

Evaluation the Effect of Incorporation of virgin coconut oil On Thermal Conductivity and tensile strength of Acrylic Soft Denture Liner Materials

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Abstract

AIMS: Evaluation the effect of incorporation of different concentration (1.5% and 2.5% by volume) of virgin coconut oil to heat cure acrylic soft denture lining material on thermal conductivity, and tensile strength.

Material and method: Sixty specimens of heat cure acrylic soft denture lining materials. The specimens were divided into two major groups according to the tests (30 for Thermal conductivity test, and 30 for Tensile strength test). Each group was sub divided into three minor groups, (10) specimens of heat cure acrylic soft denture lining materials without any incorporation (control group), (10) specimens of heat cure acrylic soft denture lining materials with incorporation of 1.5 % virgin coconut oil, and (10) specimens of heat cure acrylic soft denture lining materials with incorporation of 2.5 % virgin coconut oil. Thermal conductivity specimens were fabricated with dimensions of (40 mm diameter × 2.5 mm thickness), also The (Lee disc) Technologies, Department equipment was used to evaluate thermal conductivity test. Tensile strength specimens were fabricated with dimensions of (80mmx9mmx 3mm) for (length, width, and thickness), also the Universal Instron testing machine was used to evaluate the tensile strength test.

Result: Data statically analyzed by One-way ANOVA and LSD tests. The results of thermal conductivity tests was showed highly significant differences at $P < 0.01$. At the same time the tensile strength test showed the highly significant differences at $P < 0.01$ in the all studies groups.

Conclusion: The incorporating of 2.5% of virgin coconut oil into heat cure acrylic soft denture lining material causes increases of thermal conductivity, and increases of tensile strength.

Keywords: Soft denture liners, Virgin coconut oil, Thermal conductivity, Tensile strength.

1. INTRODUCTION

Soft denture liners are made of soft polymers that can be tailored to fit the mucosal surface of hard dentures. They play a crucial role in removable prosthodontics because they can act as a cushioning effect to preserve the health of traumatized, swollen, and damaged mucosa through the fair redistribution of stresses over the entire area that is covered by the denture, preventing the distortion of oral mucosa (Das *et al.*, 2018). One of the major flaws of the heat acrylic soft liner was lower thermal conductivity that was an important feature of the soft liner which influences the patient's acceptance of the prosthesis. As well, it has main effects on the health of underlying supporting mucosal tissues and secretion of salivary glands, especially parotid gland. In older patients, the high thermal conductivity of denture base material affects patient contentment, best taste sensation, tissue protection, and lowers the feeling of the denture as a foreign body, so many modifications have been done recently to overcome this issue and enhance the thermal properties (Kul *et al.*, 2016). It is also considered one of the major flaws of the lining materials in clinical use was the adhesive failure, and preventing fluid leakage between the liner materials and denture base is essential for long-term bonding. This lack of connection can also leave a surface that bacteria could use to grow and build plaque (Issa and Abdul-Fattah, 2015). Soft liners have been utilized as carriers for antifungal drugs in treating denture stomatitis and in order to block infection by *candida albicans* (Silva *et al.*, 2011). There has been a recent increase in interest in medicinal plants as a source of new antifungal and antimicrobial agents. Some herbal extracts, in addition to polymeric systems, are utilized as safe and efficient therapeutic agents, such as extracts from the tea, ginger, neem, and flax plants (Khan *et al.*, 2016). Oils are among the most organic herbal remedies. They have recently received praise as a potential therapy for oral microbial infections. Oils are a complex mixture of various volatile compounds extracted from herbs, and thanks to their antibacterial and antioxidant capabilities, they are able to manage a variety of pathogenic organisms (Bakhshi *et al.*, 2012; Khan *et al.*, 2016). Virgin coconut oil (VCO) is an important source of energy in the diet and is often used in hair and skin care products. Virgin coconut oil (VCO) is lower calorie oil that is facily digestion and does not cause

