The effect of addition of calcium hypochlorite disinfectant on some physical and mechanical properties of dental stone

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ABSTRACT

Background: The potentially damaging effects of the immersion technique, the difficulty in covering the entire surface of the cast with the spray disinfecting solution, and the inability to assume that every impression presented to the laboratory has been disinfected has led to the need for incorporating a disinfectant directly into the calcium sulfate hemihydrate. This study was designed to evaluate the effect of the addition of Calcium Hypochorite disinfectant on some physical and mechanical properties of the dental stone.

Materials and methods: Calcium Hypochlorite disinfectant in aqueous solution in different concentrations 0.5, 1.0, 1.5 and 2.0% was added to type III dental stone. Setting time, setting expansion, reproduction of details, compatibility with impression materials and consistency are physical properties which were evaluated. The compressive strength and surface hardness as mechanical properties were also determined.

Results: The results of this study showed that the addition of 1 % of calcium hypochlorite improved some of the physical and mechanical properties of dental stone (Setting Expansion, Compressive Strength and Surface Hardness) while its adversely affected the other properties (Setting Time)

Conclusions: The 1 % of calcium hypochlorite disinfectant solution could be used to disinfect dental cast with the least effect when compared with the other concentrations of calcium hypochlorite .

Key words: Dental stone, disinfectants, calcium hypochlorite. (J Bagh Coll Dentistry 2012; 24(sp. Issue 1):36-43).

INTRODUCTION

Dentists, dental assistants and laboratory technicians are always at risk of cross-contamination, especially those who do not wear gloves because of their sensitivity to latex rubber or due to the reduction in their working skills as a result of glove-wearing.[1,2]

Dental impressions become contaminated with microorganisms from the patient's saliva and blood, which can cross–infect stone casts poured against them.[3] A number of these microorganisms cause infectious diseases that may be incurable, such as those caused by the hepatitis C and HIV viruses.[4] Practically, sterilization of either the impression or gypsum cast is considered unacceptable because of its adverse effects on the properties of materials used in construction of the impression/cast system.

American Dental Association (ADA) and the Centers for Disease Control and Prevention suggested methods for the disinfection of dental casts, including immersion in or spraying with a disinfectant.[5]

The potentially damaging effects of the immersion technique, the difficulty in covering the entire surface of the cast with the spray disinfecting solution, and the inability to assume that every impression presented to the laboratory has been disinfected has led to the need for incorporating a disinfectant directly into the calcium sulfate hemihydrate.

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Study by Abdelaziz *et al.*[6] and Ivanoveski *et al.*[7] reported a reduction in strength values with most of the gypsum products tested especially those mixed with povidone iodine, glutaraldyhde, sodium hypochlorite. Recently, a study done by Twomey *et al.*[8] showed that the addition of calcium hypochlorite as a disinfecting agent to dental stone, was microbiologically effective at 0.5%.

In this study the calcium hypochlorite disinfectant solution was used in different concentrations (0.5%, 1.0%, 1.5%, and 2% by weight) to disinfect dental stone and to determine the effect of each concentration on some physical and mechanical properties of dental stone.

MATERIAL AND METHODS

A type III dental stone (Elite model, Zherwack SPA, Rovigo, Italy) was used to prepare the samples. The calcium hypochlorite (BDH, Laboratory prepared, England) was used to prepare the testing solutions.

The stone samples were prepared and divided into five groups, according to the concentration of calcium hypochlorite 0, 0.5, 1.0, 1.5, 2.0%.

Group A → Stone powders were mixed with Distilled water

Group B→ Stone powders were mixed with 0.5%Calcium hypochlorite solution

Group C→ Stone powders were mixed with 1 % Calcium hypochlorite solution

Group D→ Stone powders were mixed with 1.5%Calcium hypochlorite solution

Group E → Stone powders were mixed with 2% Calcium hypochlorite solution

Setting time test

the setting time was conducted according to the ADA specification No.25 for gypsum product by using Standard Vicat Apparatus. [9] Setting time was determined by bringing the tip of the 1mm needle of the vicat apparatus into contact with the surface of the test material and locked in position with the thumb screw. The needle was then released and allowed to penetrate the specimen at 15 second intervals by one minute prior to the anticipated setting time (usually at loss of glass or excess water). After each penetration, the needle was wiped cleaned with a piece of gauze and the mold was moved to allow for the next penetration to be in a new area.

