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Research Article

TO STUDY THE INFLUENCE OF DIFFERENT CHEMICAL SURFACE TREATMENT AGENTS ON TRANSVERSE STRENGTH OF REPAIRED HEAT CURED ACRYLIC RESINS – AN IN VITRO STUDY

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ABSTRACT

Context: Rehabilitation of the edentulous arches with complete denture prostheses has invariably been the mainstay of prosthodontic work spectrum. However acrylic resin complete dentures are susceptible to fracture by accidental fall and also after periods of clinical use. To minimize inconvenience to the patient and save cost in the reconstruction of the dentures, quick, inexpensive maneuvers, and reliable denture repair methods are preferably opted. Auto polymerizing repair resin is the most commonly used material for repair. Attempts have been made with regards to alterations of repaired sites by changing either the joint surface contours, the processing methods, optimizing the distance between repaired sites etc, but influence of surface treatment agents and the role of various chemicals has been sparsely explored!

Aims: The aim of this study was to examine, evaluate, and compare the transverse strength of repaired conventional and hi-impact resistant heat cure denture base resins with and without surface chemical treatments , and to recommend a suitable combination having superior transverse strength in repair of denture bases.

Materials and Methods: A standard stainless steel mould according ADA specification no. 12 was used for the study in order to control the uniformity in dimensions of the heat cured acrylic specimens. A stainless steel mould of specific dimensions [64±0.3×10±0.03×2.5±0.03mm] (length, width, thickness respectively) were constructed for transverse strength testing. A total of 80 specimens were prepared, 40 specimens of each heat cure acrylic resin type (conventional and high impact), each of those 40 specimens were further sub divided into 4 subgroups of 10 specimens (Groups A to D and E to H), that employed usage of surface treatment agents, namely Acetone, Methylene Chloride & ortho -Toluidine.

Statistical analysis used: The results were tabulated, subjected to statistical analysis and comparative analysis was computed using One-way ANOVA, Tukky T test to determine whether significant differences existed between the means of the experimental groups.

Results: Results obtained were highly significant with $p < 0.001$.Methylene chloride treated *high impact* heat cured repaired acrylic samples (Group G) recorded the highest mean transverse strengths , while control *conventional* heat cured repaired acrylic samples recorded the lowest mean trasverse strengths values (Group A).

Conclusion: The high Impact strength heat activated acrylic resins specimens witnessed a greater increase in their mean transverse strengths after repair with chemical surface treatments, than the Conventional strength ones, following the following order of sequence as their counterparts: *Methylene chloride >> Acetone > Touidine*

INTRODUCTION:

Rehabilitation of the edentulous arches with complete denture prostheses has invariably been the mainstay of prosthodontic work spectrum. The introduction of acrylic resin polymers into prosthodontic clinical practise dates back to 1937, when Dr. Walter Wright added a path breaking dimension to the restorative dentistry facet with the discovery of Polymethyl methacrylate (PMMA) resins [1].

The fracture of poly (methyl) methacrylate denture bases however is a commonly encountered clinical occurrence, resulting in great inconvenience to both patient and dentist. Denture fractures occur both, outside and inside the mouth. Outside the mouth, they often occur as a consequence of impact (accident) as a result of expelling the denture from the mouth while coughing, or simply of dropping the denture while handling and cleaning them [2, 3]. Inside the mouth the causes of denture fracture can be insufficient strength of the material, faulty design and fabrication, excessive bite force, improper occlusal plane, high frenal attachment, lack of balanced occlusion, poor fit or limitation in denture base material. These all etiologies ultimately boil down to the low resistance to impact, flexural and fatigue forces of PMMA.

To minimize inconvenience to the patient and save cost in the reconstruction of the dentures, quick, inexpensive maneuvers, and reliable denture repair methods are preferably opted [4, 5]. Auto polymerizing repair resin is the most commonly used material for repair. It is easy, faster and does not cause distortion of the denture base. Chemical or mechanical treatments change the morphology or surface chemistry of the acrylic resin base material to promote better adhesion**;** thereby they serve as improved etchants which enhance the surface energy of the fractured acrylic resin. Etchants such as acetone, methyl methacrylate , methylene chloride are used for improving the bond strength between the base and the repair material. Chloroform, ethyl acetate**,** methyl formate and methyl acetate are used to improve the transverse strength of repaired autopolymerizing resin.

