Keywords
Addition silicone impression, disinfection, chlorogenic acid, surface roughness, wettability, gypsum.

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Influence of chlorogenic acid disinfectant on surface characteristics of addition silicone impression materials

Abstract

Objectives: This in vitro study was conducted to investigate the surface roughness, wettability, and compatibility with gypsum products of addition silicone impression materials after disinfection by immersion in chlorogenic acid (CA) solutions.

Material and methods: Sixty addition silicone impression material samples were prepared, using a ring mold (30 mm in diameter, 3 mm wall thickness). Thirty samples for each test (surface roughness and wettability), and blindly distributed into three groups (n = 10 per group). Another thirty addition silicone samples were fabricated by utilizing a device created in compliance with ISO 4823:2015 that was poured after the disinfection procedure with die stone to assess the compatibility with gypsum products. Specimens were separated blindly into three groups: one control group and two experimental groups (n = 10 per group). Surface roughness (Ra) was measured using a contact profilometer; the goniometer, measuring the contact angle, was used to assess wettability; and compatibility with gypsum was assessed using ISO 4823:2015, with specific grades assigned. Disinfection was done by immersion in 50 mg/ml and 60 mg/ml CA solutions for ten minutes.

Results: There was a non-significant effect on surface roughness, wettability, and compatibility with gypsum products of addition silicone impression material after immersion in CA solutions for ten minutes ($p > 0.05$).

Conclusion: within the limitation of this study, CA solution may be used as an effective disinfectant without affecting the surface characteristics of addition silicone impression materials.

Clinical relevance: CA solutions present promising natural alternative for disinfecting addition silicone impressions, ensuring effective disinfection without compromising the surface texture or the subsequent accuracy of the gypsum casts.

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INTRODUCTION

Dental impressions are a frequent procedure in oral restorations, executed so as to acquire accurate plaster cast that assists in the production of dental prostheses [1]. Precise dental imprints give the dental technician the ability to fabricate an accurate dental prosthesis and appliances, specifically designed for individual patient. Nowadays, intraoral scanners are progressively replacing the conventional impression technique; however, digital scans are costly and have multiple limitations. Consequently, the physical impressions are to date the preferable technique in the dental clinics [2]. High accuracy and stability prostheses can be produced by casts poured from silicone impressions [3]. Silicones are frequently chosen by dentists because they have high flexibility and recovery while being removed from the mouth, in addition to the capacity to be poured up to 1 week with minimal changes in their dimensions, approximated at 0.3% [4]. Dental impressions are commonly polluted with oral fluids like saliva and blood. The dentists use the impression material that comes into contact with oral fluids, and therefore, there are possibilities to have an infection if not treated with caution. Cross-infection between dental clinics and dental laboratories is prevalent [5]. Following that, to limit the spread of infections, the American Dental Association (ADA) and the World Dental Federation (FDI) advised that the dental impressions should be disinfected immediately after withdrawal from the oral cavity, either by immersion or spraying techniques, utilizing disinfectant solutions [1]. Immersion is the most trustworthy technique because it ensures that every face of the imprint and the tray comes into close contact with the disinfection solution [6]. The dental imprints should be able to keep their dimensions and surface details [7], as well as their surface should be moist and smooth, which is crucially important [8]. Therefore, the chosen disinfectant must have an efficient effect against microbes, and at the same time has no detrimental influence on the dimensional stability, superficial characteristics, and the accuracy of the resultant casts of the dental impressions [9]. Sodium hypochlorite and glutaraldehyde are the most widely employed disinfectants [10]. The impression materials may react with the chemical disinfectants, depending on the procedure, sort of disinfectant, concentration, and even the time of immersion [11]. It is well known that the quality of impression materials can be impacted by disinfectants that contain oxidizing compounds or organic alcohols. As a result, alternative disinfection techniques are better, and it is important to carefully examine their effects on the impression materials [12]. Surface roughness and wettability of impression materials are important factors in the final prosthetic results, and any alteration in their magnitude can considerably influence the success of the treatment and the quality of the resultant gypsum cast [13]. Chlorogenic acid (CA) is a phenolic compound belonging to the hydroxycinnamic acid family. CA is frequently observed in various plants and traditional drugs. CA demonstrates a wide variety of biological actions, and recent researches have showed that CA possesses the capacity to be an efficient antimicrobial agent by immediate aiming the cell wall and membrane of bacteria to induce irreversible osmotic destruction [14]. New research showed that CA disinfection of alginate impression material by spraying revealed an important inhibiting action on selected oral pathogens, especially Staphylococcus aureus, while the dimensional stability of the alginate impression material was not affected [14]. Because no study has investigated the effects of CA disinfectant on the surface characteristics of addition silicone impressions, this experiment was conducted to evaluate its effects on the surface roughness, wettability, and compatibility with gypsum products of addition silicone impressions using the immersion technique.

