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Tensile Strength and Water Sorption of The Modified Soft Liner with Two Types of Plasticisers

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Abstract

Aims: Evaluate some mechanical and physical properties of Acrylic-based soft- liner modified with two types of plasticisers by adding plasticisers Di-2-ethylhexyl phthalate (DEHP) and glycerol in two distinct weight percentages (2% and 5%).**Materials and Methods:** a Total of 90samples were prepared ,45 specimens for tensile strength test with a Dumbbell-shaped specimens and a central cross- sectional area of (25 × 4 × 2 mm) were produced by an acrylic-based soft liner(EZ- soft liner, Korea) divided into 5 groups according to the amount of plasticiser added, and 45 specimens were prepared for water sorption , with the a dimension of(10 diameter x 5mm thickness) and divided into 5 group also according to the amount of plasticiser added. The anaylsis of sorption was based on the intial dry weight and on the wet and dry weight after immersion. Software for statistics was used to examine the data (SPSS).
Results: In comparison to the other groups, the groups that were changed by plasticisers exhibited a considerable decrease in tensile strength for both materials. Sorption was higher in the group C and D than in the control group.

Introduction:

A soft denture liner, which supports and cushions the fragile mucosa and alveolar ridge, is the most likely replacement prosthesis for rehabilitation for the heat-polymerized acrylic resin denture [1].

Resilient liners are used to relieve mouth ulcers caused by dentures, ridges with tissue undercuts, non-resilient, poor soft tissue coverage, and ill-fitting dentures. They also help to provide more consistent force distribution and reduce localized pressure [1,2].

Gradually modifying the denture foundation, they can also impact a denture's functionality (such as eating, speaking, and appearance) and potentially lead to psychological problems in elderly denture users [4]. The most often utilized long-term soft liners are made of plasticisers, which keep the material soft and resilient therefore, they are used for extended periods of time months or years. In order to reduce the modulus of elasticity of the soft material to the appropriate level, the plasticiser must lower the polymer's "glass transition temperature" to below oral temperature[5].

When these materials are used in clinical settings, the most common problems that arise include hardening, resilience loss, water sorption, color change, affinity for microbial adherence and development, and separation from the denture base[6].

Aims of the study:

The aim of this research was to evaluate the mechanical properties of soft-liner that had been modified with two distinct types of plasticisers and to find out how strong the combination of plasticisers and soft-liner was.

Methods and Materials:

The inclusion of plasticiers:

By substituting an identical volume percent of plasticisers integrated into the soft-liner for the volume percentage fraction of the monomer, the weighted plasticisers were introduced to the acrylic-based soft-liner (EZ-soft liner, Korea)[7].

In order to establish a homogeneous mixture of plasticisers and monomer, a digitized electrical balance with an accuracy of 0.001 was used to prepare each concentration as directed(Worner Lab Co., China). Using a dental vibrator, for five minutes, the soft-liner monomer with plasticiser addition was shaken[8].

The main study groups are:

Group (A): 0% additives in control group

Group (B): 2% glycerol in experimental group

Group (C): 5% glycerol in experimental group.

Group (D): 2% DEHP(Di-2-ethylhexyl phthalate)in experimental group.

Group (E): 5% DEHP(Di-2-ethylhexyl phthalate)in experimental group.

Tensile strength:

Type II dumbbell-shaped specimens were produced according to ISO 37, (2017) specifications, as shown in Figure 1(A). Plastic molds in the shape of dumbbells were used to construct the mold spaces inside the dental stone[10], as shown in Figure 1(B).

The previously mentioned method was used to create the experimental and soft-liner control samples.

The testing process was completed using a universal testing machine (Gester, China). The specimen moved at a constant speed 500 mm/min after its end was tensioned in the tensile machine's grips[9].

The tensile strength was obtained using the following formula, per ISO 37 (2017).

$TS = F/\mathrm{A}$ (MPa)

Where:

F: the greatest Newtonian force at fracture (N)

A: area cross-sectional of the constricted section(thickness x width) in (mm^2)

Water sorption:

45 samples total, 9 in each group, were created with the following measurements:10 diameter x 5 mm in thickness[11] as shown in Figure (2). After processing, the samples were dried using silica gel in a 37°C desiccator until their weight stabilized. The initial weight (W1) of the specimens was ascertained by weighing them using an electronic balance with an accuracy of 0.001 grams. Following that, the samples were submerged in distilled water and

maintained for 14 days[12] in an incubator at (37 ± 1)°C on the thermostat. Following that, the samples were taken out of the water using tweezers, dried with absorbent paper until they were completely dry, waved in the air for fifteen seconds, and then weighed once more. This mass (W2) was seen to be the moist mass.

