Acrylic teeth ridge lap area chemical treatment trough tensile strength test investigations

Adelina Elena Stoia, Mircea Pielmusi, Sorin Lakatos, Cosmin Sinescu, Mihai Rominu, Adrian Gheorghe Podoleanu

Abstract—The purpose of this study was associated to the surface treatments effect evaluation of three different organic solvents on the bond strength of artificial acrylic teeth to denture base repair resin.
40 large size acrylic molars were used to mille 40 acrylic cylinders. The cylinders were randomly assigned to four experimental groups, each containing ten cylinders. The cylinders flat surfaces were considered bonding areas.
The surface treatment regimens were: Group 1: polishing (control group), Group 2: ethylene chloride treatment; Group 3: ethyl acetate treatment; Group 4: acetone treatment.
A self-cured denture base repair resin (Duracryl – Spofa Dental) was used for manufacturing the bonding test specimens, according to the ADA specification No. 15. Each specimen was stored 30 days in distilled water and tested in tensile at a speed of 1 mm/min. The mean values of the tensile bond strength test registered were statistically significant among groups, ranging from 13,67 MPa (group 4, acetone) to 29,14 MPa (group 2, ethylene chloride).
The chemical treatment of acrylic teeth ridge lap area with ethylene chloride, leads to an enhanced bond strength of artificial teeth to the denture base resin compared to the control group, group 3 (ethyl acetate) and 4 (acetone), but reaches lower value levels compared to the ANSI/ADA Nr. 15 according to which tensile strength value must be, if statistically significant, 31 MPa

Keywords— acetone, acrylic teeth, chemical treatment, denture base resin, ethyl acetate, ethylene chloride tensile strength.

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I. Introduction

THE advantages of acrylic teeth is their ability to realize an adhesive bond to the denture base resin. Although the bonding seems to be satisfactory, clinical failures are frequently reported in practice [1–3], especially to those pertaining to frontal group, (Fig.1). Previous studies have demonstrated that debonding of teeth from the base resin is the most frequent repair in practice, (Fig.3), (Fig.4) the bond between acrylic denture teeth and denture base materials being unpredictable [2-5]. Previous studies report that 30% of denture repairs are due to debonded teeth [6-7], situation that generates stress and additional costs for the patients [6].
It is now known that a large variety of factors can generate the failure at the acrylic tooth–denture base resin interface. The failure between artificial acrylic tooth and denture base resin has causes such as wax residues on denture teeth ridge lap area [6], tin-foil substitute contamination [6–9], and different laboratory processing steps [9–11], the type of tooth material (conventional acrylic teeth or cross-linked teeth) [14,18], different or polymerizing processing methods applied to the base resins [2,19].

Fig.1. Acrylic tooth detached from denture base resin

The wide variety of new materials, the different types of denture base resins and different type of artificial teeth materials and the variety of processing methods is responsible for a large variability of the results. In the chemical structure of both acrylic teeth and self cured denture base resin, linear or cross linked polymers are to be found, among which methylmethacrylate, poly(methylmethacrylate), and other different monomers and additives. The polymers are the main component of the teeth and denture base resin. The polymers are the components that determine their technological and physical behavior, which are characterized by long chains of repeated monomeric units.

Fig.2. Completes denture debonded acrylic tooth repair aspects .

Plastic denture teeth are made essentially of polymethylmethacrylate copolymerized with a cross linking agent as, for example, glycol dimethacrylate. It is also known that strongly cross-linked polymers are insoluble in organic solvents

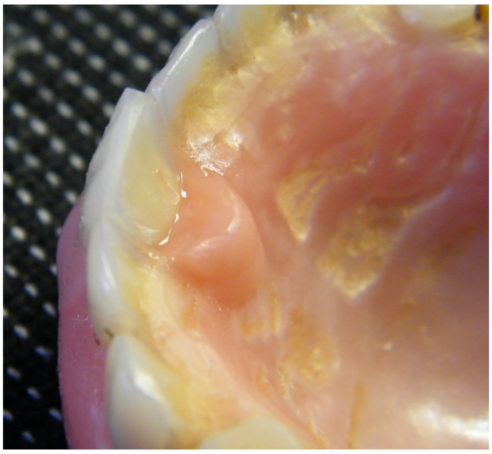

Fig.3. Completes denture debonded acrylic tooth repair aspects: reattached tooth, oral view.