MATERIAL AND METHODS

The samples in this experimental study were made from an addition silicone impression material (Zhermack, Italy). They were made from heavy and light bodies for each test: surface roughness, wettability, and compatibility with gypsum. Following the ADA NO.19, the processes and test specimens were set up at 23 ± 2 ºC and 50% ± 10% relative humidity. Prior to testing, the apparatus was kept at this temperature and humidity for a minimum of ten hours. The testing solutions, distilled water, and CA solution concentrations (50 mg/ml and 60 mg/ml) were also set under the same conditions. The addition silicone impression was adapted at a temperature of 23 ± 2 ºC in a moisture-resistant container.

Specimen grouping:

A total number of 60 disc-shaped specimens were employed, 30 samples for each test (surface roughness and wettability). Another 30 samples were set up following ISO 4823:2015 criteria for assessing elastomeric impression materials that are used to assess the compatibility with gypsum products. They were divided into three test groups:

Group A: ten samples were left unimmersed as a control group.

Group B: ten samples were immersed in a 50 mg/ml CA solution for ten minutes.

Group C: ten samples were immersed in a 60 mg/ml CA solution for ten minutes.

Specimen preparation for surface roughness and wettability tests:

A custom-made mold, 30mm in diameter and 2 mm in thickness, was utilized to make the samples (13). Following the manufacturer's instructions, the specimens were made by placing the mold on a clean glass slab before filling it with the material. To develop an entirely leveled specimen, a second glass plate was positioned above the mold, and five seconds of hand pressure were used. To mimic the temperature of the patient's mouth, the samples were placed in a water bath set at 35 Cº and after the complete setting of the material, the samples were removed from the mold and placed in clean containers [15].

Specimen preparation for testing the compatibility with gypsum products:

Thirty additional silicone impression specimens were prepared utilizing a metallic test block that is fabricated according to ISO 4823:2015 criteria for evaluating the addition silicone materials. It has four pieces: a ruled block, a ring mold, a riser, and a slit mold. The latter is used to inspect the compatibility of the gypsum with the impression material. The ruled block has five V-shaped lines etched into it: three vertical lines (A 50 µm, B 20 µm, and C 75 µm), and two horizontal lines (D1 and D2), each with a depth of 75 µm, which should be replicated in the impression samples. Addition silicone is prepared according to the manufacturer's instructions, and after complete setting, they were disinfected according to the disinfectant group, rinsed with water, and air dried. Next, the addition silicone sample was securely attached to the ring mold, placed on the riser top, and firmly pressed to force the sample up until its ruled surface was leveled with the top of the ring mold. The slit mold was then assembled with the ring mold. As recommended by ISO 4823:2015, a mixture of type III stone (Zhermack, Italy) was poured over the impression sample that was placed on a mechanical vibrator. According to the manufacturer's instructions, the slurry was made by combining 30 ml of water with 100 g of stone for 60 seconds. The stone cast samples were removed from the mold following one hour [15].

Preparation of chlorogenic acid solutions:

The tested disinfectant solutions were prepared by dissolving CA powder (Bidepharm, China) in a mixed solvent of absolute ethanol (RCI Labscan, Thailand) and sterile distilled water [16]. To prepare the 50 mg/mL and 60 mg/mL concentrations, CA powder was precisely weighed on a high-accuracy digital balance. The powder was first dissolved in a minimum amount of absolute ethanol (20% of the total mixed-solvent volume) to ensure complete solubility, then diluted with distilled water to the required volume and mixed. The solutions were prepared freshly before every test and stored in amber-colored glass containers to prevent any potential photo-degradation of the ingredients.

