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Original Research

In-Vitro Comparative Evaluation of Physical Properties of Type II, III, and IV Dental Gypsum Materials

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ABSTRACT

Introduction: Dental gypsum materials are extensively utilized in the field of dentistry in the manufacture of casts and dies. Their physical characteristics, like compressive strength, setting time, and setting expansion, are important to the accuracy and longevity of dental restorations. The various types of gypsum materials mostly used include Type II, Type III, and Type IV gypsum materials which are used in different clinical and laboratory procedures.
Materials and Methods: It represented an in-vitro experiment done on 100 samples separated into three categories; Type II (n=34), Type III (n=33), and Type IV (n=33). Standardized molds were used to prepare specimens which were mixed as per instructions. The parameters measured were compressive strength, initial and final setting time, and setting expansion. The compressive strength was determined by use of universal testing machine, time by Vicat apparatus and expansion by a linear expansion measuring apparatus. One-way ANOVA analysis and post hoc tests were used to analyze data, with the level of significance being $p < 0.05$.
Results: Type IV gypsum proved to have the highest compressive strength and least setting expansion in that order, Type III and Type II. Type II had the shortest setting time and Type IV had the longest setting time. The statistical significance of the differences between all groups was very high ($p < 0.001$).
Conclusion: Type IV gypsum is better with respect to strength and dimensional stability, is suitable in precise work, Type III offers balanced properties and Type II is used in preliminary work. The correct choice of materials is the key to the best clinical results.

Keywords: Dental gypsum, Type II gypsum, Type III gypsum, Type IV gypsum, Compressive strength.

BACKGROUND

The most popular materials used in dentistry are dental gypsum products which are versatile, easy to manipulation, cost-effective and they can be used to recreate oral structures with precision. Such materials find application in various dental procedures like study models, working casts, dies and even prosthetic appliances [1]. The physical and accuracy of the gypsum products used in dental treatments are of high concern particularly in the areas of prosthodontics, orthodontics and restorative dentistry. Therefore, one should study the characteristics and the behavior of the different types of dental gypsum material in order to attain the optimum clinical outcomes [2]. Mineral calcium sulfate dihydrate which is naturally available is used to prepare gypsum products which when heated to form calcium sulfate hemihydrate [3]. This hemihydrate reacts with water to produce its first dihydrate state and therefore it produces a hardened mass. This environment response is accompanied by a number of physical and mechanical transformations which affect the performance of the material. The American Dental Association (ADA) specification classifies dental gypsum products into five types depending on the applications of the products and the physical characteristics. The most widely used of them are Type II (model plaster), Type III (dental stone) and Type IV (high-strength dental stone), applied in daily dental practice and laboratory practice [4]. Dental plaster, which is also referred to as type II gypsum, has a porous structure, low strength, and fairly high settling expansion. It is normally employed in diagnostic casts and model mounts where strength is not a major consideration [5]. It can be manipulated easily and can be used cheaply though it has certain limitations which makes it applicable to the preliminary applications. It is less compressive however, and more porous which can lead to a reduction in accuracy and durability of casts, especially in cases involving mechanical stresses [6]. Dental gypsum or Type III gypsum has better physical characteristics than Type II. It is better organized, more compressive, and less setting expansion, which may be applied to working casts, full dentures making, and orthodontic models. The type III gypsum is highly sought after in the dental laboratories due to its strength and accuracy balance. Nevertheless, it may also be limited in its application in situations when the level of precision and abrasion resistance is extremely high [7]. High-strength or die stone or type IV gypsum is another special type of gypsum required where high mechanical properties and dimensional accuracy is required. It possesses high compressive strength, low setting expansion and high surface hardness [8]. All these properties make it appropriate to make dies to be used in fixed prosthodontics such as crowns and braces where precision is of utmost importance. The reduced growth will ensure that there will be better marginal restorations fit hence more clinical success. Type IV gypsum though, is more technique sensitive and costly as compared to Type II and III [9]. Compressive strength, setting time, setting expansion, surface hardness, and porosity are some of the physical properties of gypsum materials, which have a major impact on the clinical performance of gypsum [9]. The compressive strength determines the ability of the material to withstand forces in the handling and laboratory operations. Setting expansion affects the dimensional accuracy of the casts and can have an impact on the fit of the dental prostheses. The hardness of the surface and the abrasion resistance is crucial in the making sure that the detail reproduction is done during the process of waxing and finishing. Moreover, these properties can also be additionally affected by the ratio of water to powder, mixing method and conditions of the environment and, hence, variations in performance can even be present with the same kind of gypsum material [10]. The scope of application of gypsum materials is very wide and the materials are very important in the field of dentistry thus there is the need to investigate and compare the physical properties of the materials in standard conditions. Such comparative evaluations may help make a selection of the most suitable material that can be applied to specific clinical and laboratory practice. Besides, the material science and manufacturing practices have also come up with improved gypsum products with improved features and there is need to check on their performance after some time [11]. In-vitro research offers a controlled condition to evaluate the physical properties of dental materials without interference of intraoral factors. The studies enable accurate measurement and comparison of material properties like strength, expansion, and hardness hence giving useful information on the behavior of materials [12]. The Type II, III and IV gypsum material can be compared to identify the strengths and weaknesses of each material and enable the clinicians and technicians to make informed decisions. Furthermore, the differences are to be understood so that to improve the quality of dental restorations and minimize the errors in the manufacture of the prostheses [13]. The improper selection of the gypsum material will bring inaccuracy, improper fitting and consequently breaking of the dental appliances and thus increased time in the chair and patient dissatisfaction [14]. Therefore, clinical performance and treatment outcomes should be enhanced by conducting a systematic analysis and comparison of these resources. Therefore, the proposed research is important in determining the comparative physical characteristics of Type II, Type III, and Type IV dental gypsum materials in standardized in-vitro conditions.

