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Evaluation of some adhesive materials for repairing gypsum models

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ABSTRACT

The aim of this study was to evaluate some adhesive materials that are used in dentistry for repairing of gypsum cast. The specimens were prepared with dimensions 121×16×10 mm length, width and thickness, respectively. The total number of specimens was 96 (48 specimens for dental plaster, while the other 48 specimens were for dental stone). The length of each specimen was measured and recorded on its surface, then the specimens were fractured into two pieces and reattached together with one of the three adhesive materials, reattachment was done either immediately (time= 0) or after 4 minutes of adhesive application. These specimens were divided into six groups for each gypsum product, which involved: Group 1: Control, unrepaired specimens; group 2: Polycarboxylate cement, time= 0; group 3: Polyacrylic acid solution, time= 0; group 4: Polyacrylic acid solution, time= 4 minutes; group 5: Cyanoacrylate adhesive, time= 0; group 6: Cyanoacrylate adhesive, time= 4 minutes. The length of each specimen was measured again and differences in length for each repaired specimen was measured. Then all specimens were subjected to the flexure of transverse strength test. Data were analyzed using analysis of variance and Duncan's Multiple Range Test.

The results indicated that using of cyanoacrylate adhesive, time= 0 and polyacrylic acid solution, time = 4 minutes had significantly higher transverse strength providing maximum adhesion for each gypsum product. The results of this study also showed that there were dimensional changes with polycarboxylate cement adhesive and such changes not observed with cyanoacrylate and polyacrylic acid solution adhesives.

Key Words: Adhesive material, gypsum products, cyanoacrylate, polycarboxylate cement.

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INTRODUCTION

Gypsum product used in dentistry is a form of calcium sulfate hemihydrate and is classified as 1 of 5 types according to ADA Specification No. 25.[1, 2] Which type of gypsum product is selected depends on the purpose for which the replica is to be used.[3]

Gypsum materials are popular as die materials because of ease of use, cost, compatibility with most impression materials and appropriate setting expansion and familiarity.[4–6] Unfortunately, the most common disadvantage is brittle nature of gypsum occasionally leads to fracture, particularly through the teeth, which form the weakest part of any model.[7, 8] It has always been a temptation for dentists and technicians to glue broken abutment teeth back on a master cast, with cement or an adhesive,

after accidental fracture and proceed with fabrication of a removable partial denture framework.[9, 10]

This study was undertaken to select the most suitable adhesive material for gypsum products. In particular, zinc polycarboxylate cement, capable of bonding to tooth enamel,[11] and aqueous polyacrylic acid, capable of reacting with calcium,[10] were chosen. A cyanoacrylate, which is recommended in dentistry for impregnating stone dies,[12–15] and pin cementing,[16, 17] was also tested. In addition to evaluation of the effect of the tested adhesive material on the dimensions of the repaired gypsum products.

MATERIALS AND METHODS

Three adhesive materials were used in this study as listed in Table (1). The gypsum products used were the dental plaster (Al–Ahleia, Iraq) and dental stone (Zeta Selenor, Italy). A metal rectangular shape mold (without base) was used in order to prepare specimens of gypsum products with 121 mm long, 16 mm wide and 10 mm thick[18] (Figure 1).

Table (1): Adhesive materials

Adhesive Materials	Type	Manufacturer	Batch No.
Adhesor Carbofine (Powder and Liquid)	Zinc Polycarboxylate Cement (Powder–Liquid)	Spofa Dental a.s., Cernkostelecka 84, Cz–100 31 Prague 10, CZECH REPUBLIC	1174086
Adhesor Carbofine (Liquid)	41.5% Polyacrylic Acid Solution in Water Zinc Polycarboxylate Cement (Liquid)	Spofa Dental a.s., Cernkostelecka 84, Cz–100 31 Prague 10, CZECH REPUBLIC	1174198
Quick Star	Cyanoacrylate Adhesive	Furkan Ltd, Sti, TURKEY	980501