Immersion procedure:

According to the test group, the samples were immersed in 50 mg/ml CA solution and 60 mg/ml CA solution for ten minutes. The control samples remained untreated. Prior to testing, the samples were rinsed under running water for 15 seconds and air-dried.

Assessment of surface roughness:

The surface roughness was evaluated accurately as close as 0.001 µm by utilizing a stylus-type, contact surface, digital roughness tester (Ra) measurement device (Profilometer, HSR210, China). Ra serves as a marker of surface roughness [17]. The sample was settled on a firm, leveled surface while the stylus′s diamond-tip moved physically in five access points and remained in contact with the surface (figure 1). Every specimen was given three measurements, and the readings appeared on a digital scale independently. The mean of the three readings was considered as the value of the surface roughness of the specimen [10].

Assessment of wettability:

Wettability was evaluated by measuring the contact angle of all specimens′ surfaces using a contact angle goniometer (Nanoscience instruments, USA). At room temperature, every sample was mounted on adjustable mechanical table of the Goniometer, and a distilled water drop has been employed as the wetting liquid that was applied by a fitted needle. The dropped water has been monitored using optical equipment that has a high-definition digital camera, and the images were captured as the drop of water contacted the specimen′s surface (figure 2). The contact angle was measured after one minute twice, one on the left and one on the right of the drop, and the mean of the two readings was taken as the contact angle of the specimen (figure 3) [18].

Assessment of compatibility with gypsum products:

Every gypsum sample was taken out of the mold, captured on camera, and enlarged. All gypsum samples were examined utilizing ISO 4823:2015, with an alteration by grading assignments to all samples of gypsum when evaluating the 50 µm line on the gypsum (figure 4).

Score 1: smooth cast surface and a clear, uninterrupted line.

Score 2: uninterrupted line, losing the sharpness, and tiny surface defects.

Score 3: destruction of line specifics, larger surface holes, and porousness.

Score 4: a rough look, lack of line continuousness, obvious porosity, and the surface damaged.

Statistical analysis:

The Shapiro-Wilk test evaluated the normal distribution, whereas Levene's test determined the appropriate post hoc test. The one-way ANOVA test and post hoc tests analysis (Tukey HSD) were utilized for statistically analyzing the results of surface roughness and wettability, while the Kruskal-Wallis test and Dune′s test were used to analyze the compatibility with gypsum. Statistical significance was set at $p < 0.05$. GraphPad Prism (version 8.0; GraphPad Software, San Diego, California, USA) was used for statistical analysis.

RESULTS

Regarding the surface properties of the addition silicone impression material, the parametric statistical analysis via Ordinary One-way ANOVA demonstrated that immersion disinfection with chlorogenic acid did not induce any significant alterations. No statistically significant differences were observed in surface roughness ($P = 0.3570$), as demonstrated in table 1, or in wettability (contact angle measurements) ($P = 0.3484$), as shown in table 2, between the tested groups. Furthermore, the non-parametric analysis using the Kruskal-Wallis test for surface compatibility with gypsum showed no significant differences ($H = 0.000$, $P > 0.9999$) as seen in table 3, between the control group and the groups that were immersed in 50 mg/ml and 60 mg/ml of CA for ten minutes.

