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Influence of Different Denture Base Resins on the Degree of De-Bonding in Terms of the Width of the Micro-Gap Created at Resin Base - Soft Liner Interface: An In-Vitro Study

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Abstract: ***A major drawback of soft liner materials is their limited durability. The study was carried out with an intent to investigate the durability of silicone soft liner with three commonly used acrylic based denture resin material – heat cure, high impact and self cure and relate them to the width of the micro-gap formed at resin base-soft liner interface after accelerated aging procedure. Greater the width of micro-gap formed, greater will be the potential for micro-leakage and microbial colonization, faster will be its de-bonding from the denture base and hence lower will be its durability. The rationale behind this study was to rate the three commonly used forms of acrylic based denture resin materials (heat cure, high impact, self cure) on the basis of their ability to form durable bonds with the silicon soft liner and offer suggestions to the dental clinicians regarding which acrylic based denture resin material should be preferably chosen for complete denture fabrication in cases where a silicone soft liner material is indicated to ensure optimum durability of the prosthesis.***

Keywords: Micro-gap, Viscoelasticity, Thermo-cycling, Silicone elastomers, Micro-leakage, Plasticized acrylics

1. Introduction

Soft denture liners are resilient polymeric materials that have proved to be an excellent clinical adjunct in the management of patients with chronic denture soreness and have also found a wide range of applications in the field of maxillofacial prosthesis. Their effectiveness in handling such cases has been attributed to their inherent elasticity and viscoelastic property that enable them to control the distribution of stresses over the denture bearing mucosa and they also provide a cushioning effect to the cyclic forces of mastication. Soft liners have been categorised into two groups --- Plasticized acrylics and Silicone elastomers. Among the two, silicone elastomers are more popular due to their comparatively greater durability. However, failure of adhesion of silicone soft liners to the denture base lead to the existence of a micro-gap at resin base- soft liner interface which becomes a source of micro-leakage. Such micro-gaps may also harbour micro-organisms which perpetuate and proliferate causing de-bonding of the silicone soft liner from the denture base resin. This phenomenon limits the clinical serviceability of the silicone soft liners. Several factors affect the quality of bond between the denture base and soft material – the resilient lining material used, use of adhesive, surface treatment given to the denture base material and nature of denture base material. Studies have been available in the literature evaluating the quality of bond at this interface with variable soft liners used and with variable surface treatment given to the denture base surface standardizing other parameters. This study has been performed to elaborate the quality of bond at the resin base-soft liner interface with three different forms of acrylic denture base resins used standardizing the other parameters. Three different forms of acrylic denture base resins used in this study are heat cure acrylic denture base resin; high impact acrylic denture base resin and cold cure acrylic denture base resin.

2. Aim of the Study

To evaluate the influence of three different denture base resin materials on the degree of de-bonding at resin base - soft liner interface with standardized other parameters.

Objectives of the study

1) To measure the initial width of micro-gaps present at the interface of resin base-soft liner interface with three different resin base materials used in the study before the accelerated aging procedure.
2) To measure the final width of the micro-gaps formed at the resin base-soft liner interface with three different resin base materials used after the accelerated aging procedure.
3) To calculate the differences between the final width and the initial width of the micro-gaps created at the resin base - soft liner interface with the three different resin base materials used in the study.
4) To compare the difference between the final width and the initial width of the micro-gap created at the resin base - soft liner interface with the three different resin base materials used in the study.
5) To establish a link between the width of the micro-gaps formed at the resin base - soft liner interface with the three different resin base materials used in the study.

3. Materials and methods

Twenty circular disc specimens of thickness 2mm ***(Figure 1a)*** and diameter 16mm ***(Figure 1b)*** were prepared each

from three different denture base resins – Heat cure, High impact and Cold cure ***(Figure 2a)*** making the total sample size of the study sixty ***(Figure 2b)***. Thus, the total numbers of samples were divided into three groups of twenty specimens each. **[Table 1]**. To each of these specimens, a room temperature vulcanized (RTV) silicone soft liner (Silagum Comfort, DMG, Hamburg, Germany) is applied on one of the surfaces in thickness of 2mm making the total thickness of the specimens as 4mm and the nature of the interface between the denture base resins and silicone soft liner ***(Figure 3)*** were observed under the Scanning electron microscope both initially and after thermal cycling.

Figure 1 (a): Circular disc specimen of thickness 2mm

Figure 1 (b): Diameter of the circular disc specimen = 18mm.

Figure 2 (a): Three different denture base resins used in the study – Heat Cure ((DPI heat cure, Dental products of India Ltd. Mumbai, India), Cold cure (ProBaseCold, IvoclarVivadent AG Liechenstein), High impact heat cure (Trevalon HI, Dentsply India Pvt. Ltd., Gurgaon, India)

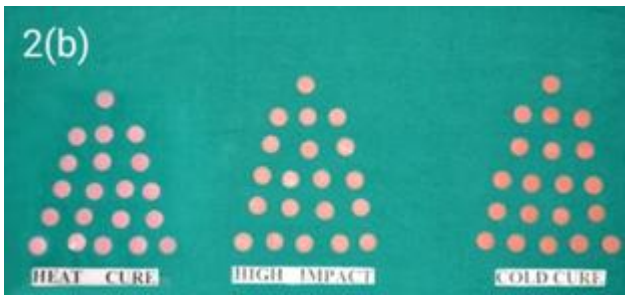

Figure 2 (b): Three study groups of 20 specimens each making the total sample size of the study = 60

Figure 3: Room temperature vulcanized silicone soft liner (Silagum Comfort, DMG, Hamburg, Germany) applied on one of the surfaces in thickness of 2mm making the total thickness of the specimens as 4mm and the nature of the interface between the denture base resins and silicone soft liner were observed under the Scanning electron microscope

Table 1: Study Groups

Groups	Material	No. of Specimens
Group A	Heat cured resin –Silicone soft liner	20
Group B	High Impact heat cured resin – Silicone soft liner	20
Group C	Cold cured resin –Silicone soft liner	20
Total sample size		**60**

Specimens preparation:

16mm diameter circular metal discs ***(Figure 4a)*** were cast which are to be used as template for cutting 16mm circular wax patterns out of modelling wax sheet of thickness 2mm ***(Figure 4b, 4c)***. These circular wax patterns of 16mm diameter and 2mm thickness are to be invested in dental plaster ***(Figure 4d)*** and de-waxed to get the desired size moulds ***(Figure 4e)***.