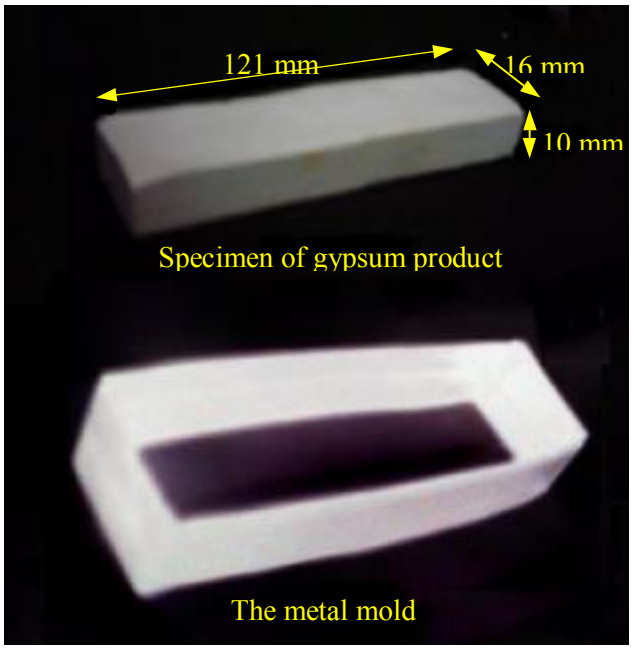


Figure (1): Specimen of gypsum product and the metal mood

The dental stone was mixed with water at water powder ratio of 32 gm of stone: 100 ml of water according to the manufacturer's instructions.

The metal mold was placed on glass slab and by using a dental vibrator (BEGO, Germany) the slurry was poured slowly into the mold in order to eliminate any porous, then another glass slab was placed over the filled mold to ensure flat and parallel ends.

After a setting period of 20 minutes,[5] the glass slabs were taken off and the specimen was easily removed from the mold. All specimens were stored in open air at a temperature range of 20 $\pm$ 2 ºC for 60 minutes.[4]

Forty eight specimens were prepared by this method. The same procedure was used to prepare another 48 plaster specimens. So total number of specimens was 96, and the number of specimen was 8 for each subgroup.

Two reference points on each side of specimen were determined, from which the length of each specimen was measured with a micrometer (Baird and Tatlock, Germany) and recorded on its surface. The specimens were then fractured into two pieces by applying load at the middle of specimen using transverse strength procedure (Figure 2) and reattached together with one of the three adhesive materials and at two time duration. The specimens were divided into 6 groups for each gypsum product as described in Table (2). The repaired specimens were held in contact for 10 minutes and left undisturbed for an additional 20 minutes.[3] The length of each specimen was again measured to determine dimensional change.

Figure (2): Fractured specimen

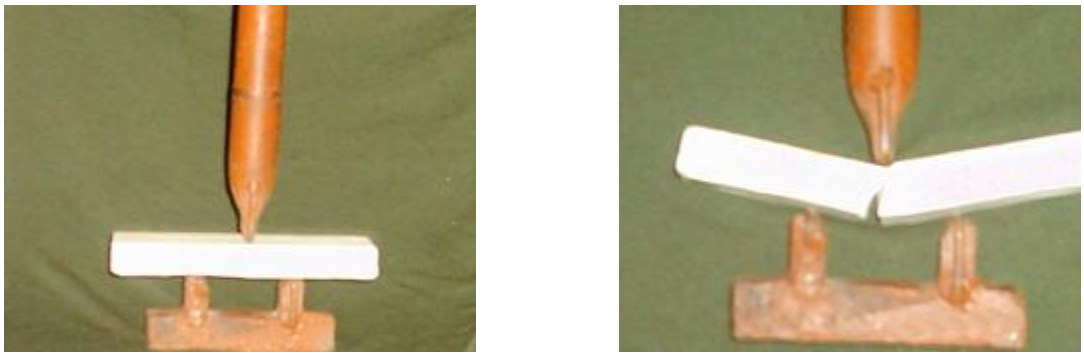
Table (2): Tested groups

Gypsum Product	Groups					
	1	**2**	**3**	**4**	**5**	**6**
Dental Stone	Unrepaired Specimens (Control)	Polycarboxylate Cement Time = 0	Polyacrylic Acid Solution Time = 0	Polyacrylic Acid Solution Time = 4	Cyanoacrylate Adhesive Time = 0	Cyanoacrylate Adhesive Time = 4
Dental Plaster	Unrepaired Specimens (Control)	Polycarboxylate Cement Time = 0	Polyacrylic Acid Solution Time = 0	Polyacrylic Acid Solution Time = 4	Cyanoacrylate Adhesive Time = 0	Cyanoacrylate Adhesive Time = 4

Time = 0: Reattachment of fractured specimens immediately after application of the adhesive materials.
Time = 4: Reattachment of fractured specimens after 4 minutes of adhesive material application.

All specimens were then subjected to the flexure of transverse strength test (Figure 3 a, b) to show the strength of adhesive materials when compared to that of unrepaired specimens. The constant distance between the supports for the flexure test was 40.5 mm.[1] The test was performed by unconfined compression machine (Inc. Model CN 472, EVANSTON, Ill, USA).

Statistical analysis of data included analysis of variance (ANOVA) in order to study the effect of different adhesive materials with 2 time intervals on the transverse strength of plaster and stone groups, and Duncan's Multiple Range Test to compare between the significantly different groups.



