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RESEARCH ARTICLE - MEDICAL TECHNIQUES

Evaluation of the Yttrium Oxide Effect on Some Mechanical Properties of (Type III) Dental Stone

Najwah Yousuf Hameed[1*], Fatima Kadhim Ghadeer[1], Maytham Jalil Fadheel[2]

[1]Department of Dental Technology, College of Health & Medical Technology - Baghdad, Middle Technical University, Baghdad, Iraq

[2]Department of Chemistry, Graduate School of Natural and Applied Sciences, Çankırı Karatekin University, Çankırı, Turkiya

[*] Corresponding author E-mail: najwah.hameed@mtu.edu.iq

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Abstract

For many years, gypsum compounds have been used in dentistry. They're used to make casts for various dental laboratory operations. Gypsum products have important characteristics such as "quality, abrasion resistance, compressive strength, hardness, linear setting expansion during setting, and detail replication". Additionally, the use of additives such as gum arabic, ferric oxide, calcium oxide, and calcium carbonate has greatly improved the compressive strength of gypsum products. The purpose of this study was to investigate the effects of yttrium oxide (Y_2O_3) addition on the hardness and compressive strength of dental stones. Thirty dental stone specimens of (type III) were prepared and separated into (3) groups: group (A) control group, no additives, group (B) 3% Y_2O_3, and group (C) 5% Y_2O_3. The control and experimental groups' mechanical parameters (surface hardness and compressive strength) were measured, and a Shore D hardness tester was used to indent the specimens. An electronic universal testing apparatus with computer control was used to conduct the compressive strength test. The Tukey-HSD test found no difference in surface hardness between the control and experimental groups, a non-significant difference in compressive strength between the control group and dental stone +3% Y_2O_3, and a significant difference in compressive strength between the control group and dental stone +5% Y_2O_3. Between dental stones with 3% and 5% Y_2O_3, there was a substantial difference in compressive strength. The addition of yttrium oxide at weight ratios of 3% and 5% to dental stone did not affect the surface hardness. The addition of 5% yttrium oxide decreased the compressive strengths.

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Keywords: Type III Dental Stone; Yttrium Oxide; Surface Hardness; Compressive Strength.

1. Introduction

Gypsum components are among the most often used dentistry products for the production of dental dies as well as dental casts, which are then utilised in the construction of indirect dental restorations. Natural gypsum minerals were used to make gypsum products. According to their properties and uses, Gypsum products were grouped into five categories by the American Dental Association (ADA) based on their characteristics and intended applications: impression plaster (type I), dental plaster (type II), dental stone (type III), and dental stone high strength (type IV), and dental stone high strength/high expansion (type V) [1]. Although gypsum products were not used directly as restorative materials in dentistry, they were nonetheless thought of as very important adjunctive materials that were used in a variety of dental laboratory treatments [2]. Dental stones were often used as model materials in the creation of dental prostheses. The usual operations in the laboratory for the manufacturing of prostheses might scrape or abrade the surface of the stone model [3, 4]. The ability of a dental stone to withstand various forces during the manufacturing of a prosthesis was then influenced by its surface characteristics [5, 6]. The additive, water/powder ratio, and mixing times were all aspects that could influence the strength of a gypsum product. Chemicals could be used to affect the handling capabilities and features of gypsum products [7]. Several trials were made for enhancing gypsum product properties via the addition of chemical compounds. Some additions, such as ferric oxide, Arabic gum, calcium carbonate, and calcium oxide, considerably improved the strength when compressed the gypsum product [8]. The use of inorganic filler particles has increased the strength of dental materials. Quartz, colloidal silica, and silica glass including barium, strontium, and zirconia are some of the numerous types of inorganic filler particles available today. The mechanical properties of the materials could be altered by the addition of filler particles of varying shapes and sizes [9]. Yttrium oxide, also called yttria is a white, solid and air-stable substance. Yttrium oxide appears in the form of a white powder. Yttrium has multifunctional applications in biomedicine and materials engineering [10]. This study's primary goal was to examine the influence of yttrium oxide (Y_2O_3) addition on the two mechanical properties of dental stone (type III): surface hardness and compressive strength.

Nomenclature & Symbols			
USA	United States of America	˚c	Degree Centigrade
Y_2O_3	Yttrium Oxide	Mm	Millimeter
SEM	Scanning Electron Microscope	ANOVA	Analysis of Variance
SD	Stander Deviation	%	Percentage
ml	Milliliter	Mpa	Mega Pascal
gm.	Gram		

2. Materials and Methods

Dental stone (type III) from Labstone, Kalabhai, India, and yttrium oxide (Y_2O_3) from Changsha Santech, China, were the materials employed in this study.