Following each sorption cycle, The samples were dried in a desiccator set to 37 °C using silica gel,until the desired weight was stable, the samples were often reweighed using a digital electrical balance with 0.001 precision. After desiccation, the ultimate weight (W3) was recorded as this[13].

This is how the % absorption was calculated:

absorption (%) = $\frac{W2-W3}{W1} \times 100$

W1: The initial weight of the specimen.

W2: The specimen's weight after absorption.

W3: Final weight of the specimen upon drying (Figuerôa *et al*.,2018).

Results:

Tensile strength:

The tensile strength mean and standard deviation for the materials used to the soft-liner in the study are provided in Table (1). In comparison to the control group, the additive groups (plasticisers) exhibited decreased tensile strength in terms of mean and standard deviation.

The results of the ANOVA test indicated that the groups with plasticiers had statistically significant differences at (p=0.0001) as shown in Table (2).

Figure (3) given Duncan's test of several ranges, which demonstrated:

▪ The tensile strength mean control group (soft-liner with no additives) had a significantly the higher mean of tensile strength (1.896) and was significantly not different from the group with 5%glycerol with a mean of (1.842)

▪ Additionally, there is no difference between the groups with 2% glycerol (1.358) and 5% DEHP (1.114).

▪ Significantly, the group with 2% DEHP had the lowest mean value (0.7888).

Water Sorption:

The water sorption mean and standard deviation values for the experimental and control groups are shown in Table (3). The results indicated that the experimental groups' water sorption had increased relative to the control group.

The experimental group's water sorption was shown to be significantly higher than the control group's at $p \leq 0.05$, according to the one-way analysis of variance (ANOVA) tables (4).

Duncan’s multiple comparison test in Figure (4)showed that:

▪ The water sorption of the control group, with a mean of (5.27222), and the experimental group, which included 5% DEHP concentrations, with a mean of (4.63444), did not vary statistically.

▪ The addition of 2% concentration of glycerol resulted in a mean of (7.67778) as compared to that of the control group at $p \leq 0.05$ was significantly different from other groups .

▪ The experimental group that included 2% DEHP concentrations in its water sorption had a mean of 9.523333, which was not significantly different from the group that included 5% glycerol, with a mean of 10.53667.

Discussion:

Poor tear strength and a gradual loss of softness were two of the most significant problems[14].

Ethanol and the plasticisers that leaches into the oral environment[15,16], along with the material's absorption of water, together affect the loss of viscoelasticity[17].

Plasticisers are used to improve the cost, ease of processing, and flexibility of polymers. In an ideal world, plasticisers would be cost-effective, easy to use, and compatible with the host polymer[18].

Hong[17]*et al*.,(2020)found that citrate ester-based plasticizers work better when utilized with soft polymer materials used for dentistry. Despite the limits of this in vitro investigation, the findings indicate that adding a plasticizer based on citrate ester may improve the durability of dental soft polymer materials.

Tensile strength:

Rubbers that are utilized as soft-liners and tissue conditioners are only exposed to shear and compression forces, but their tensile properties are important for evaluating their overall performance and quality. This is because they are therapeutically linked to the material's ability to withstand rupturing while the relined denture is being used in conditions of low oral humidity[(20)].

Elongation provides information about a material's capacity to bend before failing, tensile strength, on the other hand, represents a rubber's largest strength under stress. Some rubbers are just subjected to compression and shear, just like with soft lining materials, although tensile properties are recognized as an inclusive indicator of rubber quality. Tensile strength and hardness give a general indication of compatibility of the materials since hard material with low tensile and elongation strength would not be suitable for use as a soft lining material[(21)].

Table (1) shows that the plasticiser-treated groups to the control, the mean tensile strength decreased, with the specimens treated with 2% DEHP seeing the most drop ($p < 0.0001$).

The findings of this study disagree with those of Mohad and Fatalla (2019)[(21)], who found that the use of concentrations of 2%, 3% by weight (adding KAL (SO4)2 micro-particles to the soft-liner) and KAL(SO4)2 solution at concentrations of 5%, 10% (immersing the soft liner in KAL(SO4)2 solution) resulted in a significant increase in the mean values of the experimental groups. The weight KAL(SO4)2 microparticles showed the greatest growth, which was recorded at 3%. Our results are consistent with those of Kareem and Al-Nema (2023)[(23)], who found that all disinfected soft-liners had a decrease in tensile bond strength when compared to the control; this decrease was significant when it came to the NaOCl group but not the protefix tab, chlorhexidine, or microwave groups.

