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# Synthesis and Characterization of New Silicone Hydrogels Contact lenses Based on TRIS-DMA-AA-NVP Via Photo Polymerization for Biomedical Application

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## ABSTRACT

The purpose of the present work is to designate the synthesis of innovative soft silicone hydrogel contact lenses founded on Acrylic acid (AA), N,N dimethylacrylic amide (DMA), and 1-vinyl 2-pyrrolidone (NVP) was polymerized via free fundamental polymerization in the existence of 1,6 hexandioldiacrylate (HDODA) as a crosslinker and 1-hydroxycyclohexyl phenyl ketone as photoinitiator. The polymerized materials were characterized fully for its use fullness as an intraocular lens by various techniques. FTIR was implemented to discover the whole conversion of 3-(methacryloyloxy) propyl TRIS (trimethylsiloxy) silane monomer into silicone hydrogels contact lens. The silicon hydrogels contact lenses were manufactured from silicon and different hydrophilic monomers, copolymerization of 3-(methacryloyloxy) propyl (TRIS) (trimethylsiloxy) silane with acrylic acid, N,N-dimethylacrylamide, and N-Vinylpyrrolidone (NVP) with different ratio (70,80,90)%. To explore three sequences of silicone hydrogel ingredients for their classification, water component, transmittance, mechanical feature, oxygen penetrability (Dk), protein adsorption and bacterial connection as potential contact lens materials as well as tackles the connections between water kinship and optical, mechanical, oxygen permeable with biological features. The outcomes displayed that the water affinity might be moderated through the hydrophilic monomers. The Equilibrium Water Component (EWC) rose with increasing hydrophilic monomer value. Generally, the outcomes revealed that visible light transmittance inclines to increase as well as tensile mechanical features obtained in decreasing trend relying on the growing EWC. The Dk worth declined firstly then was rose once the EWC was from 25 to 75%. The sum of Staphylococcus aureus close to the silicone hydrogels surface of the was fell by 61 to 140. This work may provide information on preparing functional silicone hydrogels for contact lenses application.

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## 1. Introduction

The usage of non-natural materials (or “biomaterials”) inside the body being a replacement prostheses has perceived a speedy increase over the last few years Ratner et al. [1]. Consequently, to examine the connections between implantation, materials and body tissues has developed to be

gradually of significance. Once inserted, the biomaterial experiences various interactions with the host biological milieu and the “biocompatibility” of the given material relies upon numerous elements,

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Abbreviations	
<i>CLs</i>	Soft contact lens
<i>SCL</i>	Silicone contact lens
<i>EWC</i>	equilibrium of water component
<i>DK</i>	Dkare's units of Oxygen penetrability
<i>Ws</i>	Weight of lens after immersion
<i>Wd</i>	Weight of lens before immersion
<i>CA<sub>t</sub></i>	Concentration during time
<i>K<sub>l</sub></i>	Reaction rate constant
<i>t</i>	Time of adsorption
<i>CA<sub>0</sub></i>	Initial concentration
<i>MPS</i>	Mega pascal
<i>HDODA</i>	1,6 hexandioldiacrylate
<i>NVP</i>	1-vinyl 2- pyrrolidone
<i>AA</i>	Acrylic acid
<i>DMA</i>	N,N dimethyl acrylic amide
<i>TRIS</i>	Silicone (Si) 3-(methacryloyloxy) propyltris (trimethylsiloxy) silane.
<i>PH</i>	Measure of how acidic/basic in water
<i>Photo initiator</i>	1-hydroxycyclohexyl phenyl ketone (PI184)
<i>PBS</i>	Phosphate buffer saline
<i>ETH</i>	Ethanol
<i>N<sub>2</sub></i>	Nitrogen

connected to both the host and embedded material. Today, delicate contact lens is among of the biomaterials that has received great clinical exposure.

Contact lenses made of hydrogel are manipulated for rectifying vision for about 30 years. But, due to the oxygen penetrability of contact lenses that are conventional made of hydrogel which is based chiefly on their water content might not be up to the demands of the cornea, especially

below the closed eye, stimulate the presentation of contact lenses that are made of silicone-hydrogel. The usage of contact lenses made of silicone-

hydrogels tamed in a novel generation of lenient contact lenses having greater oxygen penetrability than that of hydrogels that are conventional. Noticing that the contact lens' surface is in straight contact with the cornea and conjunctiva, it looks clear that the surface features are significant factors to be talked because of the clinical associations that could have. Contact lenses made of silicone-hydrogel constituents show diverse surface features on account of the combination of diverse composition that are chemical as well as surface treatment [2], [3]. Surface treatments are done for the sake of gaining wettable surfaces [4],[5].

Putting contact lenses is perhaps the greatest omnipresent usage of a medical hydrogel in our society. A hydrogel is a cross-linked polymer containing hydrophilic units which normally dissolve in water. However, crosslinking prevents the polymer from dissolving. Recently, silicone hydrogel (SiHy) contact lenses are developed to be the mainstream product in the market of contact lens due to their superior oxygen penetrability, that is 3 to 6 times greater than conventional poly-HEMA grounded hydrogel lenses Efron et al. [6]. Since oxygen is able to transfer easily through the silicone units in SiHy lenses, the oxygen permeability is enhanced significantly as well as is not restricted by the water component as conventional hydrogel lenses are. The improvement allows a high level of comfort as well as developed corneal healthiness throughout prolonged wear (even over the night wear) by sustaining a adequate level of oxygen attentiveness at the ocular surface.

While SiHy lens are highly successful, the adsorption of tear components to contact lenses remains a main risk of contact lens putting which could cause user discomfort and reduced visual acuity Heynen et al. [7], and eventually leads to discontinuation of lens putting [8], [9]. Consequently, contact lenses as well as lens-care products are frequently engineered to decrease deposition and improve wear comfort.

Unfortunately, the advantageous hydrophobic segments in SiHy lenses also reduce surface wettability, which is highly correlated with wear comfort. Irritation and dry eye syndrome are induced when tear films are unable to spread across the hydrophobic lens surfaces. Thus, the lens material itself is a predominate factor to the level of comfort and the tendency to sorbs tear components. For example the surfaces of lotrafilcon B lenses are plasma coated a continuous ultra-thin hydrophilic layer which improves the wettability Read et al. [10], and which also lowers the lipid

deposition significantly. While using hydrogel lenses to deliver therapeutic drugs to eyes is not a new idea, little research has been done in controlled release of comfort agents or lubricants molecules from lenses. A screening study was performed in this thesis research to select possible agents to be loaded into several SiHy macromere formulations, which opens the door to produce lenses that can deliver an additional level of comfort over many hours. The present work is pointing to explore the outcome of those monomers on a contact lens that is silicone-dependent from TRIS, DMA, NVP and AA in relation to oxygen and water absorbability, protein approval, and wettability. Hence, the resultant TRIS-AA, TRIS-DMA-AA as well as TRIS-DMA-NVP-AA hydrogels are characterized by FTIR spectrum, equilibrium water component, oxygen penetrability, optical permeability, contact angle, mechanical properties, the adsorption process of protein, and cytotoxicity.

