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Wetting Characteristics of Addition Silicon Materials Subjected to Immersion Disinfection – An *In-Vitro* Study.

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Abstract - *An* in-vitro *study was conducted to assess wetting characteristic of four brands of addition silicon materials subjected to immersion disinfection using four different disinfectants. Among the non-disinfected specimens, the lowest contact angle was recorded for Aquasil ultra (21.63), followed by Imprint II (29.06), Aquasil LV (44.10) and Take1 (44.55). While 5.25% phenol increased the contact angle of all the silicon materials; 0.05% iodophor increased the angle of Take 1 and Imprint II and 0.5% sodium hypochlorite increased the angle of Imprint II and decreased for Aquasil ultra. However, 2% glutaraldehyde did not significantly change the contact angle of any of the four impression materials.*

KEY WORDS: Immersion disinfection, contact angle, addition silicon material, contamination, wetting, hydrophilicity.

INTRODUCTION

The excellent physical properties, dimensional stability and ability to produce accurate replica of oral structures are the important properties of the elastomeric impression materials[1]. Since 1970, and especially in the past decade, these materials have gained acceptance and account for a large share of the impression material market. Mandikos [2] reported on the clinical use of Polyvinylsiloxanes (addition silicone) stated that it has achieved a high level of dentist and patient acceptance because it is clean, odourless and tasteless. Polyvinylsiloxanes have applications in fixed prosthodontics, removable prosthodontics, operative dentistry and implant dentistry. Earlier generation addition silicones were hydrophobic as their chemical structure constituted hydrophobic, aliphatic hydrocarbon groups which surrounded the siloxane bond, thus preventing the attraction between the siloxane and water molecules [3]. However, newer hydrophilic addition silicones have higher wettability and improved gypsum castability [4]. The hydrophilicity of an impression material is important to create accurate impressions and help obtain accurate casts [5]. While, pouring a cast, the decreased contact angle of the impression material allows for displacement rather than entrapment of air which permits fabrication of a void free cast[6] and leads to an accurate dental prosthesis. The wetting process determines the hydrophobic or hydrophilic nature of an impression material. Wettability is quantified by measuring the contact angle created by the drop of liquid on the solid surface.

Dental personnel reportedly have three times greater risk than the general population for contacting infection and developing the carrier states [7]. The dental impressions they handle are invariably initially contaminated with saliva and blood. The principal potential route of infection transmission from a patient to dental personnel are believed to be contaminated impressions and casts made of dental stone poured against these impressions [5,8]. Although various physical and chemical methods of disinfection for elastomeric impression materials have been suggested, use of chemical disinfectants is the most effective and practical method as it ensures disinfection of all the surfaces of the impression [9]. Various chemical disinfectants such as glutaraldehyde, chlorine compounds, iodophors and phenols have been registered as immersion disinfection of elastomeric impression materials by the ADA[10-12]. Recommended time period suggested by Centers for Disease Control (CDC) and American Dental Association (ADA) for immersion disinfection of elastomeric impression materials is 10 minutes[13,14], though some studies have reported 30 minutes time period for immersion disinfection[1,5,15,16].

Chemical disinfection of impressions is a routine procedure and the disinfectants used, alter the hydrophilic properties of impression materials [9,17], it is therefore recommended that each disinfectant and impression material combination be individually evaluated [18].

The purpose of this *in- vitro* study were to assess the wetting characteristics of four different brands of addition silicon material by measuring the contact angle; to evaluate the change in wettability of these materials following immersion disinfection (both for a period of 10 and 30 minutes) using four different disinfectants; and to compare the wettability between disinfected and non-disinfected material specimens.

MATERIAL AND METHODS

Four brands of addition silicone impression material were tested in four different immersion disinfectants (Table 1). 180 specimens were prepared (45 samples each brand). Five samples each, out of the 45 were tested against the four disinfectant solutions. Five samples of each impres-