This variability of results increases the need for further examination techniques in order to improve the bond strength of acrylic teeth to denture base resins.

Standards and test method standards have become very important in recent years, because many test methods use arbitrary conditions and procedures. For that reason, technologists have supported the development of standard procedures and the use of these in product specifications. A test method standard must be able to specify all the device parameters, the test piece details, the steps in the procedure and the presentation of the results. The American Dental Association (A.D.A.) specification No.15 defines standards regarding artificial resin teeth, the minimum bond strength required between artificial teeth and denture base materials and also the bond test method.

The aim of this study is not focused on the development of new dental laboratory technologies regarding the repair of the detached teeth from the denture base resin. The study aim involves only the investigation of the chemical treatment effect induced by few organic solvents to the acrylic teeth ridge lap area, in order to improve their bond strength to denture base resin.

Fig.4. Mechanical treatment of acrylic tooth ridge lap area.

From the literature and also from praxis it is known that many attempts have been made to improve the bonding at the interface of acrylic teeth and denture base resin among which: mechanical treatments (Fig.4) [4,7,12,13], chemical treatments (the treatment of the tooth ridge lap area with monomer, organic solvents, or a combination of these [7,10,14]), treatments that have been reported efficient by some researches [12,15–17] and inefficient by others [6,10,13].

II. MATERIALS AND METHODS

A. Sample Preparation

The samples were realized according to ANSI/ADA Specification Nr. 15 .

Acrylic teeth and also self cured denture base resin belong to plastic materials family which has here complicated characteristics and behavior necessitating their own test procedures. In order to establish the bond strength between chemical treated artificial acrylic teeth and self cured denture base resin the tensile test was elected. Tensile strength is known to be the maximum tensile stress exhibited during a test, but occasionally is taken as the stress at break. The most common type of stress-strain measurement is made in tension, which is by stretching the material. A tensile stress is thus applied, defined for a section of uniform cross-sectional area A_0 by the formula $A_1 = F_1/A$ where: A_1= tensile stress and F_1 =

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tensile force. The statement of results as per unit thickness implies that the property is proportional to thickness, is clear that size or shape will influence the final result.
The precise size and shape of test pieces has his importance in order to obtain ideally results when materials must be compared. The dumb-bell shapes are the most frequently used for tensile testing, but the sharp so called shoulders would generate a lower breaking load, because the shape has also some undesirable stress raisers.
After the milling procedure of the 40 artificial acrylic large molars (Spofa Dental) 40 cylinders with 5 mm height and 6 mm diameter were obtained. The milling steps were realized with the JMA Dakar Alexandro Altun SA milling keys device, a trepan bur with 6 mm internal diameter and a diamond disc, attached in the mandrels milling machine..

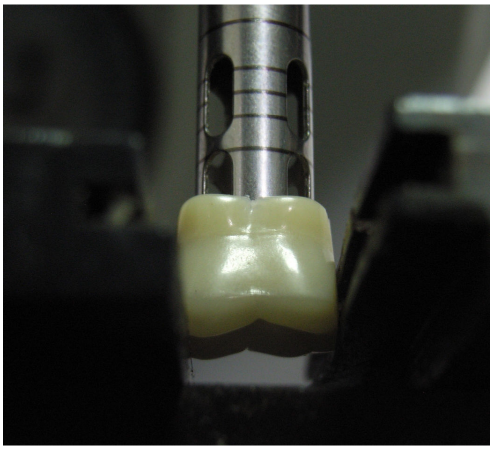

Fig.5.Vestibulo-occlusal aspect of the cylinder milled with the trepan bur inside the acrylic tooth

The molars with the axial faces parallel milled were clamped in to the jaws of the device so that the vertical movement of the trepan bur, attached to the Dakar mandrel, milled the lateral surface of the acrylic cylinder

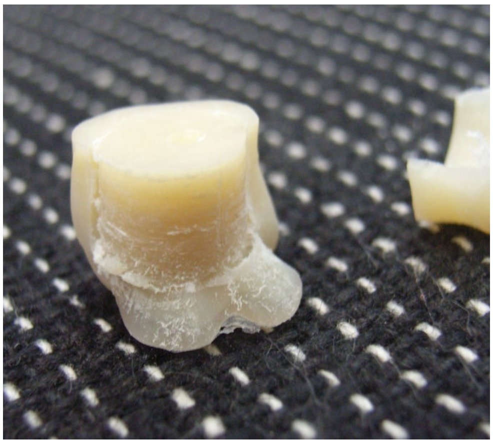

Fig.6. The lateral surface of the acrylic cylinder.