weight gain as it improves the metabolic activity. It improves vitamin absorption from the stomach, supports the defense mechanism of the body, lowers the risk of atherosclerosis and cardiovascular illnesses, and inhibits cancer agents (Lukić *et al.*, 2016). Virgin coconut oil (VCO) is well known and widely used in Indonesia. It can be extracted from fresh coconut flesh and has many benefits, it is cheap and easy to get, colorless and fragrant, and has no side effects when swallowed and the previous study showed that virgin coconut oil (VCO) can decrease plaque and gingival indexes significantly (Peedikayil, *et al* 2015). Virgin coconut oil (VCO) was used as a potent antifungal herbal medicament and successfully incorporated into heat cure acrylic soft denture lining material to obtain a material with a continuous natural drug delivery system against *Candida albicans* (Alamen, and Naji, 2018). The aims of this study are to evaluate the effect of virgin coconut oil incorporated with soft denture lining material on thermal conductivity and tensile strength.

2. MATERIAL AND METHOD

2.1. Samples grouping

Heat cure acrylic soft liner material, Vertex, Netherland, and Virgin coconut oil, Nature Way dent, Philippine, this material can be used in this study. The sixty specimens of heat cure acrylic soft denture lining materials, the specimens were divided into two major groups according to the tests to be used (30 for thermal conductivity test, and 30 for tensile strength test). Each group was sub divided into three minor groups, (10) specimens of heat acrylic soft denture lining materials without any incorporation (control group), (10) specimens of heat acrylic soft denture lining materials with incorporation of 1.5 % Virgin coconut oil, and (10) specimens of heat acrylic soft denture lining materials with incorporation of 2.5 % Virgin coconut.

1. Control Group: 10 specimens without incorporation of virgin coconut oil
2. Experimental Group (1.5%): 10 specimens with incorporation of 1.5% by volume of virgin coconut oil (VCO).
3. Experimental Group (2.5%): 10 specimens with incorporation of 2.5% by volume of virgin coconut oil (VCO).

2.2 Incorporation virgin coconut oil to soft liner material

The virgin coconut oil (VCO) was added in two different concentrations 1.5% and 2.5% by volume, and mixed with a liquid soft liner material to create the experimental specimens. To obtain an accurate P/L ratio, the volume of virgin coconut oil (VCO) was subtracted from the volume of soft liner liquid material (Alamen, and Naji, 2018), which was showed as (Table1).

Table 1: preparation and mixing of soft liner materials (Muttagi and Subramanya, 2017).

Sample	Soft liner Powder (g)	Soft liner Liquid (mL)	virgin coconut oil (mL)
control	12 g	10 mL	0 mL
1.5% VCO	12 g	9.85mL	0.15 mL
2.5% VCO	12 g	9.75mL	0.25 mL

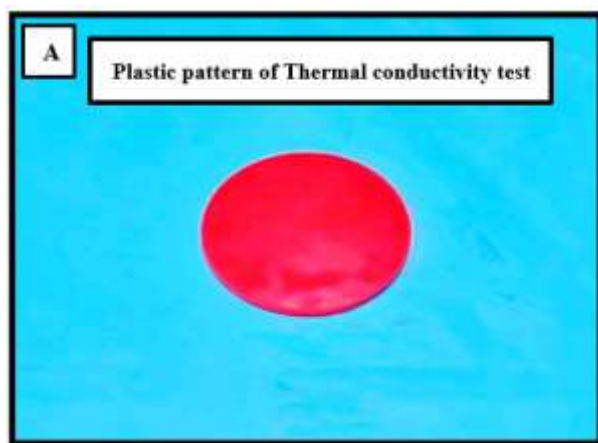
Virgin coconut oil (VCO) was thoroughly put to a dry, clean glass jar together with soft lining liquid materials, and then the combination was thoroughly homogenized using a probe sonication apparatus device for 20 seconds at 120 W and 60 KHz (Muttagi and Subramanya, 2017). In accordance with the manufacturer instructions, the soft liner powder ingredients were quickly added to the prior mixture and mixed with it (Alamen, and Naji, 2018).