METHODOLOGY

This comparative study was done in vitro to determine the physical characteristics of Type II, Type III, and Type IV dental gypsum materials through standard laboratory conditions. A total of 100 specimens were ready and examined on chosen physical characteristics, such as compressive strength, setting time and setting expansion.

Study design

It was an experimental in-vitro study design. The experiment was conducted under controlled laboratory conditions to exclude other external factors that would affect the physical properties of the materials.

Sample size and grouping

One hundred samples were made and split into three groups according to the kind of dental gypsum material employed:

Group I: Type II gypsum (Dental plaster) -34 samples.

Group II: Type III gypsum (Dental stone) 33 samples.

Group III: Type IV gypsum (High-strength dental stone) 33 samples.

Each group was further broken down according to physical property under testing (compressive strength, setting time, and setting expansion).

Materials used

In this study, commercially available Type II, Type III and Type IV dental gypsum products were used that belonged to standard manufacturers. Each and every material was addressed as per the instructions of the manufacturers to establish uniformity.

Specimen preparation

The specimens were packed in standardized cylindrical molds to test compressive strength and proper molds to test expansion and setting time. The ratio between water and powder was kept according to the recommendations of the manufacturer. The gyspsum powder was slowly introduced into the measured amount of water and left to soak after 30 seconds. A mechanical vacuum mixer was used to mix the mixture to limit the amount of air to be incorporated and provide homogeneity. Molds were then filled with the mix that was to be poured on a vibrator to remove air bubbles and to have the correct flow. The specimens were left to dry at room temperature (23 ± 2 o C) and relative humidity of around 50 ± 10. The samples were then taken out of their molds with care after the initial setting then stored under standardized conditions of 24 hours before being tested.

Testing procedures

Compressive strength:

The compressive strength was tested on specimens with the help of a universal testing machine. Constant crosshead speed was used until fracture was attained by the action of a compressive load. The highest weight at fracture was measured and translated into compressive strength (MPa).

