ORIGINAL RESEARCH

Effect of Ultraviolet-C Light Exposure Time on the Dimensional Stability of Addition Silicone Dental Impressions: An *In Vitro* Study

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Received on: 25 June 2024; *Accepted on*: 27 August 2024; *Published on*: 23 September 2024

Abstract

Aim: To compare the effect of different ultraviolet-C (UV-C) light exposure times on the dimensional stability of addition silicone dental impressions.

Materials and methods: The dimensional stability of the addition silicone dental impressions was assessed by measuring specific dimensions on dental casts that were recovered from an upper acrylic resin model of dental implants. The impressions were reproduced using a customized tray adapted in a three-point simplex dental articulator permitting only opening and closing movements. Addition silicone dental impressions were divided into five groups ($N = 12$) according to the UV-C light exposure time. Group A was untreated; group B received 10 minutes; group C, 20 minutes; group D, 30 minutes; and group E, 40 minutes. All the impressions were poured with type IV dental stone and the internal edges of the upper silicone retainers of impression copings were used as five reference points (E, D, C, B, and A) to determine six linear measurements between ED, CB, EA, AD, EB, and CD points using a traveling microscope of 0.001 mm accuracy. One-way analysis of variance (ANOVA) was used for the statistical analysis ($p < 0.05$).

Results: Expansion and contraction were noted among ED, CB, EA, and EB measurements, whereas only expansion was noted among AD and CD measurements. The ANOVA analysis showed there was no significant difference in the arithmetic means for the measurements between and within group A and the other groups ($p > 0.05$).

Conclusion: The UV-C light exposure time of 10, 20, 30, and 40 minutes did not have any negative effect on the dimensional stability of the addition silicone dental impressions evaluated.

Clinical significance: In the daily routine dental practice, dental impressions need to be washed and disinfected immediately after making to prevent cross-infections. The UV-C light has been proposed as a promising method for disinfection, but only a few studies have been published about its effect on the dimensional stability of dental silicones.

Keywords: Addition silicone impression material, Disinfection, Ultraviolet rays.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3712

Introduction

Dental impressions are negative imprints of hard and soft oral tissues and are considered the first milestone in the sequence of procedures performed for the fabrication of dental casts into which gypsum or other die materials can be processed to create dental replicas used for dental treatments.[1,2] Certainly, different types of impression materials used can act as a vehicle for transferring many microorganisms present in the patient's blood, saliva, or dental plaque representing a serious threat if proper precautions are not taken.[3,4] In the dental literature, evidence is there regarding the pathogenesis of viruses of hepatitis B and C, herpes simplex, tuberculosis, and AIDS.[5–7] In this regard, the contaminated dental impression could be a source for cross-infections between dentists, dental assistants, and laboratory technicians involved in dental impressions handling, transportation, or storage procedures.[3]

Several methods and techniques have been recommended to disinfect the impression materials used in the dental practice such as spray method and immersion method using disinfection solutions, and demonstrated to be effective for this purpose.[8] Immersion disinfection ensures that all surfaces of the dental impressions are exposed to the disinfectant; however, some impression materials show an imbibition phenomenon. On the other hand, the spray method of disinfection decreases the distortion, but it may not reach all the material superficies such as areas of undercuts, and also can lead to occupational exposure because of the release of air.[9] In addition, other methods such as the use of microwave, ozone, autoclave, ethylene oxide, electrolyzed oxidizing water, direct current glow discharge, and argon radio frequency glow discharge have been proposed.[7,8] However, some of them are corrosive, not compatible, harmful chemically, and can

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How to cite this article: Bravo-Cueto AG, Tinedo-López PL, Malpartida-Carrillo V. Effect of Ultraviolet-C Light Exposure Time on the Dimensional Stability of Addition Silicone Dental Impressions: An *In Vitro* Study. J Contemp Dent Pract 2024;25(6):507–513.

Source of support: Nil

Conflict of interest: None

affect the dental impression properties.[10] As a matter of fact, it is elemental to identify an ideal method of disinfection with probed antimicrobial activity that does not affect the mechanical and physical properties (e.g., dimensional stability, hardness, tensile strength, and wettability) of the dental impression materials.

