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Comparison of Repeated Chemical and Microwave Disinfection on Compressive Strength of Gypsum Casts - An In Vitro Study

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ABSTRACT

Objectives: The aim of this study was to compare two disinfection methods (microwave disinfection and chemical immersion disinfection) and to determine the best disinfection method for the gypsum cast which produce the least changes on compressive strength.

Materials and Methods: A total of 36 specimens were prepared using standardized carbon steel dies. The specimens were divided into three groups (n=12 each): Control group contains gypsum rinsed with distilled water, Study group I consists of gypsum casts immersed in 0.5% Sodium Hypochlorite and Study group II consists of gypsum casts irradiated in a microwave oven. Compressive strength of the specimens was evaluated using a universal testing machine, where each specimen was placed on the test platform and compressed to record the deformation at various loads.

Results: In this study, the mean compressive strength values obtained were 24.69 MPa for Group 1, 13.77 MPa for Group 2, and 23.93 MPa for Group 3. Statistical evaluation showed a significant variation among the groups, with Group 2 exhibiting considerably lower compressive strength than Groups 1 and 3.

Conclusion: Based on the findings, it can be concluded that immersion in sodium hypochlorite significantly reduces the compressive strength of the tested material, whereas microwave disinfection does not cause a notable decrease compared to the control.

Keywords: Gypsum; Compressive strength; Chemical disinfection; Microwave disinfection**.**

INTRODUCTION :

Gypsum products are one of the most widely used dental materials, which are used to make dental replicas like models, casts and dies. Dental casts are employed for a variety of diagnostic, educational, and therapeutic purposes, including the fabrication ofremovable and fixed prosthodontic prostheses, orthodontic appliancesand surgical guides. The dimensional accuracy, ease of manipulation, and cost-effectiveness of gypsum products make them essential material in dentistry.Despite their critical role in dental procedures, Cross-contamination may occur if appropriate infection control protocols are not followed.

During the cast pouring process, gypsum materials can become contaminated with pathogenic microorganisms present in saliva, blood, and oral biofilms. Numerous studies have documented the survival and, in some cases, proliferation of bacterial and fungal species on the porous surfaces of untreated dental casts.

The risk of nosocomial infection or cross-infection among patients, dental practitioners, and laboratory personnel underscores the necessity for stringent disinfection protocols. It is imperative that dental professionals implement evidence-based sterilization and disinfection procedures, such as the immersion or spray application of approved disinfectants, to mitigate the risk of microbial transmission and ensure compliance with current infection control standards outlined by organizations such as the Centers for Disease Control and Prevention (CDC) and American Dental Association (ADA)[5,6]. In dentistry, impressions are treated as semi-critical instruments and must be disinfected thoroughly or sterilized. However, autoclaving those impressions is impractical because the heat and pressure can distort their dimensions.

The most common chemical disinfectants routinely used by dentists are alcohols, aldehydes, chlorine combination, phenols, bisguanides, iodide combinations, and ammonium. Gypsum casts can be disinfected by spraying, immersing into a disinfecting solution, by adding an antimicrobial agent to the plaster mix, by manipulating the plaster with a disinfectant solution[3], microwave disinfection[4] and autoclave disinfection[1]. Different disinfectants used for disinfection of dental gypsum are formaldehyde, chlorine compounds, glutaraldehyde, phenols, iodophors and ozonated water. Immersion in sodium hypochlorite for 10 min at a concentration of 1:10 dilution (0.525%) is recommended for immersion disinfection.[2] Microwave disinfection of dental gypsum cast has shown to reduce the of bacteria on the casts after 5 minutes of microwave oven irradiation in an ordinary household microwave oven set at 900 wattage.[3] So, for the purpose of this study, two disinfection methods were selected i.e., chemical disinfection by immersion method and microwave disinfection as both of them have proved to be effective in disinfection of gypsum casts. In case of microwave disinfection, there is no effect on the efficacy whether the casts are wet or dry at the time of disinfection.

This study was aimed to compare these two methods (microwave disinfection and chemical immersion disinfection) and to determine the best disinfection method for the gypsum cast which produce the least changes on compressive strength.

