Dental Research Journal

Original Article

Comparative evaluation of the antibacterial effect of ultraviolet radiation on alginate and condensation silicone impressions compared to hypochlorite

Farshad Bajoghli[1], Farzaneh Mohammadzadeh Rostami[2], Hossein Gugunani[3], Arezoo Mazaheri Nazarifar[4]

[1]Department of Prosthodontics, Dental Implants Research Center, Dental Research Institute, Isfahan University of Medical Sciences, [2]Department of Bacteriology and Virology, School of Medicine, Isfahan University of Medical Sciences, [3]Department of Prosthodontics, Dental Research Center, Dental Research Institute, Isfahan University of Medical Sciences, Isfahan, [4]Department of Prosthodontics, School of Dentistry, International Campus, Tehran University of Medical Sciences, Tehran, Iran

ABSTRACT

Background: Dental impressions are a known potential vector for cross-contamination between patients and the dental laboratory. Effective disinfection is, therefore, a critical step in infection control protocols. This *in vitro* study aimed to evaluate and compare the antibacterial efficacy of ultraviolet (UV) radiation and 0.525% sodium hypochlorite solution for disinfecting two common impression materials: condensation silicone and alginate.

Materials and Methods: This *in vitro* study employed a comparative experimental design to evaluate disinfection efficacy. A total of 195 samples were utilized, comprising 90 discs each of condensation silicone and alginate, alongside positive and negative controls (n = 9 and n = 6, respectively). All samples were experimentally contaminated with standardized suspensions of three pathogenic species: *Streptococcus pyogenes* (beta-hemolytic Group A), *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. The disinfection protocols consisted of either exposure to 0.525% sodium hypochlorite spray for 10 min or treatment with UV radiation using a dedicated device ("Fast Steril"). Antibacterial efficacy was quantitatively assessed by enumerating the mean colony-forming units (CFUs) postdisinfection. Statistical analysis was performed using the Kruskal–Wallis and Mann–Whitney *U*-tests, with the significance level defined at $\alpha = 0.05$.

Results: The analysis revealed a statistically significant difference in bacterial reduction based on the microbial species ($P < 0.001$). UV radiation demonstrated superior efficacy compared to sodium hypochlorite in disinfecting condensation silicone impressions ($P < 0.05$). Conversely, no significant difference was observed between the two disinfection methods for alginate impressions. Regarding bacterial susceptibility, the mean reduction in CFUs for *S. pyogenes* was significantly greater than for *S. aureus* and *P. aeruginosa* ($P < 0.001$), between which no significant difference was found ($P = 1.0$).

Conclusion: Within the limitations of this study, UV radiation proved to be a more effective disinfection method for condensation silicone impressions than sodium hypochlorite spray. For alginate impressions, both methods were equally effective. Given its efficacy and the superior dimensional stability of UV-treated impressions reported in the literature, the adoption of UV radiation is recommended as a viable and efficient method for disinfecting both

Received: 13-Sep-2025
Revised: 08-Nov-2025
Accepted: 22-Nov-2025
Published: 30-Dec-2025

Address for correspondence:
Dr. Arezoo Mazaheri Nazarifar,
Department of Prosthodontics, School of Dentistry, International Campus, Tehran University of Medical Sciences, Tehran, Iran.
E-mail: arezoomnf@gmail.com

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_530_25

How to cite this article: Bajoghli F, Rostami FM, Gugunani H, Nazarifar AM. Comparative evaluation of the antibacterial effect of ultraviolet radiation on alginate and condensation silicone impressions compared to hypochlorite. Dent Res J 2025;22:56.

condensation silicone and alginate impressions, thereby mitigating the risk of cross-infection in dental practice.

Key Words: Cross-infection, dental impression, disinfection, infection control, *Pseudomonas aeruginosa*, sodium hypochlorite, *Staphylococcus aureus*, *Streptococcus pyogenes*, ultraviolet rays