Ultraviolet (UV) light is the region of the electromagnetic spectrum between X-rays and visible light with a wavelength of 100–400 nm. Considering the wavelength, UV light can be divided into four types: UV-A (wavelength: 315–400 nm), UV-B (wavelength: 280–315 nm), ultraviolet-C (UV-C) (wavelength: 200–280 nm), and vacuum UV (wavelength: 100–200 nm).[11] Ultraviolet-C light was shown to drastically reduce microbes, including bacteria, fungi, yeasts, and viruses because, after the exposition, genetic damage occurs due to the photodimerization between the pyrimidine nucleotide molecules (uracil dimers) in the DNA/RNA strands. Subsequently, the formation of cyclobutene pyrimidine dimers results in DNA disassembly and ultimately disrupts cellular replication and other cellular functions.[12,13] Reportedly, for this powerful effect, UV-C light is considered a new method to disinfect dental impressions, and its performance has been demonstrated in recent investigations.[2,8,10] The use of UV-C light in dentistry was gaining notoriety during the COVID-19 pandemic due to its effect in the disinfection realm, becoming an interesting topic to investigate dental materials. Actually, the disinfection of the impressions efficiently is considered mandatory in dental and laboratory practice because the current understanding is geared toward special care for safety concerns to control the transmission of viruses such as coronavirus.[14]

According to the literature, some studies showed the effect of UV-C light in reducing the microbial load in dental impression materials using different exposure times (e.g., 3, 6, 10, 15, and 40 minutes).[2,15,16] In addition, some investigations reported the effect of UV-C light in the dimensional stability of impression materials showing no significant dimensional changes on alginate, and addition and condensation silicones considering 3,[17] 10,[18] 20,[19] and 40[20] minutes, or in polyether material using 20 minutes.[21] However, based on current findings, there is a lack of uniform standardization of UV-C light exposure time for physical and mechanical properties evaluation of dental materials and this topic remains controversial.

Hence, the objective of this *in vitro* study was to compare the effect of different UV-C light exposure times on the dimensional stability of addition silicone dental impressions. The null hypothesis was that the different UV-C light exposures times used would not affect the dimensional stability of the addition silicone dental impressions evaluated.

Materials and Methods

The present *in vitro* study was conducted in a private dental laboratory in Lima-Peru. The ethical approval was obtained from the Institutional Ethical Committee of the Universidad Privada San Juan Bautista with the code N° 1367-2021-CIEI-UPSJB. This study was conducted during the year 2022.

In the present study, the dimensional stability of the addition silicone impressions was assessed indirectly by measuring specific dimensions on dental casts that were recovered from an upper acrylic resin model of dental implants considered the master model. A total of 60 samples were fabricated and divided into 5 groups with 12 samples each based on the UV-C light exposure time as follows:

Fig. 1: Master model

- Group A: Control group. This group did not receive any UV-C exposure time ($n = 12$).
- Group B: Ten minutes UV-C light exposure time ($n = 12$).
- Group C: Twenty minutes UV-C light exposure time ($n = 12$).
- Group D: Thirty minutes UV-C light exposure time ($n = 12$).
- Group E: Forty minutes UV-C light exposure time ($n = 12$).

Inclusion and Exclusion Criteria

The inclusion criteria were dental casts with implant platforms permitting the adequate position of the impression copings and dental casts parallel to the horizontal surface. The exclusion criteria included all the dental casts with bubbles and fissures that failed to reproduce the areas around the implant platforms due to errors at the time of impression material manipulation or at the time of pouring.

Sample Preparation

The protocol was designed considering the Checklist for Reporting *In-vitro* Studies (CRIS Guidelines),[22] and the process was performed in line with a previously reported technique,[18,19] with some modifications for the open tray dental implant impressions. The master model had five workshop dental implants of 4.6 × 12 mm (Tapered internal implant, BioHorizons, Birmingham, AL, USA) positioned on the maxillary arch, two implants were ubicated in the region of molars (E and D reference points), two implants were ubicated in the region of premolars (C and B reference points), and one implant was ubicated in the middle of the central incisors (Fig. 1). The procedure considered in this study was as follows:

Fabrication of Custom Tray

A 2.5 mm thick wax pattern (Koriwax, Montesuori Lab, Lima, Peru) was adapted for impression material on the master model and this whole assembly was then duplicated in alginate (Tropicalgin, Zhermack, Badia Polesine, Italy) to obtain a stone mold. On this stone mold, a wax pattern of 2.5 mm thickness was adopted. This wax pattern was then flasked and dewaxed. Packing was done with auto-polymerizing acrylic resin (New Stetic, Antioquia, Colombia) and curing was performed in a traditional mode. Subsequently, the custom tray was retrieved, finished, and polished. Round bur was used to make five holes of 13 × 13 mm in the occlusal surface of the custom tray for the 4.5 mm impression copings (Direct pick-up copings, BioHorizons, Birmingham, AL, USA).

Support Structure for the Master Model

A three-point simplex type dental articulator with condylar housing free permitting only the opening and closing movements was used. The contact of the incisal guide pin with the guide table enabled to maintain the distance between the master model and the custom tray. The jig was fixed on the lower frame of the articulator and the master model was attached to this using cyanoacrylate cement. The master model was fixed on the jig considering a height of 45 mm between the platforms of the implants and the upper frame of the articulator for the clearance. While making the impressions, the contact of the incisal guide pin with the guide table formed a vertical stop that helped to standardize the thickness of the impression material for all the samples. It was verified that the impression copings protruded through the custom tray without interference.

Impression Technique

Five 4.5 mm impression copings were placed on the implant platforms of the master model and were fastened using the coping screws inserted by using the hex driver with 10 Ncm torque. A one-step putty wash technique was used for impressions. The custom tray was loaded with putty soft elastomeric impression material (Panasil putty soft, Kettenbach GmbH & Co. KG, Eschenburg, Germany) standardized in the measuring spoon stock, while the light body elastomeric impression material (Panasil initial contact light, Kettenbach GmbH & Co. KG, Eschenburg, Germany) was injected around the coping bodies using an automatic dispenser (Bredent, Senden, Germany) leaving the screws exposed. The custom tray was positioned in the upper frame of the articulator using a transversal pin and guided over the master model with the help of the incisal guide pin to contact the guide table. Before the material was polymerized, finger was used to wipe the impression material from the top of the coping screws so they were exposed for access. The elastomeric materials were manipulated and mixed considering the manufacturer's instructions. The custom tray was allowed to stay on the master model for 5 minutes. After the impression material was polymerized, the coping screws were loosened using the hex driver, the custom tray was separated with a flat instrument and was rinsed and dried for 15 seconds to simulate saliva removal. Excess water was shaken off using air blow from a syringe.

Groups as per UV-C Light Exposure Time

The samples were grouped according to the UV-C light exposure time (groups A, B, C, D, and E). An ultraviolet cabinet WX-208A model (Made in China, imported by Selemed of Peru) was used. The technical specifications were: Dimensions of 35 × 22 × 25 cm, voltage of 220 V, UV lamp with 9 W of power, and wavelength of 254 nm. The distance between the lamp and the base of the custom tray was 70 mm and the distance between the lamp and the addition silicone was 10 mm.

Dental Casts Preparation

After the exposures, the B, C, D, and E groups received the implant analogs (BioHorizons, Birmingham, AL, USA) that were fitted to the impression copings. Group A (control group) received the implant analogs without prior exposition, and the 60 samples were completed. The impressions were poured with type IV dental stone (ResinRock, Whip Mix, Louisville, KY, USA) which was vacuum mixed (Mestra, Vizcaya, Spain) using water/powder ratio of 20 mL/100 gm according to the manufacturer's instructions. In addition, a dental lab vibrator (Vibra 20, Tecnodent, Buenos Aires, Argentina) was used. After 30 minutes the impressions were removed from the custom tray. The bases of the samples were poured with type II dental stone (Dentalabor, Industrias Cram, Lima, Peru) and were positioned into rubber sockets for dental models. Afterward, the dental casts were placed parallel to the surface using a level tool (Fig. 2).