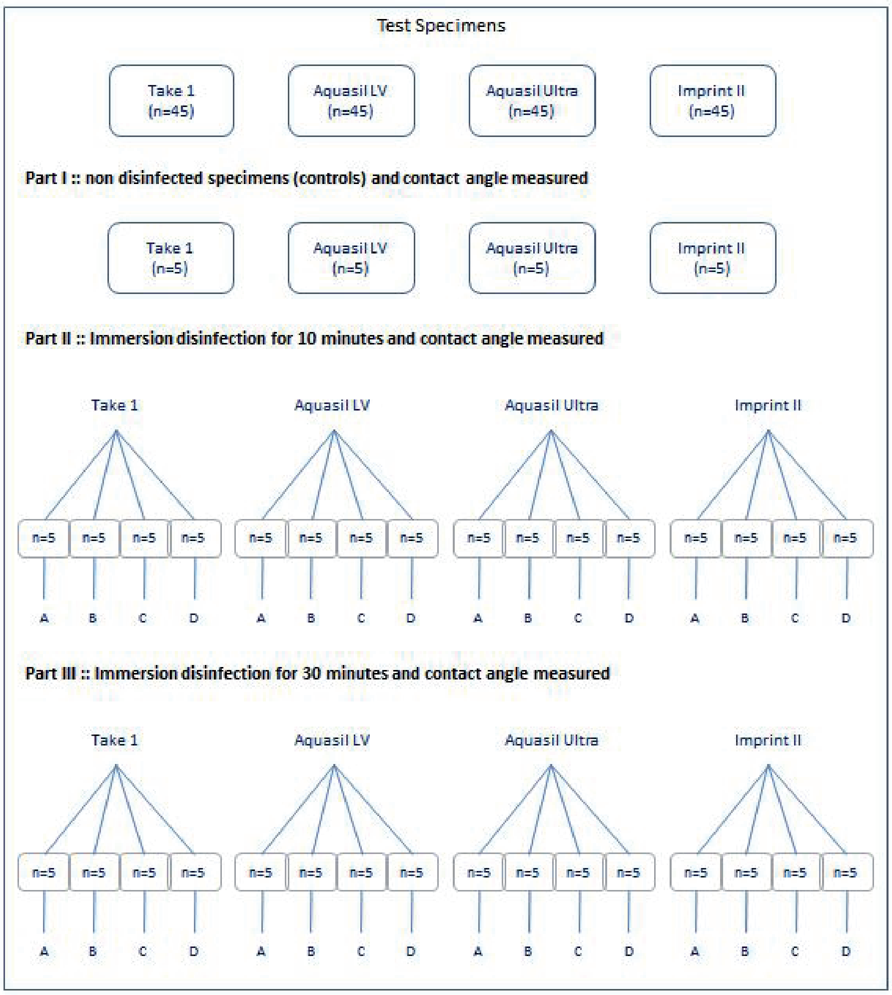
* MDS

Table 1. *Enumeration of the addition silicon materials and disinfectants used in the study.*

	Addition silicone materials	*Disinfectants*
1.	Take 1 (Kerr, U.S.A. MI 48174-2600)	2% glutaraldehyde (Raman and Weil Pvt Ltd,Daman, India)
2.	Aquasil LV (Dentsply,U.S.A. DE 19963-0359)	5.25% phenol (RechemLaboratory Chemicals,Chennai India)
3.	Aquasil ultra (Dentsply, U.S.A. DE-19963-0359)	0.5% sodium hypochlorite (Nice Chemicals,Pvt Ltd, Cochin India)
4.	Imprint II (3M ESPE,U.S.A. MN 55144-1000)	0.05% iodophor (Nice Chemicals,Pvt Ltd, Cochin India)

Table 2. *Comparison between contact angles of control (non-disinfected) specimen of four impression materials (using Tukey's test).*

	Imprint II	*Aquasil ultra*	*Aquasil LV*	*Take 1*
Take 1	P<0.001	P<0.001	P=0.909	-
Aquasil LV	P<0.001	P<0.001	-	-
Aquasil ultra	P<0.001	-	-	-
Imprint II	-	-	-	-



A- 2%Glutaraldehyde, B- 0.5% Sodium Hypochlorite , C- 5.25% Phenol, and D- 0.05%Iododphor.

Figure 1. *Experimental design of the study.*

sion material were not subjected to any disinfection treatment and acted as a control. The experimental design is showed as Fig 1.

Sample preparation

The Aquasil LV material was hand mixed while Take 1, Imprint II and Aquasil ultra were automixed. The mixing tip of the auto-mixing device was embedded in the impression material to avoid any air bubble entrapment. Samples were prepared in a custom-made brass mould consisting of three holes of 32 mm diameter and 3 mm thickness. The mould was placed on a clean glass plate and the holes were overfilled with the material. Another glass slab of the same size was placed on top of these holes and hand pressure was applied for 30 seconds to obtain flat surface specimens. Impression samples were allowed to set for a time suggested by manufacturers with an additional 15 minutes before they were separated from the mould. All specimens were inspected and those with surface defects were discarded and remade. Impression samples were handled with sterile forceps throughout the experiment and immediately placed in a container to avoid surface contamination. One hour after setting, the specimens were immersed in disinfectant solutions for 10 minutes or 30 minutes and then rinsed under tap water for 30 seconds and dried with forced air.