The total elapsed time, from the start of mix until the needle failed to penetrate the specimen completely, was taken as the vicat setting time. The test was repeated five times to determine the average value of the setting time.

Setting expansion test

the setting expansion was conducted according to the ISO specification No. 6873 150, through the use of the extensometer apparatus. [10]

The stopper was fixed to provide a trough of not less than 100mm in length. The standard mix of 300gm of stone powder was added to 90 ml of test solutions. The mix was prepared and poured into the trough until it was filled completely.

The initial reading (IR) was done with testing device at 1minute before the setting time.

One end of the specimen was allowed to expand unrestrained for 2 hours, after that the final reading (FR) was taken.

The setting expansion as percentage of the original gauge length was calculated to the nearest 0.01%.

The Difference between FR and IR was considered as the change in length of the specimen, and the percentage of the setting expansion was calculated from the following formula: -

$$\Delta L\% = \frac{FR - IR}{\Delta L} \times 100$$

$\Delta L\%$: percentage of setting expansion.

ΔL: actual length of specimens

The average percentage of five specimens, for each group, was considered as the percentage of the setting expansion.

Reproduction of details test

The ability of the test specimens to reproduce details was conducted according to the method described in the ADA specification No.25 for gypsum by using a test block. [9]

The rubber ring was placed over the test block so that the intersection of cross line and the groove 0.5 mm wide was in the center of the ring, the prepared mix was poured into ring while the block with the ring was vibrated.

The ring and the stone specimen were separated from the test block after 1 hour, and then ready to be evaluated.

The evaluation was conducted by10 dentists who observed and scored the testing specimens twice, the time separated between the 1st reading and 2nd reading was 10 –14 days according to WHO.

The evaluations were made in random order and the evaluators were unaware of the type of specimen being evaluated. Each specimen was evaluated on the bases of a I – IV scoring system.

Criteria for evaluation of reproduction ability of stone specimens was arranged to evaluate the 0.5mm line which scored as follows:

Score I: The line was continuous and clear for the full width of the ring.

Score II: The line was continuous and clear for more than half the width of ring.

Score III: The continuity and clearness of the line was less than half the width of the ring.

Score IV: The line failed to be reproduced along the width of the ring.

Compatibility with Impression Materials

Determination of the compatibility with the impression materials was conducted according to ADA specification No. 25 for gypsum products. [9]

Three types of impression materials were used; alginate, silicone and Zinc Oxide Eugenol impression material.

Consistency Test

The determination of the consistency was according to the British Standard Specification for dental gypsum products ISO NO.6873, by using Modified Vicat Apparatus. [10]

The apparatus consisted of a rod, plunger and additional weights such that the total mass is 100_+0.1g (Figure 3.5)

300 g of stone powder was added to 90 ml of the testing solutions, the mix was poured in to the conical ring mold (large upper most)

Penetration commenced after 3 Minutes, 4 Minutes and 5 Minutes from the start of the mixing and the results was recorded.

The average of nine penetrations (three mixes) was taken as a measure of consistency.

Compressive strength test

Compressive strength values were determined according to the ADA specification No. 25 for gypsum.[9], [10] compressive strength specimens for each group were prepared by vibrating the mixed material in to cylindrical molds 20mm in diameter and 40mm length. The constructed specimens were released from the mold at one-half hour from the start of the mixing. Half of these specimens were stored in air at room temperature 23.0 ±2.0 ^{o}C and 50 ±10 % relative humidity until they were crushed at one hour after the start of mixing. This measured wet compressive strength. The other half of specimens were stored in the same conditions for 24 hours, and then they were incubated at 37^{o}C for seven days before they were subjected to the test. This measured dry compressive strength. Calculation of the compressive strength was determined from the value of the maximum load at the point of specimen fracture according to the following formula: [11]

Surface area = Area of circle= π cm2

$$\text{C.S.} = \frac{\text{Force}}{\text{area}} = \frac{\text{Kg}}{\text{cm}^2}$$

Surface hardness test

10 specimens for each group were prepared. Each specimen had a diameter of 20mm and a length of 40mm. Half of the specimens were tested after 24 hours and the other half after 7 days.