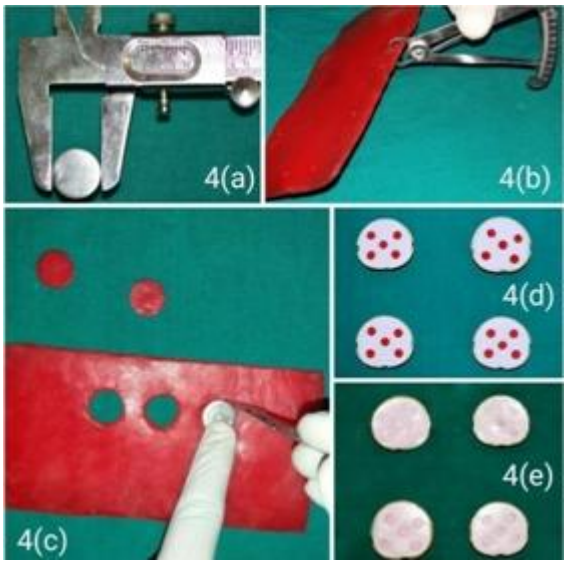

Figure 4(a): 16mm circular metal disc templates; **Figure 4(b):** Modelling wax of thickness 2mm; **Figure 4(c):** Circular wax patterns being cut from modelling wax of

thickness, 2mm using 16mm metal disc as template; **Figure 4(d):** Circular wax patterns invested in flasks; **Figure 4(e):** Moulds of desired shape and size obtained after de-waxing

The powder and the liquid components of the different denture base resins were mixed in the ratios prescribed by the manufacturers and the acrylic doughs are to be packed into the mould and flasked. The mode of curing and the curing cycles employed were as per manufacturers' instructions. After curing, acrylic discs of desired dimensions (2mm thickness and 16mm diameter) are obtained which are finished using acrylic finishing burs.

The surface treatment given to acrylic disc specimens was the application of Silagum Comfort Soft Relining Primer (DMG, Hamburg, Germany) as per manufacturer's instructions.

Silagum Comfort soft relining silicone soft liner (DMG, Hamburg, Germany) was dispensed through the dispenser gun on to the treated surface of acrylic discs and the specimens were pressed gently against two glass slabs to ensure uniform spread of the liner materials over the treated acrylic surface. Once the liner material is set the excess material at borders is trimmed off using a scalpel. The liner material is finished to 2mm thickness using silicon trimmimg wheels such that the total thickness of the specimens become 4mm [2mm denture resin + 2mm silicone liner]

Silagum Comfort Soft Relining Varnish base and Silagum Comfort Soft Relining Varnish catalyst are mixed and applied on the liner surface thereafter as per manufacturer's instructions.

Procedure:
The specimens were then sputter coated with gold using sputter coating device to make them electro conductive and the nature of the interface between the denture base resin and silicone soft liner was observed under the SEM. The specimens were then subjected to accelerated aging procedure by thermo-cycling. They were immersed alternately in two different water baths maintained at 5 degree C and 55 degree C with 60 secs dwell time. The specimens were thermo-cycled for 1000 cycles. The specimens were again sputter coated and the denture resin – soft liner interface was again observed under SEM.

4. Observations & Readings

All the 60 prepared specimens when observed initially under Scanning Electron Microscope (SEM) before thermo-cycling process displayed complete junction at the interface without any micro-gap discernible. However the boundaries of the two materials could be clearly demarcated ***(Figure 5a, 5b, 5c).***

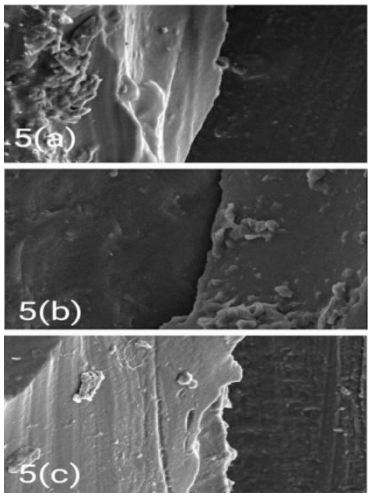

Figure 5(a): Nature of the interface between Heat cure denture base resin material and silicone soft liner as observed under Scanning electron microscope (SEM) before thermal cycling; **Figure 5(b):** Nature of the interface between High impact heat cure denture base resin material and silicone soft liner as observed under Scanning electron microscope (SEM) before thermal cycling; **Figure 5(c):** Nature of the interface between Cold cure denture base resin material and silicone soft liner as observed under Scanning electron microscope (SEM) before thermal cycling.