DISCUSSION

Silicone impressions are extensively utilized because of their outstanding detail reproduction, elastic rebound, dimensional stability, and polymerization shrinkage of no more than 0.05 [19]. The oral microbes could be transferred to the exterior surroundings at the time of impression making. To avoid the dispersion of contagious diseases because of cross-contamination, the recording materials should be decontaminated [8]. Elastomeric impression materials are disinfected using the immersion technique as advocated by ADA because of its enhanced antimicrobial efficiency and the capability of polymerization shrinkage compensation that improve the material precision [20]. The most often used chemicals for impression disinfection are alcohols, aldehydes (glutaraldehyde 2%), chlorine solutions, phenols, biguanides, iodide combinations, and ammonium [21]. Nevertheless, these chemical disinfectants may impact the qualities of impression materials, and accordingly, the excellence and accuracy of dental casts and the final restoration [22]. In recent years, there has been a growing focus on the identification and development of new medicines derived from natural products, and CA is one of these substances that has been recently used in disinfection. CA has been utilized for disinfecting polydimethylsiloxane microfluidic equipments [23], and latest research on the waterlines of the dental unit showed that pathogens are significantly reduced by CA [24]. Disinfecting the dental imprints should not influence the impression′s surface roughness, which is an important aspect in determining whether the impression would precisely duplicate the oral structures that are reflected on the accuracy of the plaster model and the final prostheses. The dental casts poured from rough impressions will have a rougher superior layer compared to the impression. A decrease in plaque stagnation can be observed in a prosthesis with a roughness that is no more than 0.2 μm, and with higher values, a greater accumulation of food is anticipated [25]. In this study, the surface roughness of addition silicones is not affected by immersion in CA solutions for 10 minutes. This finding was consistent with Abdulaali & Abass [15], where they used a natural disinfectant on the addition silicones and noticed there were no significant changes in the surface roughness. The results were also in line with a study done by Kotha et al. [26], which examined the reaction of important elastomers with different disinfection methods. The study's findings may be explained by the hydrophobic properties of silicones, which rendered the impressions' surfaces extremely resistant to their attack [27].

The potential of a liquid for dispersing on a solid surface is termed wettability. The contact angle, which is produced between a liquid′s drop and the surface under consideration, is used to measure the wettability. The influence of disinfection on impression materials′ wettability is an important aspect because it directly impacts the sizes and number of air bubbles that develop in stone casts poured from the material [13]. This experiment revealed no significant differences in the wettability of the samples between the control group and the tested CA solution groups. This result is compatible with Abdulaali & Abass [15], Hammed & Al-Khafaji [28], and Kotha et al. [26], who used natural and chemical disinfectant and noticed that silicone impression materials had a good resistance to disinfection procedure. This also could be linked to the suitable immersion time that is advised by the CDC and ADA, which advises that elastomeric impressions should only be immersed for no more than half an hour [29]. The hydrophobicity and hydrophilicity of the elastomeric materials will determine the manner in which the gypsum slurry will engage with the impression to develop a bubble-free die [30]. This study displayed no significant differences between the control stone samples and the stone samples poured from addition silicone samples immersed in CA disinfectant. This result was congruent with a study executed by Vrbova et al. [22] wherein scanning electron microscopy, micro computed tomography, and Light microscopy were utilized to examine the dimensional changes. They found that addition silicone impression materials have exceptional resistance to the disinfection process.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that the immersion in CA solution at both tested concentrations could be an effective alternative disinfection protocol without compromising the structural integrity of the addition silicone impression material. The natural disinfectant maintained the surface roughness and wettability unchanged, demonstrating optimum compatibility with dental gypsum. These findings suggest that CA can be safely utilized as a bio-friendly dental disinfectant without inducing adverse alterations in the material's clinically essential physical properties.

LIMITATIONS

This study carried out entirely under in vitro lab settings, that may not completely duplicate the complicated, changing environment of the oral cavity, such as the presence of saliva, patient-specific temperature fluctuations, and moisture. The evaluation was confined to specific concentrations of chlorogenic acid and focused on immediate compatibility with a single type of dental gypsum; hence, the long-term aging effects of the disinfectant on the elastomeric impression material over extended storage periods were not assessed. Further clinical trials and microbiological challenge tests in simulated clinical settings are required to fully validate the clinical handling and long-term shelf-life of the CA-treated impressions.

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none
Data Availability Statement
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Conflict of interest
Declared none.

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Table 1: Descriptive statistics and One-Way ANOVA comparing the surface roughness of specimens disinfected with the different concentrations of CA solutions.

Disinfectants	Immersion time	Mean ± Std. deviation	F	Sig.
Control	No treatment	0.2923 ± 0.1752	1.070	0.3570
CA 50 mg/ml	10 minutes	0.2209 ± 0.1371		
CA 60 mg/ml	10 minutes	0.2075 ± 0.09334		

Note: CA: Chlorogenic acid; Std. deviation: Standard deviation; F: F-statistic from One-Way ANOVA; Sig.: Significance level ($p > 0.05$ indicates non-significant difference).

Table 2: Descriptive statistics and One-Way ANOVA comparing the wettability of specimens disinfected with the different concentrations of CA solutions.