The objective of the present study is to explore and validate the impact of various surface treatment agents **(Acetone, Methylene Chloride & O- Toluidine)** on the transverse strength of repaired conventional and high impact heat cured acrylic resin specimens.

SUBJECTS AND METHODS:

1. Fabrication of Standard Mold:

Metal patterns with dimensions of 65mm x 10mm x 2.5mm (length, width, thickness respectively) were accurately constructed for transverse strength test, as per ADA specification no. 12 as the guidance protocol. These metal patterns were invested each time when the acrylic samples were to be prepared. Specimens were finished to a size of 2.5 × 10 × 64 mm with 600-grit silicon carbide paper under water irrigation and were stored in water at 37ºC for 7 days before the surface treatments.

2. Grouping of specimens:

A total of 80 specimens were prepared, 40 specimens of each heat cure acrylic resin type (conventional and high impact); each of these 40 specimens were further sub divided into 4 subgroups of 10 specimens as follows:

Group A: control group (without surface treatment),
Group B: surface treatment with acetone
Group C: surface treatment with methylene chloride
Group D: surface treatment with toluidine
} Conventional strength

Group E: control group (without surface treatment)
Group F: surface treatment with acetone
Group G: surface treatment with methylene chloride
Group H: surface treatment with toluidine
} Hi-Impact strength

3. Repair method:

The specimens were sectioned in the middle using high speed metal disc under copious irrigation. For all groups butt joint surfaces were produced, the surfaces of test specimens to be surface treated with chemical etchants

was swabbed with chemical etchants, namely **acetone for 30 seconds, toluidine for 5 seconds and methylene chloride for 30 seconds.** The specimens were returned and positioned into the same stone indices (repair index) in such a way that a 3 mm gap existed between the two sections of the specimen. Specimens were repaired with auto polymerizing acrylic resins using sprinkle on technique (10 grams of powder with 7.5 ml of liquid).

4. Testing of the Transverse strength:

Each specimen was subjected to the 3- point bending test at a crosshead speed of 5 mm/min at a 50-mm distance with an **Instron test apparatus**. (Instron 5982, Instron Industrial products, Liberty Street, PA, U.S.A.) The direction of the load was similar to the load direction that affects repaired maxillary denture.

Transverse strength is measured by the following equation:-

$$TS\ (\delta) = 3WL/2bd^2$$

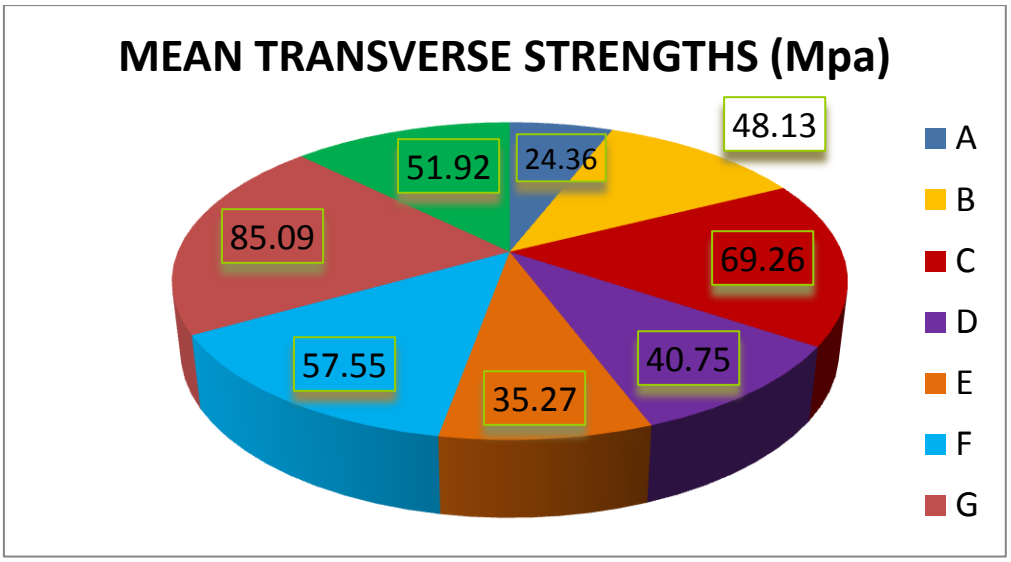
TS – Transverse Strength (N/m2)
W - Fracture load (N)
L - Distance between supports (50mm)
b – Specimen width (10mm)
d - Specimen thickness (25mm)