Setting time:

A Vicat apparatus was used to measure the initial set time and final set time. The period between the beginning of the mix and the first and last set of the material was captured in minutes.

Setting expansion:

An expansion measuring device was used to measure linear setting expansion. The decrease in length of the specimen during pouring to full setting was recorded and expressed as a percentage.

Standardization and calibration

The instruments utilized in the study were first calibrated before testing. All specimen preparations and tests were conducted by the same operator in order to reduce operator bias. The environmental conditions were kept at the same level during the study.

Statistical analysis

The data gathered were tabulated and examined with the help of the corresponding statistical software. A descriptive statistic, mean and standard deviation, was done on each group. One-way analysis of variance (ANOVA) was used to compare the groups in inferential statistics, and then, to conduct pairwise comparisons; the post hoc tests were conducted. The p-value was taken to be less than 0.05 to be considered significant.

Ethical considerations

Since this was an in-vitro trial that did not involve any human or animal participants, there was no need to obtain ethical clearance.

RESULTS

A total of 100 specimens were evaluated to compare the physical properties of Type II, Type III, and Type IV dental gypsum materials. The parameters assessed included compressive strength, initial and final setting time, and setting expansion. The data obtained were statistically analyzed, and the findings are presented below.

Compressive strength

Type IV gypsum exhibited the highest mean compressive strength, followed by Type III and Type II. The differences among the groups were statistically significant.

Table 1: Comparison of compressive strength (MPa) among groups

Group	Sample Size (n)	Mean (MPa)	Standard Deviation	p-value
Type II	34	12.45	1.82	<0.001
Type III	33	21.76	2.15	<0.001
Type IV	33	34.92	2.48	<0.001

Type IV gypsum demonstrated significantly higher compressive strength compared to Type III and Type II (Table 1).

Setting time

Type II gypsum showed the shortest initial and final setting times, whereas Type IV exhibited the longest setting time.

Table 2: Comparison of setting time (Minutes)

Group	Initial Setting Time (Mean ± SD)	Final Setting Time (Mean ± SD)	p-value
Type II	8.12 ± 0.95	14.36 ± 1.21	<0.001
Type III	10.45 ± 1.02	18.27 ± 1.34	<0.001
Type IV	12.88 ± 1.11	22.54 ± 1.56	<0.001

The increase in setting time from Type II to Type IV was statistically significant (Table 2).

Setting expansion

Type II gypsum showed the highest setting expansion, while Type IV showed the least expansion.

Table 3: Comparison of setting expansion (%)

Group	Mean (%)	Standard Deviation	p-value
Type II	0.28	0.04	<0.001
Type III	0.20	0.03	<0.001
Type IV	0.12	0.02	<0.001

A statistically significant reduction in expansion was observed from Type II to Type IV (Table 3)

Overall comparison of physical properties

Table 4: Summary of physical properties

Property	Type II	Type III	Type IV
Compressive Strength	Lowest	Moderate	Highest
Setting Time	Shortest	Moderate	Longest
Setting Expansion	Highest	Moderate	Lowest

This table summarizes the comparative performance of all three gypsum types (Table 4).

Statistical analysis (ANOVA and post hoc findings)

One-way ANOVA revealed a statistically significant difference among the three groups for all tested parameters ($p < 0.001$).

Table 5: ANOVA results

Parameter	F-value	p-value
Compressive Strength	152.34	<0.001
Initial Setting Time	96.21	<0.001
Final Setting Time	110.87	<0.001
Setting Expansion	134.65	<0.001

Post hoc Tukey test showed significant pairwise differences between all groups (Type II vs Type III, Type II vs Type IV, and Type III vs Type IV) for all parameters.

The results clearly indicate that Type IV gypsum possesses superior mechanical properties with minimal expansion, making it suitable for precision work. Type III offers a balance between strength and expansion, while Type II is best suited for preliminary applications due to its lower strength and higher expansion. All differences observed were statistically highly significant.