In the Fig.5, Fig.6, Fig.7, are captured the milling steps procedure trough which the acrylic cylinders were obtained from the 40 acrylic artificial molars.
The trepan bur was used to mille the lateral surface of the cylinders, the diamond disc was used to mille to flat the ridge lap area and the occlusal surface of the acrylic teeth as it can be seen in the Fig. 5, Fig.6, Fig.8. In Fig. 7 aspects regarding the removal process of the 4 axial surfaces of the acrylic teeth and of the lateral surface realization of the acrylic cylinders were captured.

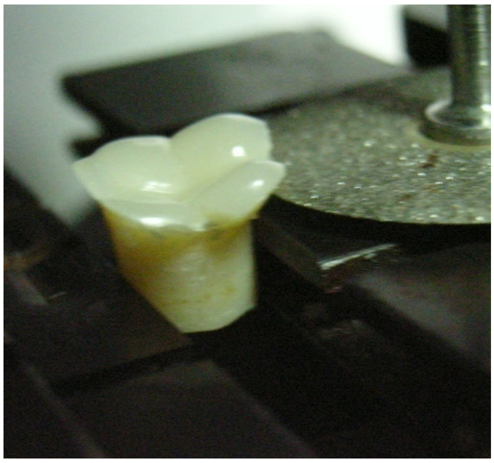

Fig. 7. The second base milling of the acrylic cylinder.

Fig. 8 The shape of the metallic object

Fig.9. The two wax halves ready to be attached

Some of the tensile test specimen manufacturing steps are captured in Fig. 8, Fig. 9., Fig.10., Fig. 11.

Fig.10. Wax sample mould patterns manufacturing process.

The 2 flat bases of each one of the acrylic cylinders were submitted to the chemical treatment as it follows: Group 1 no treatment, Group 2. Ethylene Chloride, Group 3 Ethyl Acetate, Group 4 Acetone. After the chemical treatment the samples of the 4 groups were submitet to time domain C Scan OCT investigations. Following the C Scan OCT investigations the cylinders were each one placed in to the pattern moulds, the dough stage dumping of the denture base resin paste being the next step of the manufacturing procedure of the tensile test samples.

Fig.11. Mould patterns acrylic resin dough stage tamping

The finalization of the denture base resin curing process was followed by the realization of the final shape of the tensile test sample in accordance with ANSI/ADA specification Nr.15. as it can be seen in Fig.12.

All the samples were tensile tested, using Multitest 5i (Mecmesin) at 1 mm /min speed, according to one of the nine test speeds of ISO 527: Speed A 1 mm/min ±50%. Tensile stress is known as the tensile force per unit area of the original cross-section within the gauge length supported by the test piece at a given moment. The standard unit is mega Pascal (MPa) = MN/m2 (Mega Newton/metre2) = N/mm2

Fig.12. The tensile sample shape in accordance with ADA Nr.15

III. RESULTS

Table. 1. The registered tensile strength values (in MegaPascals).

Grup 1 Control	Grup 2 Ethylene Chloryde	Grup 3 Ethyl Acetate	Grup 4 Acetone
27,71 MPa	27,42 MPa	17,80 MPa	11,55 MPa
26,49 MPa	26,34 MPa	21,31 MPa	15,85 MPa
27,25 MPa	28,31 MPa	19,87 MPa	8,34 MPa
25,09 MPa	31,85 MPa	23,97 MPa	12,86 MPa
28,87 MPa	31,40 MPa	32,23 MPa	18,33 MPa
26,90 MPa	30,09 MPa	21,82 MPa	12,48 MPa
28,39 MPa	27,65 MPa	20,82 MPa	15,54 MPa
27,56 MPa	28, 24 MPa	24,10 MPa	12,32 MPa
28,67 MPa	32, 10 MPa	18,08 MPa	17,43 MPa
27,19 MPa	27,96 MPa	31,90 MPa	11,98 MPa

The MegaPascals tensile strength values from the Table 1. are obtained with the formula: $R = F / S$, where F = force and S = surface