After being subjected to thermo-cycling procedure, all the 60 specimens were again observed under SEM, and this time all the specimens exhibited separation of the boundaries of the two materials and development of micro-gap at the junction either in continuous or discontinuous manner. Calibration was done and the width of the micro-gap was measured for all specimens at three randomly selected regions of the scanned sections ***(Figure 6a, 6b, 6c)*** and the average of the three values is to be taken as the final value of the widths of the micro-gap for each specimen ***[TABLE 2, 3, 4]***

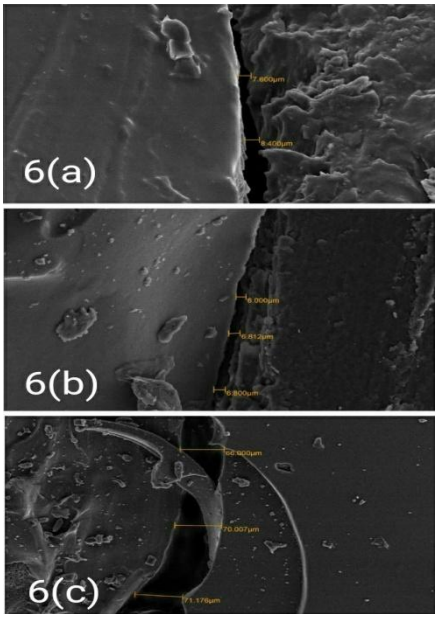

Figure 6(a): SEM photomicrograph revealing the development of micro-gap at interface of Heat cure denture base resin and silicone soft liner after subjecting the specimens to accelerated aging procedure; **Figure 6(b):** SEM photomicrograph revealing the development of micro-

gap at interface of High impact heat cure denture base resin and silicone soft liner after subjecting the specimens to accelerated aging procedure; **Figure 6(c):** SEM photomicrograph revealing the development of micro-gap at interface of Cold cure denture base resin and silicone soft liner after subjecting the specimens to accelerated aging procedure

5. Readings

Table 2: Width of the micro-gap at resin base – soft liner interface after thermal cycling of the Group A specimens (Unit of calibration=µm). Final values of the width of the micro-gaps calculated by taking the average of the three values obtained at three randomly located points a, b & c.

S.No.	Group A readings			Group A Final Value (a+b+c)/3
	a	b	c	
1	7.6	8.4	7.6	7.8
2	7.8	7.5	7.6	7.6
3	8.3	8.4	7.6	8.1
4	9.1	9.4	10.0	9.5
5	7.6	8.0	7.6	7.7
6	8.2	8.1	8.5	8.2
7	8.3	8.5	8.6	8.4
8	7.8	7.6	7.5	7.6
9	7.5	7.2	7.3	7.3
10	8.1	8.5	8.3	8.3
11	7.8	7.6	7.4	7.3
12	7.6	8.3	7.8	7.9
13	9.1	9.8	8.9	9.2
14	8.2	7.8	8.4	8.1
15	6.6	8.9	7.5	7.6
16	7.7	8.5	8.6	8.2
17	6.1	7.2	6.3	6.5
18	6.9	8.9	7.3	7.7
19	7.2	9.2	8.5	8.3
20	8.2	8.2	7.9	8.1

Table 3: Width of the micro-gap at resin base – soft liner interface after thermal cycling of the Group B specimens (Unit of calibration=µm). Final values of the width of the micro-gaps calculated by taking the average of the three values obtained at three randomly located points a', b' & c'.

S.No.	Group B readings			Group B Final Value (a'+b'+c')/3
	a'	b'	c'	
1	6.0	6.8	6.8	6.5
2	6.2	6.5	6.6	6.4
3	6.9	6.9	6.2	6.6
4	6.8	7.3	6.9	7.0
5	7.6	7.5	7.5	7.5
6	5.6	5.8	5.9	5.7
7	8.1	8.6	7.8	8.1
8	7.5	7.5	7.0	7.3
9	7.1	6.8	7.6	7.1
10	8.2	9.0	7.7	8.3
11	6.6	6.7	6.5	6.6
12	5.3	5.9	5.9	5.7
13	7.8	7.1	6.9	7.2
14	8.0	8.1	8.1	8.06
15	7.7	8.3	7.8	7.9
16	7.2	6.8	6.8	6.9
17	5.8	6.2	6.5	6.1
18	8.1	8.5	8.2	8.2
19	7.7	7.2	7.1	7.3
20	6.7	6.8	6.6	6.7

Table 4: Width of the micro-gap at resin base – soft liner interface after thermal cycling of the Group C specimens (Unit of calibration=µm). Final values of the width of the micro-gaps calculated by taking the average of the three values obtained at three randomly located points a", b" & c".

S.No.	Group C readings			Group C Final Value (a"+b"+c")/3
	a"	b"	c"	
1	66.0	70.0	71.1	69.03
2	74.0	80.2	76.6	76.9
3	70.2	73.3	70.1	71.2
4	73.0	86.4	79.8	79.3
5	77.0	72.5	77.3	75.6
6	81.1	83.9	87.7	84.2
7	88.0	96.8	82.4	89.2
8	55.0	62.6	67.6	61.7
9	62.0	67.3	61.9	63.7
10	60.0	66.4	73.4	66.6
11	40.4	49.0	55.5	48.3
12	77.5	82.2	88.9	82.6
13	71.4	76.6	74.0	74.0
14	50.9	40.1	49.8	46.9
15	58.6	60.9	69.8	63.1
16	60.0	67.4	81.0	69.4
17	71.0	73.0	74.8	72.9
18	55.2	59.6	62.3	59.03
19	80.9	86.8	89.6	85.7
20	61.3	67.0	68.2	65.5

6. Statistical Analysis & Results

- Descriptive statistics has been employed to interpret the results of this study.
- Shapiro-Wilk test has been used as the test of normality to assess whether the data readings of the three groups followed normal distribution or not.
- Box plots have been used to rule out the presence of any significant outliers in the three groups.
- The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the mean widths of the micro-gaps of the three groups.
- Finally, a post-hoc bonferroni test has been used for inter-group comparisons.
- Level of significance (α) for this study was taken to be 0.05 %.
- The software used for the statistical analysis was SPSS (Statistical Package for Social Sciences) and Epi-info version 3.0
- Microsoft word and Excel have been used to generate graphs and tables.

