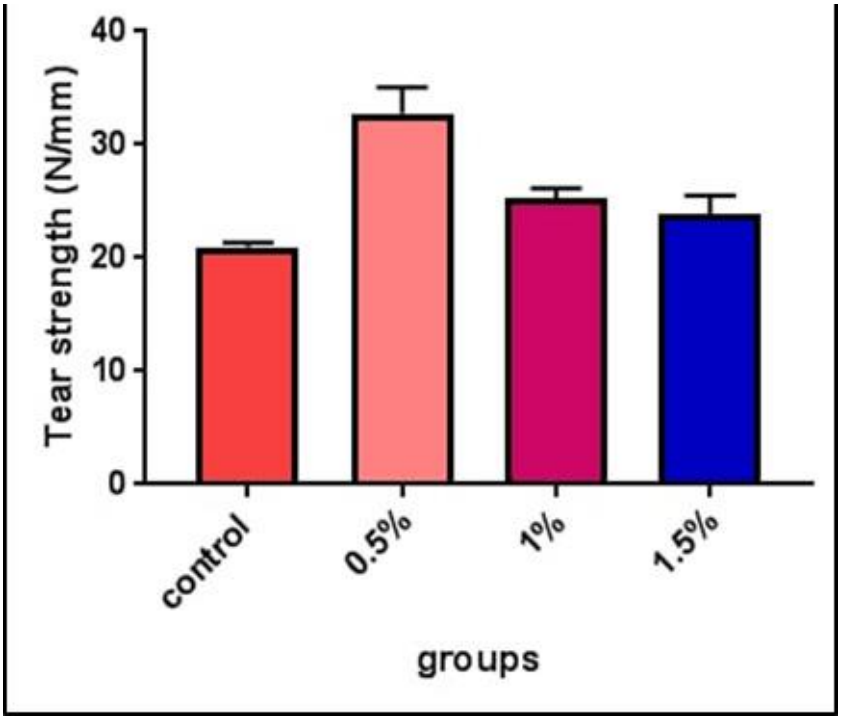

Fig. 5. Bar chart representing tear strength test results.

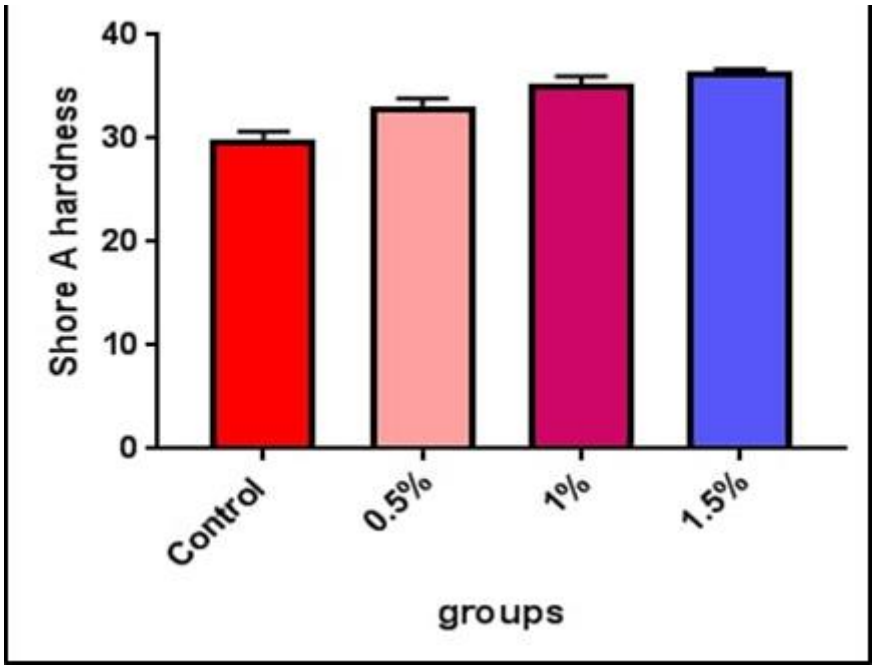

Fig. 6. Bar chart represents shore A hardness test results.

change, and loss of the retentive substrate. Such problems become the interesting subject for numerous studies that investigating properties (i.e. tear strength, surface roughness and surface hardness) [9].

Nano cellulose fibers was selected in this study because it has good physical and mechanical proper-ties (high hardness, rigidity and thermal stability) and it provides the highest reinforcement to rubber products which is ascribed to its small fibers size (high surface area) and chemical reactivity. Nano cellulose fiber is also abundant and inexpensive [10].

Numerous factors affect the silicone elastomer's mechanical characteristics. The molecular weight distribution, which has a significant impact on the material's mechanical properties, is the most significant of them. The method of combining silicon polymer and cellulose nanofiber, an organic polymer that produces a broader and combines two forms of molecular weight distribution, results in a network de-scribed as a bimodal network [11].

When compared to unreinforced silicone (control group), the findings of the tear strength

Table 4. Multiple comparison of Tukey HSD for shore A hardness test.

(I) Groups		Mean Difference (I-J)	Sig.
Control	0.5%	-3.18000	0.000
	1%	-5.32000*	0.000
	1.5%	-6.60000	0.000
0.5%	Control	3.18000*	0.000
	1%	-2.14000*	0.001
	1.5%	-3.42000*	0.000
1%	Control	5.32000*	0.000
	0.5%	2.14000*	0.001
	1.5%	-1.28000*	0.043
1.5%	Control	6.60000*	0.000
	0.5%	3.42000*	0.000
	1%	1.28000*	0.043

* The mean difference is significant at the 0.05 level.

Table 5. Surface roughness results and ANOVA table of pilot study (μm).

