Surface detail reproduction and dimensional accuracy of molds: Influence of disinfectant solutions and elastomeric impression materials

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ABSTRACT

This study compared the surface detail reproduction and dimensional accuracy of molds after disinfection using 2% sodium hypochlorite, 2% chlorhexidine digluconate or 0.2% peracetic acid to those of molds that were not disinfected, for four elastomeric impression materials: polysulfide (Light Bodied Permlastic), polyether (Impregum Soft), polydimethylsiloxane (Oranwash L) and polyvinylsiloxane (Aquasil Ultra LV). The molds were prepared on a matrix by applying pressure, using a perforated metal tray. The molds were removed following polymerization and either disinfected (by soaking in one of the solutions for 15 minutes) or not disinfected. The samples were thus divided into 16 groups (n=5). Surface detail reproduction and dimensional accuracy were evaluated using optical microscopy to assess the 20-µm line over its entire 25 mm length. The dimensional accuracy results (%) were subjected to analysis of variance (ANOVA) and the means were compared by Tukey's test (α=5%). The 20-µm line was completely reproduced by all elastomeric impression materials, regardless of disinfection procedure. There was no significant difference between the control group and molds disinfected with peracetic acid for the elastomeric materials Impregum Soft (polyether) and Aquasil Ultra LV (polyvinylsiloxane). The high-level disinfectant peracetic acid would be the choice material for disinfection.

Key words: *Dimensional accuracy; dental disinfectant; dental Impression materials.*

Reprodução de detalhes da superfície e estabilidade dimensional de moldes: influência das soluções desinfetantes e elastômeros

RESUMO

Este estudo comparou a reprodução de detalhes da superfície e estabilidade dimensional de moldes obtidos após desinfecção utilizando hipoclorito de sódio 2%, digluconato de clorexidina 2%, ou ácido peracético 0,2% a moldes que não foram desinfetados com quatro elastômeros: polissulfeto (Light Bodied Permlastic), polieter (Impregum Soft), silicona reação por condensação (Oranwash L) e silicona reação por adição (Aquasil Ultra LV). Os moldes foram preparados sobre matriz contendo linhas de 20, 50 e 75 µm realizado sob pressão com moldeira de metal perfurada. Os moldes foram removidos após a polimerização e desinfetados (utilizando uma das soluções por imersão, armazenados em frascos fechados durante 15 minutos) ou não desinfetados. Assim, as amostras foram divididas em 16 grupos (n=5). A reprodução detalhes da superfície e a precisão dimensional foram avaliadas usando microscopia óptica na linha 20 µm com 25 mm de comprimento, de acordo com a norma ISO 4823. Os resultados de precisão dimensional (%) foram submetidos à análise de variância (ANOVA) e as médias comparadas pelo teste de Tukey com 5% de nível de significância. A linha de 20 µm foi completamente reproduzida por todos os elastômeros, independentemente do processo de desinfecção. Não houve diferença estatisticamente significativa entre o grupo controle e moldes desinfetados com acido peracético para os elastômeros Impregum Soft (polieter) e Aquasil Ultra LV (silicona reação por adição). O desinfetante de alto nível ácido peracético seria o material de escolha para a desinfecção.

Palavras-chave: *Estabilidade dimensional; desinfetante dental; materiais de moldagem.*

INTRODUCTION

High-accuracy impression materials (elastomeric impression materials) were first used in dentistry in the 1950s[1]. Currently, four different elastomeric impression materials are used: polysulfide, polyether, polydimethylsiloxane and polyvinylsiloxane, each of which has specific chemical reactions and setting characteristics[1]. Impression materials should

reproduce hard and soft tissues in order to obtain biologically, mechanically, functionally and esthetically acceptable restorations[2], and in addition to being capable of recording the anatomic topography of the desired area, they should remain dimensionally stable[3]. The dimensional accuracy of a material is usually time-dependent; for example, a material may be highly dimensionally accurate soon after its initial polymerization but less accurate after storage for a period of time[4]. Dimensional changes may occur in the molds as a result of features inherent to the impression materials such as wettability, handling properties and viscosity, or to thickness of the material between the oral structures and tray, method of fixing the impression material to the tray, time elapsed until cast pouring, material's hydrophilicity, by-product loss, polymerization shrinkage, thermal shrinkage due temperature change (from mouth to room temperature), incomplete elastic recovery, and, in some cases, soaking[1].