All the specimens were tested with the Brinell hardness tester

The resulting hardness value, known as the Brinell hardness number (BHN), was calculated from the following formula: [11]

$$\text{BHN} = \frac{L}{\frac{p\,D}{2}\left(D - \sqrt{D^2 - d^2}\right)} = \frac{\text{Kg}}{\text{mm}^2}$$

L → load in Kg

D → diameter of ball =2.5mm

d → diameter of indentation in mm

Statistical analysis

The Descriptive statistics included (Arithmetic mean, Standard deviation and Graphical presentation) and the Inferential statistics which included (one- way ANOVA test and the multiple comparison tests utilizing the LSD, Least Significant Difference test, were used in this study.

RESULTS AND DISCUSSION

Setting test

The incorporation of the calcium hypochlorite disinfectant solution in different concentrations, from 0.5 to 2% by weight, with dental stone resulted in a significant retardation in the setting time of the testing groups when compared with the control group, table (1, 2), figure (1). The retardation effect increased as the concentration of calcium hypochlorite increased, this finding is in agreement with that of Harcourt & Lautenschlager, [12] Saso *et al*., [13], Al-Shakily, [14] Al-Fahdawy & Al-Ameer [15], and Berko [16].

The retardation effect of the addition of calcium hypochlorite to dental stone may be due to the fact that the retarder may work on the principle of changing the solubility of the hemi-hydrate and dihydrate crystals so that the conversion of the hemihydrate to dihydrate decreases causing the chemical reaction to slow down. [17]

Poisoning of growing crystals with chlorite ions led to retardation in crystal growth and accordingly improper intermeshing. This can also explain the retardation effect of calcium hypochlorite disinfectant solution. [18]

Setting expansion test

The results of this study showed that the incorporation of the calcium hypochlorite disinfectant solution in different concentrations with dental stone mixture produced an advantageous effect. Table (3, 4)

All the testing groups showed lower setting expansion than the control group with exception for group E (2%), which had no data because of the delayed setting time of more than 120 minutes, this finding is in agreement with the results of Al-Shakily [14], Berko [16] and disagree with the results of Breault *et al* [19], Ivanovski *et al*.[20] , & Edwards *et al*. [21].

Change in the morphology of the resulted gypsum crystals produced changes in the crystal's thrust and consequently tendency for expansion will change. [13]

Reproduction of details test

It was found that the addition of calcium hypochlorite disinfectant solution in different concentrations produced a significant effect on the reproduction of details of dental stone, except for group B (0.5%) and group C (1.0%) in which there was no significant effect on the reproduction of details of dental stone, table (5,6). This finding is in agreement with the results of Edwards et al. [21], Al-Shakily [14], &Berko [16] and in disagreement with that of Saso *et al.* [13].

According to our knowledge the explanation of this phenomenon was not found in any published data concerning the effect of this disinfection method on the detail reproduction of dental stone. However, it may be attributed to the change in the water requirement of dental stone as a result of incorporation of calcium hypochlorite disinfectant solution leading to a change in the recommended consistency for satisfactory detail reproduction. Another explanation is that the bleaching effect of the chlorine on the cast surface may have masked the lines from the evaluator during scoring.

Compatibility with impression materials

The compatibility of the dental stone specimens mixed with calcium hypochlorite disinfectant solution in different concentrations with different impression materials can be seen in the following:

- With Alginate Impression materials they were compatible at all testing concentrations of calcium hypochlorite disinfectant solution, table (7).
- Similar results were found with silicone impression materials except the concentration of 1.5 % which was not compatible, table (8, 9).
- With the ZOE impression material they were compatible at 0.5% and 1.0% of calcium hypochlorite while for 1.5% and 2.0% they were incompatible, table (10, 11).

According to our knowledge the explanation of these phenomena were not found in any published data concerning the effect of this disinfection method on the compatibility of dental stone with impression materials. However, it may be due to some kind of interaction of calcium hypochlorite with that of impression materials leading to reduction in the sharpness of the line reproduced. It also might have been related to the low wetting behaviors of the disinfected dental stone against the surface impression materials. [22] These results in agreement with results of Berko. [16]

Consistency test

The results of this study showed that the addition of calcium hypochlorite disinfectant solution to dental stone produced a change in the consistency of dental stone. This finding is in agreement with the results of Spratley and Combe [23] and in disagreement with the results of Twomey *et al* [8], table (12, 13).

According to our knowledge, the explanation of this phenomenon was not found in any published data concerning the effect of this disinfection method. However, it can be presumed that the additive may have altered the water requirement of a particular stone by changing the strength of the surface forces on the particles in the suspension. This led to reduction in the adhesive forces amongst them and so the resistance to flow arising from contact of individual particles in the suspension resulting in reduction in viscosity. [24]

Compressive strength test

The test for compressive strength was conducted in different time intervals after the beginning of the mixing process (1 hour and after 7 days).