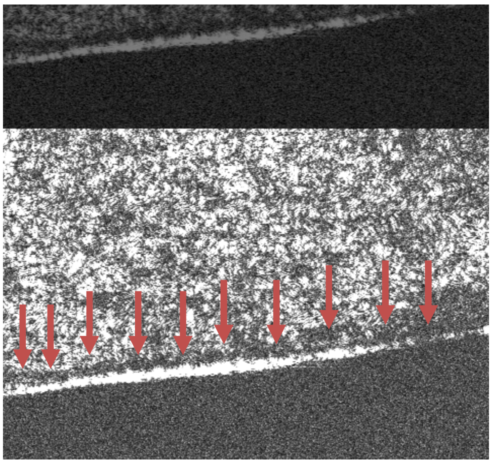

Fig.13. Acetone effect induced to the superficial layer of acrylic teeth.

The C scan OCT time domain investigations allowed capturing data imaging regarding the effect of the organic solvents used in this study to the superficial layer of the acrylic teeth submitet to chemical treatment as it can be seen in Fig.13.
The tensile test strength values at which the acrylic tooth denture base resin adhesive interface cracked as it can be seen in Fig. 14 were one by one captured and registered in tables (Table.1) .

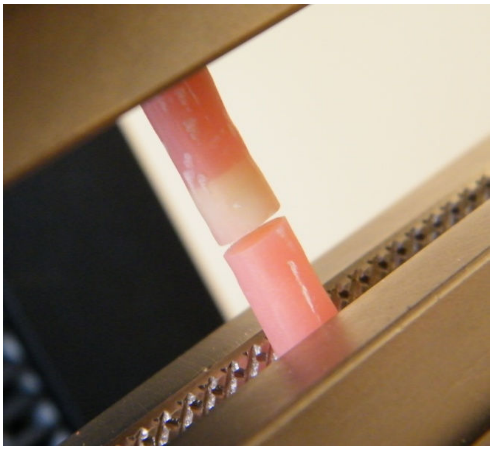

Fig.14. Detaille of the tensile test sample after the adhesive fracture

Table 2 Test Kolmogorov - Smirnov

Continue...	(Mean & standard deviation known)		
Variable	N	max D	p
MPA	40	.197462	p < .10

Table.3. Non-parametric test post-hoc (Mann-Whitney U)

Mann-Whitney U Test (grup1234.sta)

NONPAR STATS — By variable TRAT — Group 1: 87-DICLORET Group 2: 88-AC_ETIL

variable	Rank Sum DICLORET	Rank Sum AC_ETIL	U	Z	p-level	Z adjusted	p-level	Valid N DICLORET	Valid N AC_ETIL
MPA	136.0000	74.00000	19.00000	-2.34338	.019116	-2.34338	.019116	10	10

Mann-Whitney U Test (grup1234.sta)

NONPAR STATS — By variable TRAT — Group 1: 87-DICLORET Group 2: 90-ACETONA

variable	Rank Sum DICLORET	Rank Sum ACETONA	U	Z	p-level	Z adjusted	p-level	Valid N DICLORET	Valid N ACETONA
MPA	155.0000	55.00000	0.00	-3.77964	.000157	-3.77964	.000157	10	10

Mann-Whitney U Test (grup1234.sta)

Continue... — By variable TRAT — Group 1: 87-DICLORET Group 2: 94-NO_TRAT

variable	Rank Sum DICLORET	Rank Sum NO_TRAT	U	Z	p-level	Z adjusted	p-level	Valid N DICLORET	Valid N NO_TRAT
MPA	128.0000	82.00000	27.00000	-1.73864	.082108	-1.73864	.082108	10	10

Mann-Whitney U Test (grup1234.sta)

NONPAR STATS — By variable TRAT — Group 1: 88-AC_ETIL Group 2: 90-ACETONA

variable	Rank Sum AC_ETIL	Rank Sum ACETONA	U	Z	p-level	Z adjusted	p-level	Valid N AC_ETIL	Valid N ACETONA
MPA	153.0000	57.00000	2.000000	-3.62846	.000286	-3.62846	.000286	10	10

Mann-Whitney U Test (grup1234.sta)