Water Sorption:

The amount of water that the body has absorbed after being adsorbed on the surface when a restoration is being fabricated or is in use is known as the water sorption of the material[(22)].

Although El-Hadary and Drummond (2000)[(24)] mention the fact that throughout their lifespan, these products come into contact with saliva, food, water, and cleansers, which could lead to water sorption and the loss of plasticisers and other soluble components. Under ideal conditions, a resilient liner would have few insoluble components and show low water sorption[(15,25)].

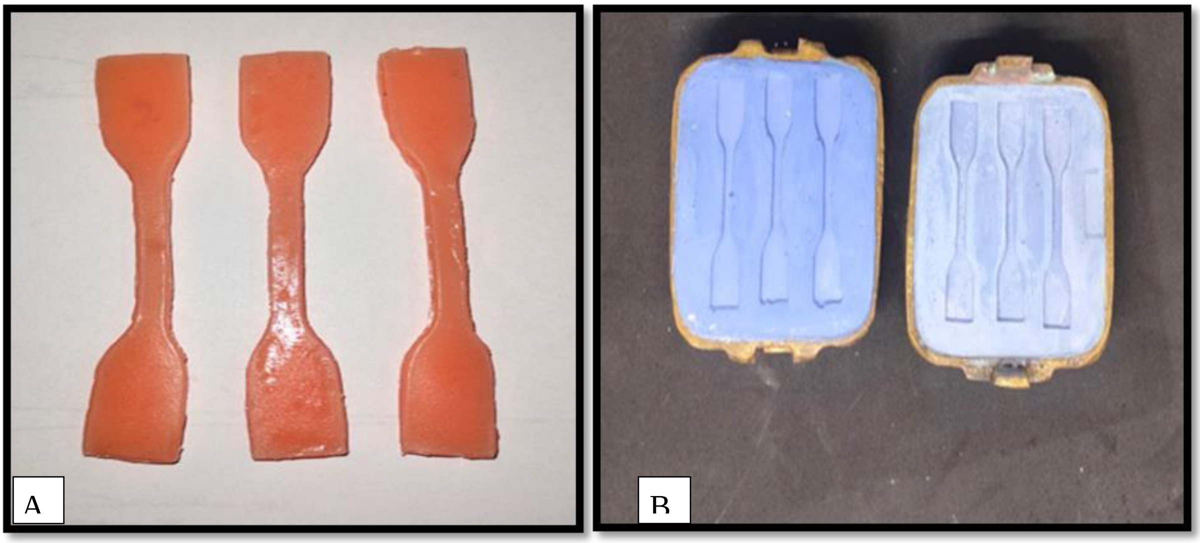
At various plasticiser concentrations, the addition of soft-liner results in an increase in the water sorption values. This effect may be caused by immersion in water, monomer residues, immersion in leaching agents, and plasticiser residues. Therefore, increased absorption of water is the outcome of improved microporosity caused by the water[(26-28)].

Our research's findings differ from those of Ergun et al. (2022)[(29)], who came to the conclusion that adding modified ZrO2 nanofiller would be a potential solution to the problems with water sorption and solubility associated with the usage of denture liners.

Consistent with our findings, Garg and Shenoy (2016)[(30)]found that the acrylic-based self-cure soft denture liner had the greatest water sorption in pure water and the lowest in artificial saliva from Shellis and 5.25% sodium hypochlorite.

Conclusions:

Tensile strength was improved by adding plasticisers to the soft-liner material at two different concentrations (2% and 5%). Modified soft liner containing 5% DEHP plasticisers showed the lowest water sorption, whereas modified soft liner containing 5% glycerol showed the highest water sorption.