2.3 Tests used in present study:

2.3.1 Thermal conductivity test:

A-Mold preparation

The disc shapes of plastic patterns were prepared with dimensions of (40mm diameter and 2.5mm thickness), (Hasan and Ali, 2018; Kamil and Al Judy, 2018), by using the plastic plate with laser cutting machine (CNC), (figure 1: A and B).



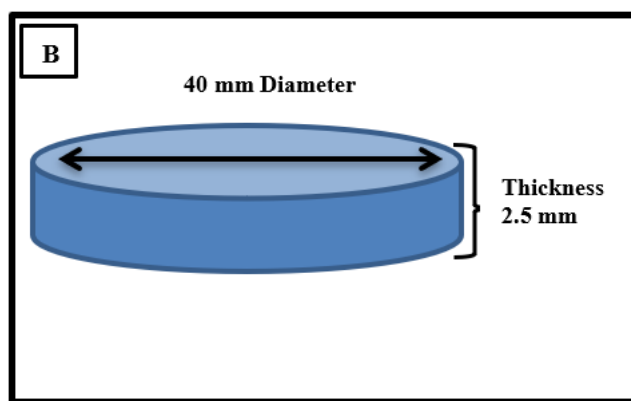


Fig. (1): (A) Plastic pattern of Thermal conductivity, (B) Dimensions of Thermal conductivity specimen

B- Specimen preparation

After the proportioning and blending of virgin coconut oil (VCO) with heat acrylic soft liner materials for the current study, all specimens were packed, cured, and deflashed after completing all steps, then the specimens were cooled under tap water to counteract overheating, and after making finishing and polishing were done as a conventional technique (Noori and Jaber, 2021). All thermal conductivity specimens were kept in an incubator with sterile water for 48 hours at 37°C to eliminate any remaining monomers before beginning testing according to (ADA specification NO.12, 1999).

C- Testing procedure

The Lee disc, a thermal conductivity device, was used in the testing process showed as figure (2). The Lee disc which consists of three copper discs (A, B and C) and it have a hole inside each disc to accommodate thermometers. Between copper discs A and B, the specimen was positioned. An electrical plate heater of 60 watts was positioned between discs (B and C). After tightening the clamp screw that holds all of the discs together, the electricity to the heater was turned on. The temperature in disc (C, B) increased more than disc A after the heater turned on due to the presence of specimen that served as an isolator, while the current 0.25 Ampere, and voltage 6 Volt delivered to the heater were monitored using a transformer. The reading was recorded and thermal conductivity was calculated when the temperature at discs C and B reached equilibrium and all components of the apparatus had been stable to within 0.1°C for 30 minutes, and thermal conductivity was calculated from the following equations (Abdulhamed and Mohammed, 2010; Noori and Jaber, 2021):

$$e = \frac{I.V}{a_A T_A + as \frac{T_A + T_B}{2} + 2aH \frac{T_B + T_C}{2} + a_B T_B + a_C T_C}$$

e : The losses in temperature per time in seconds and the difference in between discs and surrounding temperatures.

I : The electric current through a heater (Ampere)

V : The voltage within a heater (Volt)

a_A, a_B, a_C : explain the surface area of disc A, B and C respectively in m^2

as : Mean the specimen surface area in m^2

aH : Mean the heater surface area in m^2

T_A, T_B, T_C : This explain the temperatures of discs A, B and C respectively in °C (degree centigrade).

After getting the value of (e) can calculate the thermal conductivity from the following equation:

$$K = \frac{ed}{2\pi r^2 (T_B - T_A)} \left[as \frac{T_A T_B}{2} + 2a_A T_A \right]$$

K : Mean the thermal conductivity in $w/m \cdot ^\circ C$.

d : Mean the thickness of the specimen in m

r : Mean the diameter of the specimen in m

T_A, T_B, T_C : This explain temperature in disc A, B and C measured in °C

as : Mean the specimen surface area in m^2

a_A : Mean the disc A surface area in m^2 .



Fig. (2): Thermal conductivity apparatus (Lee disc)

2.3.2 Tensile strength test:

A- Mold preparation

Thirty flat shaped rapid specimens were prepared plastic mold with dimension (80mmx9mmx 3mm) for (length, width and thickness) respectively, (Al-Husayni, 2013; Hasan and Hummudi, 2017). The plastic pattern prepared by using a laser cutting machine (CNC), (Figure 3: A and B).

