Studying the Effect of Tea Tree Oil on the Surface Hardness, and Detail Reproduction of Type III Dental Stone

Yahya Khalid Yahya [1], Aseel Mohammed Al-Khafaji [1]

1Department of Prosthetic Dentistry, College of Dentistry, Baghdad University, Baghdad, Iraq.

The corresponding author (:email: aseel.khafaji@codental.uobaghdad.edu.iq **)**

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Abstract

Gypsum materials have been utilized throughout various industries, such as dentistry, to perform several procedures. Restorative dentistry involves a substantial risk of spreading pathogenic germs from saliva to molds. Hence, it is necessary to disinfect these casts after every clinical and laboratory procedure. This study aims to assess the impact of tea tree oil (TTO) as a disinfecting solution on the characteristics of type III dental stones, such as surface hardness and detail reproduction, by immersion techniques. A total number of 60 stone specimens were created, with 30 samples designated for each test. Three groups were randomly chosen, each consisting of ten samples. The control group was immersed in distilled water for 10 minutes as the negative control. The test groups were exposed to 0.75% and 1.0% TTO. The study revealed that after disinfection with TTO, all of the specimens achieved the reproduction of detail test requirements, and there was no noticeable alteration in the surface hardness. Based on the results of all trials, it is evident that both 0.75% TTO and 1% TTO are suitable for disinfecting dental stone, making TTO a great choice for dentists and dental laboratory staff to sterilize casts.

Keywords: Tea Tree essential oil, Type III dental stone, Surface Hardness, Reproduction of Details, Disinfection

1. INTRODUCTION

Gypsum and its associated byproducts have a long history of usage in a wide range of industries. Casts and other dental laboratory procedures mostly include gypsum components. There is a very significant danger of cross-contamination with stone casts in dental work because of the numerous potential paths for infectious organisms to be transported from the patient's saliva to the impression and cast. So, following every clinical and laboratory operation, these molds should be disinfected [1]. The primary risk faced by a dental practitioner is the potential for contracting and transmitting serious transmissible diseases.

Equipment parts, tools, impressions, and castings have been identified as potential sources of microbial contamination due to their ability to facilitate the spread of infections through blood and saliva. Therefore, additional measures need to be implemented when designing, managing, and installing prostheses. (2). From a laboratory standpoint, cleaning the imprints before creating the stone cast can effectively remove visible contamination like blood and saliva containing residues found in the mouth, such as non-adherent microorganisms, cellular material, and food debris. (3). Dental impressions or gypsum models need to be disinfected before being used, according to the American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC)(3,4). Cast disinfection is considered essential to constructing disinfect models as well as establishing a cross-contamination control process due to the challenges and issues associated with impression disinfection. (5). It is important to keep the physical features of the mold or die, such as gypsum's ability to maintain its size, from being damaged by the disinfection solution while effectively eliminating microbes. (6). Michael et al.'s research found that the mechanical characteristics of stone specimens were considerably altered following 24 hours of immersion and spraying disinfection with 0.5% sodium hypochlorite (NaOCl) compared to the control group. (7,8). Another study found that the mechanical properties of type III and IV dental stones were significantly changed after being chemically disinfected with 1% Virkon, 0.525% sodium hypochlorite, and a different slurry solution. (3). The perfect disinfectant or sanitizer should be safe, non-corrosive, effective for different formulations, and reasonably priced. Essential oils are volatile and fragrant compounds produced naturally by plants through secondary metabolism. They possess various therapeutic properties and have been valued for their safety and effectiveness in promoting human health since ancient times. (9,10). Tea tree oil (TTO) is a naturally derived antibacterial with broad-spectrum properties that has been used for over 80 years in medicine to treat many different medical conditions. (11). Reports show M. alternifolia oil kills E. coli, Staphylococcus species, Lactobacillus, Actinomyces viscosus, S. epidermidis, B. subtilis, S. aureus, and S. typhimurium,(12–14). Moreover, it is biostatic against Pseudomonas aeruginosa, Serratia marcescens strains, and Halobacterium violaceum(15). Studies discuss the efficacy of TTO as a disinfectant against coronaviruses. (16). In dentistry, natural plant components are becoming more common in toothpaste and mouthwashes. (17). TTO reduces oral bacteria to prevent dental caries, periodontal disease, oral mucosal infections, and other oral ailments. (18) Research has found that using essential oils on dental implant surfaces prevents the formation of biofilms. It can expedite the healing process and improve the effectiveness of therapy and recovery following oral surgery. (19,20). On the other hand, there is not a great deal of study on the impact that TTO has on dental stone. Given these results, TTO is an excellent choice for the study that is currently going on. To the best of the authors' knowledge, there is no previous research that evaluates the influence of TTO disinfecting solution on certain characteristics of type III dental stones. Given this, the purpose of the current study was to analyse several physico-mechanical properties of type III dental stone that had been submerged in TTO as a disinfectant solution for 10 minutes. These properties included surface hardness and replication of details. Under the supposition that TTO, when used as a disinfectant, does not affect the surface hardness and reproduction of type III dental stone features, the null hypothesis was rejected.