Contact angle measurement

The wetting characteristic of the sample was evaluated by measuring the contact angle with the help of Telescopic Goniometer, Kernco Model No: GII (Kerno Instrument Co, Texas, and USA). This was done by placing a drop (0.05 ml) of saturated solution of calcium sulphate dihydrate over the surface of each sample and the contact angle was measured from the flat surface of impression material to a line that formed a tangent to the drop at the point of solid-liquid interface. The readings were taken within one minute after the drop was placed. Wettability was determined by measuring the magnitude of the contact angle formed between the drop of liquid and surface of the sample. Six readings were taken for each sample, with a drop of liquid placed at six different sites. Mean of six readings was calculated to obtain the final reading for each sample.

Statistical analysis

Intra-group comparison of the contact angles for each tested material specimen were analysed using ANOVA (Fisher's test). For multiple comparisons between the groups and disinfectants Tukey's HSD test for multiple comparisons was used. For comparing the difference between the contact angles at 10 minutes and 30 minutes Paired 't' test was used. The level of significance was fixed at 5%.

RESULTS

Among the non-disinfected specimens, the lowest contact angle was recorded for Aquasil ultra (21.63) followed by Imprint II (29.06), Aquasil LV (44.10) and Take1 (44.55). Table 2 shows pair-wise comparison of the control specimens. It was observed that, there was no significant difference in the contact angle recorded for Take 1 and Aquasil LV, while other tested specimens showed statistically significant difference when compared to Take 1 and Aquasil LV.

Intra-group comparison within the contact angles of the control and disinfected specimen of the 4 tested materials specimen were undertaken and statistically significant difference was noted for all of the 4 materials at the end of 10 minutes (Table 3) and 30 minutes (Table 4).

Multiple comparisons were made between contact angles of the non-disinfected and disinfected specimens (Table 5). At the end of 10 minutes, it was evident that immersion in 5.25% phenol resulted in statistically significant increase in contact angle of all four tested specimens. Iodophor(0.05%) increased the contact angle of Take 1 and Imprint II and 0.5% sodium hypochlorite increased the contact angle of Imprint II and decreased for Aquasil ultra. However, 2% glutaraldehyde did not significantly change the contact angle of any of the tested specimens. At the end of 30 minutes of immersion disinfection, comparative results obtained were same as that seen at 10 minutes of disinfection, except that 0.5% sodium hypochlorite increasing the contact angle of Aquasil LV, Imprint II and decreasing for Aquasil ultra.

The measured contact angles at the end of 10 and 30 minutes of immersion disinfection for each of the tested specimen brand has been depicted in Fig 2-5. Increase in contact angle at the end of 30 minutes was observed with some tested samples. Also, reduction in contact angle was noted when immersed in certain disinfectants. Each material responded differently when immersed in different disinfectants.

Take 1(Fig2) : 2%Glutaraldehyde increased the contact angle ($t=16.26, p<0.0001$) and 0.05% iodophor decreased ($t=2.61, p=0.01$). Aquail LV(Fig3) : A decrease in the contact angle was seen with 5.25% phenol ($t=12.56, p<0.0001$) and 0.05% iodophor ($t=3.31, p=0.003$). Aquasil ultra (Fig 4): An increase in the contact angle was seen with 2% glutaraldehyde ($t=5.93, p<0.0001$) and 5.25% phenol ($t=3.32, p=0.004$). Imprint II (Fig5): An increase in the contact angle was seen with 2% glutaraldehyde ($t=5.13, p<0.0001$), 5.25% phenol($11.51, p<0.0001$) and 0.05% iodophor ($t=7.39, p<0.0001$) and decrease with 0.5% sodium hypochlorite ($12.98, p<0.0001$).

DISCUSSION

The contact angle is a thermodynamic variable that depends on the tension at interfaces between the surfaces. The tension at a liquid-gas interface is defined as $\gamma l,g$; the tension at a solid-liquid interface is defined as $\gamma s,l$; and the tension at a solid-gas interface is defined as $\gamma s,g$. The wetting angle as per the Young's equation is determined as $\cos\theta = (\gamma s.g — \gamma s,l)/ \gamma l,g$ during the thermodynamic equilibrium[19]. The ability to alter one or more of these surface-energy components makes it possible to manipulate the wetting properties of a surface. As Young's equation indicates, the ability of a solid to become wet is proportional to its surface energy. The contact angle also varies depending on the surface texture of solid such as roughening of solid surface decreases the contact angle but it increases the wettability[16].