The specimens for the wet compressive strength failed in testing after1 hour. It was expected from the theory of setting that the strength of stone increases rapidly as the material hardens after the initial setting time.[10] In this study it was found that the addition of calcium hypochlorite had a retarding effect on the setting time and the specimens for the testing groups did not reach the initial setting time after 1 hour, so the specimens failed after 1 hour. While the results for the specimens tested after 7 days for the dry compressive strength showed that the addition of calcium hypochlorite caused a reduction in strength except for group C (1.0%), which found no significant effect on the compressive strength when compared with the control group. Table (14, 15,16,17).

The reduction in compressive strength of dental stone mixed with calcium hypochlorite is in agreement with the results of Saso *et al.*[13], Al-Shakily [14] Al-Fahdawy & Al-Ameer [15], and Berko [16] and in disagreement with those of Al-Shakily [14] Al-Fahdawy & Al-Ameer [15], Craig *et al.*[26]

The improvement in the compressive strength with 1% concentration of calcium hypochlorite is in agreement with Twomey *et al.*[8]

The reduction in compressive strength for the other concentrations could be attributed to the reduction in the inter crystalline cohesion.[27] It may also be due to the alteration in the crystal morphology which could affect the ability of the crystals to intermesh and grow leading to improper intermeshing and reduction in inter crystal cohesion.[28]

Surface hardness test

Our investigation showed that incorporation of calcium hypochlorite disinfectant solution in the stone mixture improved the surface hardness of the dental stone samples when tested after 24 hours. The highest BHN was recorded at 1% but with no significant effect. However, a significant reduction in the surface hardness was obtained when the concentration increased up to 1.5 %.

For the samples tested after 7 days, the addition of calcium hypochlorite at different concentrations had no significant effect on the surface hardness of the dental stone, table (18, 19, 20, 21).This finding was in agreement with Al-shakily [14] and Paul *et al*. [25], but they were in conflict with the results of Berko[16]

The discrepancy in the results may be due to the different concentrations of calcium hypochlorite used which may greatly affected the inter crystalline pattern and eventually reduced the inter crystalline cohesion as demonstrated by Skinner and Philip's.[18]

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Table 1: one-way analysis of variance for setting time

	d.f.	F	P	Sig.
Between groups	4	1612.665	0.000	H.S.
Within groups	20			
Total	24			

Table 2: LSD for the setting time

Test groups	Mean Difference	P	Sig.
A-B	-47.53000**	0.000	H.S.
A-C	-82.30000**	0.000	H.S.
A-D	-90.13000**	0.000	H.S.
A-E	-129.59000**	0.000	H.S.

** The mean difference is highly significant when the P < .01

Table 3: one -way analysis of variance for the setting expansion

	d.f.	F	P	Sig.
Between groups	3	20.044	0.000	H.S.
Within groups	16			
Total	19			

Table 4: LSD for setting expansion

Test groups	Mean Difference	P	Sig.
A-B	0.0140**	0.002	H.S.
A-C	0.0140**	0.002	H.S.
A-D	0.0300**	0.000	H.S.

** mean difference is highly significant when P < 0.01

Table 5: one-way analysis of variance for details reproduction

	d.f.	F	P	Sig.
Between groups	4	16.281	0.000	H.S.
Within groups	45			
Total	49			

Table 6: LSD for the reproduction of details

Test groups	Mean Difference	P	Sig.
A-B	-3.00	0.21	N.S
A-C	-3.00	0.21	N.S.
A-D	-9.50**	0.00	H.S.
A-E	-17.50**	0.00	H.S.

** mean difference is highly significant when P < 0.01

Table 7: one–way analysis of variance for the compatibility of dental stone with alginate impression materials

	d.f.	F	P	Sig.
Between groups	4	0.616	0.654	N.S.
Within groups	45			
Total	49			

Table 8: one–way analysis of variance for the compatibility of dental stone with silicone impression materials

	d.f.	F	P	Sig.
Between groups	4	12.545	0.000	H.S.
Within groups	45			
Total	49			

Table 9: LSD for the compatibility of dental stone with silicone impression materials

Test groups	Mean difference	P	Sig.
A-B	0.5000	0.659	N.S.
A-C	-0.6000	0.596	N.S.
A-D	-6.4000**	0.000	H.S.
A-E	-0.7000	0.537	N.S.