2. MATERIALS AND METHODS

Specimen preparation

The main components utilized in the study were Dental stone type III (Elite model, Zhermack S.p.A., Rovigo, Italy), Distilled water (Dis water, Iraq), and Tea tree oil (Now foods; Bloomingdale, IL 60108, USA). The mixing technique, testing circumstances, and equipment used were following Revised ANSI/ADA Standard No. 25-2015. An incubator from Memmert GmbH, Germany, was utilized to preserve the specimens at a temperature of 23 ±2ºC and a relative humidity of 50(±10%) to avoid contamination or alterations in the stone's physical properties before testing. They allocated a minimum of 15 hours for suitable exposure to the conditions above. All equipment utilized for mixing and testing was sterile, devoid of moisture, and free from contaminants, including dental stone remnants. The dental stone was kept in a safe, moisture-proof pouch, firmly sealed to avoid contamination or alterations to its physical properties. Before use, the dental stone powder was effectively blended by swirling it thoroughly with a dry spatula inside the bag. Water was measured with a graduated cylinder accurate to 0.5 mL, while dental stone powder was measured with an electronic balance accurate to 0.01 g. According to the manufacturer's guidelines, dental stones are often mixed manually for 1 minute at a water-to-powder ratio of 30 mL per 100 g to achieve a consistent and practical mixture. The dental stone mixture was prepared according to Revised ANSI/ADA Standard No. 25-2015 and then poured into a rubber ring of 20 mm in height and 30 mm in diameter to create the stone specimens. The dental stone combination was consistently vibrated using a vibrator at 4000 revolutions per minute (rpm). To minimize air bubbles and decrease porosity during the pouring process. Glass slabs were positioned on the top and bottom edges of the rubber ring to create examples with surfaces that looked uniform, sleek, and parallel. After 30 minutes of mixing, all stone samples were removed from the rubber ring and left for a whole day at an average temperature of 23± 2°C and a relative

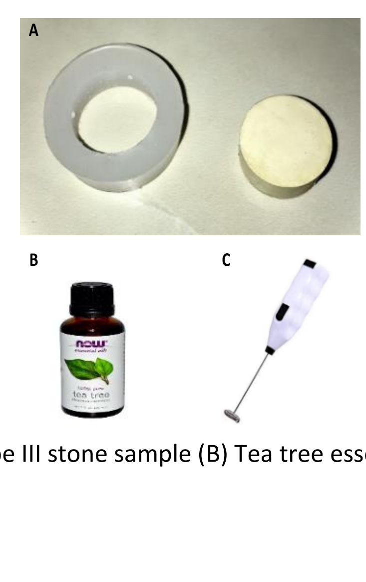

Fig. 1. (A) Rubber ring and type III stone sample (B) Tea tree essential oil and (C) Electric hand mixer.

humidity of 50 ±10%, as depicted in Figure 1A.

TTO disinfectant solution preparation

The concentration, handling, and storage of the testing solutions were conducted according to the manufacturer's requirements. The TTO disinfecting solution was utilized for the initial time in conjunction with a dental stone. The experimental concentrations (0.75% and 1%) and immersion duration (10 min) in this study were chosen based on previous research that utilized Tea Tree Oil (TTO) as a disinfectant with various dental materials like acrylic, soft liner, and dental impression materials.(21–26) The TTO displayed in Figure 1B was diluted for use in the test according to the following equation(27) :

$$C_1V_1=C_2V_2 \tag{1}$$

Where C_1=100% TTO concentration, V_1=volume of TTO removed, C_2=required TTO concentration, and V_2=volume of the final solution. Mixing was carried out for one minute using an electric hand mixer, as shown in Figure 1C—preparation of the disinfecting chemical solutions. TTO was diluted by organic solvent Polysorbate 80 (Tween 80 Sigma, USA) and by (1%volume) to improve TTO solubility and ease of solution mixing(27–29) .To make a 0.75% TTO disinfection solution, combine 1.5 ml of TTO and 2 ml of Tween 80 with 200 ml of distilled water. A 1.0% TTO disinfection solution was made by combining 2 ml of TTO and 2 ml of Tween 80, then adding it to 200 ml of distilled water.