Figure(1):A:The tensile strength test specimens B: stone mold spaces after removal of plastic models

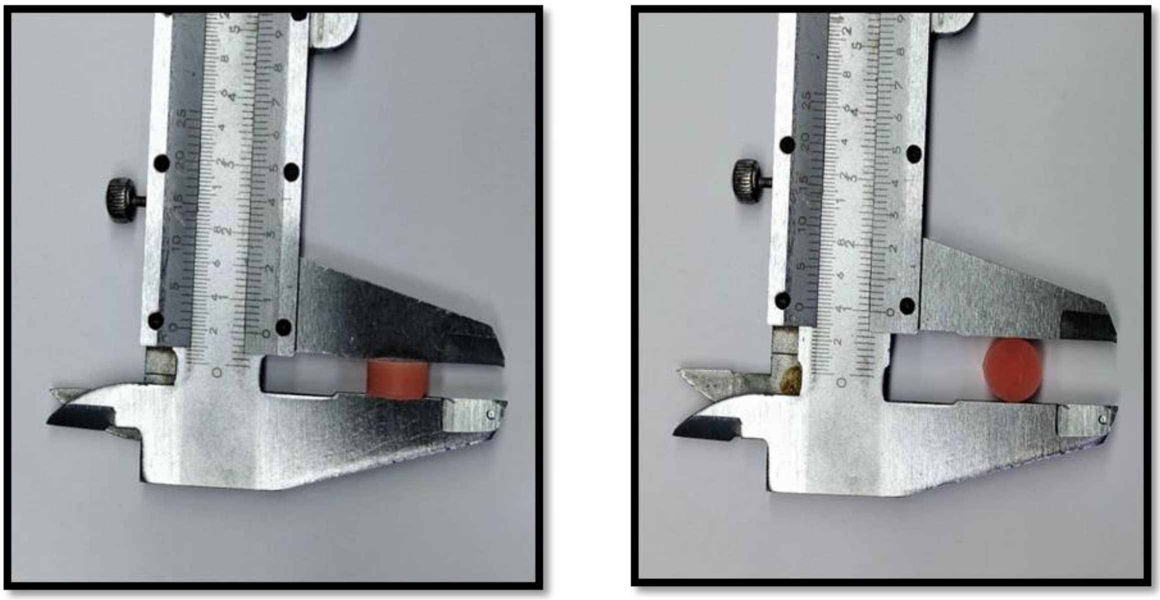


Figure (2): dimensions of water sorption specimens.

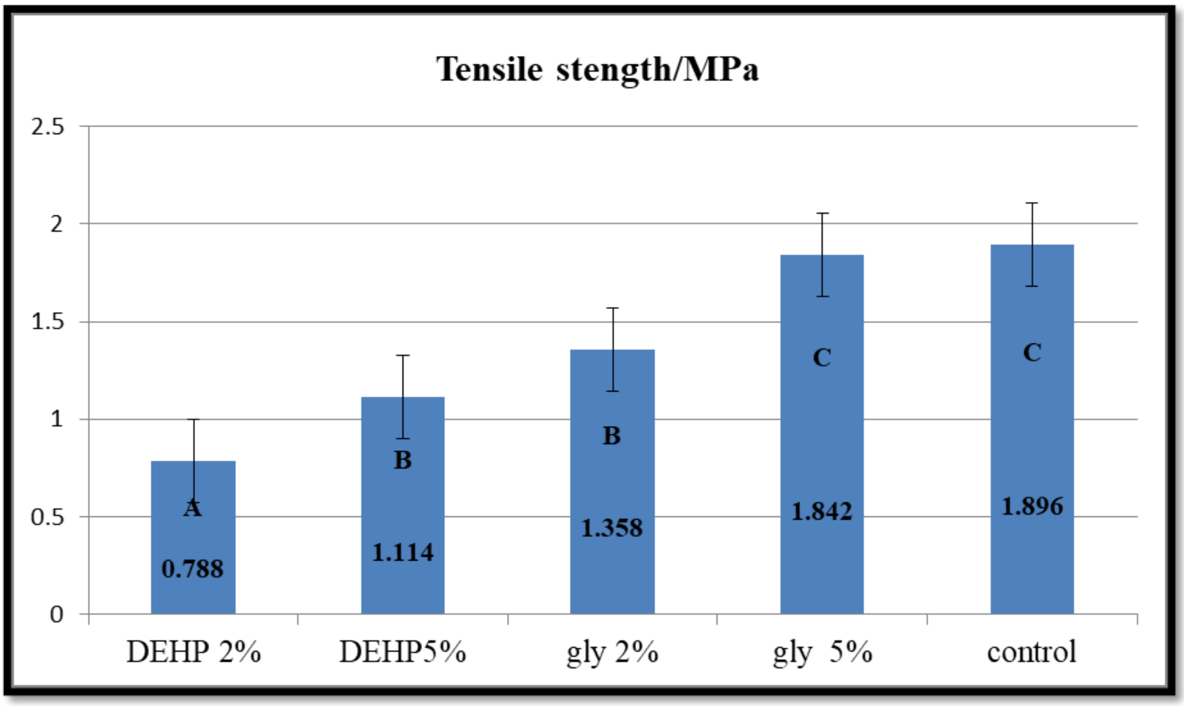


Figure (3): Bar chart representation of Duncan’s multiple range test for tensile strength