Shapiro- Wilk Test

***Group A specimens*:**

H_0 – The data values of Group A specimens are normally distributed (Null hypothesis)

H_1 – The data values of Group A specimens are not normally distributed (Alternate hypothesis)

Sample size (n) = 20

α = 0.05

Sum of squares (SS) = $(X_1 - X_{mean})^2 + (X_2 - X_{mean})^2 + (X_3 - X_{mean})^2 + \ldots (X_{20} - X_{mean})^2$

= 8.06

b) Statistic = 2.751
W (Shapiro-Wilk statistic) = b^2/SS = 0.938
Looking for W value of 0.938 with n=20 in Shapiro-Wilk table, we found that the p value lies between 0.1 and 0.5. Interpolating 0.938 between these value (using liner interpolation) we arrive at p value = 0.226.

Since, p value (= 0.2)>α value (= 0.05), null hypothesis is retained that the ***data readings of Group A specimens are normally distributed.***

Table 5: Test for Normality = Shapiro – Wilk Test for Group A Readings

S. No.	Group A Final Readings (a+b+c)/3 (Unit of Calibration = µm)	Sorted Values (Unit of Calibration = µm)	N= 20 Coefficient Values (from Annexure I)	Diff.	a*diff
1	7.8	X_1=6.5	a1=0.4734	X_{20}-X_1=3	1.4202
2	7.6	X_2 =7.3	a2=0.3211	X_{19}-X_2=1.9	0.61
3	8.1	X_3=7.3	a3=0.2565	X_{18}-X_3=1.1	0.2821
4	9.5	X_4=7.6	a4=0.2085	X_{17}-X_4=0.7	0.1459
5	7.7	X_5=7.6	a5=0.1686	X_{16}-X_5=0.7	0.118
6	8.2	X_6=7.6	a6=0.1334	X_{15}-X_6=0.6	0.08
7	8.4	X_7=7.7	a7=0.1013	X_{14}-X_7=0.5	0.0506
8	7.6	X_8=7.7	a8=0.0711	X_{13}-X_8=0.4	0.0284
9	7.3	X_9=7.8	a9=0.0422	X_{12}-X_9=0.2	0.0084
10	8.3	X_{10}=7.9	a10=0.0410	X_{11}-X_{10}=0.2	0.0028
11	7.3	X_{11}=8.1			
12	7.9	X_{12}=8.1			
13	9.2	X_{13}=8.1			
14	8.1	X_{14}=8.2			
15	7.6	X_{15}=8.2			
16	8.2	X_{16}=8.3			
17	6.5	X_{17}=8.3			
18	7.7	X_{18}=8.4			
19	8.3	X_{19}=9.2			
20	8.1	X_{20}=9.5			
Total =b=					2.751

SS (Sum of Squares) = 8.06, W=b^2/SS, p Value (from Annexure II) 0.226

Group B specimens:
H_0 – The data values of Group B specimens are normally distributed (Null hypothesis)
H_1 – The data values of Group B specimens are not normally distributed (Alternate hypothesis)
Sample size (n) = 20
α = 0.05
Sum of squares (SS) =($X_1 – X_{mean)}^2$ + ($X_2 – X_{mean)}^2$ + ($X_3 – X_{mean)}^2$ +..... ($X_{20} – X_{mean)}^2$
= 11.9063

b) Statistic = 3.3764
W (Shapiro-Wilk statistic) = b^2/SS = 0.957

Looking for W value of 0.957 with n=20 in Shapiro-Wilktable, we found that the p value lies between 0.1 and 0.5. Interpolating 0.957 between these value (using liner interpolation) we arrive at p value = 0.4951

Since, p value (= 0.4) >α value (= 0.05), null hypothesis is retained that the ***data readings of Group B specimens are normally distributed.***

Table 6: Test for Normality = Shapiro – Wilk Test for Group B Readings

S. No.	Group B Final Readings (a'+b'+c')/3 (Unit of Calibration = µm)	Sorted Values (Unit of Calibration = µm)	N= 20 Coefficient Values (from Annexure I)	Diff.	a*diff
1	6.5	X_1=5.7	a1=0.4734	X_{20}-X_1=2.6	1.2308
2	6.4	X_2 =5.7	a2=0.3211	X_{19}-X_2=2.5	0.8027
3	6.6	X_3=6.1	a3=0.2565	X_{18}-X_3=2	0.513
4	7	X_4=6.4	a4=0.2085	X_{17}-X_4=1.66	0.0346
5	7.5	X_5=6.5	a5=0.1686	X_{16}-X_5=1.4	0.236
6	5.7	X_6=6.6	a6=0.1334	X_{15}-X_6=0.9	0.12
7	8.1	X_7=6.6	a7=0.1013	X_{14}-X_7=0.7	0.0709
8	7.3	X_8=6.7	a8=0.0711	X_{13}-X_8=0.6	0.0426
9	7.1	X_9=6.9	a9=0.0422	X_{12}-X_9=0.3	0.0126
10	8.3	X_{10}=7	a10=0.0410	X_{11}-X_{10}=0.1	0.0014
11	6.6	X_{11}=7.1			
12	5.7	X_{12}=7.2			
13	7.2	X_{13}=7.3			
14	8.06	X_{14}=7.3			
15	7.9	X_{15}=7.5			
16	6.9	X_{16}=7.9			
17	6.1	X_{17}=8.06			
18	8.2	X_{18}=8.1			
19	7.3	X_{19}=8.2			
20	6.7	X_{20}=8.3			
Total =b=					3.3764

