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The Impact of Aloe Vera Herbal Extract on the Antifungal and Mechanical Properties of Maxillofacial Prosthetic Silicones

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Abstract

Objectives: The study aimed to evaluate the antimicrobial efficacy and some mechanical properties of maxillofacial silicone after incorporating aloe vera oil.

Materials and Methods: Two concentrations of aloe vera oil were added to the room temperature vulcanized maxillofacial silicone. Three tests were conducted (disk diffusion test, tear strength, and shore A hardness) using standardized conditions. Statistical analysis involved the use of one-way ANOVA and Tukey's post-hoc tests.

Results: It was revealed that aloe vera oil has strong antifungal properties for 1% and 2% incorporated specimens as there was large inhibition zone (5.94 mm and 8.45 mm respectively) around the incorporated specimens compared to control specimens. Tear strength was decreased after the addition, while hardness was increased especially for 2% incorporated specimens but still within acceptable limits.

Conclusions: The study contributes valuable insights into the development of antimicrobial silicone material reinforced with Aloe vera oil, advancing maxillofacial materials towards improved patient outcomes and enhanced health.

Keywords: Aloe Vera; Candida albicans; Disk Diffusion; Shore A Hardness; Tear Strength.

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Introduction

For those with facial damage, congenital malformations, or post-surgical interventions, maxillofacial silicone prostheses are essential in restoring facial aesthetics and function [1,2]. Wearers must receive the necessary care to ensure their longevity and well-being, and disinfection is an essential component in preventing microbial colonization and maintaining hygiene [3,4].

One of the most significant issues with using silicone prostheses is the microbial colonization of their surface by bacteria, fungus, and plaque, which can lead to mucosal infection and/or inflammation [5,6]. A medicinal cost plant might hold the key to finding a novel antimicrobial agent considering the global consumption of antimicrobial medications, which has resulted in the evolution of resistant bacteria species [7]. Many plant extracts can serve as natural alternatives to manufactured medications since medicinal plants are affordable, safe, and efficacious [8,9].

Aloe vera is regarded as the most powerful, significant to the economy, and well-liked plant in the scientific community. About 200 active chemicals, including amino acids, carbohydrates, enzymes, vitamins, minerals, saponins, anthraquinones, lignin, and salicylic acid, are present in various plant sections, along with about 75 nutrients [10]. The rind

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contains carbohydrates, lignin, pectin, hemicellulose, and cellulose, while the blossoms include volatile substances and ascorbic acid. Analogously, different organic acids, enzymes, phenolic compounds, minerals, and vitamins can be obtained from the leaves [11,12].

Aloe vera is widely recognized for its anti-inflammatory, antioxidant, antidiabetic, immune-boosting, anti-aging, and anticancer qualities. It also relieves sunburn. Owing to its distinct composition, aloe vera has been used in a variety of industrial applications [13]. This study provides an overview of the medicinal properties of aloe vera as well as its uses in culinary and cosmetic products. Furthermore, spoken about are risks connected to using aloe vera and related safety measures.

Materials and Methods

Materials used

In this study, aloe vera oil (Nature in Bottle, India) and VST-50 room temperature vulcanized silicone (Factor II Inc., USA) were used.

Specimen grouping

In this in-vitro prospective investigation, 90 silicone specimens (30 for antifungal testing, 30 for hardness testing, and 30 for tear testing) were used. The specimens were separated into three groups (10 each) based on the amount of oil combined with silicone (0% Control, 1%, and 2%).

Acrylic molds preparation

AutoCAD 2015, developed by Autodesk Inc. in San Rafael, CA, USA, was used to create the dimensions, which were then cut using a laser cutting device (JL-1612, Jinan Link Manufacture and Trading Co., Ltd., China) according to each test. The mold consists of three parts: the base, the mold space into which silicone was poured, and the lid. G-clamps, nuts, and screws are used to attach the mold pieces together.