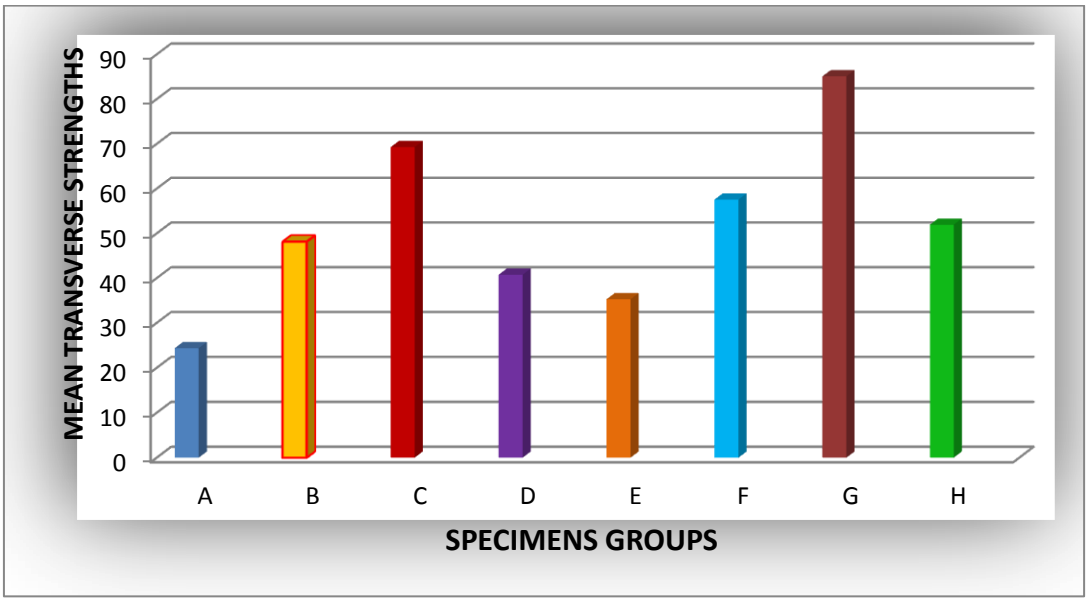
RESULTS:

S No:	SPECIMEN GROUP	RANGE		MEAN	SUM (∑xi∑xi)	STANDARD DEVIATION	VARIANCE	*P value (one-way ANOVA)*
		Min.	Max.					
1	A	20.6443	27.8272	24.3508	243.5078	2.3565	5.5529	<0.0001
2	B	24.7958	70.7755	48.1292	481.2919	9.5089	90.4192	
3	C	33.8761	91.7143	69.2639	692.6391	16.5147	272.7369	
4	D	29.5685	49.9956	40.7497	407.497	6.327	40.0311	
5	E	32.4271	37.3938	35.2266	352.2663	1.5886	2.523766	<0.0001
6	F	35.8703	64.3892	57.5487	575.4874	8.839	78.12734	
7	G	43.6078	103.574	85.0901	850.9008	15.7154	246.9747	
8	H	31.9358	69.016	51.9208	519.2079	10.6776	114.0118	

***Table 1** shows the Range, Mean, Summation, Standard deviation and Variance of transverse strength (MPa) of Conventional and High Impact Heat cured acrylic samples, with and without being surface treated with reinforcing chemical agents, and subsequently repaired with Autopolymerising self cure resins.*

Pie chart & Bar graph depicting the Mean transverse strength of all repair groups specimens pictorically.