Disinfection is defined as a clinical stage designed to destroy most microorganisms (viruses, bacteria and spores) from the surface of an impression[5], and is an important biosafety measure. In absence of disinfection, treatment procedures can expose dentists, hygienists and laboratory workers to direct or cross-contamination[5,6]. During the impression procedure, the materials come into contact with fluids such as blood and saliva, which may contain pathogenic microorganisms capable of transmitting infectious diseases such as herpes, hepatitis, tuberculosis or AIDS[5,7].

Disinfection can be accomplished by physical or chemical action. However, physical action may result in temperature increase, which can cause measurable deformations in the molds[5]. For impression materials, the use of solutions with chemical action is recommended[5]. Disinfectants must perform effectively as antimicrobial agents while not adversely affecting the dimensional accuracy or feature fidelity of the impression material and resulting gypsum cast[8]. Disinfection should be carried out with the product that requires the least amount of time for the disinfection process[9]. The most frequently used disinfectants are glutaraldehyde, formaldehyde, alcohol, iodine solution, synthetic phenol, sodium hypochlorite and other chlorine-releasing solutions[5]. Other potential disinfectants may be used to eliminate pathogens, provided they do not alter the properties of elastomeric impression materials. Peracetic acid has been cited in the literature as a promising alternative for disinfection due to its antimicrobial efficiency [10], but there is no report on its use as a disinfectant for elastomeric impression materials.

This study compared the surface detail reproduction and dimensional accuracy of elastomeric molds prepared using polysulfide, polyether, polydimethylsiloxane or polyvinylsiloxane elastomeric impression materials and disinfected using 2% sodium hypochlorite, 2% chlorhexidine digluconate or 0.2% peracetic acid, to those of models produced using molds that were not disinfected. The null hypotheses tested were that surface detail reproduction and dimensional accuracy of elastomeric molds are not affected by either [1] the elastomeric impression material or [2] the disinfectant solution.

MATERIALS AND METHODS

This study used the light-body elastomeric impression materials polysulfide (Light Bodied Permlastic, batch number 1-1311, Kerr, Romulus, MI, USA), polyether (Impregum Soft, batch number 1220700759, 3M Deutschland, Seefeld, Germany), polydimethylsiloxane (Oranwash L, batch number 133520, Zhermack, Badia Polesine, RO, Italy) and polyvinylsiloxane (Aquasil Ultra LV, batch number 100223, Dentsply Caulk, Milford, DE, USA).

Dimensional accuracy and surface detail reproduction were evaluated in accordance with ISO 4823[11]. The molds were prepared on a matrix (38 mm outer diameter and 29.97 mm internal diameter) containing three parallel lines 20, 50, and 75 µm wide and 25 mm long, spaced 2.5 mm apart. Two additional lines marked X and X′ were used to determine the dimensional accuracy and surface detail reproduction on the 20 µm line.

Before the impression procedure, the matrix was cleaned ultrasonically and dried with compressed air. The elastomeric impression materials were prepared according to the manufacturers' instructions. A perforated metal tray (31 mm internal diameter × 5 mm high) was placed on a glass plate and filled with the molding material. The tray was joined to the matrix and a 20 N force was applied using a pneumatic press to simulate the impression process and permit leakage of excess material[5].