2.1. Mould preparation

A specialized silicon mold, by the ISO standard (ISO 6873/2013 Dental Gypsum Products), consists of 12 units (20 mm in diameter and 40 mm in height) [11]. As indicated in Fig. 1, this mold was utilized for all groups' cylindrical specimen preparation (no. 30).

Fig. 1. The mold

2.2. Groups of specimens

- Group A: 10 samples (100% dental stone)
- Group B: 10 samples (97% dental stone + 3% Y_2O_3).
- Group C: 10samples (95% dental stone + 5% Y_2O_3).

2.3. Preparation of the gypsum samples

The dental stone (control group) was manually mixed for 10-15 seconds with distilled water at an amount of powder to liquid of 100 g/34 ml (as determined by manufacturer instructions), then mixed by machine for 30 seconds in a vacuum mixer (Mestra, Spain). To minimise surface tension, a brush was used to cover the inner surface of the mold with the mixed stone, and then A vibrator (Mestra, Spain) was used to put the mixed stone into the mold., as shown in Fig. 2. Before being removed from the mold, one hour was given for the specimens to set. The dental stone and yttrium oxide powder were weighted for each experimental group using an electronic digital scale (Italy) based on the percent by weight (97% dental stone +3% Y_2O_3 and 95% dental stone +5% Y_2O_3). The yttrium oxide powder was mixed with distilled water for 30 seconds using a magnetic stirrer machine (JOANLAB, China), the dental stone was added to the mixture and mixed using a vacuum mixer, then the mixed stone was poured into the mold, vibrated, and left to set for 1 hour. and finally the specimens were separated from the mold [12].

2.4. Hardness test measurement

The specimens' surface hardness was measured using an ISO719 (ASTMD) shore "D" hardness tester with an accuracy of 0-100HD (Time group Inc, China). The gadget was positioned vertically above a flat specimen that was supported by a flat, stiff base Fig. 3. The distance between the specimen surface and the hardness tester's indenter is approximately 5 to 12mm. The contact time between the specimen and the indenter was 6 seconds. Five hardness measures were collected from the scale reading for each specimen, and the mean of these values was calculated [13, 14].

2.5. Test measurement for compressive strength

The values compressive strength of the samples were determined using a computer-controlled electronic 'universal testing equipment' at a cross-head speed of 1 mm/minute and a loading rate of 5 KN/min. The specimen is shown in Fig. 4 between the metallic testing table and the Instron universal testing equipment. The specimens were crushed into fragments by the continually growing compressive force, at which point digitalized values in Newton/mm2 (MPa) were recorded. Compressive strength values for each sample were calculated [15].

Fig. 2. Used a vibrator to pour into the mold

Fig. 3. The specimen's hardness test

Fig. 4. Compressive strength test

2.6. Scanning electron microscope (SEM)

A specimen was scanned with an electron beam under high magnifications in the scanning electron microscope test to produce a magnified image for analysis [16]. SEM analysis, which was performed on three specimens, was used to investigate the morphological classification of the samples. It was representative of each group (A), (B), and (C). The SEM photomicrographs were taken with a power of 500 X [11].

3. Results

The mean and SD of surface hardness and compressive strength for all groups are shown in Table 1. It was found that the highest mean surface hardness was obtained in dental stone +3% Y_2O_3, while the lowest mean value was obtained in dental stone (control), while the highest mean value of compressive strength was obtained in dental stone (control), and the lowest mean value was obtained in dental stone +5% Y_2O_3.

Table 1. Descriptive Statistics of surface hardness and compressive strength for all groups

Groups	Surface hardness Shore (D)			Compressive strength (Mpa)		
	N	Mean	±Std	N	Mean	±Std
Dental stone (Control)	10	8.50	2.93	10	15.17	1.329
Dental stone +3% Y_2O_3	10	72.00	2.23	10	14.50	1.224
Dental stone +5% Y_2O_3	10	71.08	1.79	10	8.33	0.816

Further analysis of the surface hardness and compressive strength values was done by using the Tukey –HSD test, as displayed in Table 2. The surface hardness value of the experimental groups (dental stone +3% Y_2O_3 and dental stone +5% Y_2O_3) and the (control group) was t statistically non-significantly different. The difference in compressive strength between the dental stone +3% Y_2O_3 group and the type III dental stone (control group) was not statistically significant. However, there was a statistically significant difference (P <0.05) between the other groups.