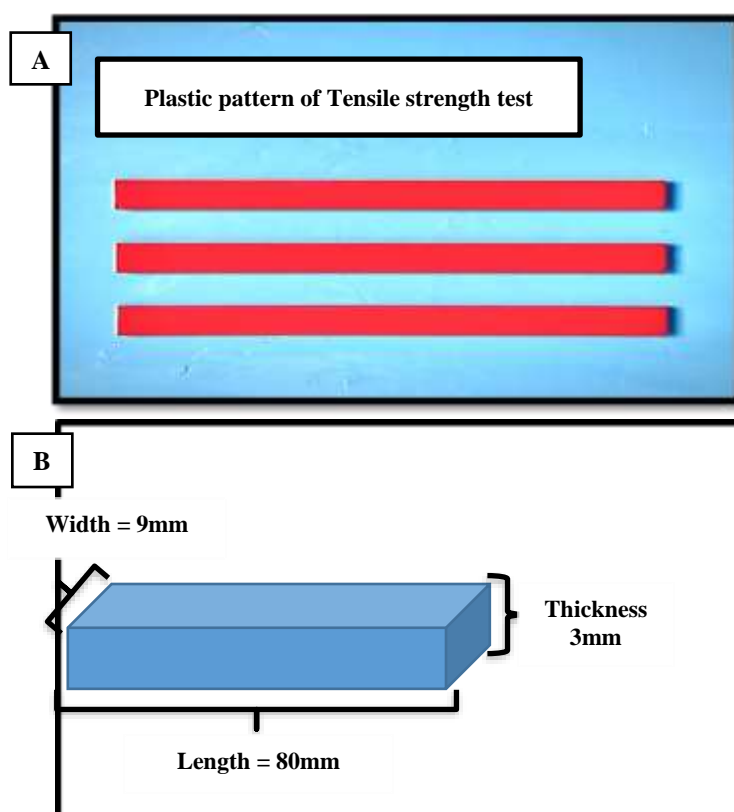


Fig. (3): (A) Plastic pattern of Tensile strength, (B) Dimensions of Tensile strength specimen

B- Specimen preparation

After the proportioning and blending of virgin coconut oil (VCO) with heat acrylic soft liner materials for the current study, all specimens were packed, cured, and deflasked after completing all steps then , the specimens were cooled under tap water to counteract overheating, and after making finishing and polishing were done as a conventional technique (Kadhun and Fatihallah, 2021). All tensile strength specimens were kept in an incubator with sterile water

for 48 hours at 37°C to eliminate any remaining monomers before beginning testing according to (ADA specification NO.12, 1999).

C- Testing procedure

The Objective method using a universal Instron testing machine with grips suitable for testing the tensile strength of experimental and control groups (**Hasan and Hummudi, 2017**). The specimen was placed in a universal Instron testing machine in which the lower part kept steady, while the upper part moved at a regular rate (500 mm / min) (**Kadhum and Fatihallah, 2021**). The maximum strength when each specimen was broken by elongation was recorded by the computer program, figure (4). The computation of tensile strength from the following formula:

Tensile strength (N/mm^2) = F/A (MPa)

F: Maximum load (N)

A: Cross section area (mm^2)