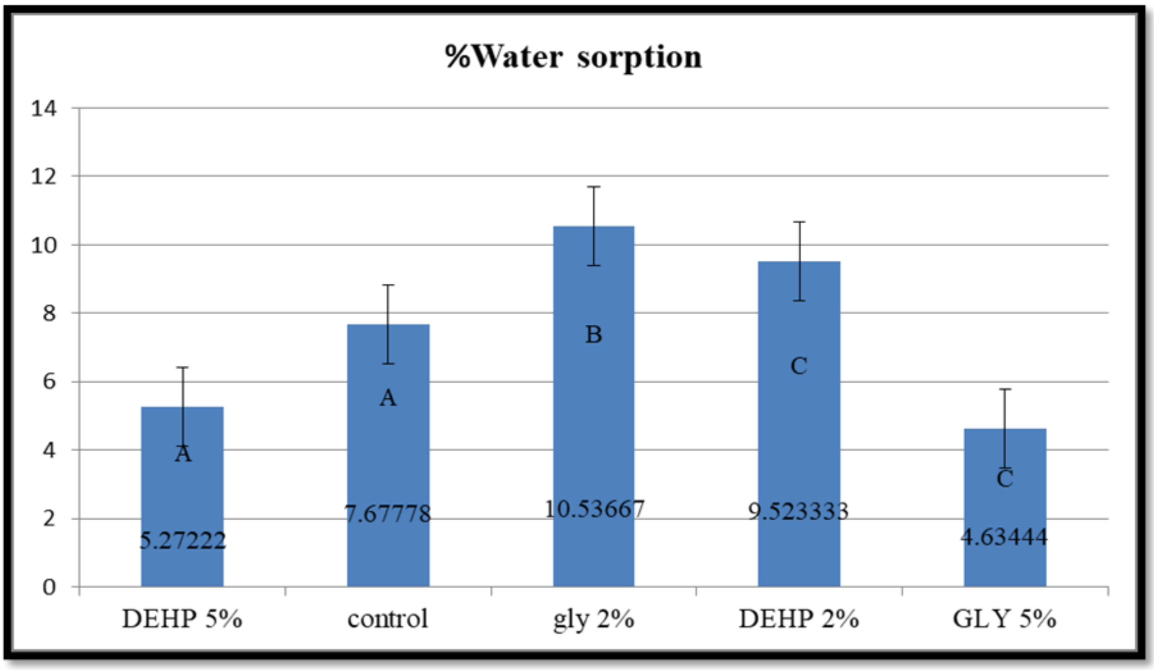


Figure (4): Bar chart representation of Duncan’s multiple range test for water sorption

Table (1): show mean value and standard deviation of tensile strength groups

Study groups	Number of samples	Mean	Std.deviation
Group (A) Control	9	1.896	0.22063
Group (B) Glycerol 2%	9	1.358	0.21429
Group (C) Glycerol 5%	9	1.842	0.26357
Group (D) DEHP 2%	9	0.788	0.05020
Group (E) DEHP 5%	9	1.114	0.12341

Table (2): ANOVA of tensile strength:

Source of variance	Sum of squares	Df	Mean square	F	Significance
Between Groups	8.533	4	1.124	30.919	0.000
Within Groups	1.369	40	0.036		
Total	9.902	44			

Table (3): shows mean value and standard deviation of water sorption:

Study groups	Number of samples	mean	Std.deviation
Group(A) Control	9	5.27222	1.77284
Group(B) Glycerol 2%	9	7.67778	1.30045
Group(C) Glycerol 5%	9	10.53667	0.92374
Group(D) DEHP 2%	9	9.523333	1.15448
Group(E) DEHP 5%	9	4.63444	0.62171

Table (4): shows one way ANOVA of water sorption

Source of variance	Sum of Squares	df	Mean Square	F	Significance
Between Groups	238.654	4	59.663	40.276	.000**
Within Groups	59.255	40	1.481		
Total	44				

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