The statistical tool used to derive comparison was TUCKEY HSD tests with Q statistic & p values. Results obtained were highly significant with $p < 0.001$.Overall Mean transverse strength of the repaired specimens is in the following order of descending magnitudes, starting from the highest to the lowest values:

METHYLENE CHLORIDE TREATED ***High Impact*** Heat cured Repaired Acrylic Samples
(Group G)

↓

METHYLENE CHLORIDE TREATED ***Conventional*** Heat cured Repaired Acrylic Samples
(Group C)

↓

ACETONE TREATED ***High Impact*** Heat cured Repaired Acrylic Samples **(Group F)**

↓

ORTHO- TOLUIDINE TREATED ***High Impact Heat*** cured Repaired Acrylic Samples **(Group H)**

↓

ACETONE TREATED ***Conventional*** Heat cured Repaired Acrylic Samples **(Group B)**

↓

ORTHO- TOLUIDINE TREATED ***Conventional*** Heat cured Repaired Acrylic Samples **(Group D)**

↓

CONTROL High ***Impact*** Heat cured Repaired Acrylic Samples **(Group E)**

↓

CONTROL ***Conventional*** Heat cured Repaired Acrylic Samples **(Group A)**

Figure 1: Chemical reagents employed as surface treatment reinforcing agents

Figure 2: Heat cured acrylic samples retrieved from flask

Figure 3: Auto polymerising chemically curing resins used to repair the sectioned heat cured resin samples

Figure 4: Finished polished conventional strength heat cured acrylic samples

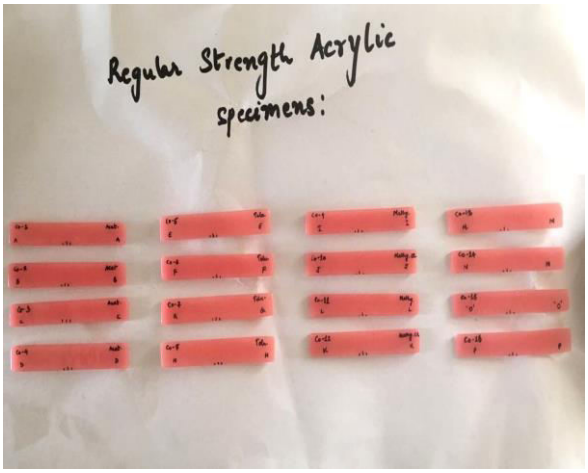


Figure 5: Finished & polished High-Impact resistance heat cured acrylic samples

Figure 6: Sectioned heat cured conventional & High-Impact acrylic resin samples prior to surface treatment with respective chemical reinforcing reagents

Figure 7: Surface treatment (reinforcement) of fractured ends of heat cured samples

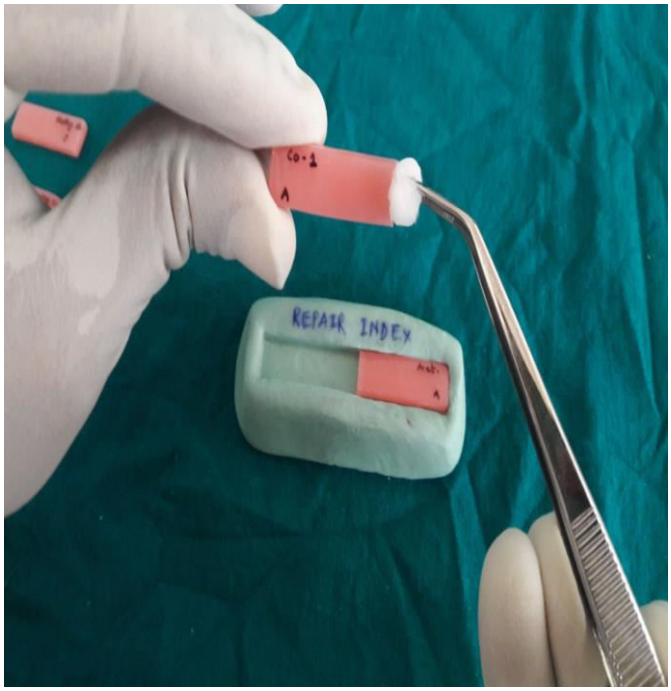


Figure 8: Repair of acrylic samples with auto polymerizing resin using "sprinkle on" method