INTRODUCTION

Dental impression making is a critical step in restorative treatment, providing a precise three-dimensional replica of the oral structures.[1] This replica allows for the fabrication of restorations that reconstruct tooth form and function and enables laboratory work to proceed in the patient's absence.[2,3] Dental impressions are a potential source of infection in prosthetic workflow and can lead to the transmission of infection, especially in individuals with weakened immune systems.[4,5] For this reason, the American Dental Association (ADA) and the Centers for Disease Control and Prevention have published guidelines for the disinfection of dental impressions.[6] All patients should be considered potential carriers, and their impressions should be handled similarly to those of a high-risk patient.[7] Rinsing under water cannot completely remove saliva and blood from the impression surface because salivary mucins and adhesive salivary proteins interfere with simple washing.[8] Therefore, a suitable method for disinfecting dental impressions is essential. Since impressions cannot be sterilized by heat, chemical disinfection is the most common disinfection method. Chemical disinfection is divided into two methods: immersion and spraying.[7] The hydrophilic nature of the materials, the presence or absence of surfactants, and their tolerance to immersion in water or other fluids are key elements in selecting the appropriate chemical protocol for impression materials.[9,10] To date, a global standard method for disinfecting impression materials has not been achieved.[11,12] An alternative disinfection strategy employs ultraviolet (UV) radiation. The efficacy of UV light is contingent upon several factors, including exposure duration, intensity, ambient humidity, and the requirement for direct line-of-sight to the microbial organisms. Furthermore, its application is constrained by significant limitations: the need for multiangular exposure to ensure comprehensive surface coverage and the imperative to remove organic debris from the impression before treatment to achieve optimal efficacy. However, the nonchemical nature of this method, the lack of dimensional changes in the impression, and its broad spectrum of effectiveness are advantages of this method.[13] Therefore, given the critical role of impression disinfection in preventing cross-contamination and the potential advantages of UV radiation such as avoiding dimensional change and chemical residue over conventional chemical disinfectants, this *in vitro* study aimed to comparatively evaluate the antibacterial efficacy of a specific UV radiation device ("Fast Steril") against the standard chemical agent, 0.525% sodium hypochlorite, on two widely used impression materials: Condensation silicone and alginate.

MATERIALS AND METHODS

Study design

This *in vitro* investigation utilized a comparative experimental design to assess disinfection efficacy across two impression materials and three bacterial species.

Ethical approval and study design

This *in vitro* investigation employed a cross-sectional experimental design to assess disinfection methodologies for dental impression materials. Although the study did not involve human subjects or biological samples, ethical approval was secured from the Ethics Committee of Isfahan University of Medical Sciences (approval code: IR. MUI. RESEARCH. REC.1402.051) in compliance with the institutional regulatory standards.

Sample preparation and experimental groups

The experimental design incorporated 195 specimens distributed across four categories: 90 alginate disks, 90 condensation silicone disks, 9 positive control disks (allocated equally among three bacterial species), and 6 negative control disks (assigned proportionally to assess both impression material types). This configuration enabled comprehensive evaluation of both material-specific characteristics and disinfection efficacy across experimental conditions.

Microbiological procedures and contamination protocol

Standardized bacterial suspensions of *S. aureus* ATCC 25923, *P. aeruginosa* ATCC 27853, and

Group A beta-hemolytic *Streptococcus pyogenes* ATCC 19615 were prepared for contamination of the impression material disks. Each bacterial strain was initially streaked onto blood agar plates using sterile swabs and incubated aerobically at 37°C for 24–48 h. Following incubation, isolated colonies were transferred to test tubes containing Tryptic Soy Broth and subjected to secondary incubation at 37°C until achieving a turbidity equivalent to the 0.5 McFarland standard, indicating a concentration of approximately 1.5×10^8 colony-forming units (CFUs)/mL. The alginate and condensation silicone disks were systematically contaminated by immersion in these standardized bacterial suspensions before comparative evaluation of sodium hypochlorite and UV irradiation disinfection protocols.[13,14]

Sample fabrication and sterilization protocol

All instrumentation utilized in this study underwent sterilization through autoclave treatment at 121°C and 15 PSI for 20 min before sample preparation. Alginate (Iralgin, Golchai, Iran) and condensation silicone (Sildent, Lascod S. P. A., Florence, Italy) were manipulated in strict accordance with manufacturer specifications. The materials were subsequently cast into specialized metal molds to generate standardized disks measuring 30 mm in diameter and 7 mm in height.

A total of 180 experimental disks were fabricated (90 per material type). These specimens were systematically randomized into six experimental groups (n = 15 per group) for each bacterial species, with additional allocations for positive and negative control groups to ensure methodological rigor. This allocation strategy enabled precise comparison of disinfection efficacy across both material types and microbial challenges.