Disinfection of the dental impression material is an essential procedure for preventing and controlling cross infections. Impression materials harbor organisms like Streptococcus viridans, Diphtheroids, Streptococcus pneumoniae

Table3. *Mean contact angles of four tested material specimens (Control and after 10 minutes of immersion disinfection)*

	Mean contact angle with (standard deviation)					
		10 minutes of immersion disinfection				
Tested specimens	*Control*	*2% Glutaraldehyde*	*0.5% Sodium hypochlorite*	*5.25% Phenol*	*0.05% Iodophor*	*ANOVA (p value)*
Take 1	44.55 (1.268)	43.00 (1.207)	44.30 (0.570)	55.23 (2.597)	55.18 (0.963)	86.68 (p<0.001)
Aquasil LV	44.10 (0.190)	44.73 (0.450)	45.66 (2.630)	53.31 (0.569)	45.68 (1.284)	38.66 (p<0.001)
Aquasil ultra	21.63 (0.320)	20.50 (0.372)	19.96 (0.341)	27.16(1.178)	22.33 (1.145)	69.47 (p<0.001)
Imprint II	29.06 (0.804)	28.60 (0.374)	33.90 (0.223)	37.03 (0.247)	37.20 (0.431)	39.9 (p<0.001)

Table 4. *Mean contact angles of four tested material specimens (Control and after 30 minutes of immersion disinfection)*

	Mean contact angle with (standard deviation)					
		30 minutes of immersion disinfection				
Tested specimens	*Control*	*2% Glutaraldehyde*	*0.5% Sodium hypochlorite*	*5.25% Phenol*	*0.05% Iodophor*	*ANOVA (p value)*
Take 1	44.55 (1.268)	45.03 (0.336)	44.77 (0.483)	54.65 (0.237)	54.13 (0.834)	256.06 (p<0.001)
Aquasil LV	44.10 (0.524))	45.26 (0.663)	45.61 (0.894)	50.16 (0.552)	44.25 (0.460)	75.79 (p<0.001)
Aquasil ultra	21.63 (0.320)	21.76 (0.559)	20.16 (0.263)	28.46 (0.472)	22.42 (0.429)	290.67 (p<0.001)
Imprint II	29.06 (0.804)	30.92 (1.379)	31.60 (0.514)	38.19 (0.201)	38.66 (0.452)	160.04 (p<0.001)

Table 5. *P values for paired comparison of contact angles between non-disinfected and disinfected specimen at the end of 10 minutes and 30 minutes of disinfection.*

	Non-disinfected specimen (Control)	*Disinfected specimen*			
		2% Glutaraldehyde	*0.5% Sodium hypochlorite*	*5.25% Phenol*	*0.05% Iodophor*
10 minutes of Disinfection	Take 1	0.486	0.999	0.001	0.001
	Aquasil LV	0.944	0.383	0.001	0.373
	Aquasil Ultra	0.189	0.023	0.001	0.317
	Imprint II	0.537	0.001	0.001	0.001
30 minutes of Disinfection	Take 1	0.835	0.989	0.001	0.001
	Aquasil LV	0.063	0.01	0.001	0.996
	Aquasil Ultra	0.989	0.001	0.001	0.55
	Imprint II	0.064	0.001	0.001	0.001

to a greater extent and Candida albicans, Pseudomonas aerugenosa and Staphylococcus albus to a lesser extent[20]. Although various methods for disinfection of impression materials have been suggested, immersion disinfection has shown to be effective in disinfecting the surface of the impression[21] and hence can be considered as a reliable method because it guarantees all surfaces of impression and impression tray to come in contact with the disinfectant[22]. Broad-spectrum chemical agents offer effective antimicrobial activity without distorting the impressions[15]. However, past studies evaluating effect of used immersion disinfection solutions on wettability of impression materials has shown varied results. Some studies show wettability of impression material increased [9,23,24] while others contrastingly showed decreased wettability [17,19,25] and some indicated no effect of disinfectants on wettability [16,17,19].

The varied results in different studies can be ascribed to difference in measure of contact angle due to variation in brand of materials tested, technique used and nature of liquid drop used to measure the contact angle. Unless study protocols are similar, effective comparison cannot be possibly drawn, and not many available studies have followed the present study protocol making it difficult to compare.