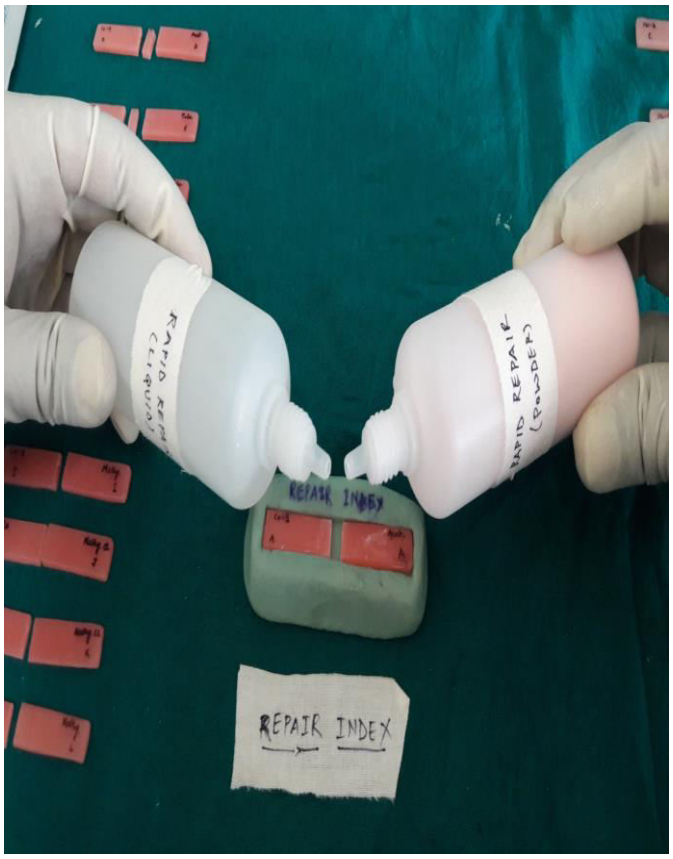
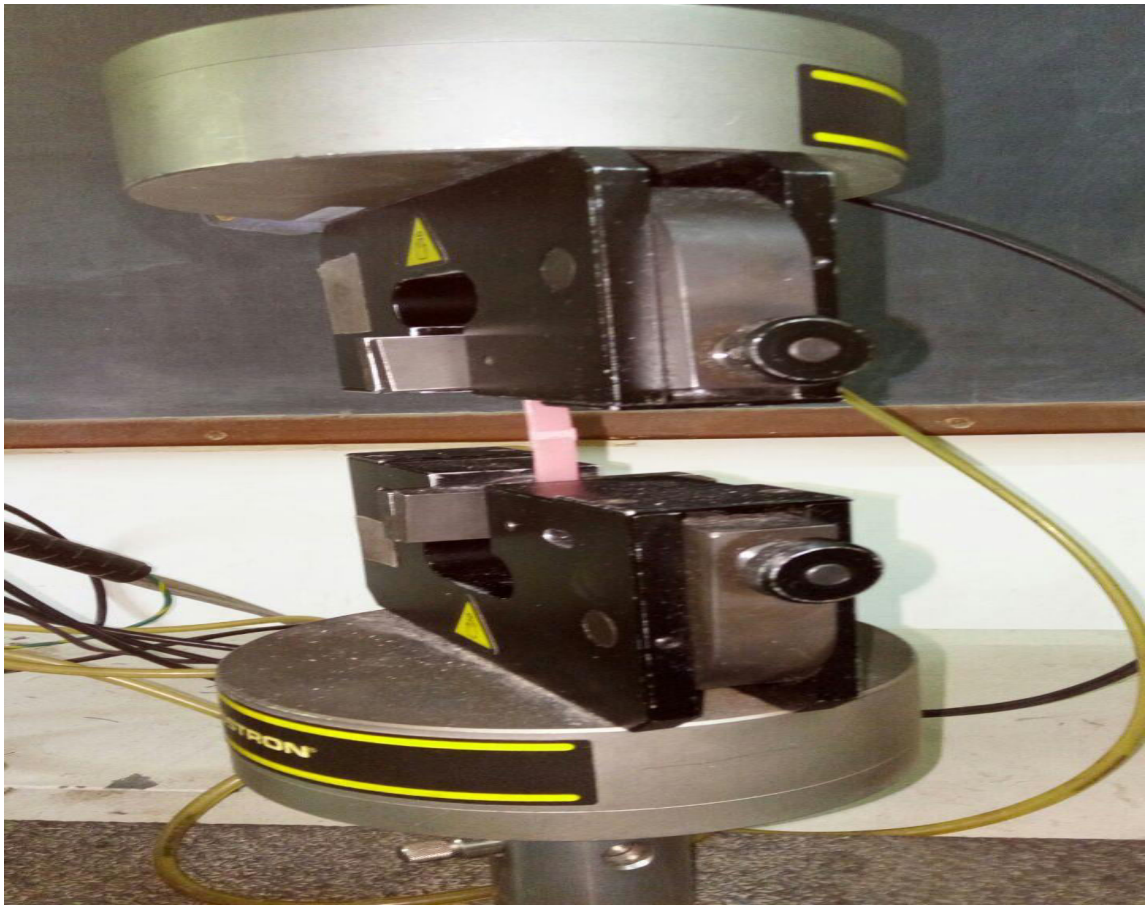