SS (Sum of Squares) = 11.9063, W=b^2/SS, p Value (from Annexure II) 0.4951

Group C specimens:
H_0 – The data values of Group C specimens are normally distributed (Null hypothesis)
H_1 – The data values of Group C specimens are not normally distributed (Alternate hypothesis)
Sample size (n) = 20
α = 0.05
Sum of squares (SS) = ($X_1 – X_{mean)}^2$ + ($X_2 – X_{mean)}^2$ + ($X_3 – X_{mean)}^2$ +..... ($X_{20} – X_{mean)}^2$
= 2479.8
b) Statistic = 49.077
W (Shapiro-Wilk statistic) = b^2/SS = 0.9712
Looking for W value of 0.9712 with n=20 in Shapiro-Wilktable, we found that the p value lies between 0.5 and 0.9. Interpolating 0.938 between these value (using liner interpolation) we arrive at p value = 0.7819.
Since, p value (= 0.7) >α value (= 0.05), null hypothesis is retained that the data ***readings of Group C specimens are normally distributed.***

Table 7: Test for Normality = Shapiro – Wilk Test for Group C Readings

S. No.	Group C Final Readings (a"+b"+c")/3 (Unit of Calibration = µm)	Sorted Values (Unit of Calibration = µm)	N= 20 Coefficient Values (from Annexure I)	Diff.	a*diff
1	69.03	X_1=46.9	a1=0.4734	X_{20}-X_1=42.3	20.02
2	76.9	X_2 =48.3	a2=0.3211	X_{19}-X_2=37.4	12.009
3	71.2	X_3=59.03	a3=0.2565	X_{18}-X_3=25.17	6.4561
4	79.3	X_4=61.7	a4=0.2085	X_{17}-X_4=20.9	4.3576
5	75.6	X_5=63.1	a5=0.1686	X_{16}-X_5=16.2	2.7313

6	84.2	X_6=63.7	a6=0.1334	X_{15}-X_6=13.2	1.7608
7	89.2	X_7=65.5	a7=0.1013	X_{14}-X_7=10.1	1.0231
8	61.7	X_8=66.6	a8=0.0711	X_{13}-X_8=7.4	0.5261
9	63.7	X_9=69.03	a9=0.0422	X_{12}-X_9=3.87	0.1633
10	66.6	X_{10}=69.4	a10=0.0410	X_{11}-X_{10}=1.8	0.0252
11	48.3	X_{11}=71.2			
12	82.6	X_{12}=72.9			
13	74	X_{13}=74.0			
14	46.9	X_{14}=75.6			
15	63.1	X_{15}=76.9			
16	69.4	X_{16}=79.3			
17	72.9	X_{17}=82.6			
18	59.03	X_{18}=84.2			
19	85.7	X_{19}=85.7			
20	65.5	X_{20}=89.2			
Total =b=					49.007

SS (Sum of Squares) = 2479.8, W=b^2/SS, p Value (from Annexure II) 0.226

Table 8: Shapiro-Wilk Test summary

Groups	Shapiro – Wilk			Results
	Shapiro-Wilk Statistic (W)	Sample Size (n)	P value	
A	0.938	20	0.225	Normally distributed
B	0.9574	20	0.449	Normally distributed
C	0.9712	20	0.760	Normally distributed

Box Plots

Box plots comparing the width of micro-gaps between Group A, B and C specimens showed no outliers in Group B and Group C specimens' readings but two possible outliers (6.5µm, 9.5µm) in Group A specimens' reading. The possible outliners were included in the study because there was very small difference between these values and 1.5 times inter-quartile range below the lower quartile (in case of 6.5µm) and the upper quartile (in case of 9.5 µm).

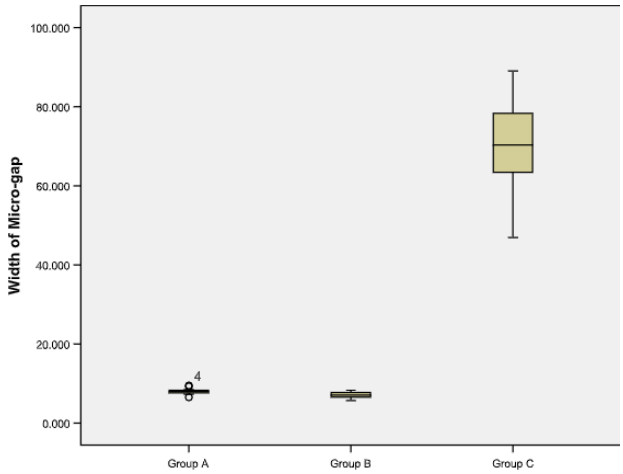

Figure 7: Box plots showing comparison of the width of the micro-gaps between the specimens of three groups.

One -Way ANNOVA test

H_0 – The mean values of the micro-gap widths of all three groups are equal. (Null hypothesis)

H_1 – There is significant difference in the mean values of the micro-gap widths between the three groups. (Alternate hypothesis)

Level of significance = α = 0.05

Table 9: Data Summarized for Application of One-Way ANNOVA analysis

Groups	n	Mean	Std. Dev.	Std. Error
Group A	20	7.97	0.6514	0.1457
Group B	20	7.058	0.7916	0.177
Group C	20	70.243	11.4244	2.5546

Sum of squares total (SS_T) = Sum of squares of all 60 observation readings - Sum of all 60 observation readings/ N (where N= sum total of specimens in the three groups.