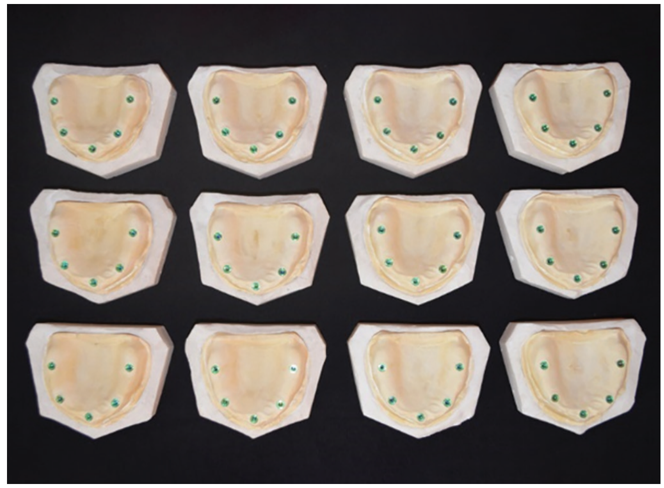

Fig. 2: Dental casts grouped after the pouring

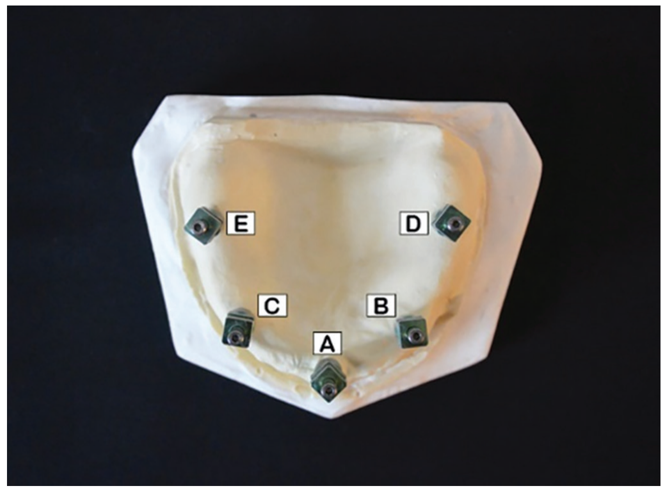

Fig. 3: Reference points for the measurements considered in the study

Measuring Linear Dimensions on the Dental Casts

All measurements were made using a traveling microscope of 0.001 mm accuracy. Five impression copings were fastened on the implant platforms and the coping screws were tightened using a 10 Ncm torque. The internal edges of the upper silicone retainers of the impression copings were used as five reference points (E, D, C, B, and A) to determine six linear measurements between ED, CB, EA, AD, EB, and CD points (Fig. 3). The measurements of the six dimensions selected were repeated three times for each dental cast and the mean of three readings was used. All the measurements

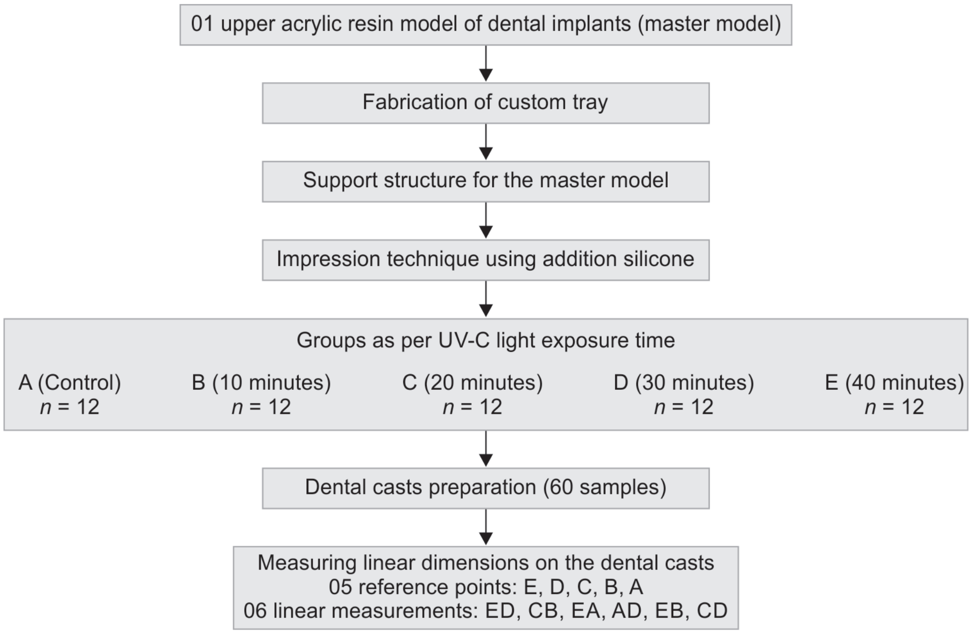

Fig. 4: Methodology flowchart

were made by a single calibrated operator which was blinded to the UV-C light exposure time used. The flowchart depicts the methodology (Fig. 4).