## 2. Experimental methods

### 2.1. Preparation of Silicone Hydrogels

Hydrogels that are made of silicone were underwent the process of polymerization from TRIS, DMA, AA, and NVP monomers with different ratio (10%,20%,30%) by polymerization process that is free-radical in the existence of cross-linking agent HDODA as well as photo motivator PI184, as listed in **Table 1**. The reaction mix were emptied from gas using nitrogen for 30 min to eliminate the oxygen. Then the mix was moved in a dim milieu at room heat for 30min. Afterward, pouring into polypropylene molds, the mix was healed below 365 nm UV light for 40 min. Then, demolding process took place, the lens material was refined by soaking in 50% ethanol for 24 h at 50 °C to eliminate the monomers that are un-reacted and photo motivator. After that, the lens was engrossed in refined water for 12 h at 50 °C to wash out the ethanol. Finally, the lens was conserved in PBS (pH 7.4) at chamber heat. For all constructions, the percentages of HDODA and PI184 were 0.625 wt % as well as 0.4 wt %, respectively Tran et al. [11].

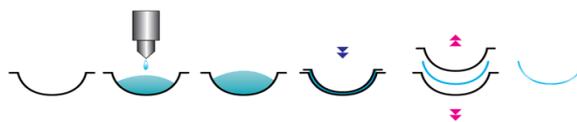


Figure 1. The process of making contact lenses [12].

Table 1. Formulations of silicone hydrogel through copolymerization of TRIS, DMA, AA, NVP.

Sample	Feed monomer D	Feed monomer A	Feed monomer N	Feed monomer VP	Feed monomer Si	Time irradiation	EW C%	DK	Contact angle (°)	Modulus (MPa)
A1	0	4.5	0	0	0.5	2	58	92	92.0	0.001
A2	0	4	0	0	1	3	52	103	115.312	0.00157
A3	0	3.5	0	0	1.5	11	32	61	131.5	0.001
B1	2.25	2	0	0	0.5	2	60	120	61.3	0.00127
B2	2	2	0	0	1	3	55	140	41.5	0.00112
B3	1.75	1	0	0	1.5	7	25.6	64	113.14	0.002703
C1	1.5	1.5	1.5	0.5	0.5	4.30	75	84	75.6	0.00058
C2	1.33	1	1.33	1	1	3	63	86	101.124	0.0039

## 2.2. Equilibrium Water Content

Dried hydrogel pieces were implemented to control the water content, the water content was regulated by submerging the hydrogel (0.1gm) in 100 ml of distilled water 24 hrs through a lengthy period of time. Excess water was eliminated from surface by blotting with lens-cleaning tissue just before measurements. The Equilibrium Water Component (EWC) in distilled water was regulated through the weight of water's ratio in the hydrogel to the entire hydrogel weight at equilibrium of hydration. EWC was measured through the usage of the ensuing equation.

$$EWC = \frac{W_s - W_d}{W_s} \times 100\% \quad (1)$$

Where  $W_s$  as well as  $W_d$  correspond to the weight of the swollen example as well as dried sample, correspondingly [13].

## 2.3. Oxygen Permeability

Oxygen penetrability is fundamentally controlled through EWC in hydrogels that are conventional. Such happens as oxygen is capable of passing over the water more than over the substance itself. Oxygen penetrability is designated as the  $Dk$ , where  $D$  is the diffusivity of the substance as well as  $K$  is the solubility of the substance. The connection amid EWC as well as oxygen penetrability was established to be (Morgan & Efron equation).

$$Dk = 1.67e^{0.0397EWC} \quad (2)$$

Where 'EWC' is Equilibrium water component of the substance. The  $Dk$ 's units of identified being Barrer:

$$DK(\text{barrer}) = \frac{10^{-11}(\text{cm}^2 \times \text{mlO}_2)}{\text{sec} \times \text{ml} \times \text{mmHg}} (3) [14]$$

## 2.4 Optical Transparency

The membrane's transparency was studied with the use of UV-visible spectrophotometer, sample were made through cutting to a slight piece (1 cm × 1 cm) after by solvent evaporation method as well as engrossed in refined water for 24 hrs to approaching equilibrium of swelling. The calculations were done from 200 to 700 nm wavelength at chamber heat Tran et al. [11].

## 2.5 Contact Angle

The estimation of the outward wettability of the lens made of silicone hydrogel substance depended on the test of contact angle. Calculations showed that with the use of a contact angle goniometer (DSA 100, Krüss GmbH, Hamburg, Germany) at room heat, the contact angle assessment was the average of five measurements Tran et al. [15].

## 2.6 Mechanical Features

After swelling in refined water, the specimens were sample 2cm × 3cm rectangular form. The specimens that are dry were obtained by placing them into an oven at 40°C in one day. The tensile features of the examples were calculated at a crosshead speed of medium, in agreement with ASTM D1708 standard, using a tensile tester (transact, motorized force test stand, Esm, Mark -10, Eden Prairie, MN, USA). Kim et al. [16]

## 2.7 Protein Deposition

The membranes of the hydrogel were engrossed in solution of phosphate buffer (PBS, pH 7.4) 5ml for 24 hrs. Then, drenching the membranes of hydrogel in sole solution of protein of bovine serum albumin for 3 hrs at 37 °C the usual temperature of the human eye's surface, the attentiveness of solution of the protein was 0.5mg/ml. Later, a membranes' adsorption of the of hydrogel were located mildly in to PBS for 5 second to eliminate extra solution adhering to the membranes of the hydrogel. The membranes were after that put in a tube made of glass having 1wt% aqueous sodium dodecyl sulfate's solution (SDS) to eliminate the adsorbed proteins found on the membranes. The sum of the adsorbed proteins on the surface of the membrane was measured from the attentiveness of proteins into the solution of SDS with the use of Bradford evaluates reagent kit at the end, protein deposition of all specimens was calculated by a UV-Vis spectrophotometer Tran et al. [11].

## 2.8 Evaluation of bacterial adhesion

The lenses are made of different types of mixtures consisting of a mixture of silicon and hydrogel. The lenses are kept within a saline solution. The tasters were washed with 100 ml of sterile saline three times Tasters were saved in 3 ml of PBS solution. Adhesion examination was performed by the method of editing the adherent bacteria by ultrasound, where the lenses were exposed to bacterial isolates by dilution  $10^{-4}$  and  $10^{-5}$  respectively and for each isolation for 30 minutes and 60 minutes, then the lenses were put in sterile vials having 1 ml of PBS solution and then The super waves were shown at a rate of 75 kHz placed in a water bath with a depth of 1 cm at a temperature of 30°C for a period of (15-15) minutes after which the vials were transferred to the vortex vibrator for 1-2 minutes. Then withdraw about 100 ml of the solution containing the free bacteria for the

samples and spread on the dishes containers on TSA incubated the dishes for 24 hours at 37°C and the cell numbers were calculated with a value of cfu / mm<sup>2</sup> Alkhozai et al. [17].