In the present study, non-disinfected specimen of Aquasil ultra showed least contact angle and its wettability increased when immersed in phenol though decreased with sodium hypochlorite, and remained unaltered with glutaraldehyde and iodophor. The wettability of Take 1 impression material significantly reduced when immersed in phenol and iodophor but remained unaltered when disinfected with 2% glutaraldehyde and sodium hypochlorite. Lepe *et al*[9], on the other hand, showed a slight increase in wettability of Take 1 when immersed in 2% glutaraldehyde. The wettability of Imprint II remained unaltered when immersed in 2% glutaraldehyde, while other solutions increased its contact angle. However, Lepe *et al*[9] showed decrease in wettability of Imprint II with 2% glutaraldehyde when immersed for 30 minutes whereas wettability remained unchanged with 10 minutes of spray disinfection for medium viscosity Imprint II[16]. For Aquasil LV, immersion in phenol showed decrease in its wettability while it remained unaltered when immersed in other solutions. Contrastingly, Lepe *et al*[9] reported decrease in its wettability with 2% gluteraldehyde when immersed for 30 minutes.

The results suggest that 2% glutaraldehye can be universally recommended, while it does not suggests phenol to be used as immersion disinfectant for any of the four silicone materials. A study has shown that sodium hypochlorite disinfectant was effective in reducing the bacteria from the surface of silicone impression material[26] and in the present study was the only disinfectant which significantly reduced the contact angle of Aquasil ultra and hence can be considered a preferred choice for it. It can also be recommended for Take I and Aquasil LV but not for Imprint II (as contact angle increased post disinfection). However, Soo-Hwa et al[27] showed that contact angle of Aquasil ultra and Imprint II remained unchanged after 30 minutes of sodium hypochlorite disinfection. A significant increase in contact angle of Take 1 (>10°) and Imprint II (>9°) after phenol and iodophor immersion disinfection indicates them to be un-recommendable.

Post immersion disinfection, an increase in contact angle of the impression material seen can be attributed to interaction of disinfectant and surfactants incorporated in newer hy-

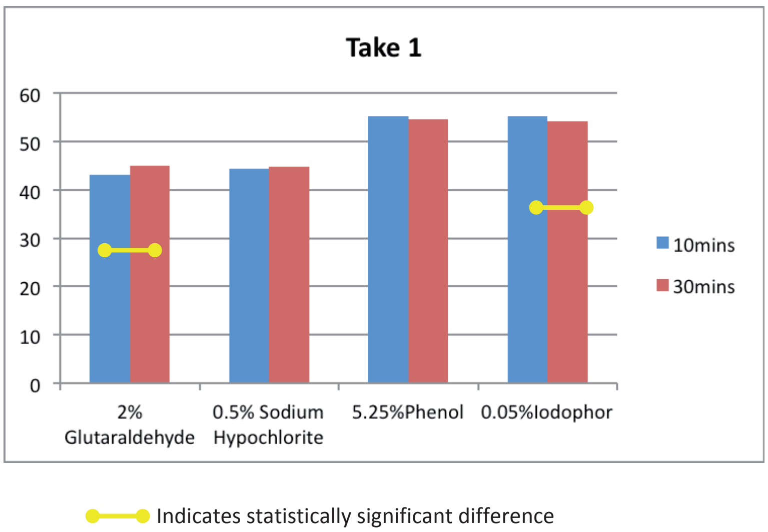


Figure 2. *Comparison between the contact angles at the end of 10 and 30 minutes of immersion disinfection (Take 1)*

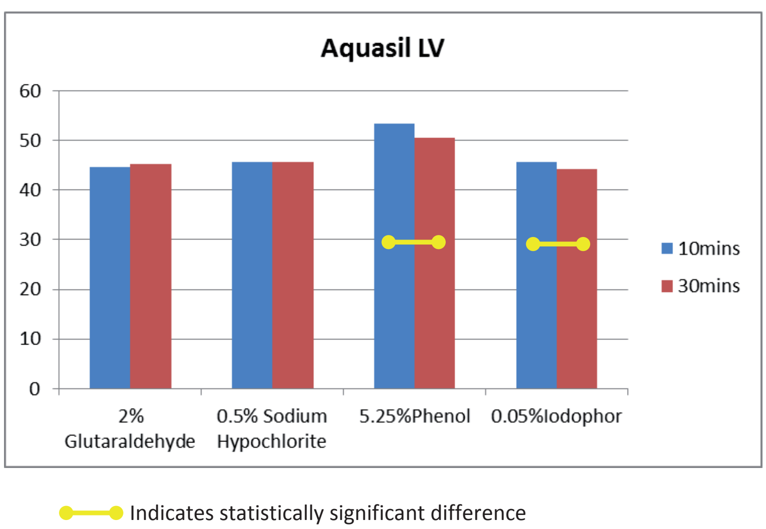


Figure 3. *Comparison between the contact angles at the end of 10 and 30 minutes of immersion disinfection (Aquasil LV)*