Disinfectants	Immersion time	Mean ± Std. deviation	F	Sig.
Control	No treatment	68.67 ± 4.435	1.097	0.3484
CA 50 mg/ml	10 minutes	66.66 ± 3.819		
CA 60 mg/ml	10 minutes	68.65 ± 1.535		

Note: CA: Chlorogenic acid; Std. deviation: Standard deviation; F: F-statistic from One-Way ANOVA; Sig.: Significance level ($p > 0.05$ indicates non-significant difference).

Table 3: Kruskal- Wallis statistical comparison of gypsum compatibility scores of specimens disinfected with the different concentrations of CA solutions.

Disinfectants	Immersion time	Median (IQR)	Kruskal-Wallis statistic	Sig.
Control	No treatment	1.000 (1.000 - 1.000)	0.000	>0.9999
CA 50 mg/ml	10 minutes	1.000 (1.000 - 1.000)		
CA 60 mg/ml	10 minutes	1.000 (1.000 - 1.000)		

Note: CA: Chlorogenic acid; IQR: Interquartile range; Kruskal-Wallis statistic: Chi-square value from Kruskal-Wallis test; Sig.: Significance level ($p > 0.05$ indicates non-significant difference).

Figure 1: contact profilometer (surface roughness tester).

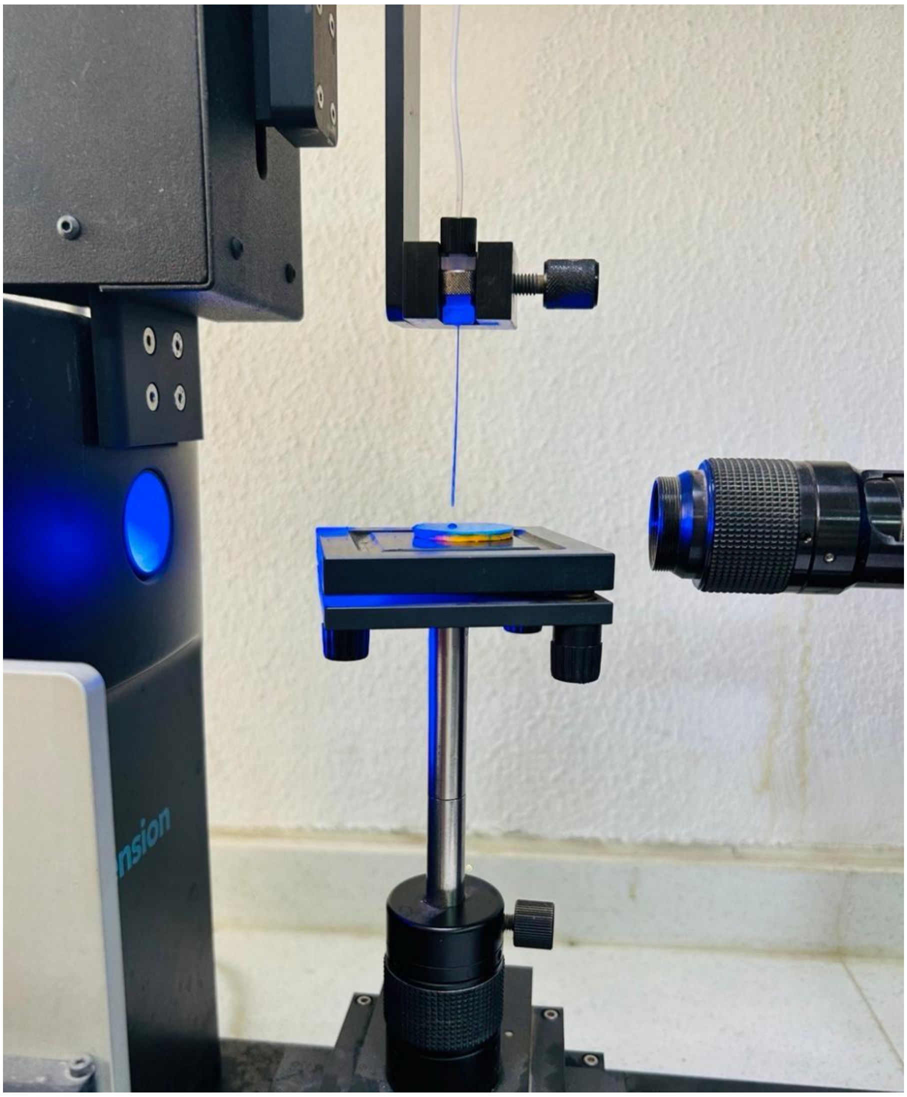

Figure 2: Sessile drop contact angle measurement of addition silicone impression material using a goniometer.