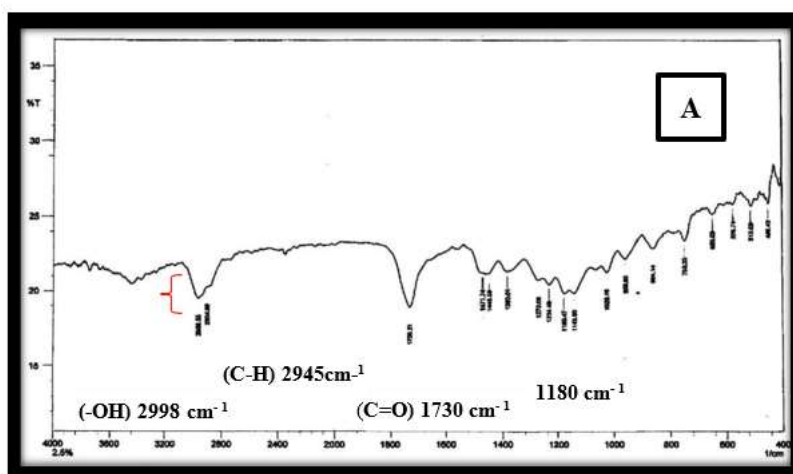


Fig. (4): The Specimen is subjected to tensile strength test

3. RESULTS

3.1 Fourier Transform Infrared spectroscopy (FTIR):

The Fourier Transform Infrared spectroscopy spectrum of the heat cured acrylic soft liner specimen (control group) revealed hydroxyl bond (OH) at peak at 2996 cm^{-1} , alphabetic group (C-H) at peak at $2876\text{--}2927\text{ cm}^{-1}$, carbonyl bond (C=O) at peak at 1728 cm^{-1} , and ester group (C–O–C) at peak at $1143\text{--}1180\text{ cm}^{-1}$, as shown in figure (5-A), and Furthermore, the FTIR analysis of a heat acrylic soft liner with virgin coconut oil added at two concentrations (1.5% and 2.5%) revealed a peak at 2998 cm^{-1} ; other readings did not differ from the control group, and the soft lining material and virgin coconut oil did not interact chemically, as shown in figure (5-B). The moisture content, or the amount of water the specimen has absorbed, can have a bearing on the pattern's little changes that have been observed (**Alamen, and Naji, 2018**).



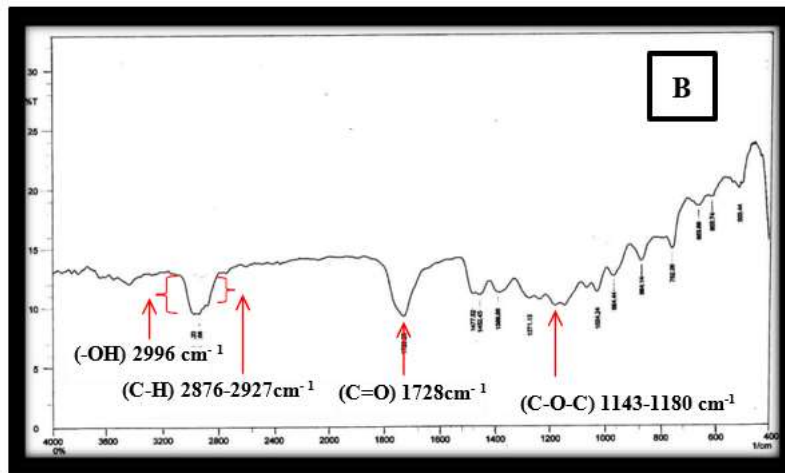


Fig. 5: (A) FTIR of control groups, (B) FTIR of soft liner with incorporation of virgin coconut oil

3.2 Scanning Electron Microscope (SEM)

The soft liner specimen (control group) without any incorporation was measured using a "scanning electron microscope" with a magnification power of 800x. The distribution of the coconut oil particles within the soft liner particles was also measured using this method. The soft liner specimen's results (control group) revealed irregular porous with a clearly rough surface, as seen in figure (6-A).

The SEM of soft liner with incorporation of 1.5% the coconut oil illustrated regular distribution of oil particles within the soft liner matrix. The results showed closed all porous of acrylic soft liner with smooth surface, and The SEM of soft liner with incorporation of 2.5% the coconut oil illustrated more regular distribution of oil particles within the soft liner matrix. The results showed no porous of acrylic soft liner with clearly smooth and uniform surface, figure (6-B).