Contamination and disinfection protocol

The experimental disks were subjected to controlled contamination by immersion in individual containers housing standardized bacterial suspensions (0.5 McFarland standard) of *S. aureus* ATCC 25923, *P. aeruginosa* ATCC 27853, or Group A beta-hemolytic *S. pyogenes* ATCC 19615 for a duration of 2 min. Following contamination, each disk was aseptically retrieved using sterile forceps and underwent an initial rinsing procedure consisting of 60 mL sterile distilled water applied for 30 s to remove nonadherent bacteria. The disinfection phase employed two distinct methodologies: one group of disks received chemical disinfection through complete surface spraying with 0.525% sodium hypochlorite solution followed by a 10-min contact time, while the second group underwent physical disinfection using a GermGuardian Portable UVC Wand (“Fast Steril”) (Guardian Technologies LLC, Euclid, Ohio, USA) maintained at a standardized distance of 1 inch (2.54 cm) from the surface for 10 s of continuous exposure.[13]

Microbiological assessment and quality control

All disks received a final rinse with 60 mL sterile distilled water for 30 s following disinfection procedures. Microbial sampling was performed by systematically swabbing the entire surface of each disk with a sterile dry swab, which was subsequently streaked in a linear pattern onto blood agar plates. All plates underwent aerobic incubation at 37°C for 48 h. CFUs were enumerated manually following the incubation period. To eliminate observational bias, the microbiologist performing colony counts was blinded to group assignments throughout the enumeration process. The UV irradiation disinfection methodology is visually documented in Figure 1.

Statistical analysis

Quantitative data analysis was performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation. The Kolmogorov–Smirnov test confirmed nonnormal distribution of the data, and Levene’s test indicated violation of homogeneity of variances. In addition, a significant interaction effect was observed between the independent variables.

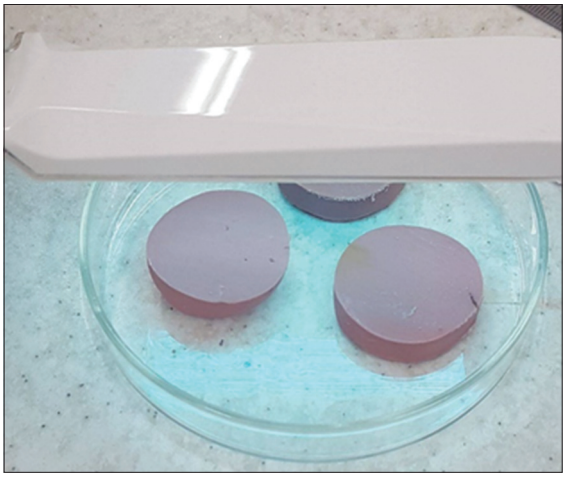

Figure 1: Application of ultraviolet (UVC) radiation for disinfection of impression material disks using the GermGuardian Portable UVC Wand, maintained at a standardized distance of 1 inch (2.54 cm).

Consequently, nonparametric analyses were conducted using the Kruskal–Wallis test for overall group comparisons, followed by pairwise Mann–Whitney *U*-tests with Bonferroni adjustment for multiple comparisons. A significance level of $\alpha = 0.05$ was applied for all statistical tests.

RESULTS

The validation of experimental conditions was confirmed by the control groups. All positive control samples demonstrated 100% microbial growth, while all negative control samples maintained 100% sterility throughout the study. The quantitative assessment of disinfection efficacy is presented in Figure 2, which illustrates the mean CFU counts and corresponding standard deviations for three microbial species on both alginate and condensation silicone impression materials following application of two disinfection protocols: UV irradiation and sodium hypochlorite treatment. The bar chart provides a comparative visualization of the bacterial reduction achieved by each disinfection method across both material types.

Statistical analysis of microbial reduction

The Kruskal–Wallis test demonstrated a statistically significant difference in colony counts among the three microbial species ($P < 0.001$). *Post hoc* analysis using Bonferroni-corrected Mann–Whitney *U*-tests revealed that *S. pyogenes* (Group A beta-hemolytic) showed significantly different susceptibility compared to both *P. aeruginosa* ($P < 0.001$) and *S. aureus* ($P < 0.001$). However, no significant difference was observed between *S. aureus* and *P. aeruginosa* ($P = 1.000$).