Specimen groups and immersion in disinfectant solutions

A total number of 60 specimens of type III dental stone were divided into two groups: 30 for surface hardness testing and 30 for detail reproduction testing. These samples were then randomly assigned to three groups, each containing 10 samples.

Group A used distilled water immersion for 10 minutes as a negative control, without any disinfection treatment.

Group B: Stone samples were submerged in a 0.75% solution of TTO for 10 minutes.

Group C: Stone samples were submerged in a 1% solution of TTO for 10 minutes.

Disinfection of stone specimens by immersion method

The stone samples were placed in a container of an appropriate size and completely submerged in the disinfection solutions that had been prepared for ten minutes at room temperature before use. Following the removal of the samples from the solution, they were washed with distilled water and then allowed to dry themselves naturally for one hour at a temperature of 23±2 °C and a relative humidity of 50±10 %. After that, they were stored in an incubator with a desiccator until the time arrived for the tests to be performed. A tweezer was used to move the stone samples into and out of the cleaning solutions when they were being cleaned.

Testing procedure

A. Surface hardness test

The Shore (Durometer) hardness assessment employed in this investigation corresponds with all applicable international standards and remains simple. Each durometer type has been designed to a specific scale (A, B, C, or D) and can yield a number between 0 and 100. A value of 0 is acquired if the indenter entirely penetrates the sample; on the contrary, a reading of 100 is obtained. The Shore D hardness tester (Time Group Inc., China) was used to test each specimen. According to the manufacturer, the device applied a constant force of 50 N on the sample's surface with a pointed indenter. After the pointed indenter had penetrated the specimen's outermost layer, the hardness test results appeared on the device's screen after roughly 5 seconds. The findings are shown as the average of five measurements on each specimen: one in the center, two to the right, and two to the left of the center (30,31).

B. Reproduction of details test

Using specially manufactured test equipment (a test block, a ring mold, and a slit mold), this test was carried out following the Revised ANSI/ADA Standard No. 25-2015. Using AutoCAD software, the design of the test apparatus was duplicated as a print file that could be printed by a 3D printer (Max UV385, Asiga), with an accuracy of 10 µm, photo polymerized resin for dental models (MAZIC D) was used as the 3D printing material. The following characteristics apply to the equipment are illustrated in (Figures 2A and 2B).

A-The test block's upper surface includes five grooves at an angle of 90°±5°, with widths of X= 50±8 µm, Y=20±4 µm, and Z=75±8 µm. The distance between each groove is 2.5 mm. In addition, there are two additional grooves, each with a width of (75±8 µm) and the same V-shaped angle as the previous grooves shown in (Figure 2C).

B-A ring mold with an interior diameter of 30 mm and a height of 6 mm is used to pour silicone impression or duplicating material onto test blocks with grooved surfaces.

C-A slit mold with internal diameters of 20 mm and 30 mm was also used.

A non-reacting mold release agent (separating agent) was applied to the ring mold before placing it on the text block. Silicone duplicating material was combined according to the manufacturer's recommendations at a 1:1 ratio until slightly overfilled. A glass plate was placed on the mold, and a load of 1500 g was applied for 5±1 sec before being withdrawn to allow the material to be set. The ring mold was gently removed after 30±1 min to prevent distortion. A non-reacting mold-releasing agent was applied to the slit mold, which was then covered with silicone duplicating material and placed over the ring mold. The dental stone was prepared as previously aforementioned, poured into the slit mold, and gently vibrated for 30 seconds to prevent air bubble entrapment. Once the mold was filled, it was placed in ambient air with a relative humidity of 50±10% and a temperature of 23±2°C. The dental stone samples were then separated and appeared as shown in Figure 2D after 45±1 min. Under an optical microscope (Dino-lite) positioned at a fixed distance and ×4 magnification, the disintegration of duplicated 25-mm-long and 50 µm-wide lines was investigated to determine the effect of solutions on the samples. For type III dental stone, the relevant groove for the reproduction of details test evaluation is the 50 µm-wide "a" groove. Specimen examination under an optical microscope reveals whether a complete or incomplete groove reproduction has occurred to determine whether the specimen met this test requirement. The assessments were performed, and the examiners were not informed of the type of specimens being evaluated. Each specimen was evaluated using the I–IV scoring method(32). The following criteria were set up to evaluate the reproduction capabilities of stone specimens, and the 0.05 mm line received the following scores:

Score I: Distinct and continuous line throughout the whole ring.

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

Score III: The line's continuity and clarity were less than half the ring's width

Score IV: The line was not extending the whole width of the ring.

Statistical analysis

The average roughness, hardness, and dimensional stability test results from the control and test groups were compared using one-way ANOVA. To look into the normality of the distribution of values, the Shapiro-Wilk test was performed on all test results. The statistical parameter of interest is the test statistic (W), calculated by comparing the observed data distribution to the expected distribution of a normal distribution with the same mean and variance. The test statistic (W) measures the degree of similarity between the observed distribution and the expected normal distribution by calculating a p-value, which measures the evidence against the null hypothesis that the data come from a normal distribution. If the p-value is less than 0.05, the null hypothesis is rejected, and it is concluded that the data do not come from a normal distribution. Levene's test assessed the equality of variances for a variable calculated for the groups. A post hoc test (Fisher's LSD) was conducted to confirm the differences between the test groups. If the p-value from the ANOVA is less than 0.05, the null hypothesis can be rejected, and it can be said that at least one of the group means differs from the others. A post-hoc test determines precisely which groups differ from one another.

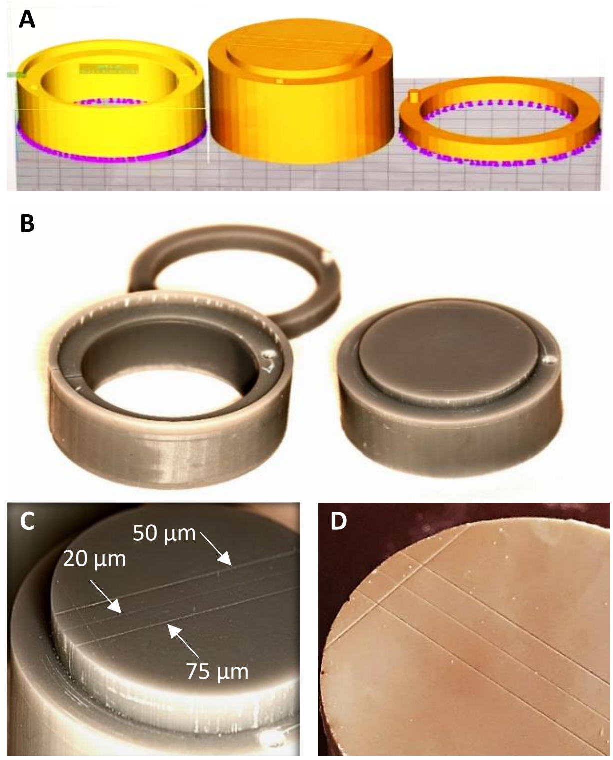

Fig. 2 (A) CAD model at the start of the printing process, (B) Printed test equipment utilized in the reproduction of details test, (C) Test Block utilized in the reproduction of details test with three parallel lines, (D) Stone sample utilized in the reproduction of details test.

3. RESULTS AND DISCUSSION

The results of the experiments show that all values were normally distributed (Table 1). For every stone sample, two evaluations were made: one before the disinfection process began (24 hours after mixing and pouring the stone) and one after one hour after the disinfection process. The difference between the two measurements was considered for evaluation. Figure 3 presents the effect of using a TTO disinfectant solution on surface hardness.

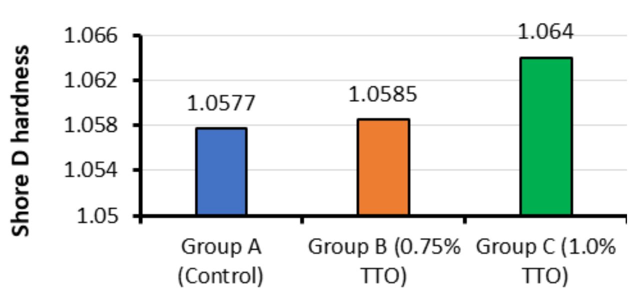

Fig.3 Results for surface hardness of type III dental stone.