The statistical analysis was done using Statistical Package for Social Sciences (IBM® SPSS® Corp., Chicago, IL, version 25.0 for Windows). All quantitative variables were estimated using measures of central location and measures of dispersion. The normality of data was checked by measures of skewness and Shapiro–Wilk tests of normality. One-way analysis of variance (ANOVA) test for independent samples was used for between and within-group comparison. Differences between the groups were considered statistically significant with $p < 0.05$.

Results

The results of the reference point distances of A, B, C, D, and E groups are shown in Table 1, these results include measures of central location and measures of dispersion. The measurements were done in millimeters (mm). The highest mean measurements between ED (38.530 ± 0.015) and EA (32.781 ± 0.159) points occurred in group B, whereas the highest mean measurements between AD (32.261 ± 0.060), EB (36.941 ± 0.146), and CD (37.274 ± 0.042) points was observed in group E. In addition, the highest mean measurements between CB (26.646 ± 0.149) points occurred in group D. Expansion and contraction were noted among ED, CB, EA, and EB measurements, whereas only expansion was noted between AD and CD measurements, respectively. The one-way ANOVA test showed no significant difference in the arithmetic means for the measurements between and within group A (control) and the other groups ($p > 0.05$). Thus, there was no difference in linear dimensional changes of addition silicone dental impressions evaluated. These results are shown in Table 2.

Discussion

The present *in vitro* study compared the effect of different UV-C light exposure times on the dimensional stability of addition silicone dental impressions. One of the major concerns in the dental practice is cross-infection control even more in the present post SARS-CoV-2 pandemic context highlighting the need to provide security to patients during dental treatments. Over the years, different studies demonstrated that the use of running water to remove patient's blood and saliva may not eliminate all the microorganisms of the dental impressions. Thus, dentists, dental assistants, and laboratory technicians must be aware of the need to use protocols for disinfecting dental impressions and casts.[7,10]

Ultraviolet-C light has been used in dentistry to disinfect dental environment,[23] impression materials,[2,8,10,15,16] root canals,[24,25] acrylic resins,[26,27] contaminated toothbrushes,[28,29] and dental implants[30–32] showing interesting results. Indeed, the largest amount of information available is related to the disinfection of impression materials (alginate, addition and condensation silicones, polyether) where UV-C light has demonstrated effectivity against microbes, including bacteria, fungi, yeasts, and viruses. Samra and Bhide[15] informed better results of UV-C light compared with glutaraldehyde and sodium hypochlorite against different microorganisms inoculated in alginate and addition silicone impression materials using 3 minutes of exposition. Ishida et al.[33] showed the efficacy of UV-C light in disinfecting irreversible hydrocolloid and silicone impression materials inoculated with *Candida albicans* using 10 minutes of exposition. Recently, Wezgowiec et al.[2] revealed the efficacy of the UV-C light for disinfection of condensation and addition silicones using 40 minutes. In such a context, the investigations above described show the use of different time exposures of UV-C light and the lack of uniform standardization is evident.

On the other hand, the effect of UV-C light on the dimensional stability of polyvinyl siloxane impressions was evaluated by Godbole et al.[18] and Nimonkar et al.[19] using an interesting technique with a modified dental articulator to standardize the thickness of the impression material. These investigations used a brass master model with five projections simulating abutments with conical pointed tips that served as reference points for the measurements.