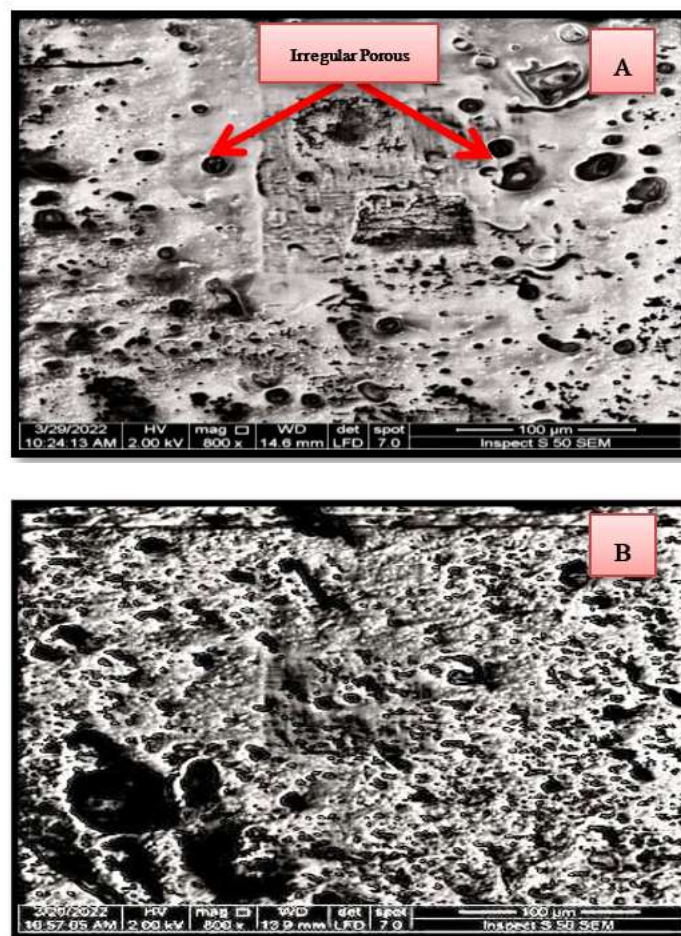


Fig. 6: (A) SEM of control groups, (B) SEM of soft liner with incorporation of 2.5% virgin coconut oil

3.3 Statistical analysis

3.3.1 Thermal conductivity:

The descriptive statistics of Thermal conductivity tests which include: mean values, standard deviation, standard error, and the two extremes values (minimum and maximum). The results showed that the control group without incorporation, had lowest mean values (0.342 ± 0.031), the mean value of 1.5 % incorporation of coconut oil to soft lining material group was (0.375 ± 0.023), while the highest mean values was represented by 2.5% incorporation of coconut oil to soft lining material group which was equal to (0.398 ± 0.027).

Table 2: Descriptive Statistics of the "Thermal Conductivity (w/m.°c)" test's

Test	Groups	No.	Mean	SD	SE	95% C.I. for Mean		Min.	Max.
						L.b.	U.b.		
Thermal Conductivity test	Control	10	0.342	0.031	0.010	0.319	0.364	0.291	0.379
	Soft liner with 1.5 % incorporation of coconut oil	10	0.375	0.023	0.007	0.359	0.392	0.337	0.403
	Soft liner with 2.5 % incorporation of coconut oil	10	0.398	0.027	0.009	0.379	0.418	0.353	0.434

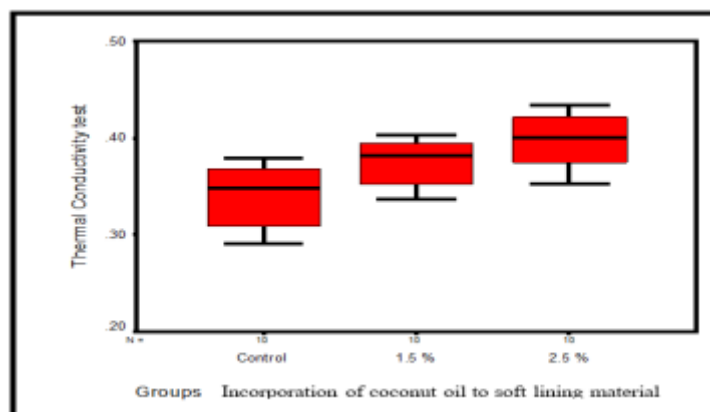


Figure 7: Box plots for Thermal conductivity test

3.3.2 Tensile strength test:

The descriptive statistics of tensile strength tests include: mean values, standard deviation, standard error, 95% confidence interval of population, and the two extreme values (minimum, and maximum) of studied readings. The results showed that the lowest mean value revealed for the control group without incorporation was (2.627 ± 0.106), the mean value of 1.5% incorporation of coconut oil to soft lining material group was (2.942 ± 0.092), while the highest mean value of 2.5% incorporation of coconut oil to soft lining material group was (3.141 ± 0.076).