** The mean difference is highly significant at the .01 level The mean difference is N.S when P > .05

Table 10: one–way analysis of variance for the compatibility of dental stone with ZOE impression materials

	d.f.	F	P	Sig.
Between groups	4	16.865	0.000	H.S.
Within groups	45			
Total	49			

Table 11: LSD for the compatibility of dental stone with ZOE impression materials

Test groups	Mean difference	P	Sig.
A-B	-1.7000	0.219	N.S.
A-C	-0.6000	0.662	N.S.
A-D	-3.1000*	0.028	S.
A-E	-9.8000**	0.000	H.S.

* The mean difference is significant at the .05 level (P < .05) ** The mean difference is highly significant at the .01 level (P < .01)The mean difference is not significant when (P > .05).

Table 12: one way analysis of variance for consistency test

	d.f.	F	P	Sig.
Between groups	4	6.897	0.003	H.S.
Within groups	40			
Total	44			

Table 13: LSD for consistency test

Test groups	Mean difference	P	Sig.
A-B	-5.7778**	0.000	H.S.
A-C	-3.6667**	0.002	H.S.
A-D	-3.7778**	0.002	H.S.
A-E	-4.0000**	0.001	H.S.

** Mean difference is highly significant when P < .01

Table 14: one – way analysis of variance for dry compressive strength of dental stone

	d.f.	F	P	Sig.
Between groups	4	59.780	0.000	H.S.
Within groups	11			
Total	15			

Table 15: LSD for the data of dry compressive strength of dental stone

Test groups	Mean difference	P	Sig.
A-B	313.16367**	0.000	H.S.
A-C	26.53833	0.266	N.S.
A-D	95.54175**	0.001	H.S.
A-E	79.61800**	0.005	H.S.

** The mean difference is highly significant at the .01 level (P < .01)The mean difference is not significant at the .05 level (P > .05).

Table 16: one–way analysis of variance for wet compressive strength data of dental stone

	d.f.	F	P	Sig.
Between groups	4	715.812	0.000	H.S.
Within groups	10			
Total	14			

Table 17: LSD for the wet compressive strength of dental stone

Test groups	Mean difference	P	Sig.
A-B	103.4091**	0.000	H.S.
A-C	-143.1818**	0.000	H.S.
A-D	2.6515	0.588	N.S.
A-E	31.8182**	0.000	H.S.

Table 18: one way analysis for variance for hardness test (after 1 day)

	d.f.	F	P	Sig.
Between groups	4	5.608	0.003	H.S.
Within groups	20		P<0.01	
Total	24			

Table 19: LSD for data of hardness test (after 1 day)

Test groups	Mean difference	P	Sig.
A-B	0.2274605	0.409	N.S.
A-C	-0.0476219	0.862	N.S.
A-D	0.6797824*	0.020	S.
A-E	0.9926396**	0.001	H.S.

* mean difference is significant when P < .05

** mean difference is highly significant when P < .01, mean difference is not significant when P > .05

Table 20: one – way analysis of variance for the data of surface hardness test of the dental stone

	d.f.	F	P	Sig.
Between groups	4	0.373	0.825	N.S.
Within groups	20			
Total	24			

Table 21: LSD for the data of surface hardness of dental stone (after 7 days)

Test groups	Mean difference	P	Sig.
A-B	0.0635	0.834	N.S.
A-C	-0.1632	0.591	N.S.
A-D	-0.2298	0.452	N.S.
A-E	-0.1964	0.519	N.S.

The mean difference is not significant when (P > .05).