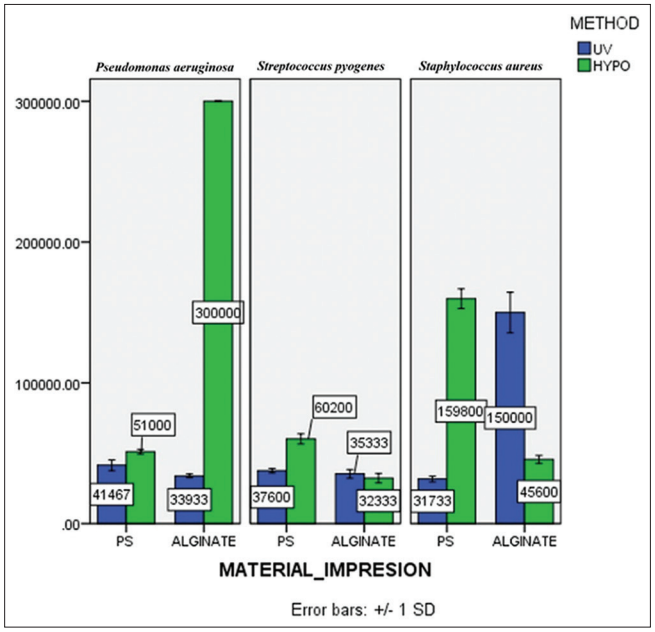

Figure 2: Comparative analysis of colony-forming unit for three bacterial species on alginate and condensation silicone impression materials following disinfection with ultraviolet radiation and sodium hypochlorite. Data presented as mean ± standard deviation; PS: *Pseudomonas aeruginosa*.

Regarding material characteristics, statistical analysis indicated a significant overall difference in disinfection efficacy between the two impression materials ($P = 0.002$), with alginate demonstrating greater resistance to disinfection protocols compared to condensation silicone.

Furthermore, a significant difference was observed between the two disinfection methods ($P < 0.001$), with UV radiation demonstrating superior antimicrobial efficacy compared to 0.525% sodium hypochlorite solution across all experimental conditions.

DISCUSSION

Dental impressions frequently come into contact with blood and saliva, which can harbor pathogenic microorganisms capable of transmitting infectious diseases. This risk of cross-contamination underscores the need for stringent infection control measures throughout impression-making and subsequent laboratory processing.[15] The present study evaluated the antibacterial efficacy of UV irradiation on condensation silicone and alginate impression materials in comparison with 0.525% sodium hypochlorite. The selection of test microorganisms was guided by their clinical relevance, high pathogenicity, and documented resistance to disinfectants. *Pseudomonas aeruginosa* presents a significant cross-infection risk in dental environments due to its intrinsic antibiotic resistance and potential to cause nosocomial infections. *Staphylococcus aureus* was included as a benchmark organism for disinfectant efficacy testing owing to its widespread antibiotic resistance. *S. pyogenes* (Group A beta-hemolytic) was selected for its established pathogenic role in oral and systemic infections.[12] Although this study focused on highly resistant pathogenic strains, future research should incorporate representative members of the normal oral microbiota to enhance clinical generalizability.

Two disinfection methods were evaluated for impression materials: UV irradiation using a fast-sterilizer device and spray application of

0.525% sodium hypochlorite with a 10-min contact time. Although the ADA recommends immersion in 0.5% sodium hypochlorite (5000 ppm free chlorine) for 10 min,[6] and manufacturers report 99.8% tuberculocidal efficacy with this protocol,[16] the spray method was selected for this investigation due to concerns regarding dimensional instability associated with immersion techniques.[17] While immersion remains the gold standard for disinfectant reliability,[12,18,19] spraying represents a clinically acceptable alternative that minimizes potential material distortion.

The present study also evaluated UV-C (UVC) irradiation as a disinfection alternative using a fast-sterilization device. The biocidal mechanism of UVC radiation primarily involves induction of genomic damage through thymine dimer formation in microbial DNA, leading to irreversible inactivation of pathogens.[20] Notable advantages of UVC over chemical disinfectants include exceptional preservation of impression dimensional accuracy and complete avoidance of chemical residue on material surfaces.[21] While this technology demonstrates well-documented efficacy in surface disinfection, it also shows promising applications in endodontic therapy, including root canal disinfection and management of periapical inflammatory conditions. These findings are consistent with previous research by Ishida *et al*.,[13] who reported complete eradication of *Candida* species on silicone impression materials following 5 min of UVC exposure, with no statistically significant alterations in dimensional stability or surface characteristics. In a 2019 investigation, Nimunkar *et al*.[22] evaluated the dimensional stability of polyvinyl siloxane impressions following disinfection using 2% glutaraldehyde, 1% sodium hypochlorite, and UV irradiation. Their findings indicated that UV irradiation, in contrast to chemical disinfectants, produced no measurable dimensional alterations. This is consistent with a body of research documenting dimensional changes resulting from chemical disinfection of dental impressions,[23,24] although some studies have reported no significant effects on dimensional stability from disinfection procedures.[25,26]

Alginate, a representative irreversible hydrocolloid, remains one of the most frequently utilized dental impression materials owing to its user-friendly application, procedural simplicity, and cost-effectiveness.[27] Nevertheless, its inherent hydrophilicity increases its susceptibility to microbial retention, while its dimensional accuracy and stability are notably compromised upon exposure to liquid disinfectants.[28] Condensation silicones, similarly employed in routine prosthetic impression procedures, represent another mainstream material in clinical dentistry.[27] Based on their prevalence and distinct material characteristics, these two impression materials were selected for the current investigation. Results demonstrated that UV irradiation yielded superior disinfection efficacy compared to sodium hypochlorite solution when applied to condensation silicone impressions. Furthermore, a statistically significant difference was observed between the two materials, with alginate exhibiting reduced susceptibility to disinfection, a phenomenon likely attributable to its heightened porosity and consequent increased potential for microbial entrapment.