### 3. Results and Discussion

#### 3.1.1. Synthesis and Characterization of (Si-co-AA)

TRIS is saleable monomer made of silicone to sustain great oxygen penetrability in contact lens, whereas (AA) was preferred due to its hydrophilicity to afford abundant greater water component. In the start, only TRIS was copolymerized with (AA). The silicone hydrogels were to underwent polymerization from TRIS and (AA) monomers in the existence of cross-linking mediator 1-6 hexanedioldiacrylate and photo initiator, 1-hydroxycyclohexyl phenyl ketone, using different percentages (10%, 20%, 30%). The combination was moved in a dim milieu at room heat for 30 min. Once being dispensed in polypropylene shapes, the combination was healed below 365 nm UV light for 2 minutes at 10%, 3 minutes at 20% and 11 minutes at 30% of Si. Nevertheless, the synthesis procedure of macromere was fairly made complex. In this paper TRIS was used as portion of silicone monomers. When TRIS was combined in the polymers, the compatibility of monomers that are hydrophilic might be heightened. Those manufactured hydrogels made of silicone display capacity to develop the transparency.

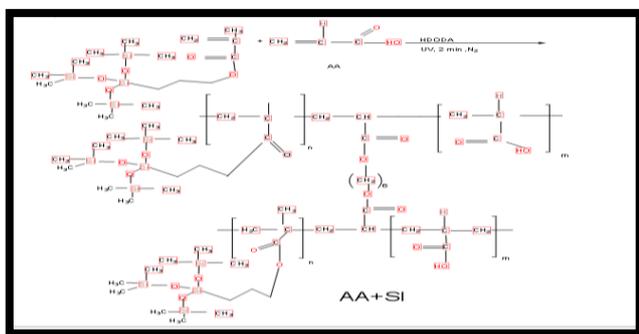


Figure 2. Copolymerization and Crosslinking of HDODA with (Si-co-AA)

#### 3.1.2. FTIR Spectrum

The FTIR Spectrum of (Si-co-AA), the hydrogel found in silicone constituents could perceive a stout group of  $-\text{Si}-\text{O}_3$  stretching at  $636 \text{ cm}^{-1}$ , two feeble group of  $-\text{Si}-(\text{CH}_3)_3$  extending at  $683$  as well as  $735 \text{ cm}^{-1}$ , a feeble band of  $-\text{CH}_3$  distortion at  $1406 \text{ cm}^{-1}$  and a robust group of  $-\text{CH}_3$  extending at  $2890 \text{ cm}^{-1}$ ; which designates absorption group at  $3400-3420 \text{ cm}^{-1}$  because of  $(-\text{OH str. Band in polymer})$ ,  $2940 \text{ cm}^{-1}$ ,  $2830 \text{ cm}^{-1}$  to  $(\text{C-H str. aliphatic backbone polymer})$ ,  $1758 \text{ cm}^{-1}$   $(\text{C=O str., ester band})$ ,  $1688 \text{ cm}^{-1}$  to  $(\text{C=O str. carboxyl band})$ ,  $1152 \text{ cm}^{-1}$  to  $(\text{C-O-C str.})$  as well as  $1085 \text{ cm}^{-1}$  to  $(\text{C-O of C-OH str.})$ . Moreover, distinctive bands at about  $900 \text{ cm}^{-1}$  as well as  $3100 \text{ cm}^{-1}$  conforming to the vinyl groups vanished completely, that showed nonexistence of unreacted monomers [18], [19].

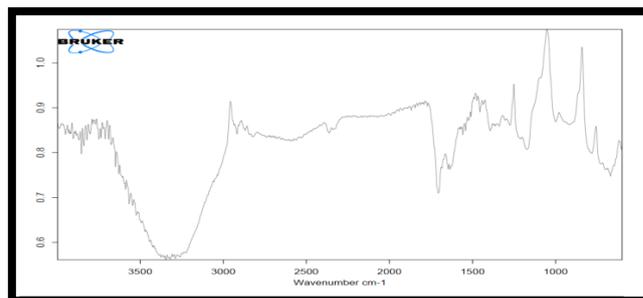


Figure 3. FTIR- Spectrum of Hydrogel of (Si-co-AA)

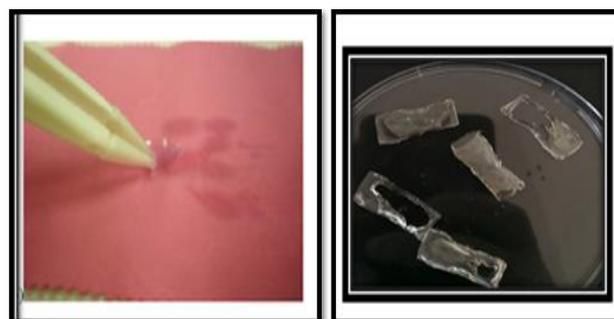


Figure 4. preparation of Si-co-AA

#### 3.1.3. Synthesis and Characterization of (Si-co-AA-co-DMA)

TRIS is a marketable monomer made of silicone to preserve great oxygen penetrability in contact lens, whereas (DMA) was selected due to its hydrophilicity to afford plentiful greater water component. In the start, only TRIS was copolymerized with (AA). The hydrogels made of silicone were to underwent polymerization from TRIS and (DMA) & (AA) monomers in the existence of cross-linking mediator 1-6 hexanedioldiacrylate and photo initiator, 1-hydroxycyclohexyl phenyl Ketone, using different percentages (10%, 20%, 30%). The combination was moved in a dim milieu at room heat for 30 min. When being dispensed in polypropylene shapes, the combination was healed below 365 nm UV light for 2 minutes at 10%, 3 minutes at 20%, 7 minutes 30% of Si. Though, the synthesis procedure of macromere was fairly sophisticated. In this paper was used TRIS as portion of monomers made of silicone. When TRIS was assimilated into the polymers, the compatibility of monomers that are hydrophilic might become improved. Those synthesized hydrogels made of silicone display ability to develop the transparency.

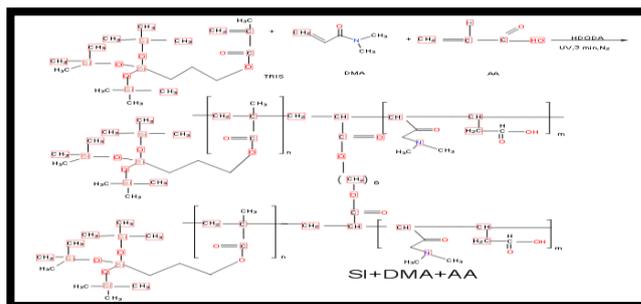


Figure 5. Copolymerization and Crosslinking of HDODA with Si-co-AA-co-DMA.