Table 3: Descriptive Statistics of the "Tensile Strength (Mpa)" test'

Test	Groups	No.	Mean	SD	SE	95% C.I. for Mean		Min.	Max.
						L.b.	U.b.		
Tensile Strength test	Control	10	2.627	0.106	0.033	2.551	2.702	2.483	2.784
	Soft liner with 1.5 % incorporation of coconut oil	10	2.942	0.092	0.029	2.876	3.008	2.786	3.082
	Soft liner with 2.5 % incorporation of coconut oil	10	3.141	0.076	0.024	3.086	3.195	3.027	3.258

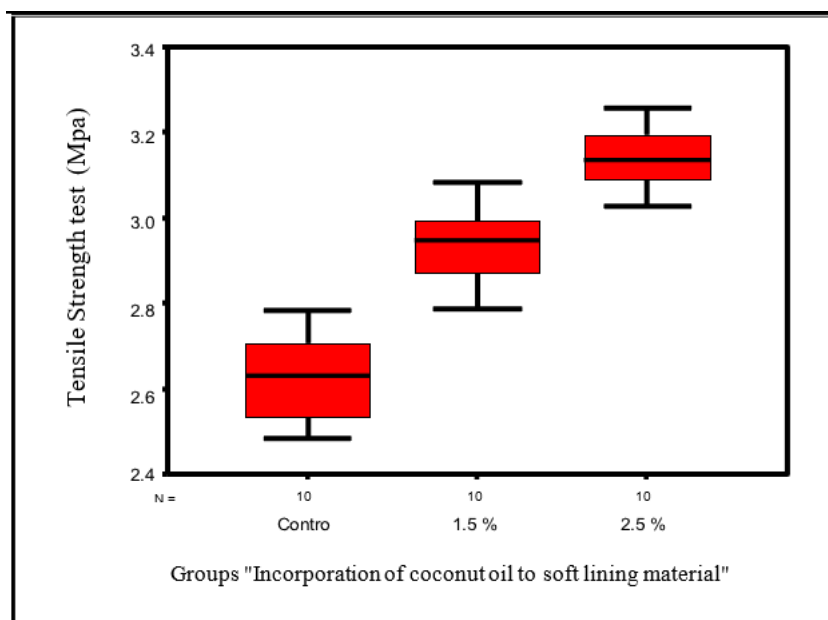


Figure 8: Box plots for Tensile Strength test

4. DISCUSSION

The goal of the current study is to establish a basic information base regarding the incorporation of extract oil into heat acrylic soft lining materials and the effects of oil on them. Additionally, virgin coconut oil has not been the subject of any previous research or published data regarding its effects on certain properties of heat acrylic soft denture lining materials, such as thermal conductivity, and tensile strength.

4.1 Thermal conductivity:

Thermal conductivity defined as the ability to limit the rate at which the heat can be transport during a given cross sectional area of specimens of the material through a given time period (**Sakaguchi and Powers, 2012**).

One of the major obstructions of soft liner materials [poly ethyl methacrylate] were lower thermal conductivity as it is influenced prosthesis acceptance by the patient and influences the health of denture supporting tissues (**Tugut et al., 2012**).

The thermal conductivity was associated to the particle size of the nanofiller, filler to resin proportion, and proper distribution of nanoparticles within the denture base powders (**Kul et al., 2016**).

In this study the results showed that the highest mean values of thermal conductivity test of 2.5% incorporation of virgin coconut oil to the soft lining material, while the results showed that the lowest mean values of the control group without incorporation, as shown in table 2.