Table 1. Normality of the distribution of values using the Shapiro-Wilk test on all test results

Tests	Group A		Group B		Group C	
	P-Value	Passed	P-Value	Passed	P-Value	Passed
Surface hardness	73 (NS)	es	0.141 (NS)	es	0.198 (NS)	es

The resulting alteration in surface hardness was determined as an alteration in the Shore D hardness value after 24 hours. The test groups' mean values are shown in Figure 3. The highest value was for Group C, then Group B, and the least was for Group A (control). One-way ANOVA revealed that the difference among the groups was insignificant (P=0.578) as shown in(table 2).

Table 2. Statistics of surface hardness test for type III dental stone utilizing one-way ANOVA

Test	Groups	N	Mean	± SD	F-Value	P-Value	Levene's test	df	p-value
Surface hardness	**Group A**	10	1.0577	0.0195	0.559	**0.578**	5.482	2	0.01 (S.)
	Group B	10	1.0585	0.0081					
	Group C	10	1.064	0.0134					

Regarding the reproduction of the details, the test outcomes showed that all specimens from the test groups (0.75% and 1.0% TTO solutions) and the control group (0.0% TTO) had successfully reproduced (Scale I for all samples) a complete 50 m-wide "a" groove. Hence, it met the requirement of ADA specifications, as shown in (Figure 4).

Despite digital technology for virtual cast construction, dental stones continue to be widely utilized in dentistry for many different uses within private practices and laboratories for cast construction, in addition to mounting casts in articulators. Its popularity may be linked to its low prices, usability, and capacity for generating accurate outcomes(33). Disinfection of the cast is essential in preventing cross-contamination because microorganisms have been detected in the cast poured against contaminated impressions. Many studies have attempted to disinfect gypsum casts by immersing or spraying the casts with disinfectant solutions(34,35).

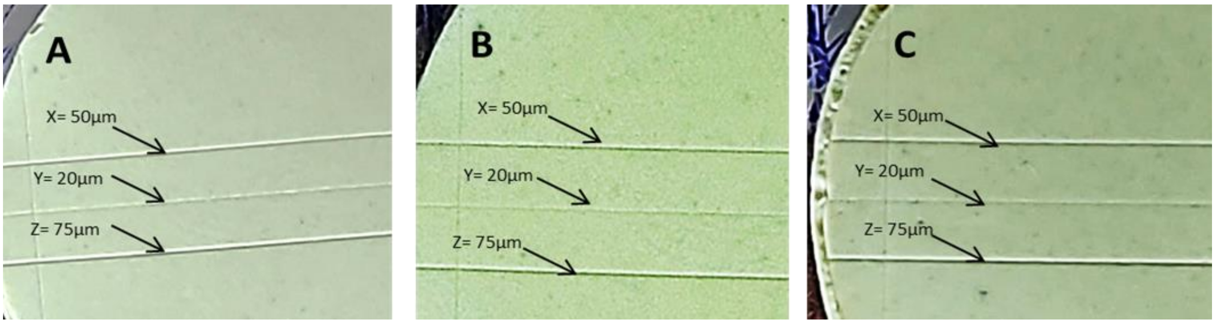

Fig.4 A sample of reproduction of details test specimens: (A) 0% TTO (B) 0.75% TTO (C) 1.0% TTO. For all groups, the results showed Score I.

Oral impressions frequently contain blood and salivary microorganisms, which can easily contaminate stone casts and survive up to seven days in set gypsum(36). An ideal disinfectant and sanitizer must also be noncorrosive, nontoxic to surface contact, effective in various forms, and inexpensive(37). Direct disinfection of stone casts by immersion, spraying, or mixing the disinfectant with water appears to be a safer and more efficient alternative(38) Natural herbal remedies from aromatic and therapeutic plants, such as essential oils, are frequently used as antibacterial, antifungal, antioxidant, and anti-inflammatory agents. These extracts have significant advantages over synthetic products because they do not develop antibacterial resistance or lead to toxicity(39,40).