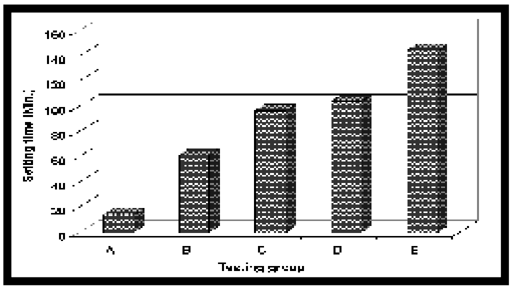

Figure 1: Setting time of dental stone

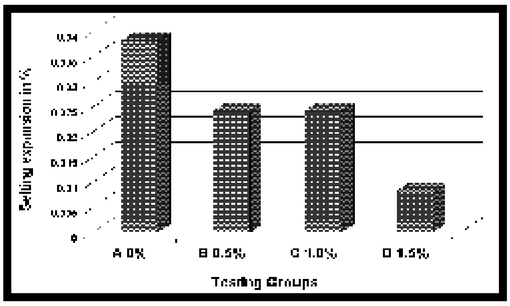

Figure 2: Setting expansion of dental stone

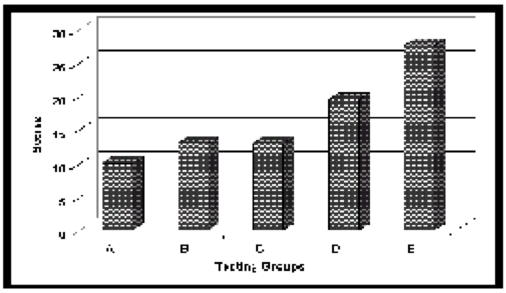

Figure 3: Reproduction of details of dental stone

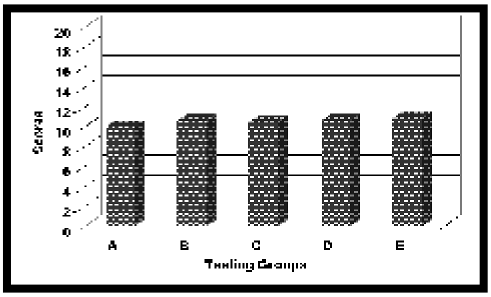

Figure 4: The compatibility of dental stone with alginate

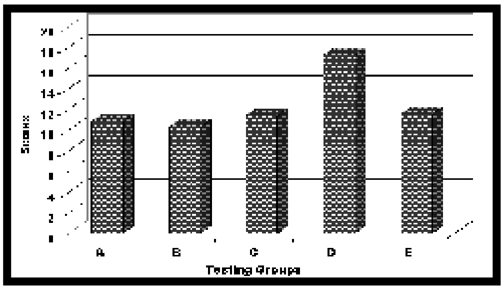

Figure 5: The compatibility of dental stone with silicone impression materials

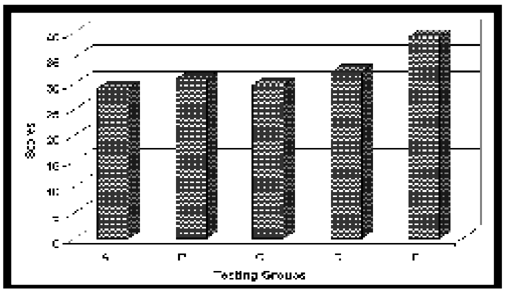

Figure 6: The compatibility of dental stone with ZOE impression materials

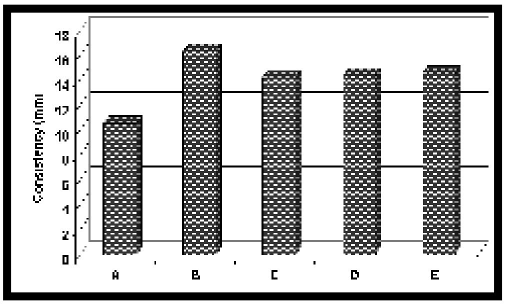

Figure 7: Consistency of dental stone

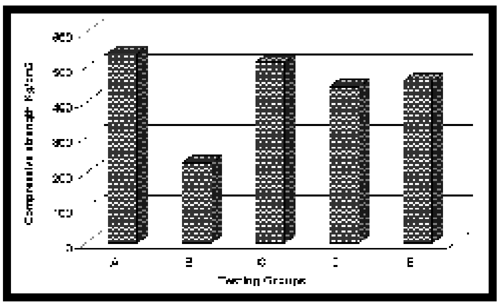

Figure 8: Dry compressive strength of dental stone

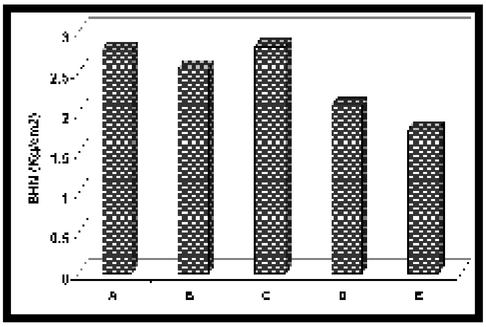

Figure 9: Surface hardness of dental stone