### 3.1.4. FTIR Spectrum

The FTIR Spectrum of (Si-co-AA-co-DMA), the hydrogel founded by silicone constituents might perceive a robust band of  $-\text{Si}-\text{O}_3$  extending at  $636\text{ cm}^{-1}$ , two feeble group of  $-\text{Si}-(\text{CH}_3)_3$  extending at  $683$  and  $735\text{ cm}^{-1}$ , a feeble band of  $-\text{CH}_3$  distortion at  $1406\text{ cm}^{-1}$  as well as a robust band of  $-\text{CH}_3$  extending at  $2890\text{ cm}^{-1}$ ; which designates absorption band;  $3433\text{ cm}^{-1}$  to ( $-\text{OH}$  str.),  $3402\text{ cm}^{-1}$  to ( $-\text{COOH}$  str.),  $2947\text{ cm}^{-1}$ ,  $2869\text{ cm}^{-1}$  to ( $\text{C}-\text{H}$  str. of backbone of polymer),  $1710\text{ cm}^{-1}$  to ( $\text{C}=\text{O}$  str., carboxyl band),  $1072\text{ cm}^{-1}$  to ( $-\text{C}-\text{O}$  of  $\text{C}-\text{OH}$  str.), the amide I group happens in the area of  $1620$ – $1670\text{ cm}^{-1}$  for N,N-dialkyl replaced amides Rogers [20]. The amide I group at  $1629\text{ cm}^{-1}$  is credited mostly to the  $\text{C}=\text{O}$  extending way by certain aids from the  $\text{C}-\text{N}$  extending way. The polarized group at  $1086\text{ cm}^{-1}$  have been given here to the symmetric stretching ways of the  $\text{N}(\text{CH}_3)_2$  group. Once DMA underwent polymerization in the hydrogels made of silicone, two new groups at  $1629$  as well as  $1086\text{ cm}^{-1}$  performed, that paralleled to the  $\text{C}=\text{O}$  and  $\text{N}(\text{CH}_3)_2$  of the monomers that are acrylamide, correspondingly. The concentration of  $1629\text{ cm}^{-1}$  and  $1086\text{ cm}^{-1}$  rise through growing the sums of DMA. The outcomes provide stout sign of the presence of DMA in the copolymers that are silicone hydrogel. Furthermore, distinctive groups at about  $900\text{ cm}^{-1}$  and  $3100\text{ cm}^{-1}$  stable. To the vinyl groups of monomers vanished totally, that designated nonexistence of unreacted monomers [18], [19].

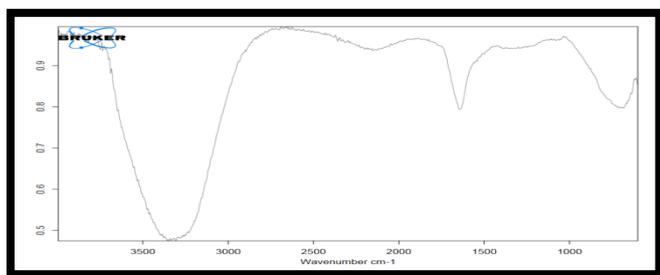


Figure 6. FTIR- Spectrum of Hydrogel of (Si-co-AA-co-DMA)



Figure 7. preparation of Si-co-AA-co-DMA

### 3.1.5. Synthesis and Characterization of (Si-co-AA-co-DMA-co-NVP)

TRIS is profitable monomer made of silicone to preserve great oxygen permeability in contact lens, whereas (DMA)&(AA) were selected for its hydrophilic aspect to offer abundant greater water component. In the start, merely TRIS underwent copolymerization with (NVP). The silicone hydrogels underwent polymerization from TRIS and (DMA),(AA)&(NVP) monomers in the existence of cross-linking mediator 1-6 hexanedioldiacrylatand photo initiator, 1-hydroxycyclohexyl phenyl ketone, using different percentages (10%, 20%,30%). The combination was moved in a dim milieu at room heat for 30 min. Once being dispensed into

polypropylene shapes, the mix was healed below  $365\text{ nm}$  UV light for 4.30 minutes at 10%, 3 minutes at 20% of Si. Nevertheless, the synthesis method of macromere was fairly difficult. In this study TRIS was employed as part of silicone monomers. Once TRIS as well as BIS was assimilated in the polymers, the compatibility of monomers that are hydrophilic might be improved. Those manufactured silicone hydrogels display potential to develop the transparency.

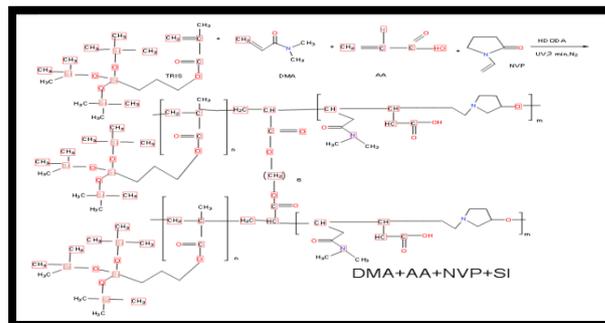


Figure 8. Copolymerization and Crosslinking of HDODA with Si-co-AA-co-DMA-co-NVP.

### 3.1.6. FTIR Spectrum

The FTIR Spectrum of (Si-co-AA-co-DMA-co-NVP), the hydrogel founded by silicone constituents might perceive a tough band of  $-\text{Si}-\text{O}_3$  extending at  $636\text{ cm}^{-1}$ , two feeble group of  $-\text{Si}-(\text{CH}_3)_3$  extending at  $683$  as well as  $735\text{ cm}^{-1}$ , a feeble group of  $-\text{CH}_3$  distortion at  $1406\text{ cm}^{-1}$  as well as a tough band of  $-\text{CH}_3$  extending at  $2890\text{ cm}^{-1}$ ; which indicates absorption band;  $3433\text{ cm}^{-1}$  to ( $-\text{OH}$  str.),  $3402\text{ cm}^{-1}$  to ( $-\text{COOH}$  str.),  $2947\text{ cm}^{-1}$ ,  $2869\text{ cm}^{-1}$  to ( $\text{C}-\text{H}$  str. of backbone of polymer),  $1710\text{ cm}^{-1}$  to ( $\text{C}=\text{O}$  str., carboxyl band),  $1072\text{ cm}^{-1}$  to ( $-\text{C}-\text{O}$  of  $\text{C}-\text{OH}$  str.),  $1688\text{ cm}^{-1}$  to ( $\text{C}=\text{O}$  of the NVP),  $1450\text{ cm}^{-1}$ ,  $1427\text{ cm}^{-1}$  and  $1265\text{ cm}^{-1}$  were allocated to the distinctive vibration of the pyrrolidone ring, and the top at  $1164\text{ cm}^{-1}$  to ( $\text{C}-\text{O}-\text{C}$  str.), the amide I group happens in the area of  $1620$ – $1670\text{ cm}^{-1}$  for N,N-dialkyl replaced amides Rogers [20]. The amide I group at  $1629\text{ cm}^{-1}$  is credited chiefly to the  $\text{C}=\text{O}$  extending way by certain participation from the  $\text{C}-\text{N}$  extending way. The polarized at  $1086\text{ cm}^{-1}$  have been allocated here to the symmetric extending ways of the  $\text{N}(\text{CH}_3)_2$  group. When DMA was polymerized into the hydrogels made of silicone, two novel groups at  $1629$  and  $1086\text{ cm}^{-1}$  seemed, which matched to the  $\text{C}=\text{O}$  and  $\text{N}(\text{CH}_3)_2$  of the monomers that are acrylamide, correspondingly. The concentration of  $1629\text{ cm}^{-1}$  as well as  $1086\text{ cm}^{-1}$  rise with rising the sums of DMA. The obtained results offer strong sign of the presence of DMA in the hydrogel made of silicone copolymers. Moreover, typical groups at around  $900\text{ cm}^{-1}$  and  $3100\text{ cm}^{-1}$  analogous. To the vinyl bands of monomers vanished entirely, that designated nonexistence of unreacted monomers [18], [19].