Figure 9: Repaired sample subjected to the three-point bending test with load applied on the central zone



DISCUSSION:

In the present study, in order to compare transverse strengths, two types of acrylic denture bases were selected:

1) **Conventional strength heat polymerization acrylic resins**
2) **High- Impact strength heat polymerization acrylic resins.**

According to ***Craig*** [6] the materials used to repair fractures are:

1) Heat- accelerated acrylic resins:
    a) Water bath
    b) Microwave processed
2) Chemically- accelerated acrylic resins.
3) Light activated acrylics, which have been shown to be fast and effective repair material.

According to ***Rached R.N. (2004)*** [7] the choice of repair material should be influenced by the consideration of following factors:

1. Time required for making repair.
2. Strength obtained with the repair material.
3. Degree to which dimensional accuracy is maintained during repair.

To fulfil these objectives, the satisfactory repairs must be easily and rapidly completed, match the original colour of the material, and maintain dimensional accuracy. Repairs performed with autopolymerized resin do not require much time and are inexpensive and easy to perform, autopolymerized resin was used as a repair material in this study due to above advantages.

Acetone, methylene chloride and ortho- toluidine are organic solvents by nature. They were chosen as surface treatment chemical reagents or reinforcing agents in this study. The mechanism of their reinforcement of repair strength of denture bases can be attributed to the fact, that chemical surface treatment creates superficial crack propagation, as well as the formation of numerous pits approximately 2µm in diameter. This surface morphologic change may enhance the mechanical retention between a fractured surface and repaired acrylic resin. This may be attributed to superior adhesion because of monomer infiltration into the pits and cracks [8]. Thus the increased transverse strength following surface treatment can be reasoned out to be the resultant tight adhesion, the increased mechanical interlocking, farther

improving adhesion between surfaces to be joined [9].

In regard to the distance between the repaired ends of the fractured parts, 3 mm gap was used. It was reported by ***Beyli and Vonfraunhofer [3],*** that the gap size between the broken pieces should be 3mm or less to minimize the bulk of repair material used, which will decrease the degree of polymerization contraction and reduce any color difference between the denture base and repair material. Also one of the principal factors in the strength of repair is the type of joint used in repair. Beyli and Vonfraunhofer [2] noted that the butt joint repair was superior to the other joint type; hence the butt joint type was used in this study.