Sum of squares of all 60 observation readings = $(7.8)^2 + (7.6)^2 + (8.1)^2 + - - - - - - - - (6.5)^2$

Sum of all 60 observation readings (X) = 7.8+7.6 + 8.1 + - - - - - - - - - - - - - - - -(6.5) / N

SS_T = 54973.8061

Sum of squares between (SS_B)= $(\sum X_A)^2 / n_A + (\sum X_B)^2 / n_B + (\sum X_C)^2 / n_C - X^2 / N$ (where X_A, X_B and X_C are sum of observations of group A, B and C respectively) & (n_A, n_B and n_C are the number of specimens in group A, B and C respectively).

$(159.4)^2/ 20 + (141.16)^2 / 20 + (1404.4)^2 / 20 - (1705.42)^2/ 60$

SS_B = 52474.0617

Sum of squares within (SS_w) = SS_T - SS_B

SS_W = 2499.7895

Total degrees of freedom (Df_T) = N-1 (where N is the total no of specimens)

Df_T = 59

Degrees of freedom between groups (Df_B)= k-1 (where k = total no of groups)

Df_B= 2

Degrees of freedom within groups (Df_w) = N-k

Df_w = 57

Mean sum of squares between groups (MS_B) = SS_B/ Df_B

MS_B = 26237.0083

Mean sum of squares within groups (MS_W) = SS_W/ Df_W

MS_w= 43.856

F-statistics for One Way Annova = MS_B / MS_w

F statistics = 598.2542

P value calculated using SPSS software for F-ratio value of 598.2542 with 2 degrees of freedom in the numerator (Df_B) and 57 degrees of freedom in the denominator (Df_w) is < 0.000001.

P value < 0.00001 (Level of significance = α = 0.05)

Thus, we reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that ***there is a significant difference between the mean values of the widths of the micro-gap between three groups.***

Table 10: Result Summary for One-way ANNOVA analysis

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	p Value
Between Groups	2	52474.0167	26237.0083	598.2542	<0.001
Within Groups	57	2499.7895	43.856		
Total	59	54973.8061			

Post-hoc bonferroni test
Number of comparisons/ statistical analyses to be performed = 3 (Group A to Group B, Group A to Group C and Group B to Group C)

Corrected Bonferroni p value = α/3 = 0.05/3 = **0.016**

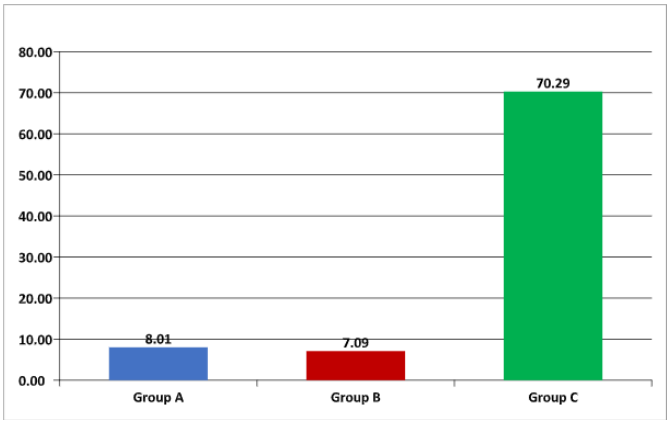

Figure 8: Bar graphs showing comparisons of the mean widths of the micro-gaps between the three groups

Table 11: Post – hoc bonferroni test results

Comparison groups		Mean difference	Standard deviation	Standard error	Observed p value	Bonferroni p value	Results
Group A	Group B	0.92	1.3247	.2292	0.99984	0.16	NOT statistically significant
Group A	Group C	62.27	11.153	2.5587	< 0.001		Statistically significant
Group B	Group C	63.2	11.162	2.5607	< 0.001		Statistically significant

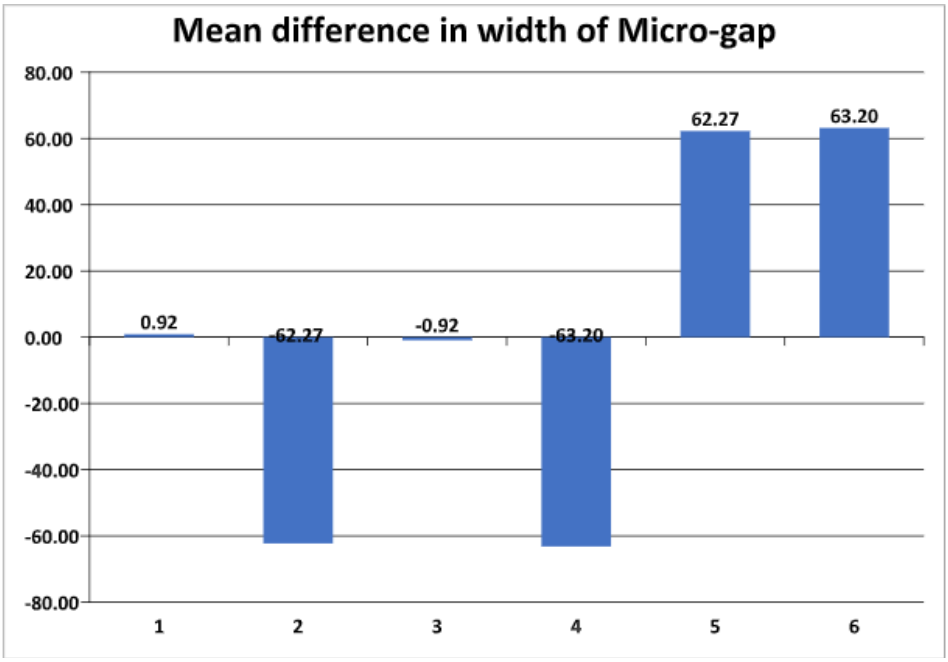

Figure 9: Bar graphs showing intergroup comparisons in terms of the mean differences in the widths of the micro-gaps among the three groups. Bar 1, 5 & 6 show the mean differences in the width of the micro-gaps between Group A and B, Group A and C & Group B and C respectively. While the negative bars 2, 3 & 4 show reverse comparisons i.e. between groups C and A, B and A & C and B respectively.