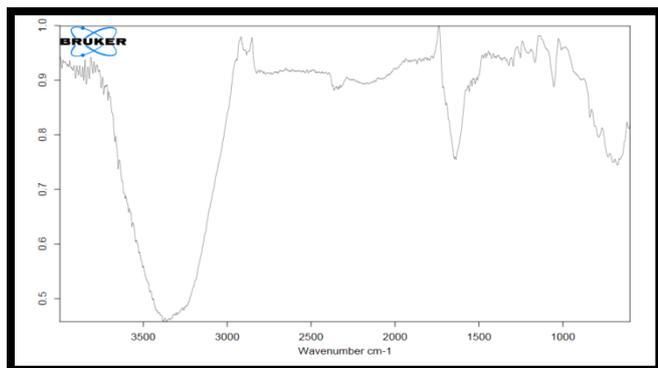


Figure 9. FTIR- Spectrum of Hydrogel of (Si-co-AA-co-DMA-co-NVP)



Figure 10. preparation of Si-co-AA-co-DMA-co-NVP

### 3.2. Equilibrium Water Content

The water component of a hydrogel material is associated with the number of hydrophilic sites in the polymer. The hydrogel's hydrophilic nature of materials is derived from the ability of hydrophilic group (negatively charged) to share an electron with a molecule of water and inversely related to the number of crosslink McCarey et al. [21].

The water content of different ratios of AA signifies the water content to time for diverse percentage of acrylic acid. Hydrophilic monomer which has been too effectively employed in contact lens made of hydrogels is acrylic acid (AA). After put to a lenient lens of polymer construction, it consequence in a lenient lens with ionized bands (negatively charged) inside the matrix of the polymer, letting the lens to absorb extra water. The greater the sum of (AA), the greater the EWC of the subsequent polymer or lens, that's allowing oxygen permeability to rise considerably. Once Si/AA lenses are made they want to be ionized (i.e.; the atom of the hydrogen in the carboxyl band is eliminated). The alteration of the carboxyl group ( $\text{CO}_2\text{H}$ ) to the further hydrophilic ionized form (the anion that is carboxylate,  $\text{CO}_2^-$ ) lead to increasing the water content. Nevertheless, this negative charge leads to the carboxylate ions to prevent each other frequently denoted to as 'growing the network'. This has the outcome of letting the network to take in extra water. If the polymer was not ionized, then the substance might get an unexpanded network Musgrave et al. [22]. To rise the water component of contact lenses through copolymerization of polar monomers such as acrylic acid AA, DMA, and (NVP) are polymerized with Silicon into silicon hydrogels, which increases the water content due to the hydrophilic of the co monomers that manipulated to rise the ability of the hydrogels to take up more water. The EWC of silicone hydrogel with rising DMA content rose from 25.6% to 75%. The alike outcome was stated in Zhang's study Omali et al. [23].

Greater component of monomer of zwitterionic sulfobetaine in hydrogel shown a greater EWC since the unit of sulfobetaine might cooperate with water by both electrostatic forces and hydrogen ties, that delivered a tougher water attraction. As predicted, the amide band of DMA offers extra hydrogen bonding sites for water; consequently, a greater kin ship for water was created in the silicone hydrogels by a more DMA component. The results show that higher hydrophilic monomers gives higher water content in the hydrogel contact lenses.

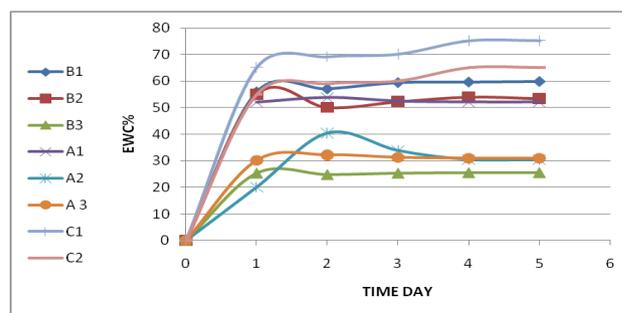


Figure 11. EWC% for different ratios of monomers.

### 3.3. Oxygen Permeability

Generally, the silicone constituent has an exceedingly great ability to permeate to oxygen greater than Dk standards. As predictable, the Dk of hydrogel made from silicone grew higher along with the rise of silicone monomer.

Conventional contact lenses depend on water to transmit oxygen over the lens. Dk restrictions differs from traditional hydrogels, where oxygen can be transported. Over the silicon constituent in the silicone hydrogel substances, which leads to a great distance increased oxygen permeability. Investigate Dk as well as water content of diverse hydrogel made of silicone lenses on the market as well as discovered an opposite relationship amid Dk as well as water content likewise, several previous works showed opposite relationship between Dk as well as EWC due to silicone hydrogel lenses water is the restricting element in the permeability of oxygen Chien et al. [24].

The Dk of silicone was barrers, as well as the value grew higher to barrers once the component of monomers made of silicone rose to 30%. Subsequently, we modified the mingling ratio of (NVP, AA and DMA) monomers that are hydrophilic to inspect the connection amid hydrophilic monomers content as well as Dk Fig. 8. The Dk worth of the silicone hydrogel without hydrophilic monomers wear around barrers. As the rise of hydrophilic monomers component from (70 to 90)%, the Dk worth decreased faintly as well as approached a lowest value of barrers at the 70% hydrophilic monomers component. The Dk worth reserved about barrers once the hydrogel made of silicone with hydrophilic monomers component in a range from 82 to 142. Later, the Dk values started to slowly increase by the rise of hydrophilic monomers component. Once the hydrophilic monomers component surpassed 80%, the Dk worth rose severely as well as come close to barrers at the hydrophilic monomers content of 80%.