Mixing

As advised by the manufacturer, the mixing ratio was 10 parts A (base) to 1 parts B (catalyst) by weight. The manufacturer also suggests utilizing a vacuum mixer or vacuum chamber (Figure 3) to prevent air entrapment, which affects mechanical qualities. To achieve the greatest results from mixing and curing, the operation should be carried out at 23°C and 50% relative humidity [19]. The samples with additional oil were created by adding the oil to silicone material at two different concentrations (1%, and 2% by weight). To establish an appropriate base to catalyst ratio, the additional oil's weight was deducted from the weight of the base (Part A) and then added to the catalyst (Part B).

Preparation and storage of specimens

Specimens were made by covering the mold cover with two layers of alginate solution as a separating medium, then gently pouring silicone mixture into all sample areas, slightly overfilling to assure completeness. The top piece of the mold was then joined over the matrix part with mild hand pressure, screws, nuts, and G-clamps to remove air bubbles and excess silicone. Polymerization took 24 hours at room temperature (23±2°C), following which samples were carefully removed from the mold. Cleaning included washing with tap water, drying with paper towels, and fine-tuning with a scalpel to remove excess material [14].

Disk diffusion test

To conduct the Disc Diffusion test, Sabouraud dextrose agar (Oxoid, England) was prepared and put into sterile petri plates per manufacturer directions. The disc

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diffusion technique, as recommended by WHO, was used to evaluate the antifungal properties of Aloe vera oil put into silicone material specimens. To generate a fungal suspension, 4-8 isolated Candida albicans colonies were selected from the incubated culture and placed in a test tube containing 4 mL of normal saline. A sterile cotton swab was then used to inoculate a tiny quantity of the fungal solution and streak it equally across the surface of the Sabouraud dextrose agar medium. The infected plates were then allowed to dry for ten minutes.

Disk shaped specimens (10 mm diameter and 2 mm thickness) were used. The specimen discs were carefully placed on the agar with sterile forceps and gently pushed to establish appropriate contact with the agar surface. Plates were then incubated at 30 ºC for 18-24 hours. The inhibition zones were then measured using a millimeter scale.

Tear strength

Specimens with an apex and two ends were designed and tested in accordance with the ISO 34-1:2015 standard. The thickness measures 2±0.2mm. A digital caliper was used to determine the thickness of the angled section where tearing may occur. The testing was carried out with a universal testing equipment. The testing speed was 500mm/minute. To uniformly distribute the force within the specimen, it must be held accurately between the grips of the machine. The specimens were held 30±0.5 mm apart. The lower grip was fixed while the upper grips were movable. The highest force at break (N/mm) was measured to determine tear strength (Figure 1).

Figure 1. Tear strength test using a universal testing machine.

Shore A hardness

The test samples were made in line with ISO 7619-1 (2010) criteria, with each measuring 40mm long, 40mm wide, and 6mm thick. These dimensions were chosen to guarantee that there was enough exterior surface area to conduct five measurements with a shore A durometer (Ezitown, China) at 6mm between each spot. Furthermore, a 12mm distance from the sample margin was maintained to ensure accurate hardness testing in compliance with the standards. The average of the five hardness values was then determined for each sample.

Statistical analysis

The statistical analysis used SPSS version 26. To establish the difference between groups, independent t test, a one-way ANOVA and a Tukey's post hoc test were used with a significance threshold of P=0.05. $P < 0.05$ was judged significant, while $P < 0.01$ was regarded highly significant.

Results

Disk diffusion test

The results revealed an increase in the inhibition zone around the specimens that were incorporated with 2% Aloe vera oil compared to those incorporated with 1% Aloe vera oil (Table 1 and Figure 2), while there was no inhibition zone around control specimens (Figure 3). Control group was not included in the statistical analysis as there was no inhibition zone around control specimens.

Table 1. Descriptive statistics and one-way ANOVA test for disk diffusion test.