MATERIAL &METHODOLOGY:

This in vitro study was carried out at Indian Institute of Technology Bombay, Powai-Mumbai to compare the compressive strength of gypsum casts with repeated chemical and microwave disinfection. Sample size was determined using the mean and standard deviation values

Approximate estimates of the study were:

1. 80% power
2. Type I error to be 5%
3. Type II error to be 20%

Total sample size was 36 which was divided into 3 groups :

1. Control group: Gypsum rinsed with distilled water (12 specimens).
2. Study group I: Gypsum casts immersed in 0.5% Sodium Hypochlorite (12 specimens).
3. Study group II: Gypsum casts irradiated in a microwave oven (12 specimens).

Materials used:

1. Dental stone (KALSTONE-K)
2. Sodium Hypochlorite disinfectant solution-0.5%(Bioanalytic)
3. Custom made cylindrical stainless steel metal die (20mm× 40mm) (IDEMI, Mumbai, India)
4. Vernier caliper (THEMISTO TH-M61 Digital caliper)
5. Microwave oven (SAMSUNG)
6. Universal Testing machine (INSTRON- 5 (kN) cell load capacity, 3345R3092, USA)

Cylindrical gypsum specimen were prepared according to revised ANSI/ADA specification no 25 for dental gypsum products.

PREPARATION OF GYPSUM SPECIMEN:

Split metal moulds of inner diameter 20 mm and length 40 mm are casted. Metal clamps are used to hold them in position. The dental stones were mixed according to the manufacturer's instruction. The water was placed in a mixing bowl, and the powder was slowly added. The powder was allowed to soak and then hand spatulated. The mixed dental stone was added to the metal die in small increments. The metal moulds were placed on a glass slab to ensure a parallel bottom end. The casts were allowed to set for 1 hour at ambient room temperature of $23^0C \pm 2^0C$ and 50% ± 10% relative humidity.

PREPARATION FORCHEMICAL DISINFECTION

12 cylindrical specimens of Type III dental stones were immersed in sodium hypochlorite (study group I) for 30 minutes at room temperature. After immersion all cylindrical specimen were removed from the bath and allowed to dry for 24 hours at room temperature. The immersion bath solution were replaced following immersion of test specimens for each cycle. The whole immersion cycle was repeated for five times before compressive strength analysis.

Immersion group specimens (12 specimens) subjected to immersion disinfection for five successive days in an interval of 24 hours for bench drying, after the last disinfection (5th day) the specimens were subdivided and as previously mentioned. Disinfection by immersion was done using a suitable sized container filled with 800ml of the prepared (0.5%) sodium hypochlorite disinfectant solution, where the cylindrical specimens of type III dental stone were immersed in for 30 minutes at room temperature.

The specimens were then removed from the solution and allowed to air dry for 24 hours at room temperature of (23±2°C) and (50±10%) relative humidity. A pair of tweezers was used to pick up the stone specimens into and from the disinfectant solution the process of immersion disinfection was repeated five times in an interval of 24 hours. A five-cycle sequence of disinfection was chosen as an average for the number of applications necessary in construction of complete or removable partial dentures from the final impression appointments through delivery of the prostheses. After the last disinfection (5th day) the specimens were bench dried at room temperature.

PREPARATION FOR MICROWAVE DISINFECTION

12 cylindrical specimens of Type III dental stones were placed in a microwave oven(Samsung, Korea) for five consecutive cycles of each 5 minutes and irradiated by 2,450 MHz, 900W microwave. Between the cycles the molds were cooled for 40 minutes. A beaker containing 200 mL of water was placed in the oven to protect the device wave-producing apparatus (magnetron). During each run, only 6 samples were placed on a circle around the center of the rotating tray of the oven so that all the samples would evenly receive the microwave rays.

TESTING COMPRESSIVE STRENGTH

The following method was used to evaluate the compressive strength of control group and study group.