Table 1: Descriptive statistics of the five groups evaluated

Groups	N	Mean	SD	Median	Value		95% CI	
					Minimum	Maximum	Lower bound	Upper bound
ED								
Group A	12	38.510	0.058	38.504	38.403	38.611	38.473	38.547
Group B	12	38.530	0.015	38.532	38.501	38.550	38.520	38.540
Group C	12	38.506	0.046	38.519	38.433	38.598	38.476	38.535
Group D	12	38.490	0.074	38.483	38.385	38.631	38.443	38.538
Group E	12	38.485	0.042	38.474	38.441	38.570	38.458	38.512
CB								
Group A	12	26.637	0.103	26.660	26.380	26.738	26.571	26.703
Group B	12	26.539	0.233	26.519	26.283	26.889	26.391	26.688
Group C	12	26.585	0.114	26.602	26.425	26.751	26.512	26.658
Group D	12	26.646	0.149	26.693	26.332	26.861	26.551	26.741
Group E	12	26.626	0.132	26.587	26.458	26.851	26.542	26.710
EA								
Group A	12	32.735	0.072	32.737	32.641	32.841	32.688	32.781
Group B	12	32.781	0.159	32.793	32.503	32.985	32.680	32.883
Group C	12	32.774	0.074	32.754	32.678	32.895	32.727	32.821
Group D	12	32.731	0.106	32.730	32.593	32.976	32.664	32.799
Group E	12	32.745	0.123	32.742	32.538	32.927	32.667	32.824
AD								
Group A	12	32.176	0.077	32.183	32.069	32.334	32.126	32.225
Group B	12	32.227	0.030	32.214	32.201	32.284	32.207	32.246
Group C	12	32.230	0.047	32.240	32.138	32.291	32.200	32.260
Group D	12	32.227	0.109	32.234	32.067	32.391	32.157	32.296
Group E	12	32.261	0.060	32.264	32.134	32.324	32.222	32.299
EB								
Group A	12	36.921	0.084	36.911	36.815	37.071	36.867	36.974
Group B	12	36.927	0.084	36.917	36.821	37.081	36.874	36.981
Group C	12	36.901	0.078	36.923	36.728	37.013	36.852	36.951
Group D	12	36.884	0.119	36.910	36.681	37.031	36.808	36.959
Group E	12	36.941	0.146	36.925	36.713	37.131	36.848	37.035
CD								
Group A	12	37.246	0.044	37.256	37.168	37.321	37.217	37.274
Group B	12	37.273	0.051	37.274	37.201	37.354	37.240	37.305
Group C	12	37.257	0.032	37.248	37.223	37.328	37.236	37.277
Group D	12	37.260	0.053	37.243	37.183	37.343	37.226	37.293
Group E	12	37.274	0.042	37.259	37.203	37.331	37.247	37.301

CI, confidence interval; SD, standard deviation

By following this technique, the present study replaced the brass master model with an acrylic resin model of dental implants and the open tray impression technique was used to reproduce the casts. This technique allowed the use of the internal edges of the upper silicone retainers of impression copings as reference points for linear dimensional measurements. In addition, a traveling microscope of 0.001 mm accuracy was used for the measurements. Considering the chosen technique, it is interesting to notice that the recent investigations about dimensional stability used dental implants replacing the classic projections simulating abutments for the measurements,[21] and could be recommended for this type of study.

The results of this study showed expansion and contraction among ED, CB, EA, and EB measurements at 10, 20, 30, and 40 minutes, whereas only expansion was noted between AD and CD measurements. Godbole et al.[18] evaluated the dimensional stability of polyvinyl siloxane impressions after UV-C light exposition for 10 minutes and reported contraction among CB, EA, AD, CD, and EB measurements, and no changes in the ED measurements. Nimonkar et al.[19] revealed expansion between CB and EA, contraction between CD and EB, and no changes in ED and AD measurements using UV-C light exposition for 20 minutes. In this way, it seems that for more exposure time, more measurement changes are in the impressions experiment. However, based on the results of the present study, the dimensional changes between the control group and the exposed groups were not significative and are in line with the reports of Godbole et al.[18] and Nimonkar et al.[19] Similar results were also found by Samra and Bhide,[17] who showed that UV-C light exposition for 3 minutes did not produce dimensional

Table 2: Comparison of the ultraviolet-C light exposure time between and within groups evaluated