DISCUSSION

The present in-vitro study compared the physical properties of Type II, Type III, and Type IV dental gypsum materials and demonstrated that Type IV gypsum exhibited the highest compressive strength and least setting expansion, while Type II showed the lowest strength and highest expansion. Type III gypsum displayed intermediate properties, making it suitable for general applications. These findings emphasize the importance of material selection based on clinical requirements, particularly in procedures demanding high accuracy and durability.

The higher compressive strength of Type IV gypsum observed in this study is consistent with the findings of Fernandes et al. (2020), [15] who reported that the mechanical strength of dental gypsum is influenced by its formulation and manipulation, with higher-grade stones demonstrating superior strength. Their study also highlighted that alterations in composition can adversely affect compressive strength.

Similarly, the results align with Stern et al. (1991), [16] who compared different gypsum products and found that Type IV gypsum exhibited significantly greater strength and improved mechanical properties compared to Type III. This supports the present study's findings that denser particle structure and reduced porosity contribute to enhanced strength.

The importance of maintaining an optimal water-powder ratio, as standardized in the present study, is supported by von Fraunhofer et al. (1983), [17] who demonstrated that variations in mixing ratios significantly influence the physical properties, particularly compressive strength, of gypsum materials. Their findings validate the strict standardization followed in this study to ensure reliable results.

In agreement with the present findings, Roy et al. (2010) [18] reported that Type IV gypsum has significantly higher compressive strength than Type III and emphasized that external additives can alter material properties. This further confirms the superior mechanical performance of Type IV gypsum observed in this study.

With regard to dimensional stability, the lower setting expansion of Type IV gypsum observed in this study is consistent with Abdullah (2006), [19] who reported that high-strength dental stones exhibit minimal expansion compared to conventional dental stone. Reduced expansion is critical for achieving accurate prosthetic fit, and the present study supports this clinical relevance.

The setting time findings of the present study showed that Type II gypsum had the shortest setting time, followed by Type III and Type IV. This can be attributed to the porous structure and higher water content in Type II gypsum, which accelerates the setting reaction. Although fewer studies directly compare setting times, the observed trend is consistent with established material science principles.

Overall, the present study findings are in agreement with previous literature, confirming that Type IV gypsum offers superior strength and dimensional stability, Type III provides balanced properties, and Type II is suitable for preliminary applications. Minor differences across studies may be due to variations in methodology, environmental conditions, and material brands. Thus, this study reinforces existing evidence while providing a standardized comparative evaluation of commonly used dental gypsum materials.

LIMITATIONS

Some limitations are associated with this study that must be put into consideration when interpreting the results. Since it is an in-vitro study, the results might not necessarily be applicable to clinical conditions in which saliva contamination, temperature change, and differences in handling among others can affect the gypsum material properties. Only some of the physical properties such as compressive strength, setting time and setting expansion were evaluated, other significant attributes such as the surface hardness, abrasion resistance and dimensional accuracy were not tested. The research made use of materials of few manufacturers that might not reflect all the products in the market. And also, even though it was a standardized procedure, small differences in mixing method and environmental factors might have influenced the findings. Thus, additional in-vivo experiments and extensive material comparisons should be suggested to make more comprehensive conclusions.

CONCLUSION

Dental gypsum type IV was the most compressive and also had the least setting expansion. Gypsum type III exhibited moderate characteristics and could be used in regular applications. Type II gypsum was weaker and more expansive, and could only be used as an initial cast. The differences between the groups were all statistically significant and material-dependent performance was confirmed. Therefore, to ensure clinical success and accuracy, gypsum material must be selected properly.

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AUTHOR CONTRIBUTIONS

Ibrahim M. Abou El Leil: Conceptualization, methodology, investigation, data analysis, manuscript writing, editing, and final approval of the manuscript.

ABBREVIATIONS USED IN THE STUDY

a) ADA: American Dental Association
b) ANOVA: Analysis of Variance
c) SD: Standard Deviation

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