NONPAR STATS — By variable TRAT — Group 1: 88-AC_ETIL Group 2: 94-NO_TRAT

variable	Rank Sum AC_ETIL	Rank Sum NO_TRAT	U	Z	p-level	Z adjusted	p-level	Valid N AC_ETIL	Valid N NO_TRAT
MPA	75.00000	135.0000	20.00000	-2.26779	.023349	-2.26779	.023349	10	10

Mann-Whitney U Test (grup1234.sta)

Continue... — By variable TRAT — Group 1: 90-ACETONA Group 2: 94-NO_TRAT

variable	Rank Sum ACETONA	Rank Sum NO_TRAT	U	Z	p-level	Z adjusted	p-level	Valid N ACETONA	Valid N NO_TRAT
MPA	55.00000	155.0000	0.00	-3.77964	.000157	-3.77964	.000157	10	10

Table.4. Non-parametric test ANOVA (Kruskal-Wallis ANOVA)

Median Test, Overall Median = 26.42073 (grup1234.sta)

Continue... — Independent (grouping) variable: TRAT — Chi-Square = 26.40000, df = 3, p = .0000

Dependent: MPA	DICLORET	AC_ETIL	ACETONA	NO_TRAT	Total
<= Median: observed	1.00000	8.00000	10.00000	1.00000	20.00000
expected	5.00000	5.00000	5.00000	5.00000	
obs.-exp.	-4.00000	3.00000	5.00000	-4.00000	
> Median: observed	9.00000	2.00000	0.00000	9.00000	20.00000
expected	5.00000	5.00000	5.00000	5.00000	
obs.-exp.	4.00000	-3.00000	-5.00000	4.00000	
Total: observed	10.00000	10.00000	10.00000	10.00000	40.00000

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Table.5 Kruskal-Wallis ANOVA ranks table.

Kruskal-Wallis ANOVA by Ranks (grup1234.sta)

NONPAR STATS	Independent (grouping) variable: TRAT Kruskal-Wallis test: H (3, N= 40) = 26.44244 p =.0000		
Depend.: MPA	Code	Valid N	Sum of Ranks
DICLORET	87	10	309.0000
AC_ETIL	88	10	192.0000
ACETONA	90	10	57.0000
NO_TRAT	94	10	262.0000

IV. UNITS

After a simple analysis of the Table.3 it can be observed that comparing the p-levels significant differences were observed comparing Group.2. Ethylene Chloride with Group.3 Ethyl Acetate, and also with Group 4 Acetone., and even comparing the Group 3 with Group 4, and also with Group 1 (Control_no treatment). Between Group $ and Group 1 also significant differences were observed.

Softening or swelling of the plastics polymeric substrate by a certain type of solvent is one of the steps of the adhesion mechanism, secondary forces between interwoven polymer chains are generating the bonding of the materials together. The swelling and softening of the superficial layer of the plastic polymeric substrate are followed in some solvents case by the hardening of the superficial layer of the polymeric sample, as it can be seen in Fig. 14, figure which captures with the help of time domain C Scan OCT aspects regarding the effect of acetone induced to the superficial layer of acrylic teeth after 60 seconds treatment time. Analysing the capture shown in Fig.14 it can be seen that the superficial layer of the sample is similar to a white strip line, that could indicate in the hardening of the superficial layer of acrylic teeth sample. This hardening which affects the superficial layer of the acrylic teeth treated with acetone could be the reason of the lowest tensile test values recorded in this study as it can be seen in Table.1.

Voyutskii [20] developed the diffusion theory of adhesion of polymeric materials.

The ethylene chloride treatment enhanced the bond strength between acrylic teeth and denture base resin compared to ethyl acetate and acetone but reported to the control group the results were statistically insignificant. The bond strength values reached by group 3 ethyl acetate and group 4 acetone were not high enough to be in complete accordance with the ANSI/ADA specification Nr.15 according to which the tensile strength between acrylic teeth and denture base resin must reach the value of 31 MPa.

V. CONCLUSIONS

Within limitations of this study related to the research methodology and considering the fact that the tensile test values of ethylene chloride group are significantly higher than those of group 3 and group 4 but statistically insignificant reported to control group the following conclusion can be born

A. Ethyl acetate and acetone have not improved the bond strength of acrylic teeth to denture base resin

B. The ethylene chloride treatment does not enhance significantly the bond strength of acrylic teeth to denture base resin compared to control group

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