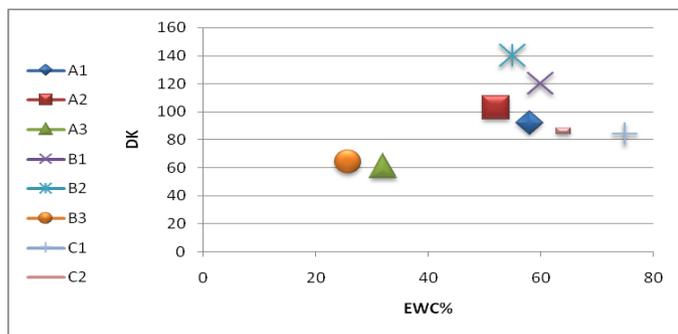


Figure 12. The correlation between Dk and EWC.

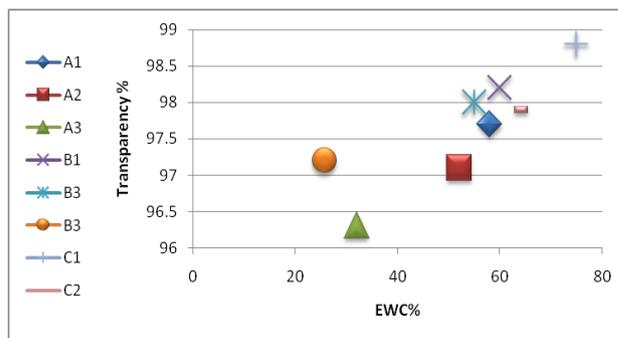


Figure 14. Value of transparency as a function of the percentage of EWC in silicone hydrogels.

3.4. Transmittance

The transparency of these hydrogels made from silicone was calculated by scanning through a UV/V is spectrophotometer into a wavelength variety around (400 as 700) nm. It was shown that the influence of structure and water component on transparency as transparency faintly dropped with the rise of silicone component. The hydrogels made of silicone with 10 to 30 % monomer silicone displayed the transmission ability from (89.5 to 93%). Then, equivalent sums of monomers made of silicone were employed with changing relative sums of DMA, AA, and NVP. The influence of the ado of ratio of hydrophilic monomers on the transparency of the hydrogels was examined. The outcome displays that transparency rise with rising hydrophilic monomers component. The transparency for lenses with 70%, 80% and 90% from hydrophilic monomers with silicon monomer correspondingly. When the composition of the silicon hydrogel contact lenses were more than 80% from hydrophilic monomers, the lens revealed the transmittance over 98%. We additionally planned the worth of transparency in contradiction of the EWC as well as originate there was a positive connection amid grew EWC as well as noticeable light transmittance.

Those outcomes showed that manufactured hydrogels made of silicone are transparent adequate for ophthalmic uses. Moreover, the transparency of constituents might be moderated through the conformations of the hydrogels made of silicone. Light transmission ability is the calculation of the contact lenses' transparency. parting stage because of the unsuccessful collaboration of silicone as well as hydrogel bands might lead to opaque lenses and limit light transmissibility. Fig. 13 displays that the light transmittance of all the hydrogel lenses varied about (96 to 97)%, signifying that whole of the samples are appropriate for contact lenses, which requires the light transmittance to become higher than 90%.

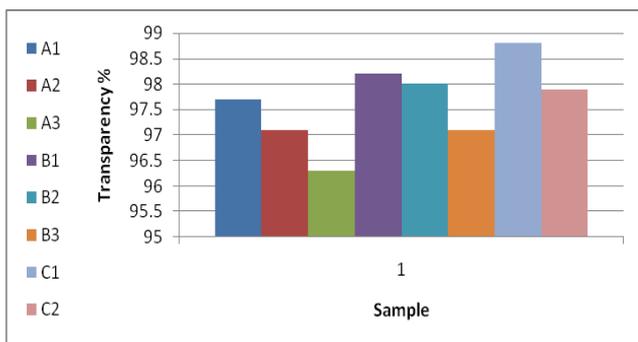


Figure 13. Light transmittance of hydrated modified silicone hydrogel examples.

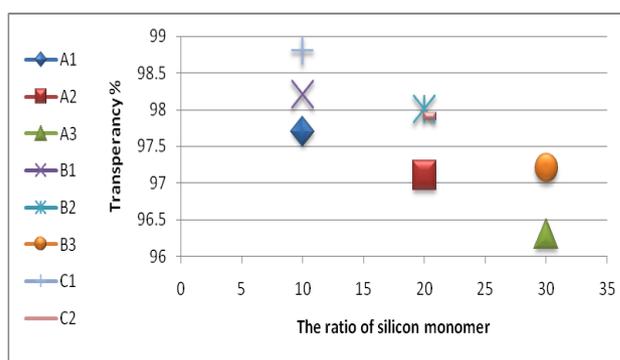


Figure 15. The value of transparency as functions of silicone monomer.

3.5 Contact angle

As a significant element affecting, the surface's wettability aspect of the lenses was assessed by the contact angle of a drop of water onto the surface which is hard. Comparable to envisaging Dk, could too be manipulated to expect the contact angle from EWC. Surface's wettability is a significant to contact lens that affecting putting comfort and reducing happenings of an eye that is dry. The surface wettability aspect of lens made from hydrogel is assessed through calculating the contact angle. Nevertheless, this process is further sensitive to ecological circumstances due to the reorientation of hydrophobic field, particularly silicone chains in the network of the silicone hydrogel. Principally, with the innate flexible construction, Si-O bonds in silicone chains can rotate away from the surface of lens matrix if it discloses to moist environment. On the contrary, the hydrophobic practical band will become major on the surface of the lens when opened to dry milieu. Briefly, the reasons for poor surface wettability are the original hydrophobic substance as well as migration of silicone bands in hydrogel made of silicone contact lens.

Contact angle as well as EWC are connected to the hydrogel's hydrophilicity. Hydrophobic TRIS dropped the hydrophilicity of the hydrogel, as well as henceforth dropped the wettability of the surface of lens. Moreover, the monomer that is hydrophobic (TRIS) is subtle to ecological circumstances due to its reorientation aspect [25], [26]. With the integrals duple construction, silicon-oxygen ties in TRIS monomers would rotate forth the monomer of the lens monomer in a dry milieu French et al. [27]. Consequently, TRIS is the monomer which affects the contact angle

worth of hydrogel made of silicone lens substantial in relation to a preceding study Zhao et al. [28].

TRIS component, the contact angle of 10 wt% was greater than 20 wt%, as well as 30 wt %. Furthermore, contact angle rose intensely in the presence of NVP, AA, and DMA for the similar TRIS component. This indicates that hydrophilic monomers could rise the wettability for polymers of hydrogel made of silicone. In the literature, NVP was capable of continue worthy wettability of the surface through 4–6 h of putting on, whereas DMA cause low wettability for the alike wearing time Lai et al. [29]. To sum up, in this paper, nearly all contact angles of hydrated lenses were below than 80 which is analogous to that of other profitable contact lenses like Lotrafilcon A (Air Optix Night & Day), as well as Balafilcon A (Pure vision) Maldonado-Codina et al. [26].