The soft liner with incorporation of 1.5% virgin coconut oil group showed a significant difference when compared to control group as well as the soft liner with incorporation of 2.5% virgin coconut oil group showed a highly significant difference when compared to control group, and the comparisons between the group of soft liner with incorporation of 1.5 % virgin coconut oil and the group of soft liner with incorporation of 2.5 % virgin coconut oil showed non-significant differences.

The result of this study agreement with the result of Hassan and Ali in 2018, a study found that the results in increased of thermal conductivity when incorporation of hallosite nanotubes into heat acrylic soft lining materials.

Also the results were in agreement with the results of Noori and Jaber in 2021, the incorporation of 10% wt. neem and 10% wt. aloe vera powders into heat acrylic soft lining material powder results in increased in the thermal conductivity.

4.2 Tensile strength test

It is the maximum stress that materials can resistance before starting localized deformity (**Sakaguchi and Powers, 2012**).

It is one of desired mechanical properties of soft lining material, it was assessed by applying the tension to the specimens (**McCabe et al., 2008**).

The result of the present study showed an assessed tensile strength in particles to soft lining material, with the maximum increase was noticed in 2% by wt. concentration, that may be due to a decreased of cross-linking degree as the nano-particles was permeation in to inter macro molecular polymer chains, so the motion of pieces of polymer chains was increased and the tensile strength was enhanced (**Waters and Jagger., 1999**).

In this study the results showed that the highest mean values of tensile strength test of 2.5% incorporation of virgin coconut oil to the soft lining material, while the results showed that the lowest mean values of the control group without incorporation, as shown in table 3.

The soft liner with incorporation of 1.5% virgin coconut oil group showed a highly significant difference when compared to control group as well as the soft liner with incorporation of 2.5% virgin coconut oil group showed a highly significant difference when compared to control group, and the comparisons between the group of soft liner with incorporation of 1.5 % virgin coconut oil and the group of soft liner with incorporation of 2.5 % virgin coconut oil too showed highly significant differences.

This result was in agreement with the results of Hasan and Hummudi in 2017 that showed the addition of three percentages (0.05 ml, 0.1 ml and 0.2 ml) of silver nitrate into the soft lining material results in increases tensile strength of the soft denture lining material.

Also the results were in agreement with the results of Mohad and Fatihalla in 2019 that showed the incorporation of aluminum potassium sulfate $KAl(SO_4)_2$ micro-particles 2% wt., 3% wt. as anti-fungal agent to the soft denture liner materials was resulted in enhanced the tensile strength of the experimental specimens.

The finding of this study was in agreement with the results of Kadhun and Fatihallah in 2021 that showed as improvement in the tensile strength of soft liner with the addition of 1.5% and 2% by wt. chitosan nano-particles that make the soft liner material to increased resistance to forces intended to cause plastic deformation.

5. CONCLUSION

- 1- In this current study, the soft denture lining materials with incorporation of 2.5% by volume of virgin coconut oil showed that increases of thermal conductivity test. Because virgin coconut oil works to fill the pores when mixed with the soft liner material, and this leads to the creation of heat conducting pathways, which helps in transferring heat from one side of the specimen to the other side quickly and smoothly and reduces the percentage of polymer insulation.
- 2- The incorporation of 2.5% by volume of "virgin coconut oil" into heat cure acrylic soft denture lining materials result showed increases in a tensile strength test. This increase in the tensile strength is caused by dispersed virgin coconut oil particles throughout the polymer matrix which makes the polymer highly elongated and highly resistant to rupturing. As a result, a big force will be needed to cause specimen deformation.
- 3- Virgin coconut oil can be utilized as effective oil and successful when incorporation with soft denture lining material.

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Nomenclature & Symbols

VCO	virgin coconut oil	g	Gram
%	percentage	mm	Millimeter
P/L ratio	powder /liquid ratio	µm	Micrometer
W	watt	mL	Milliliter
HS	Highly significant	LSD	Least significant difference
NS	non-significant	F	Maximum load (N)
SEM	Scanning Electron Microscope	A	Cross section area (mm ²) of tensile strength test
FTIR	Fourier transfer infrared spectroscopy		
ASTM	American Society For Testing and Materials		