Groups	N	Mean	Standard Deviation	Standard Error +Mean
1%	10	5.949	0.37	0.117
2%	10	8.4521	0.74329	0.23505

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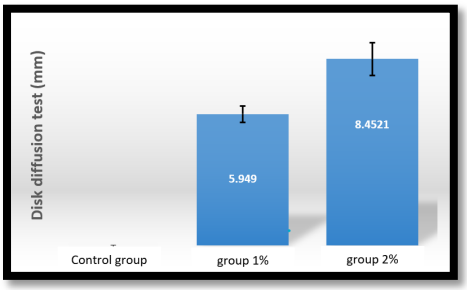

Figure 2. Bar chart representing the means and standard deviation for 2% and 1% incorporated specimens.

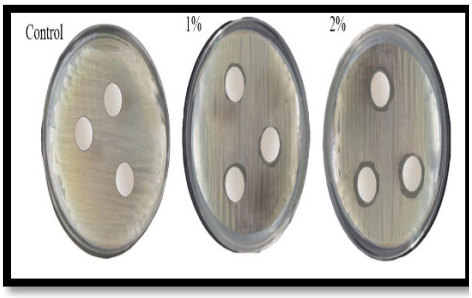

Figure 3. Disk diffusion test result for each group.

Independent T test revealed highly significant difference between 2% specimens and 1% specimens as indicated in (Table 2).

Shore A Hardness

The experimental groups (1% and 2%) revealed higher hardness levels than control group (Figure 4). Also, there was highly significant difference between the control group and group 1% and 2% respectively, while there was non- significant difference between 1% group and 2% group (Table 3).

Table 4. Descriptive statistics, one way ANOVA, and post hoc test for tear strength test.

Table 2. Independent T test for disk diffusion test.

Group	Minimum	Maximum	Mean	±SD	F	P-value	Groups	P-value
B	44.14	44.83	44.527	0.24676	30.995	0.000	A B	0.000
C	44.88	45.21	45.086	0.10824			A C	0.000
D	44.88	45.63	45.207	0.234			B C	0.395
Levene statistics=3.826, p-value=0.34								

Table 3. Descriptive statistics, one-way ANOVA, and post hoc test for shore

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	P-value	t	Degrees of freedom	p-value (2-tailed)
Equal variances not assumed	6.396	0.021	-9.533	13.202	.000

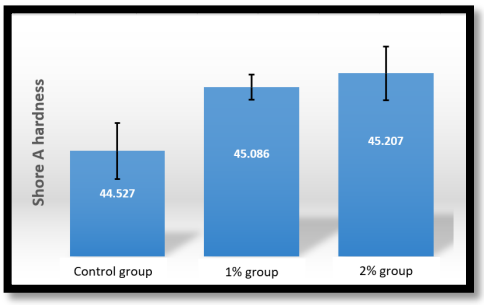

Figure 4. Bar chart representing the means and standard deviation of shore A hardness for the groups.

Tear strength

Tear strength was decreased after the addition of Aloe vera oil especially for 2% incorporated

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specimens (Figure 5) as there was a highly significant difference between 2% group and control group, also a highly significant difference between 2% and 1% groups, while there was a non-significant difference between control group and 1% group (Table 4).

Table 4. Descriptive statistics, one way ANOVA, and post hoc test for tear strength test.

					ANOVA		Tukey HSD	
Group	Minimum	Maximum	Mean	±SD	F	P-value	Groups	P-value
B	24.53	27.53	26.0300	.97183	13.728	.000	A B	0.39
C	22.51	28.51	25.2100	1.82878			A C	0.000
D	21.42	25.42	22.9200	1.17851			B C	0.003
Levene statistics=2.017, p-value=0.153								

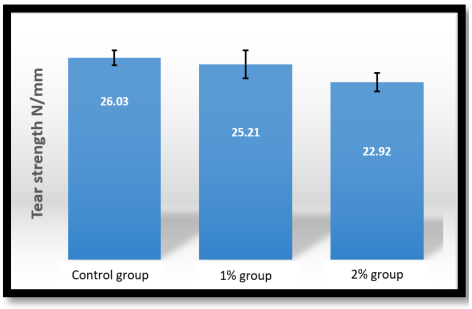

Figure 5. Bar chart representing the means and standard deviation of tear strength for the groups.