(A) (B)

Figure (3): Gypsum specimen was subjected to the flexure of transverse strength test before fracture (A) and after fracture (B)

RESULTS

Table (3) revealed that there were significant differences among six stone groups ($p \leq 0.001$), and Table (4) showed that control groups, polyacrylic acid solution, time= 4 group and cyanoacrylate adhesive, time= 0 group had significantly higher transverse strength (16.05 kg/cm^2, 16.02 kg/cm^2, 15.95 kg/cm^2, respectively). While polyacrylic acid solution, time= 0 group (10.51 kg/cm^2) and zinc polycarboxylate cement, time= 0 group (10.41 kg/cm^2) showed significantly lower transverse strength.

While for plaster groups, ANOVA (Table 5) showed that there were significant differences among six groups ($p \leq 0.001$), and Duncan's Multiple Range Test (Table 6) showed that control group (12.23 kg/cm^2), polyacrylic acid solution, time= 4 group (12.17 kg/cm^2) and cyanoacrylate adhesive, time= 0 group (11.98 kg/cm^2) had significantly higher transverse strength, while zinc ploycarboxylate cement, time= 0 group (6.58 kg/cm^2) had significantly lower transverse strength.

Table (3): Analysis of variance for the effect of different adhesive materials with 2 time intervals on the transverse strength of stone groups

Source	df	Some of Squares	Mean Squares	F–value	*p*–value
Between Groups	5	295.712	59.142	733.278	0.001
Within Groups	42	3.387	8.06×10^{-6}		
Total	47	299.099			

df: Degree of freedom.

Table (4): Duncan's Multiple Range Test for the effect of different adhesive materials with 2 time intervals on the transverse strength of stone groups

Group	No.	Mean (kg/cm^2)	± SD	Duncan's Grouping*		
Unrepaired Samples (Control)	8	16.05	0.2204	A		
Zinc Polycarboxylate Cement, Time = 0	8	10.41	0.39			C
Polyacrylic Acid Solution, Time = 0	8	10.51	0.37			C
Polyacrylic Acid Solution, Time = 4	8	16.02	0.212	A		
Cyanoacrylate Adhesive, Time = 0	8	15.95	0.25	A		
Cyanoacrylate Adhesive, Time = 4	8	14.02	0.16		B	

SD: Standard deviation.
*Means with the same letter were statistically not significant.

Table (5): Analysis of variance for the effect of different adhesive materials with 2 time intervals on the transverse strength of plaster groups

Source	df	Some of Squares	Mean Squares	F–value	*p*–value
Between Groups	5	276.47	55.29	927.099	0.001
Within Groups	42	2.509	5.96×10^{-2}		
Total	47	278.979			

df: Degree of freedom.

Table (6): Duncan's Multiple Range Test for the effect of different adhesive materials with 2 time intervals on the transverse strength of plaster groups

Group	No.	Mean (kg/cm^2)	± SD	Duncan's Grouping*		
Unrepaired Samples (Control)	8	12.23	0.388	A		
Zinc Polycarboxylate Cement, Time = 0	8	6.58	0.24			D
Polyacrylic Acid Solution, Time = 0	8	6.96	0.16		C	
Polyacrylic Acid Solution, Time = 4	8	12.17	0.24	A		
Cyanoacrylate Adhesive, Time = 0	8	11.98	0.17	A		
Cyanoacrylate Adhesive, Time = 4	8	10.02	0.17		B	

SD: Standard deviation.
*Means with the same letter were statistically not significant.

The results of this study showed that there were no dimensional changes of the repaired samples with polyacrylic acid solution and cyanoacrylate adhesive, but there were dimensional changes with zinc polycarboxylate cement adhesive material, 0.04 ± 0.005 mm for stone groups and 0.05 ± 0.006 mm for plaster groups (Table 7).

Table (7): Effects of various adhesive materials on dimensions of repaired samples of gypsum products (dimensional changes in millimeters)

Gypsum Products	Adhesive Material		
	Polyacrylic Acid Solution	Cyanoacrylate Adhesive	Zinc Polycarboxylate Cement
Dental Stone	0	0	0.04 ± 0.005
Dental Plaster	0	0	0.05 ± 0.006

DISCUSSION

Ideally, an adhesive material for gypsum products should have the following characteristics: 1) The ability to bond to calcium, 2) a low film thickness so that the repaired cast is dimensionally unaltered, 3) the ability to penetrate into the porous gypsum structure so that the set adhesive will give good mechanical interlock, and 4) be hydrophilic so that any residual moisture in the gypsum will neither repel the material nor interfere with its setting reaction.[10]

The results of this study showed that samples repaired with polyacrylic acid solution (time= 4 minutes) and cyanoacrylate adhesive (time= 0 minute) showed significantly higher transverse strength for both gypsum products (Tables 4 and 6) when compared with other adhesive materials and other time of adhesive application. These results were in agreement with other studies.[10, 18]

The effects of polyacrylic acid may be explained by assuming that at least two things can happen. First, a chemical reaction between calcium sulfate and the polyacid may lead to the formation of a salt, calcium polyacrylate. Second, because the aqueous is hydrophilic and can penetrate into the porous gypsum structure the formed calcium polyacrylate can be mechanically interlocked in the structure. It appears that a combination of chemical adhesion and mechanical attachment can account for the success of polyacrylic acid.[10] The delay of 4 minutes before reassembly of the broken fragments permits the viscous polyacid to diffuse further into the pores and gives more time for the chemical reaction with calcium sulfate to occur.