The inter-group comparisons between the mean values of the widths of the micro-gap among the three groups revealed:

1) There is no significant difference between the mean values of the widths of the micro-gaps between control group A(silicone soft liner bonded to heat cure acrylic resin) and the test group B(silicone soft liner bonded to high impact acrylic resin).

2) There is significant difference between the mean values of the widths of the micro-gaps between control group A(silicone soft liner bonded to heat cure acrylic resin) and the test group C (silicone soft liner bonded to cold cure acrylic resin).
3) There is significant difference between the mean values of the widths of the micro-gaps between the two test groups – group B (silicone soft liner bonded to high impact acrylic resin)and group C(silicone soft liner bonded to cold cure acrylic resin).
4) The mean values of the widths of the micro-gaps of group C specimens is significantly higher than the control group A and test group B specimens. This implies that silicone soft liner bonded acrylic resin prosthesis fabricated using cold cure acrylic resin exhibit lesser durability than such prosthesis fabricated using conventional heat cure or high impact heat cure acrylic resins.
5) The mean values of the widths of the micro-gaps of control group A and test group B do not differ significantly which implies that silicone soft liner bonded acrylic resin prosthesis fabricated using conventional heat cure acrylic resin and high impact heat cure acrylic resin exhibit similar durability.

7. Discussion

Complete denture therapy has been considered as the standard of care for prosthetic management of edentulous patients. However, it is very well recognized that not all patients are able to tolerate or adapt themselves to the prosthesis and frequently complain of pain, discomfort and inability to chew food. Such conditions are more often associated with irregular/sharp alveolar ridges, highly resorbed atrophied alveolar ridges, ridges with thin atrophied overlying mucosa that exhibit low tolerance threshold to pain, cases where the patients experience pain at nerve ending locations beneath the denture and also in situations where dentures exhibit compromised retention due to anatomical limitations resulting in recurrent sore spots beneath the prosthesis. The use to resilient liner materials has proved to be indispensable in management of such cases and their usages have also extrapolated in the fields of maxillofacial and implant prosthesis.

Polymethyl methacrylate (PMMA) has been the most popular material used for denture fabrication since its introduction in 1937 by Dr Walter Wright[1, 2]. Depending upon their mode of activation, the denture based resins based on Polymethyl methacrylate (PMMA) can be either heat-cured or self-cured. Among them, heat cured acrylic denture resins have been used conventionally and preferably over years for fabrication of complete denture bases due to their superior physical properties and better strength compared to self cure resins. Self cure acrylic denture resins have been more popular as denture reline and repair materials and in the fabrication of interim RPDs. Nevertheless, in some cases they are also used for fabricating definitive prosthesis like complete dentures, especially in cases where cost and time are the limiting factors and simplification of the denture processing steps are desired[3]. Attempts to improve the impact strength and fatigue properties of conventionally used heat-cured denture base acrylic resin led to the introduction of High-impact resins in the market which also has became a material of choice these days for fabrication of complete dentures.

Among the two classes of soft liner materials available in the market i.e. plasticized acrylics and silicone elastomers, the latter have been more popular due to their greater durability and hence more serviceable life. Quite unlike acrylic soft liners they are devoid of water soluble plasticizers that may leach out causing the loss of desirable properties. However, their main drawback is inability to adhere to PMMA based denture based resins due to different chemical nature. Their adherence to PMMA based resin depends on the presence of an interfacial adhesive. Nevertheless, presence of moisture and temperature fluctuations in the oral cavity can bring about dimensional changes in both the soft liner and denture base material generating interfacial stresses at resin base-soft liner interface. Such stresses may result in failure of interfacial adhesion culminating in the formation of a micro-gap at the resin base- soft liner interface[4].Bulard et al[5] in his study on the colonization of *C. Albicans* and penetration of long term resilient liners noted a high degree of colonization in the region of resin denture base – silicon soft liner interface which may be attributed to the existence of micro-gap in this region. The conditions prevailing in this micro-gap region i.e. high humidity, warm temperature, inaccessibility to self-cleansing action of saliva perpetuate the growth of microbial flora in this region resulting in progressive widening of the micro-gap at the resin base-soft liner interface ultimately resulting in de-bonding of silicone soft liner from the denture base.

Thermocycling was done to stimulate changes in the temperature that occur in the oral environment. Literature on thermocycling shows that there is no standard thermocycling methodology, dwell time and transfer time [6, 7, 8, 9].So in the present study, samples were subjected to 1000 cycles of thermocycling by dipping them in alternate water baths maintained at 5 degree C and 55 degree C with a dwell time of 60 seconds. This method was selected because it is believed to simulate 1 year of thermal variation in the oral cavity [10]caused by routine eating, drinking and breathing[11].

Uniform thickness of 2 mm of soft liner on the tissue surface of the denture is recommended by the manufacturer and several authors [12, 13, 14] to provide adequate cushioning effect. General recommendations suggest a thickness between 1.5mm to 3mm for denture bases[15]. Keeping these data in mind, the thickness of the denture base material as well as the silicone soft liner was taken as 2 mm making the total width of each specimen 4mm. Amin et al[16] in their study to investigate the nature of interface between the polymethyl methacrylate denture base materials and soft liners also used such specimens of 4mm width comprising of 2mm soft-liner material bonded onto polymethyl methacrylate denture base resin material of 2mm thickness.