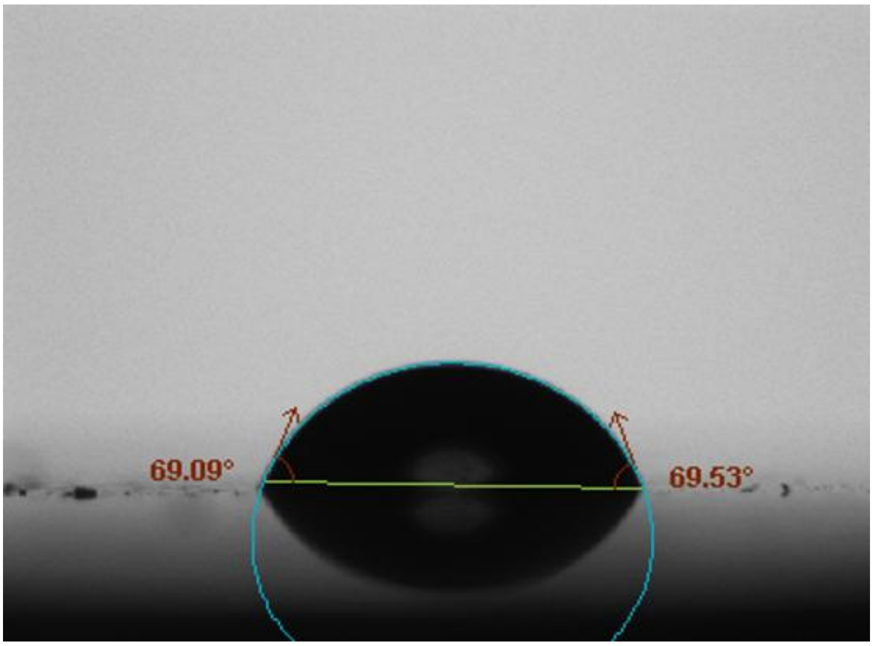

Figure 3: Representative contact angle analysis profile showing the sessile drop measurement on the addition silicone surface.

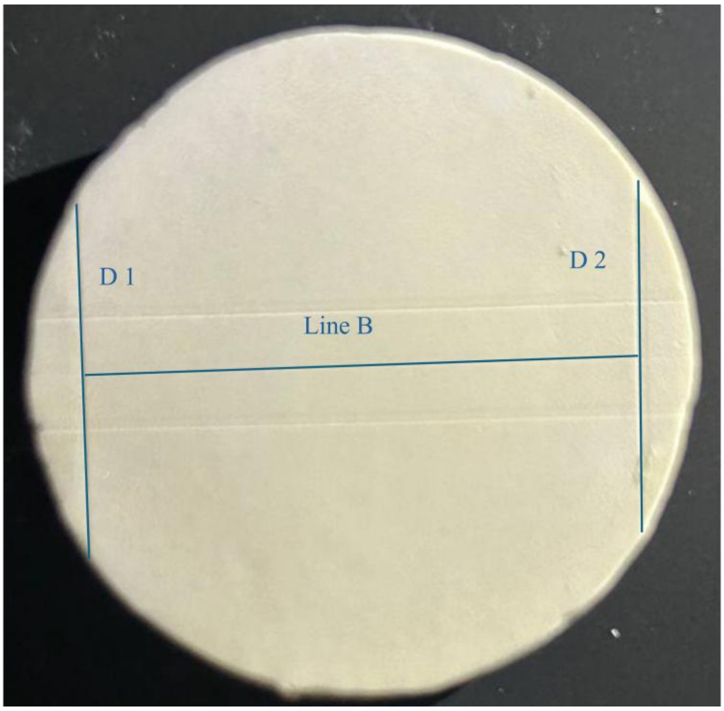

Figure 4: Evaluation of compatibility with gypsum products using modified scoring grades.