Discussion

The rich composition of bioactive substances in Aloe vera, such as acemannan, emodin, and aloin, which are known for their antimicrobial qualities, was the key behind its incorporation into RTV silicone. Through a variety of interactions, these components compromise fundamental cellular activities necessary for fungal growth and proliferation and damage the integrity of fungal cell membranes. For example, anthraquinone derivatives such as aloin and emodin can pass through the cell walls of fungi to change the permeability of the membrane and allow internal elements like proteins and ions to seep out.

The result of this disturbance is cellular malfunction and apoptosis, which effectively stops fungal growth [15].

The present investigation thoroughly assessed the efficacy of aloe vera oil at 1% and 2% concentrations in conferring antifungal characteristics on RTV silicone. Clear inhibition zones surrounding the silicone samples containing aloe vera oil were shown by agar diffusion tests, indicating that the oil had the capacity to stop fungal growth. The reason for this is that bioactive molecules from the oil diffuse into the surrounding agar media. There, they interact with the fungal cells, causing damage to their membrane integrity and preventing them from proliferating [16].

Additionally, aloe vera contains acemannan, a polysaccharide that is essential for boosting the immune system's defenses against fungal infections at the molecular level. Acemannan stimulates the generation of antimicrobial peptides and increases phagocytic

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activity through interactions with immune cells and cytokines. Acemannan may improve RTV silicone's capacity to control immune responses at the application site, which would increase the material's antifungal activity in concert [17,18].

Aloe vera oil and RTV silicone interact chemically when bioactive substances are incorporated into the silicone matrix during the curing process. Aloe vera oil molecules are incorporated into silicone polymer chains by crosslinking, which enables an antibacterial agent to release continuously throughout time. Aloin, emodin, acemannan, and other active ingredients are continuously exposed to fungal infections thanks to this sustained release mechanism, which prolongs the antifungal action [19].

Physically, aloe vera oil may change the hydrophobicity and surface characteristics of RTV silicone, affecting how well it interacts with fungi and their biofilms. Fungal colonization and persistence can be further inhibited by including hydrophilic and amphiphilic components from aloe vera oil, which can interfere with biofilm development and adhesion to silicone surfaces [20].

Notwithstanding the advantageous antifungal characteristics noted, there was a discernible compromise in the silicone's mechanical attributes, specifically regarding tear strength. In applications like maxillofacial prosthesis, where durability and longevity are critical for long-term performance, the tearing of silicone materials is important. There are several reasons why adding aloe vera oil, particularly at higher doses (2%), resulted in a reduction in tear strength. Disruption in the Silicon Network Since aloe vera oil is a non-reactive filler, it might damage the silicone matrix's crosslinked structure. Oil can prevent silicone chains from forming strong bonds during the vulcanization process, which is when silicone chains crosslink to form a sturdy network. As a result, the material develops isolated weak points that make it more [21]. Aloe vera oil serves as a plasticizer, improving the flexibility and decreasing the overall stiffness of silicone. While this can improve some qualities, too much plasticization can reduce tear resistance by weakening cohesiveness between silicone strands. The inclusion of aloe vera oil may cause gaps or abnormalities in the silicone matrix. These microstructural alterations can operate as stress concentration areas, allowing tears to form and spread more easily under mechanical loads [22,23].

Interestingly, despite the decreased tear power, the addition of aloe vera oil resulted in a modest rise in Shore A hardness. Shore Hardness is a measure of a material's resistance to indentation, with higher values suggesting stiffer material. This rise can be ascribed to oil filling up micro voids or holes in the silicone matrix, resulting in a denser material structure [24]. However, it is worth noting that the increase in hardness was minor in comparison to the loss in tear strength, indicating a complicated interplay between material attributes.

Conclusions

In conclusion, while aloe vera oil shows promise as a natural antimicrobial additive for RTV maxillofacial silicone, its incorporation necessitates a careful balance between enhancing antifungal properties and maintaining mechanical integrity. Further research is essential to refine formulations and optimize performance for practical medical applications.

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