The transverse strength test, one of the mechanical strength tests, is especially useful in comparing denture base materials in which a stress of this type is applied to the denture during mastication [6]. It is a combination of compressive, tensile and shear strengths, all of which directly reflect the stiffness and resistance of a material to fracture [10, 11]. The results of current study indicated that the transverse strength was influenced by surface treatment as transverse strength of surface treated repaired acrylic specimens was significantly higher than repaired acrylic specimens without surface treatment.

Acetone is used as a solvent by the pharmaceutical industry and as a denaturant in denatured alcohol [11]. Acetone is also present as an excipient in some pharmaceutical drug. It is also used to synthesize methyl methacrylate amongst its numerous other uses.

Methylene Chloride is primarily used as a solvent and diluents, being favoured because of its low cost, low toxicity, and agreeable odour. For example, it is commonly used to clean circuit boards and in some nail varnish removers. It dissolves a wide range of non-polar compounds. It also evaporates quickly and is relatively non-toxic, compared to alternative solvents. Thus it is used widely as a solvent and as a cleaning fluid, especially for dissolving oils [12].

Toluidine is a fairly common solvent, able to dissolve paints, paint thinners, silicone sealants, many chemical reactants, rubber, printing ink, adhesives (glues), lacquers, leather tanners, and disinfectants [12]. No guideline were available from a previous study concerning the most effective application time of toluidine; 5 seconds of surface treatment was chosen as optimum time, as with increased time of treatment, the surface texture of acrylic becomes more porous which might compromise.

Table 1 depicts that the mean transverse strength was highest for Group G (Methylene chloride treated *High Impact* Heat cured Repaired Acrylic Samples) i.e. 85.090 Mpa. The Group A (*Conventional* Heat cured Repaired Acrylic Samples), which was the Control group without being surface treated had the least mean transverse strength i.e. 24.35 Mpa. These results obtained were in accordance with the study conducted by ***ALnadawi LM (2005)*** [13] *and* ***Vojdani M, et al, (2008)*** [14]. According to their study surface treatment with methylene chloride provided **43.8%** increase in transverse strength as compared to control group. Also ***K. Krishna Kishore and Gopinadh Anne et al (2013)*** [15] performed a study along the similar lines, wherein the the effect on Transverse strength and Modulus of elasticity of repaired denture base resin after chemical surface treatment with acetone, methylene chloride and Methyl methacrylate. The transverse strength and modulus of elasticity of Methylene chloride surface treated specimens were recorded to be of highest values (84.78 Mpa & 6960 Mpa respectively). Thus ***Kishore KK and Anne G*** study yielded results which were in accordance with the present study.

Additional scopes of the study:

Apart from the chemical reagents groups included in the study, various other "mechano – chemical" methods have been tried out to reinforce the repair of the denture base resins. These include:

- ✓ Use of MICROWAVE polymerized resins.
- ✓ Use of VISIBLE LIGHT CURED (VLC) resins.
- ✓ Use of metal adhesives resins.
- ✓ Use of novel fibres – ARAMID & NYLON fibres.
- ✓ Chemical reagents like CHLOROFORM & METHYL ACETATE.

SUMMARY & CONCLUSION:

Within the limitations of the laboratory testing conditions of this study, the following conclusions were drawn from our study:

1. No chemical surface reinforcing agent and its repair method could restore the original transverse strength of the denture bases.
2. Surface treatment of the fractured heat activated acrylic resin samples with chemical reagents swabbings, however increased the mean transverse strengths of the repair, against the non treated control samples.
3. The high Impact strength heat activated acrylic resins specimens witnessed a greater increase in their mean transverse strengths after repair with chemical surface treatments, than the Conventional strength ones.
4. Methylene Chloride proved as the most efficacious surface treatment chemical reagent/ reinforcing agent, as the mean transverse strength of both types of repaired heat activated acrylic specimens, namely conventional and High Impact strengths were maximal, after its surface

treatment, followed by Acetone and Ortho-toluidine.

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