Following the soft liner application, the specimens were observed under SEM both before and after the thermocycling process. SEM observations of all 60 specimens prior to thermocycling, revealed complete junction of two materials (denture base and the soft liner) at interface without any micro-gap discernible but with the

boundary sharply demarcated. This result seems to be in confluence with the study of Amin et al[16] in which they also reported a definite demarcation line at the interface between the acrylic resin base and soft liner. They further observed that the SEM photomicrograph of their specimens comprising of acrylic resin base and acrylic soft liner in contrast showed indefinite demarcation lines at the interface. These observations explain the basic difference between the bonding mechanism of two different classes of soft liner materials to acrylic denture base resin. The indefinite demarcation line at the boundary seen in case of acrylic based soft liner materials was attributed to the formation of an interpenetrating network by molecules of two chemically similar polymers across the interface. Silicone soft liner, however, being a chemically and structurally different material cannot interact form such network with the acrylic denture base resin surface.

After thermocycling, SEM observations of all specimens of the three groups were done. Micro-gaps were discernible at the resin base – soft liner junction in all 60 specimens. However, the values of the mean width of the micro-gaps differed in all three groups.Group C specimens showed the highest mean value of micro-gap width followed by Group A. Group B showed the minimum mean value of micro-gap width. However, these values do not differ significantly between Group A and Group B specimens as revealed by statistical tests. But the mean value of the width of the microgap in Group C specimens showed markedly significantly differences from Group A and Group B specimens. The present study was performed to investigate the possibilities of existence of any correlations between the three different forms of acrylic denture base resins (Heat-cure, High impact, Self-cure) and the width of the micro-gap produced at the resin base – soft liner junction. All the specimens of the three groups used in this study received uniform surface treatments, had the same soft liner applied and were subjected to the same thermocycling protocols. So, any difference observed in the mean width values of the micro-gaps in the three groups can be related directly to the differences in the properties of the three different forms of acrylic denture base resins used in this study.

Both the acrylic denture base resin and silicone soft liners have the tendency to undergo dimensional changes in the oral environment due to water sorption and also due to solubility of their leachable contents [4, 17, 18]. Differential dimensional changes between two different materials soft liners and acrylic-based denture resins generate interfacial stresses at resin-base soft liner interface causing de-bonding and generation of micro-gap at this junction. Since in this study, all other parameters were standardised except the forms of acrylic based denture resins used, the statistically significant differences in the mean width of the micro-gaps of Group C specimens from Group A and Group B specimens may be attributed to the degree of incompatibility in the values of dimensional changes produced after the thermo-cycling process between the two materials – denture base resins and the soft liner. The self cure denture resin based specimens (Group C) exhibiting statistically significant differences in the mean micro-gap widths among the three groups corresponds to highest degree of mismatch in the values of dimensional changes that have occurred between the two materials (denture base & soft liner) after being subjected to thermo-cycling procedure.

The silicone soft liner used in this study is auto-polymerized silicon soft liner (Silagum Comfort, DMG, Hamsburg, Germany). Heat cured silicon soft liners are also available in the market which may exhibit different values of the dimensional changes after being subjected to thermo-cycling process and consequently the width of the formed micro-gaps may differ. This becomes one of the limitations of this study. Another limitation of this study is that only brand of the three forms of acrylic based denture resin and the auto-polymerized silicone soft liner have been employed in this study. Multiple brands of each of these are available in the market under different commercial names. Though the basic composition remains the same but some intra-brand compositional and manufacturing variations do exist which in turn may exert influences in the values of dimensional changes they undergo after thermo-cycling. Since this study capitalized on the postulation of dimensional change mismatch and building of stresses at the resin-base soft liner junction as the sole factor in the formation of micro-gap at the resin base-soft liner interface, such considerations become particularly significant. Further studies are required to assess the influence of these parameters on the formation of micro-gap at resin base – soft liner junction.

8. Conclusions

Absence of durable and effective bond between the acrylic denture base resin and silicone soft liner lead to the progressive formation of micro-gaps at the resin base-soft liner interface over a period of clinical use. Existence of micro-gaps may serve as a source of micro-leakage and microbial colonization at this resin base-soft liner junction causing further widening of the micro-gap and de-bonding of the silicone soft liner from the acrylic-resin based prosthesis. The study attempted to relate the width of micro-gaps formed at resin base- soft liner interface to the three commonly used forms of acrylic resins used for denture fabrication. Within the limitations of the study, following inferences can be drawn:

1) The width of the micro-gap formed at acrylic resin base – silicone soft liner interface after accelerated aging procedure differed with the different forms of acrylic denture base resin materials used in this study. Thus, the width of the micro-gap at resin base-soft liner interface is influenced by the form of acrylic denture base resin material used for fabrication of such prosthesis.
2) The width of the micro-gap formed was highest with cold cure acrylic denture resin indicating its greatest potential to cause early de-bonding of silicone soft liner when used for the fabrication of silicone soft liner bonded acrylic resin prosthesis. The width of the micro-gap formed in case of conventional heat cure and high impact denture base resins do not differ significantly and hence silicone soft liner bonded acrylic resin prosthesis fabricated from conventional heat cure and high impact resins have similar durability.
3) Cases where silicone soft liners are indicated in fabrication of an acrylic based prosthesis, in order to ensure the optimum durability of the prosthesis,

conventional heat cure or high impact denture base resins should be preferred to cold cure resins.

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