Also this study showed that use of polycarboxylate cement as adhesive material for gypsum products give significantly lower transverse strength (Tables 4 and 6). This condition may be explained by the fact that polycarboxylate cement produce relatively high film thickness when compared with other used adhesive material and this will lead to concentration of force on these weak film leading to lower transverse strength.

This study showed that such film of polycarboxylate cement lead to dimensional changes of the samples (0.04 ± 0.005 mm for dental stone and 0.05 ± 0.006 mm for dental plaster), but some researches considered such resulting dimensional changes as not having any clinical significance and occurs within the limits of physiologic tooth movement.[9] While using of cyanoacrylate adhesive and polyacrylic acid solution did not produce any dimensional change of the tested samples (Table 7) because such material has a low film thickness so that the repaired samples are dimensionally unaltered.

CONCLUSIONS

Cyanoacrylate adhesive can give adequate repairs without any dimensional changes of the repaired gypsum models.

An aqueous polyacrylic acid solution could produce adequate repairs of dry cast by applying these products to the fractured surfaces and reassembling the broken fragments after 4 minutes.

Viscous powder/ liquid polycarboxylate cements are not recommended for repair of gypsum casts.

REFERENCES

1) American National Standards/ American Dental Association. Specification 25 for Dental Gypsum Products. American National Standards Institute, New York. 2000; Pp: 244-253.
2) Mahler DB, Andy AB. Explanation for the hygroscopic setting of dental gypsum products. *J Dent Res*. 1960; 39: 578-582.
3) Heshmati RH, Nagy WW, Wirth CG, Dhuru VB. Delayed linear expansion of improved dental stone. *J Prosthet Dent*. 2002; 88: 26-31.
4) Schwedhelm ER, Lepe X. Fracture strength of type IV and Type V die stone as a function of time. *J Prosthet Dent*. 1997; 78: 554-559.
5) Moon MG, Gettys JH. Reinforcement of facial prosthetic dental stone molds. *J Prosthet Dent*. 2000; 84: 113.
6) Lindquist TJ, Standford CM, Knox E. Influence of surface hardness on gypsum abrasion resistance and water sorption. *J Prosthet Dent*. 2003; 90: 441-446.
7) McCabe JF. Anderson's Applied Dental Materials. 6th ed. Blackwell Scientific Publications, London. 1985; p: 32.
8) Mori T, Yamane M. Fractography of cast gypsum. *Aust Dent J*. 1982; 27(1): 30-38.
9) Hanson JG, Ettinger RL, Peterson LC, Rittman B, Scandrett FR. Effect on dimensional accuracy when reattaching fractured lone standing teeth of a cast. *J Prosthet Dent*. 1982; 47: 488-492.
10) Sanad ME, Combe EC, Chem C, Grant AA. The repair of gypsum cast. *J Prosthet Dent*. 1982; 48: 492-493.
11) Anusavice KJ. Philip's Science of Dental Materials. 10th ed. WB Saunders Co, Philadelphia. 1996; p: 569.
12) Fukui H, Lacy AM, Jendersen MD. Effectiveness of hardening films on die stone. *J Prosthet Dent*. 1980; 44: 57-63.
13) Richardson DW, Fletcher VA, Gardner IK, Allen JD. Film thickness of die coating agents. *J Prosthet Dent*. 1991; 66: 431-434.
14) Sanad ME, Combe EC, Grant AA. The effect of model sealant solutions on the properties of gypsum. *J Dent*. 1980; 8: 152-157.
15) Sanad ME, Combe EC, Grant AA. Hardening of model and die materials by an epoxy resin. *J Dent*. 1980; 8: 158-162.
16) Rosenstiel SF, Land MF, Fujimoto J. Contemporary Fixed Prosthodontics. 2nd ed. CV Mosby Co, St Louis. 1995; p: 654.
17) Smith BGN, Wright PS, Brown D. The Clinical Handling of Dental Materials. John Wright and Sons, Ltd. Bristol. 1986; p: 52.
18) Springmann W, Vieira DF. Changes in physical properties of joined gypsum fragments. *J Prosthet Dent*. 1977; 37: 50-56.