Groups	*Sum of squares*	*Mean square*	*F*	*p**	*p***
ED					
Between groups	0.150	0.004	1.404	0.858	0.245
Within groups	0.146	0.003	–	–	–
Total	0.296	–	–	–	–
CB					
Between groups	0.094	0.023	0.992	0.102	0.420
Within groups	1.302	0.024	–	–	–
Total	1.396	–	–	–	–
EA					
Between groups	0.025	0.006	0.502	0.624	0.735
Within groups	0.693	0.013	–	–	–
Total	0.718	–	–	–	–
AD					
Between groups	0.044	0.01	2.231	0.431	0.077
Within groups	0.274	0.01	–	–	–
Total	0.318	–	–	–	–
EB					
Between groups	0.024	0.01	0.544	0.804	0.704
Within groups	0.618	0.01	–	–	–
Total	0.642	–	–	–	–
CD					
Between groups	0.007	0.00	0.792	0.217	0.535
Within groups	0.114	0.00	–	–	–
Total	0.121	–	–	–	–

F, ANOVA factor for independent samples; *p**, Shapiro–Wilk test; *p***, One-way ANOVA test for independent samples

changes in the interabutment distance, cross-arch distance, and occlusogingival length of the dental casts evaluated. Nevertheless, Sabharwal et al.[33,34] showed a statistically significant dimensional change in addition silicones exposed to 10 minutes. This difference could be because of the inclusion of other variables such as using discs instead of dental casts, temperature, water-powder ratio, setting reaction, and setting expansion. However, the latter authors recommended using UV-C light for disinfecting addition silicone impression materials. Thus, it may be argued that there is evidence regarding contraction and expansion among the reference points after UV-C light exposition of 3, 10, and 20 minutes, but clinically insignificant. Although it is not possible to directly correlate the results of this study with others because of the difference in the materials and methods used and it seems that the addition silicone dimensional changes is statistically insignificant with UV-C light exposition for 40 minutes.

This study suggests using UV-C light as a simple and effective method for the disinfection of addition silicone dental impressions. However, recently, Wezgowiec et al.[20] investigated the effect of UV-C light in properties of addition and condensation silicones using 40 minutes exposure time and reported a significant impact on hardness of light-bodied silicones. In this way, based on the literature, it is important to consider the type and characteristics of the dental impression material to choose the appropriate UV-C light exposure time. On the other hand, based on current findings, there are diversities in UV-C disinfection devices, specifications, doses, light sources, and distances between the lamp and the samples that impact the disinfection performance and the mechanical and physical properties of dental impression materials. In fact, Nimonkar et al.[19] informed that UV-C light irradiance and distance play a crucial role in the efficacy of surface disinfection, and recommended to consider 10 cm from the UV-C light source to the impression tray. In addition, Joshi et al.[21] stated that the effectiveness of UV-C light in the disinfection protocols depends on other aspects such as accessibility of microorganisms, humidity, intensity, and duration of the exposition.

One limitation of this study is that all measurements were made considering horizontal linear dimensional changes. It is recommended that future studies include three-dimensional measurements with the help of microscopes and customized software. Another limitation is the *in vitro* study design. Clinical trials may be helpful to verify *in vivo* the dimensional stability of addition silicones because conditions of the oral cavity such as moisture and temperature may affect its properties.

Although there are studies focusing on the effectiveness of UV-C light for the disinfection of addition silicone dental impressions, investigations concerning material properties are still scarce. Future studies should be carried out in order to determine the physical and mechanical properties of addition silicone dental impressions disinfected with UV-C light. The findings of the present study suggest the use of UV-C light for the disinfection of addition silicone dental impressions as an alternative to the classic disinfection methods.

Conclusion

Considering the limitations of the present *in vitro* study, the dimensional changes between the control group and the exposed groups were of no significance. The UV-C light exposure time of 10, 20, 30, and 40 minutes do not have any negative effect on the dimensional stability of addition silicone dental impressions evaluated. The null hypothesis was therefore accepted as the different UV-C light exposure times used not affected the dimensional stability of the addition silicone dental impressions.

Clinical Significance

In the daily routine dental practice, dental impressions need to be washed and disinfected immediately after making to prevent cross-infections. The UV-C light has been proposed as a promising method for disinfection, but only a few studies have been published about its effect on the dimensional stability of dental silicones.

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