Surface hardness testing is essential to dental stone evaluation. According to the majority, harder stones will provide better wear resistance and less chance of destruction during a pattern or casting manufacturing and finishing. Dental stone, which must be sufficiently strong to resist the stresses of the construction process, has been utilized mainly to create indirect dental prostheses (41) III Dental stone samples were disinfected with TTO, and their surface hardness was evaluated 24 hours later to ensure a complete setting. It was not significantly different from the control group. The natural product affects the properties of dental stone, such as surface hardness, color, or texture, depending on the concentration, duration, and application method. Insignificant differences in the result may be due to the surface hardness of the dental stone being determined by its crystalline structure and the strength of the bonds between its atoms. TTO cannot alter these fundamental properties in this short immersion period (10 min) used in this study. As TTO disinfectant solution is being used with dental stones for the first time, the findings of this study cannot be directly compared to those of earlier studies but are generally consistent with previous research that found some disinfectant solutions did not alter surface hardness value(42). The surface hardness of stone casts immersed in slurry and 1% peroxy genic acid solutions were not significantly different (43). While Ibrahim and Al-Harbi F. (2015) found no appreciable difference in the surface hardness of dental stone following disinfection using acid glutaraldehyde and iodophor in their studies(44) Another study by Moslehifard et al. (2013) evaluated the effect of disinfectant solutions on the surface hardness of dental stone casts and found that there was no significant difference in surface hardness between the control group and the groups treated with 0.5% sodium hypochlorite, 2% chlorhexidine gluconate, or 2% glutaraldehyde(45). Different disinfection solution types, immersion times, and measurement methods may alter the findings.

Regarding the quality of the reproduction of details, the findings showed that the disinfection of type III dental stone specimens with 0.75 % and 1.0% TTO by immersion method did not affect the quality of the reproduction of details when compared to the control group, meaning that all of the specimens from both the control group and the experimental groups had successfully reproduced the test's required 50 µm-wide "a" groove. This result aligns with other studies where no noticeable difference between the experimental and control groups regarding detail reproduction was found (46). Additionally, Abdullah, in 2006, claimed that with repeated immersion in a slurry containing 0.525% NaOCl and drying of a stone cast, surface characteristics for type III stones were slightly damaged by disinfectant solution. However, the difference was insignificant, so it could be used in the lab without negatively affecting the quality of the surface details(32). Also, Al-khafaji et al. concluded that stone specimens immersed in or sprayed with NaOCl and SOLO disinfection solutions did not lose any surface details(47). The study by Zaid and Abass in 2022 found that immersion in 0.1% hypochlorous acid disinfectant for 10 minutes did not result in a significant difference in surface hardness or detail reproduction of type III dental stone compared to the control group(31). The careful mixing of dental stone in small increments and vibration of the rubber ring mold to minimize air bubbles may have helped reproduce the 0.05 mm-wide groove with little distortion. Reducing air bubble entrapment in the dental stone mixture may have improved grooved surface reproduction, exceedingly narrow grooves with little distortion. The results may not apply to clinical settings because the study was in vitro. The study did not explain tea tree oil's long-term effects or how different disinfection techniques affected dental stone.The use of tea tree oil as a disinfectant for dental stone may increase the surface roughness of the dental stone, which can negatively affect the fit of dental restorations and prostheses and lead to increased plaque accumulation and bacterial colonization. Further research is needed to investigate the long-term effects of tea tree oil on the properties of dental stone and to optimize the disinfection protocols using tea tree oil to minimize any adverse effects on the properties of dental stone. The applicability of TTO can be compared with other popular disinfectant materials. Clinically using natural plant extracts, such as TTO, as a disinfectant is becoming increasingly popular due to its effectiveness, simplicity, safety, biodegradability, absence of harmful chemicals, and cost-effectiveness. TTO's unique properties make it an efficient disinfectant, especially when used at the proper concentrations. Findings have shown that immersing type III dental stone in a diluted essential oil disinfectant is a practical way to disinfect without affecting the model's accuracy, surface roughness, and hardness. However, further research is necessary to optimize the disinfection method of stone models using this oil solution.

4. CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn. It is possible to immerse Type III dental stones in a TTO disinfectant solution to disinfect them without affecting their accuracy. The surface hardness of type III dental stones was similar to that of the control group after 10 minutes in TTO solutions.

Data Availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflicts of interest

The authors declare no conflicts of interest.

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