The molds were removed 3 min after polymerization of the elastomeric materials (polymerization time was consistent with the minimum time recommended by the manufacturers)[5] and disinfected by soaking for 15 minutes at 37º C in 2% sodium hypochlorite solution (Qboa, batch number L1-1212, Indústria Anhenbi S/A, Osasco, SP, Brazil), 2% chlorhexidine digluconate solution (Riohex 2%, batch number R1202994, Indústria Farmacêutica Rioquímica LTDA, São José do Rio Preto, SP, Brazil), or 0.2% peracetic acid solution (Peresal, bath number 4232AP0504, Ecolab Deutschland GmbH, Düsseldorf, Germany). Control samples were not disinfected. The samples were divided into 16 groups (n=5) according to disinfectant procedure and elastomeric impression material: Group 1: No disinfectant (control group) + polysulfide; Group 2: No disinfectant (control group) + polyether; Group 3: No disinfectant (control group) + polydimethylsiloxane; Group 4: No disinfectant (control group) + polyvinylsiloxane; Group 5: 2% Sodium hypochlorite solution + polysulfide; Group 6: 2% Sodium hypochlorite solution + polyether; Group 7: 2% Sodium hypochlorite solution + polydimethylsiloxane; Group 8: 2% Sodium hypochlorite solution + polyvinylsiloxane; Group 9: 2% Chlorhexidine digluconate solution + polysulfide; Group 10: 2% Chlorhexidine digluconate solution + polyether; Group 11: 2% Chlorhexidine digluconate solution + polydimethylsiloxane; Group 12: 2% Chlorhexidine digluconate solution + polyvinylsiloxane; Group 13: 0.2% Peracetic acid solution + polysulfide; Group 14: 0.2% Peracetic acid solution + polyether; Group 15: 0.2% Peracetic acid solution + polydimethylsiloxane; Group 16: 0.2% Peracetic acid solution + polyvinylsiloxane.

Surface detail reproduction was measured using an optical microscope (SZM, Bel Engineering srl, MI, Italy). The molds were examined under low-angle illumination at a magnification of 4x to 12x to determine whether the 20 µm-line was completely reproduced over the full length of 25 mm between the intersecting reference lines (X and X′), in accordance with ISO 4823[11].

Dimensional accuracy was measured on the molds using an optical microscope (STM, Olympus Optical Co Ltd, Japan) with an accuracy of 0.0005 mm. Dimensional accuracy expressed as a percentage (L) was calculated in accordance with ISO 4823[11] using the equation:

$L= [(L2 – L1) / L1] \times 100$, where L1 is the distance between the lines on the matrix and L2 is the distance between the lines on the impression material.

Then, 100% was added to the results of the equation[12] and the dimensional accuracy results (%) were subject to the Kolmogorov-Smirnov test for normality, two-way ANOVA (material x disinfectant), and the means were compared by Tukey's test at 5% significance levels.

RESULTS

The surface detail reproduction of all the elastomeric impression materials was completely reproduced on the 20 µm line regardless of disinfection procedure (100% of the 5 samples in all 16 groups).

There was a statistically significant difference in the mean values of dimensional accuracy in the interaction between disinfectant procedure and elastomeric impression material ($p = 0.00001$). The dimensional accuracy of non-disinfected Aquasil Ultra LV (polyvinylsiloxane) (Table 1) was statistically higher than that of Oranwash L (polydimethylsiloxane); however Impregum Soft (polyether) and Light Bodied Permlastic (polysulfide) did not differ from the others. There was no significant difference between the control group and the molds disinfected with peracetic acid for the elastomeric materials Impregum Soft (polyether) and Aquasil Ultra LV (polyvinylsiloxane).