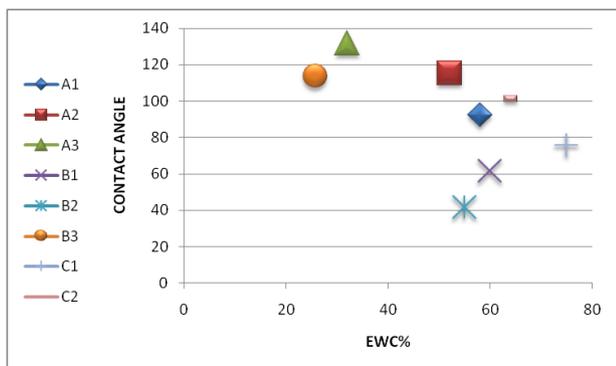


Figure 16. The correlation between EWC and contact angle for (TRIS-DMA-NVP-AA).

### 3.6. Mechanical Properties

The Young’s moduli were considered from the linear visco-elastic variety as well as shortened in Table 1. The existence of monomers made of silicone in hydrogels displays the greater Young’s modulus and the lesser elongation at break. In the instance of 30% monomers content made of silicone, it’s Young’s modulus was extreme (MPa). Generally, lenient contact lenses by moduli vacillating from to MPa are cooler to content might manage mechanical features. For modulate the water component, we put a monomer that is hydrophilic, AA, NVP and DMA, in the constructions to moderate the mechanical features of the hydrogels made of silicone. The existence of higher hydrophilic monomer might decrease Young’s modulus an dim prove presence. Young’s modulus fall together with rising hydrophilic monomer component.

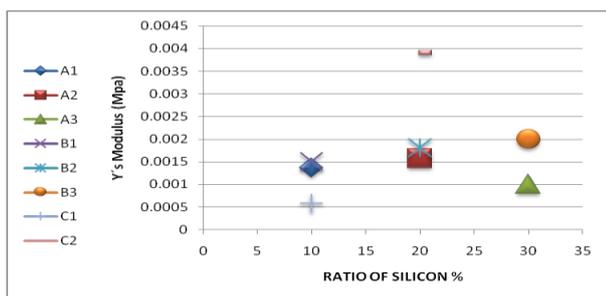


Figure 17. The correlation between the modulus and EWC for (TRIS-DMA-NVP-AA).

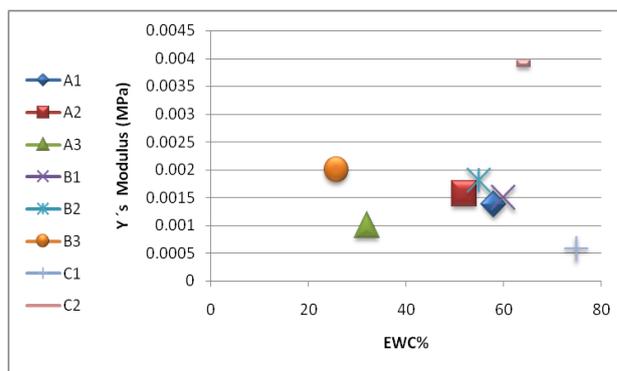


Figure 18. The correlation between the modulus silicone monomer.

### 3.7 Protein adsorption

Protein is an essential element which relays on the transport as well as metabolism of cellular membranes, hypothetically displaying in antimicrobial or infection of the corneal of the eye [30].

Biomaterials that is ophthalmic for contact lenses must not adsorb ingredients of tear film like lipid as well as protein, due to the protein deposition could be painful, raise bacterial cell interaction to the corneal epithelium, and associated with massive conjunctivitis that are papillary Silva et al. [31].

Bradford assay, originally is one of the popular methods to determine protein concentration. The procedure of adsorption protein from an aqueous solution on a solid surface is characteristically labeled in three stages. At the beginning, transportability of the protein got from the solution up to the surface that is solid befalls. This is followed by supplement of the protein to the surface, as well as lastly the protein construction endures a conformational alteration afterward adsorption. Dijt et al. [32] Luensmann [33] explored the influence of ionic charge on the approval of BSA, their outcomes displayed that rising the negative charge of the material such as AA make less the deposition of negatively charged BSA. Proteins adsorbed in greater amounts with rising neutral NVP concentrations; NVP affects protein adsorption to a degree, the amount of protein adsorbed rises with the rise in the NVP content of the hydrogels. The unique bipolar aspect of the lactam moiety in the NVP component outcomes in the poly(Si-co-NVP) hydrogels being both partly negatively charged at the carbonyl group and partly positively charged at the nitrogen end closest to the comparatively hydrophobic chain backbone. Therefore, as a result of the electrostatic attraction amid the positively charged nitrogen group and the negatively charged of protein, depending on the negatively charged BSA protein in connotation with the positive nitrogen present in NVP. Nevertheless, this explanation is depending on the supposition that the electrostatic interaction happens between individual charge groups in NVP and protein molecules Luensmann [33]. For BSA, once the TRIS component rose from (10 to 30)%, the protein's adsorption of reduced from (2.543 to 0.193)µg/cm<sup>2</sup>. The deposition of protein of contact lens is also affected through extra aspects like pH of milieu, dimension of protein, charge of protein, lens material, water component, coarseness of lens surface, as well as substantial aspects [34], [35]. In earlier study, protein adsorption was straight forward comparative to the rise of hydrophobic ingredients and TRIS component, that ensued in lessening water component [36], [37]. Nevertheless, yet other

research designates which rising BSA adsorption was affected by loading hydrophilic constituents, specifically NVP [31], [38], [39].

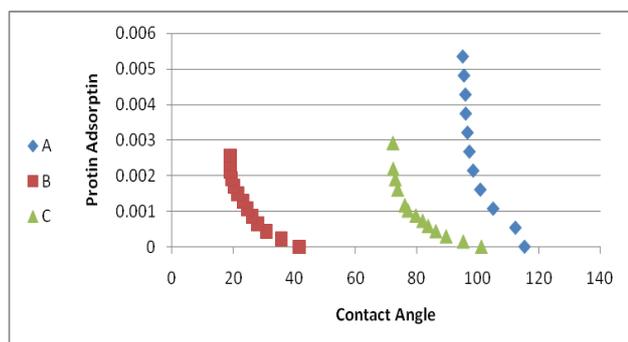


Figure 19. The influence of contact angle on the adsorption of Albumin, A mono monomer, B di monomer tri monomer.