In a 2010 comparative study, Samra *et al*. evaluated the disinfection efficacy of UV irradiation versus sodium hypochlorite on alginate and silicone impression materials. Their findings indicated that UV chamber disinfection yielded superior results compared to hypochlorite a conclusion consistent with the present study regarding silicone materials, though not observed with alginate. Further supporting the utility of UV irradiation, Aran *et al*. demonstrated its potential for significantly reducing colony counts of oral pathogens on various patient-derived impression materials, including alginate, addition silicone, and polyether. However, as their study utilized clinical impressions, the precise microbial composition remained uncharacterized. Notably, Aran *et al*. also reported that impression material type did not influence the efficacy of UV disinfection.[29] The observed differential efficacy of disinfection between alginate and silicone impression materials in the present study may be attributed to alginate's characteristically porous microstructure and its reported capacity for two to three times greater microbial absorption compared to silicone. This inherent property may necessitate extended disinfection durations beyond the 10-s UV exposure protocol employed herein. Furthermore, the use of a multidirectional UV chamber as opposed to the single-angle portable device utilized in this study may provide more uniform irradiation and enhance disinfection outcomes. It is also noteworthy that discrepancies between our results and those of earlier studies may stem from differences in microbial strains; prior investigations predominantly used

normal oral flora, whereas the present study employed standardized ATCC strains with well-defined profiles. These findings are nevertheless consistent with recent work by Wezgowiec *et al.*,[30] who demonstrated the effectiveness of UV irradiation in disinfecting both condensation and addition silicones of varying consistencies against *P. aeruginosa*, *S. aureus*, and *Candida albicans*, further supporting the utility of UV-based disinfection in dental practice.

One notable finding of this study was the significantly higher colony counts observed for *S. aureus* and *P. aeruginosa* compared to Group A beta-hemolytic Streptococcus (GAS). This differential efficacy may be attributed to the higher intrinsic resistance of *S. aureus* and *P. aeruginosa* both recognized as resilient nosocomial pathogens to various disinfection methods and antibiotics when compared to GAS.[31,32] The effective elimination of resistant nosocomial pathogens such as *S. aureus* and *P. aeruginosa* suggests potential applications of the UV disinfection device beyond dental settings, including hospital environments where such pathogens pose significant challenges to infection control. However, this extrapolation requires further validation through targeted clinical studies. In conjunction with the established advantage of superior dimensional stability reported in literature when using UV irradiation compared to chemical alternatives, the findings of this study support the conclusion that UV irradiation presents a superior alternative to chemical disinfectants for both condensation silicone and alginate impression materials.

CONCLUSION

Based on the results of this study, UVC irradiation demonstrated superior disinfection efficacy compared to sodium hypochlorite for condensation silicone impressions, while both methods showed comparable results for alginate. The differential efficacy between materials highlights the influence of material composition and porosity on disinfection outcomes. Given its minimal impact on dimensional stability and clinical practicality, UV irradiation is recommended as a preferable disinfection method for dental impression materials.

Ethics approval and consent to participate

This study did not involve human participants, human data, or human tissue. Therefore, obtaining individual informed consent was not applicable. However, the study protocol was reviewed and approved by the Ethics Committee of Isfahan University of Medical Sciences (Approval Code: IR. MUI. RESEARCH. REC.1402.051) in accordance with institutional ethical standards for *in vitro* research. All experimental procedures were conducted in compliance with relevant guidelines and regulations.

Authors' contributions

F. B. supervised the project and provided critical guidance throughout all stages of the research. F. B. additionally acquired funding and administered the project. F. M. R. contributed to the study's conceptualization, developed the methodology, and wrote the original draft of the manuscript. H. G. assisted in methodological development, conducted the investigation, and supported formal analysis. A. M. N. participated in writing the original draft and contributed to reviewing and editing the manuscript. All authors read, reviewed, and approved the final version of the manuscript.

Financial support and sponsorship

This study was supported by the Isfahan University of Medical Sciences, Isfahan, Iran (Grant No. 340572).

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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