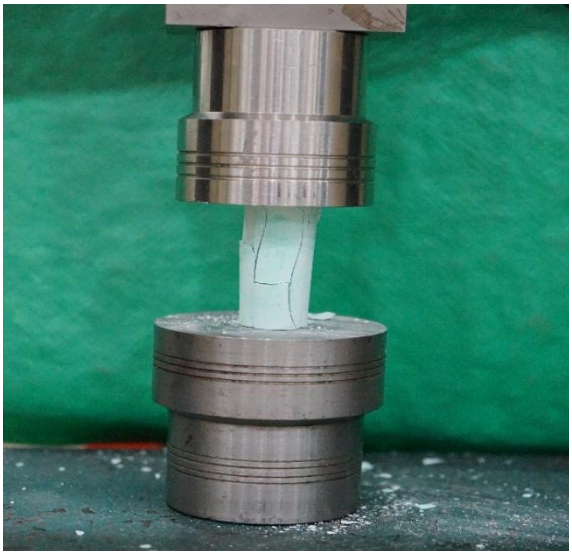
Compressive strength is the stress required to rupture a specimen that is the amount of resistance to fracture under compression load. Compressive strength of the specimens was evaluated using a universal testing machine, where each specimen was placed on the test platform and compressed to record the deformation at various loads.

The compressive strength (σ) in MPa of different specimen groups was calculated by Equation,

$\sigma = F/A$

where F is the maximum applied load in N collected from the load deformation curve and A is the cross- sectional area of the specimen in mm2.

Figure 1: compressive strength testing of gypsum specimen using universal testing machine



Statistical analysis:

Data collected was compiled on to a MS Office excel worksheet & and subjected to statistical analysis using an appropriate package like SPSS software. Descriptive statistics like frequency (n) & percentage (%) of categorical data, mean & Standard deviation of numerical data in each group were depicted.

Normality of numerical data was checked using Shapiro – Wilk test or Kolmogorov- Smirnov test. Depending on the normality of data, statistical tests were determined. For a numerical continuous data following a normal distribution, inter group comparison (2groups) will be done using t test, else a non parametric substitute like Mann Whitney U test will be used. For a numerical continuous data following a normal distribution, inter group comparison (>2 groups) was done using one way ANOVA test, else a non parametric substitute like Kruskall Wallis ANOVA test was used. Keeping alpha error at 5% and Beta error at 20%, power at 80%; p<0.05 will be considered statistically significant.

RESULTS :

In the present study, the mean compressive strength values recorded were 24.69 MPa for Group 1, 13.77 MPa for Group 2, and 23.93 MPa for Group 3(Table 1). Statistical analysis revealed a significant difference among the three groups, with Group 2 showing notably lower compressive strength compared to Groups 1 and 3 (Table 3). These findings indicate that the disinfection methods influenced the mechanical properties of the tested specimens. The Shapiro-Wilk test showed p-values of 0.081, 0.344, and 0.105 for Groups 1, 2, and 3 respectively, all above 0.05. This indicates that the data in all groups were normally distributed, allowing the use of parametric tests.

The results further demonstrated that immersion in sodium hypochlorite solution had a significant detrimental effect on compressive strength, as evidenced by the reduced values in Group 2. In contrast, disinfection using microwave oven exposure (Group 3) did not produce a significant reduction when compared to the control (Group 1). Thus, while sodium hypochlorite immersion compromised the material's strength, microwave disinfection preserved the structural integrity, suggesting it may serve as a safer alternative for maintaining compressive strength.

Table 1: Inter group comparison of Compressive strength(CS)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	10.86867*	.85449	.000**	8.7394	12.9979
	3	.70733	1.04556	.779#	-1.8810	3.2957
2	3	-10.16133*	.91244	.000**	-12.4429	-7.8797
*. The mean difference is significant at the 0.05 level.						

Table 2: Tests of Normality:

	Group	Shapiro-Wilk Statistic	df	p value
CS	1	.895	15	.081
	2	.937	15	.344
	3	.903	15	.105

S.no	Groups	N	Mean	SD	SEM	95% Confidence Interval for Mean: 95% lower bound	95% upper bound	Minimum	Maximum	F value	p value of one way ANOVA
1	1	12	24.639	2.72598	.70385	23.1297	26.1489	21.71	30.74	83.543	.000**
2	2	12	13.770	1.87648	.48451	12.7315	14.8098	11.37	17.86		
3	3	12	23.932	2.99448	.77317	22.2737	25.5903	16.57	27.92		

DISCUSSION:

Ensuring the disinfection of dental casts is vital in dentistry to prevent the spread of infections between patients, dental professionals, and lab technicians. Gypsum casts are known to harbor harmful microbes, such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Candida albicans*, which can transfer from contaminated impressions (Pavidis et al. 2005)[4]. Because these casts are frequently handled during the fabrication of dental prostheses, neglecting proper disinfection poses serious infection-control risks. Accordingly, both the American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC) advise that all dental impressions and casts be disinfected prior to any handling or transfer to dental laboratories (ADA, 2006; CDC, 2003).[5,6] Implementing effective disinfection measures not only protects patients and staff but also supports smooth prosthetic workflows, minimizing microbial contamination during critical stages like wax pattern creation, denture processing, and crown fitting (Egusa et al., 2008).[7] Therefore, it's essential to employ reliable disinfection techniques that are compatible with casting materials to maintain both safety and the quality of prosthodontic outcomes.

The dimensional integrity and mechanical robustness of gypsum casts are fundamental for producing accurate and durable dental prostheses. In both clinical and lab environments, repeated cast disinfection is often necessary to curb cross-contamination. Methods include chemical immersion or spraying, microwave treatment, ultraviolet (UV) irradiation, and ozone application. The most commonly used approach, chemical disinfection—using substances such as 2% glutaraldehyde or 1% sodium hypochlorite—is typically applied via immersion or spray. Microwave disinfection, on the other hand, eradicates microbes without relying on chemicals. While UV and ozone methods are emerging alternatives, their shallow penetration often limits them to surface-level sanitation (de Almeida et al., 2020).[8]

However, repeated chemical disinfection can negatively impact the physical properties of gypsum casts. Chemical immersion, though effective, tends to increase water absorption, porosity, and structural weakening, especially when repeated. For example, a 30-minute immersion in 2% glutaraldehyde significantly reduced the compressive strength of both Type III and IV gypsum casts (Chohan et al., 2011).[9] This weakening is attributed to the hygroscopic nature of gypsum, which absorbs the disinfectant, creating microcracks and disrupting crystal structure. Subsequent research (Amin & El-Ashiry, 2015) found that repeated immersion further degrades surface hardness and compressive strength due to increased moisture retention and chemical breakdown.[10]

By contrast, microwave disinfection harnesses electromagnetic energy to heat and eliminate microbes without direct chemical contact. Typical protocols involve microwaving damp casts at 600–900 W for 3–5 minutes. Studies indicate this method provides effective microbial reduction and may even enhance compressive strength, likely through post-setting dehydration that forms denser crystalline structures (Tan et al., 2010; Hashemipour et al., 2019).[11,12] Notably, Hashemipour et al. (2019) observed minimal surface degradation and preserved structural integrity across multiple disinfection cycles, making this method especially suitable in environments with frequent cast handling, such as dental hospitals and busy clinics.[12]

Consistent with these findings, the present study found that repeatedly microwaved casts had significantly higher compressive strength compared to those undergoing chemical disinfection. This strength gain may result from mild dehydration accelerating crystal densification and reducing microporosity. Overall, microwave disinfection emerges as a superior choice for repeated cast disinfection, it safeguards against microbial contamination without compromising, and sometimes improving, the mechanical stability of casts. This is particularly advantageous in prosthodontic and orthodontic workflows, where precision and durability of working models are paramount. Nevertheless, for safe and uniform application, microwave protocols, including power settings, duration, and specimen placement, must be standardized to avoid uneven heating or thermal damage.

CONCLUSION:

From the results of the present study, it can be concluded that the method of disinfection has a direct impact on the compressive strength of the material tested. Immersion in sodium hypochlorite solution significantly reduced the compressive strength, highlighting its detrimental effect on the structural integrity of the specimens. On the other hand, microwave disinfection did not cause a significant reduction in compressive strength when compared to the control group, indicating that it is a safer method of disinfection that preserves the material's mechanical properties.

Furthermore, the Shapiro-Wilk test confirmed that the data from all groups were normally distributed, thereby validating the use of parametric statistical tests for comparison. This strengthens the reliability of the study outcomes and emphasizes that while sodium hypochlorite may compromise material performance, microwave disinfection emerges as a viable alternative for maintaining compressive strength without adverse effects.

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