### 3.7.1 Finding the reaction order for protein albumin adsorption on contact lenses

The degree of reaction was tested from (zero, first, second order) and after plotting the results, it was found to be second order as follows:

Zero order :

$$[CA_t] = -kt + [CA_0] \quad (4) \text{the curve not liner}$$

First order:

$$\ln[CA_t] = -kt + \ln[CA_0] \quad (5)$$

Second order :

$$\frac{1}{[CA_t]} = kt + \frac{1}{[CA_0]} \quad (6)$$

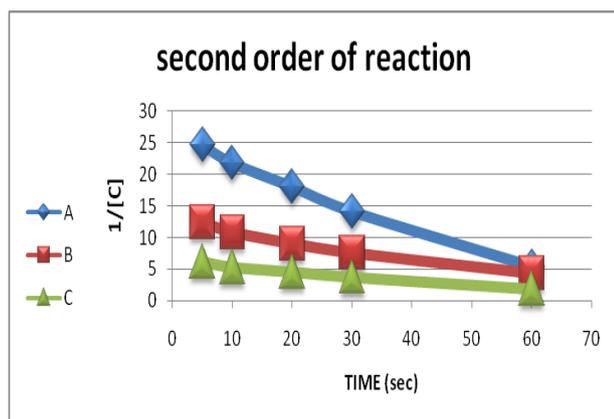


Figure 20. Effect of order reaction on the adsorption of Albumin ;A :mono monomer, B :di monomer, C: tri monomer.

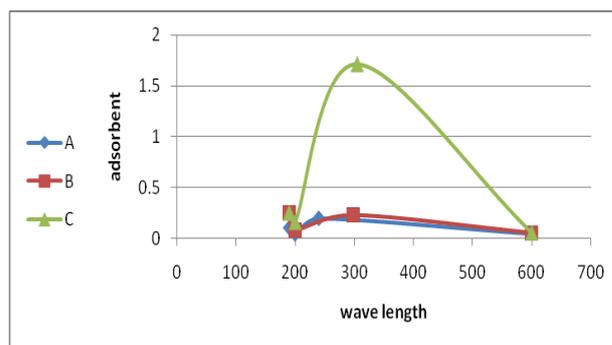
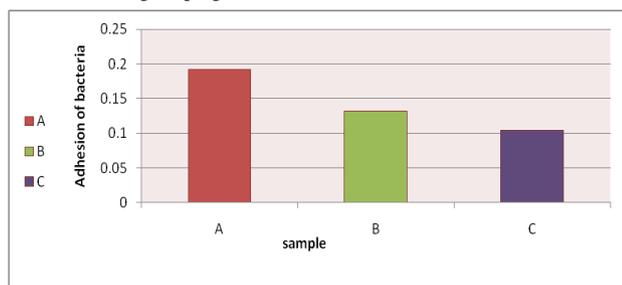


Figure 21. The correlation between the wave length and adsorbent; A: mono monomer, B :di monomer, C: tri monomer.

### 3.8 Evaluation of bacterial adhesion

Corneal bacterial inflammation (transparent tissue by the front of the eye), caused by germs, is a disease that threatens vision, and can appear in children and adults. Most germs do not have access to a complete and healthy cornea, but when the cornea is exposed, for example, after eye damage or a foreign object entering it, the germs can enter into it and lead to inflammation. The common bacteria that lead to bacterial infection of the cornea are Staphylococcus, which includes the Pseudomonas. In the present research, an assay on pseudomonas bacteria was performed. On ophthalmic features, cellular performance is noteworthy responsible for the biocompatibility of cells Lin et al. [40]. A test that is cytotoxicity was led to detect the alteration of cellular shape through the addition of the take out medium of lens that is made of hydrogel to a cell culture. The contact lenses' surface is ready to adhesion that is microbial pathogens that cause ocular contaminations Stapleton et al. [41]. Staphylococcus aureus is one of the types found recurrently in human eyes, were too noticed on contact lenses of persons Xiao et al. [42]. Hence, Staphylococcus aureus was used by way of a bacterial example to test the adhesion that is bacterial of the lens ingredients. The average sum of bacteria add-on the hydrogels made of silicone were around  $10^4$  CFU/ml. Moreover, bacterial connection for numerous mixing ratios of, AA, NVP and DMA monomers that are hydrophilic in hydrogels made of silicone were examined. The addition of monomers that are hydrophilic other than 35% pointedly reduced the adhesion of bacteria to around  $10^3$  CFU/ml. After the lenses have been exposed to bacteria (Staphylococcus) and incubated for 24 hours, we notice that the highest adhesion rate for bacteria on the lenses is after one and a half to two hours. Dilution There are different types of it, nevertheless Decamitigation was used. This was conducted by taking 1ml of bacterial growth at a certain concentration and dilute it in a ratio of 1 to 10. The process was repeated and each time we reduce it, it becomes ten to the negative one and the twelfth to the negative to the second negative, and so on the more bacteria the concentration, the more cells are attached the third dilution, for example, bacteria B more than the sixth Thus sticking more. As for the acceptable limits for the presence of bacteria on the lens . It is assumed to be a parameter, but of course it is present .Here the type of bacteria plays a role. There are dangerous bacteria as soon as they exist we refuse to use the lens. Of course there is no specific number. Here comes the role of the control group and we compare with it where we compared the results with a search Alkhozai [17]. Generally, a surface which coarser is disposed to further bacterial adhesion because inadequacies on the

surface region where contamination bonds are probable to form Tam [43]. The encouraging correlation was too stated by Giraldez et al. [44] once the further hydrophobic silicone contact lenses display larger vulnerability to adhesion that is *Staphylococcus epidermidis* to the lenient contact lenses that are conventional Giraldez et al. [45]. The obtained results agree with the previous work, It was proposed that the hydrophilicity of the lens surface is among shaping elements for adhesion that is bacterial.



**Figure 22. The value of adhered cells, A: mono monomer, B: di monomer, C: tri monomer.**

#### 4. Conclusion

In this paper, three sequences of hydrogels made of silicone were made through being underwent copolymerizing two monomers that are silicon-containing TRIS with three monomers that are hydrophilic AA, NVP as well as DMA. The used method is efficient to develop the transparency of silicone hydrogels. The EWC, soft transmittance, mechanical features, Dk, as well as bacterial attach ability of got silicone hydrogels were calculated, as well as their associations were argued in details. The outcomes displayed which the EWC value rose through the rise of monomers that are hydrophilic. With rising EWC, noticeable light transmittance inclines to rise, nonetheless flexible mechanical features offered in a decreasing trend. The outcomes also displayed that the Dk worth dropped at the beginning as well as later rose once the EWC was from (25.6 to 75)%. The deterioration point of EWC was around 42.5%. For biological aspect, the sum of the bacteria approached towards the hydrogels that are made of silicone falls by rising hydrophilic monomer. Agreeing to general experimental outcomes, The best percentage of silicone obtained in contact lenses is 20%, the silicon hydrogels (Si-co-AA), (Si-co-AA-co-DMA), and (Si-co-AA-co-NVP-co-DMA) are greatly appropriate for the use in contact lenses due to the improved mechanical features as well as little adhesion that is bacterial. In our study, we used optical polymerization in the manufacture of contact lenses instead of thermal, as it gave very fast results in minutes instead of long hours. We also used HDODA, which was not previously used in the manufacture of contact lenses, as it gave excellent results compared to the rest of the crosslinking agents. In addition, the production of new lenses with high oxygen permeability and suitable for human use and drug loading interaction lens.

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