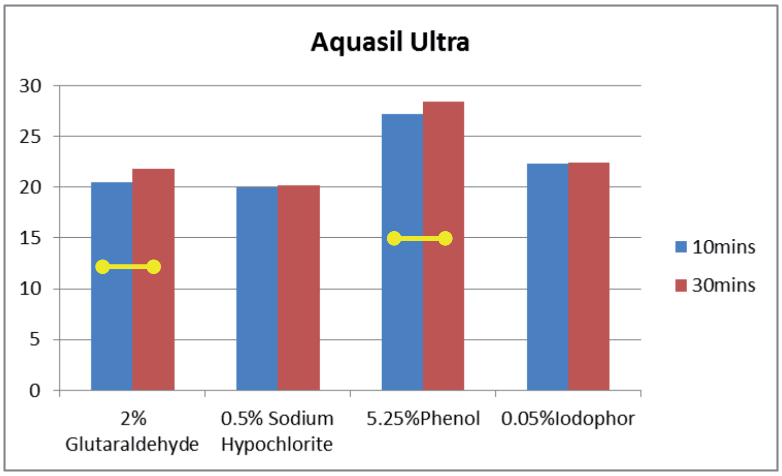


Figure 4. *Comparison between the contact angles at the end of 10 and 30 minutes of immersion disinfection (Aquasil Ultra)*

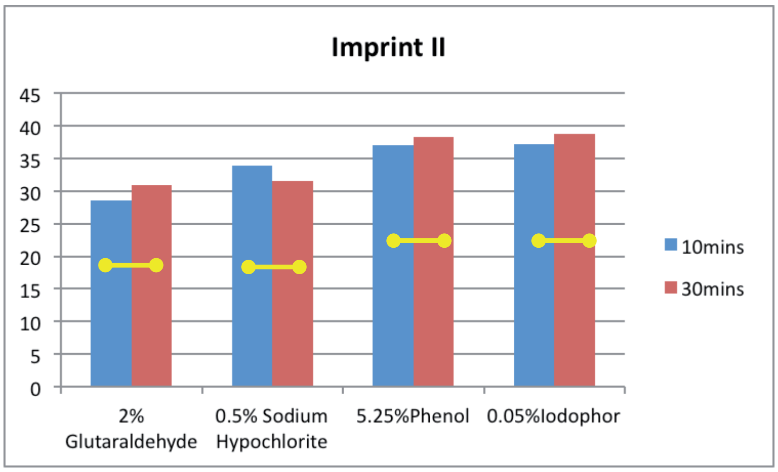


Figure 5. *Comparison between the contact angles at the end of 10 and 30 minutes of immersion disinfection (Imprint II)*

drophilic addition silicon materials (the intrinsic surfactants seem to be washed away during disinfection resulting in increase in the contact angle)[28]. Contrarily, a decrease in the contact angle could be possibly due to impression material surface having an affinity for surfactants present in disinfectant solution, which gets adsorbed on the surface of the impression material and goes into the solution in the wetting liquid[19] and another possibility is that the disinfectant may increase the surface roughness of impression material to an extent that wettability is improved[9,19].

CONCLUSION AND CLINICAL IMPLICATIONS

The present study conclusively suggests that, Aquasil ultra is the best addition silicon impression material of those compared, with regard to wetting characteristics. As compared to non-disinfected specimens, contact angle of all tested materials increased except for Aquasil ultra though 0.5% sodium hypochlorite reduced its contact angle. Immersion disinfection using 0.5% sodium hypochlorite, 5.25% phenol and 0.05% iodophor for 10 and 30 minutes altered the wettability of tested materials; but as 2% glutaraldehyde did not alter the wettability, it can be safely recommended as a immersion disinfectant for all four addition silicon materials. The study also indicates that each material responds differently depending on the disinfectant solution used; hence, it is recommended that manufacturers prepare a tailor made chart of disinfection protocol for each impression material which can be a useful guide for clinicians.

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