Surface Roughness results in (μm)					F test	P value
Cellulose Nanofiber percentage	0%	0.5%	1%	1.5%		
Mean	.32200	.33460	.37460	.42120	15.529	0.000
SD	.011269	.015010	.025570	.039670		

test given in Table 1 showed that tear strength is raised at 0.5% cellulose nanofiber concentration and de-creased at other concentrations. This might be brought on by CNF's chemical and physical interactions with the chains of silicon polymer.

The interaction between nanofibers and polymer chains lead to increasing the cross-linking system, cross-linking density, all that play a major roles in the vulcanized silicone elastomer's tear strength [12, 13, 14].

First reason CNF's surface hydroxyl group and the oxygen in the polymer chain could establish po-tent hydrogen bonds by the adsorption of polydimethylsiloxane chains to the surface. These connections, which have a high shear strength between the nanofibers and the polymer chains, make polymer chains more resistant to rupturing when subjected to tearing forces [15].

Second reason, the tear strength of elastomers can be increased by the rubber silicone substance by diffusing stress energy adjacent to the expanding faults. As a tear spreads throughout nanofibers which disperse the energy within the polymer matrix, making it more resilient to tears and requiring a higher load to complete the fracture [16].

The cause of the findings of the tear strength results test showing a decrease at CNF concentrations of 1% and higher may be attributed. Due to stress concentration sites being created at the specimen's surface or inside of it by CNF aggregation or agglomeration, which may be the result of tiny fissures forming be-tween the nanofibers and matrix, the silicone material would fail sooner than expected.

Tear strength finding results of this study coincide with Guany in 2008 [17] who found the incorpora-tion of Tulle fibers to RTV silicone

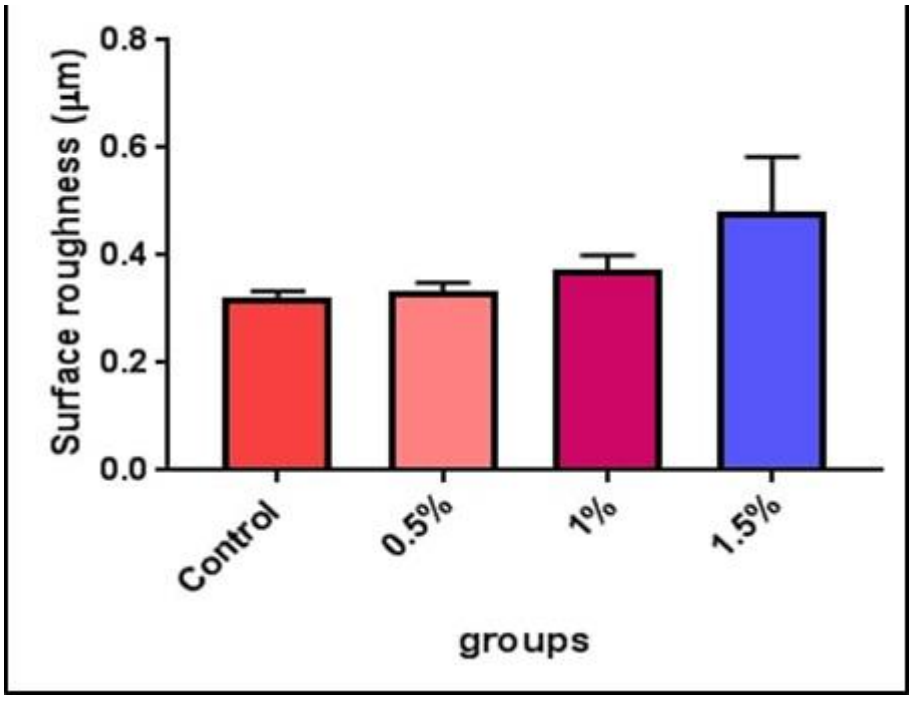

Fig. 7. Bar chart representing surface roughness test results.

Table 6. Multiple comparison of Tukey HSD for shore A hardness test.

(I) Groups		Mean Difference (I-J)	Sig.
Control	0.5%	-.012600	0.860
	1%	-.052600*	0.022
	1.5%	-.099200	0.000
0.5%	Control	.012600	0.860
	1%	-.040000	0.100
	1.5%	-.086600*	0.000
1%	Control	.052600*	0.022
	0.5%	.040000	0.100
	1.5%	-.046600*	0.046
1.5%	Control	.099200*	0.000
	0.5%	.086600*	0.000
	1%	.046600*	0.046

*. The mean difference is significant at the 0.05 level.

improve the tear when compared to non-reinforced silicone. Also, the results agree with Al-Obaidi and Moudhaffer in 2019 Who investigated the addition of the halloysite nanotubes to RTV silicone [18].

The increase in surface hardness was directly proportional to the increase of CNF concentration. This could be due to dispersing of CNF in the silicone elastomer, which increases the cross-link density, there by leading to increased hardness, this result was agreed with Tukmachi et al. in 2021 who evaluated the addition of zirconia nanopowder into elastomeric silicone [19].

The results of surface roughness indicated increase of roughness values with increased Cellulose nanofibers concentration in VST50 silicone elastomer (RTV) when compared with non-reinforced silicone (control group). For instance, it has been evaluated that the fine random dispersion of CNF in PDMS, forming PDMS/CNF composites lead to increase the surface roughness [20].

CONCLUSION

Incorporating different weight percentages of Cellulose Nanofibers (0.5% -1%) wt. into VST 50 (RTV) maxillofacial silicone significantly improved in Tear strength. with the optimum improvement obtained at concentration of 0.5% CNF by weight.

Cellulose Nano fibers increased the hardness and surface roughness of the silicone. The increase was directly proportional to the Nanofibers concentration increase. but this rise in acceptable clinical range with no effect on other material properties notably at 0.5% CNF by weight.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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