Table 2. Inferential statistic by Tukey – HSD test of surface hardness and compressive strength for all groups

Test	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P-Value	Sig.
Surface hardness	Dental stone (Control)	Dental stone +3% Y2O3	-3.50	2.5298	0.552	NS
		Dental stone +5% Y2O3	-2.58	2.6907	0.775	NS
	Dental stone +3% Y_2O_3	Dental stone +5% Y2O3	0.92	1.3809	0.908	NS
Compressive strength	Dental stone (Control)	Dental stone +3% Y2O3	0.67	0.5916	0.678	NS
		Dental stone +5% Y2O3	6.84*	0.5916	0.000	S
	Dental stone +3% Y_2O_3	Dental stone +5% Y2O3	6.17*	0.5916	0.000	S

At 500 magnifications, the SEM image of the control type III dental stone sample revealed the top layer purity and the lowest porosity ratio Fig. 5. While SEM investigation of the yttrium oxide, loaded stone specimens at 500x magnification revealed imperfections, porosity, and semi-regular crystals of dental stone, as well as Y_2O_3, which was scattered throughout the specimen Figs. 6 and 7.

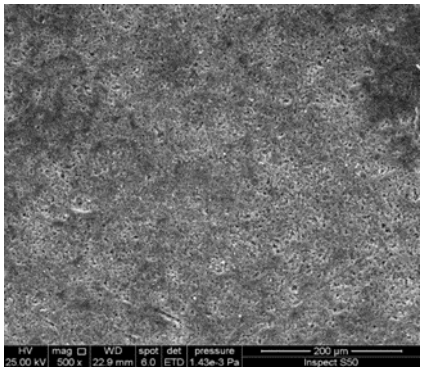

Fig. 5. SEM for control (A) group

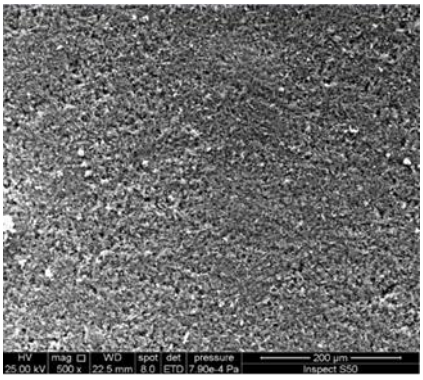

Fig. 6. SEM for (B) group

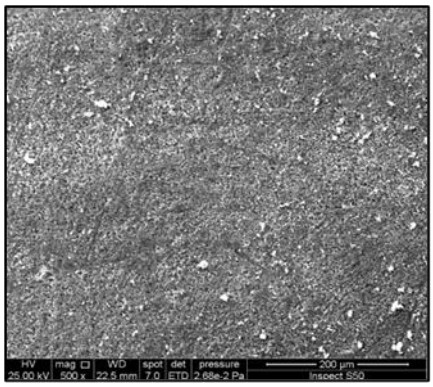

Fig. 7. SEM for (C) group

4. Discussion

To be clinically applicable, gypsum material must have high compressive fracture and strength, abrasion, and abrasion resistance. The compressive strength of gypsum product was generally associated with mixing time, the ratio of water to powder, the amount of free water in manufactured products, the volume of the mixture, chemical compositions, relative humidity, and temperature where materials were stored as well as the period time following cast pouring [17]. To evaluate dental stones, a hardness test is considered as an important factor for evaluation. In general, it is believed that when the stone was harder, then the wear resistance and destruction during casting or finishing and fabrication of the pattern will be better [18]. In the present study, adding yttrium oxide additive with different concentrations (3% and 5%) to dental stone (type III) did not make a noticeable difference (non-significant variations between the controls and experimental groups) in surface hardness of the stone since the P-value was > 0.05. The reason may be that the y_2O_3 chemical did not react with hemihydrate crystals (no formation of more crystals), or it could be that the concentration of the added chemical is not enough to make a change in the properties of the surface hardness of dental stones [19]. Compressive strength was a characteristic that results from the interaction of multiple factors. Some of such factors are intrinsic and are related to the material's compositions [20]. The strengths of the gypsum of dental products have always been known to be crushing or compressive strengths, and nearly all reports included the compressive strength measurement [21]. The results of the compressive strength test for three groups dental stones (control), dental stones +3% Y_2O_3, and type 3 dental stones +5% Y_2O_3) indicated that the highest mean value of compressive strengths obtained in dental stones (control), had non-significant effects with dental stones +3% Y_2O_3, while the lowest mean value was obtained in dental stone +5% Y_2O_3. The decrease in compact strength was often linked to a decrease in the number gypsum crystals caused by a rise in the concentration of Y_2O_3 additive in stone materials, resulting in a decrease in intercrystallization cohesiveness between the gypsum crystals [19, 22].

5. Conclusions

It can be concluded from this study that:

- At 3% and 5% concentrations, yttrium oxide did not influence the surface hardness (type III) of dental stone.
- The addition of yttrium oxide to dental stone (type III) had no effect on compressive strength at 3% yttrium oxide, but at 5% yttrium oxide decreased the compressive strength of the material.

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