DISCUSSION

The success of some forms of dental treatment depends upon the accuracy with which a restoration can be manufactured in the laboratory, using models constructed from impressions[13]. Clearly, the precision of the initial impression, in terms of both dimensional accuracy and detail reproduction, is a prerequisite for success[13]. The risk of cross-infection from a patient to a dental technician is a matter of concern[14], and in order to protect the members of the dental team, a high standard of hygiene and disinfection of dental equipment, including dental impressions, is recommended[6]. A disinfectant has dual requirements: it must be an effective antimicrobial agent yet cause no adverse response to the dimensional accuracy and surface-texture features of the impression material and resultant plaster cast[8]. The most frequently used

Table 1: Mean values for dimensional accuracy (%) for different groups.

	Dimensional Accuracy (%)			
Elastomeric impression material	**No disinfectant (control group)**	**2% Sodium hypochlorite solution**	**2% Chlorhexidine digluconate solution**	**0.2% Peracetic acid solution**
Light Bodied Permlastic (Polysulfide)	99.87 (0.03) AB a	99.62 (0.05) C b	99.70 (0.03) B b	99.71 (0.07) B b
Impregum Soft (Polyether)	99.90 (0.01) AB b	100.12 (0.14) A a	99.99 (0.16) A b	99.96 (0.06) A b
Oranwash L (Polydimethylsiloxane)	99.83 (0.02) B a	99.37 (0.10) D c	99.41 (0.02) C c	99.55 (0.04) C b
Aquasil Ultra LV (Polyvinylsiloxane)	99.98 (0.02) A a	99.82 (0.08) B b	99.88 (0.10) A ab	99.96 (0.06) A a

Mean values followed by different lowercase letters in rows and uppercase letters in columns differed statistically by Tukey's test at 5% level of significance. Standard deviations are provided in parentheses.

disinfectants are glutaraldehyde, formaldehyde, alcohol, iodine solution, synthetic phenol, sodium hypochlorite and other chlorine-releasing solutions[5]. However, there have been few examinations of the interaction between types of elastomeric impression materials and disinfection with peracetic acid solution. The current study used 3 disinfection treatments, consisting of soaking specimens for 15 minutes in 2% sodium hypochlorite, 2% chlorhexidine digluconate or 0.2% peracetic acid.

The current recommendation is to disinfect elastomeric impression materials by immersion in glutaraldehyde[5,14] or sodium hypochlorite[5]. Glutaraldehyde is considered a high-level disinfectant[15] that should eliminate some spores, the bacillus responsible for tuberculosis, vegetative bacteria, fungi and viruses [3]. However, it has been banned in some Brazilian states[3].

Substances containing chlorine, such as 2% sodium hypochlorite, are considered intermediate-level disinfectants that have limited effect on bacterial spores and non-lipid-containing viruses, but are effective against tuberculosis bacilli, vegetative bacteria and most fungi[3]. However, they also have disadvantages, such as toxicity during manipulation by health professionals, causing irritation to the eyes and respiratory system, damage to the environment and incompatibility with some types of materials such as metals.

Chlorhexidine is a cationic bisbiguanide [1,6-di (4-chlorophenyl-diguanido) hexane] agent with broad-spectrum antibacterial (Gram-negative and Gram-positive), some virus and antifungal activities[9]. It is biocompatible with oral tissues[9] and has the ability to remain on a surface and be released gradually[9,16]. Its excellent properties have motivated its increasing use in dentistry. However, microorganism response to it depends, among other factors, on the type of microorganism. A study by Casemiro et al.[9] found that *Pseudomonas aeruginosa* (Gram negative bacilli) showed no response to chlorhexidine, probably because this strain is resistant to chlorhexidine. Thus, chlorhexidine is also considered an intermediate-level disinfectant.

Peracetic acid is a combination formed from the chemical reaction of acetic acid (CH_3COOH) with an aqueous solution of hydrogen peroxide (H_2O_2) or by the reaction of tetraacetylethylenediamine with alkaline hydrogen peroxide solution[17]. In addition to being a high-level disinfectant, it is biodegradable and nontoxic. Therefore, after several debates, the World Health Organization has suggested replacing the disinfectants described above with peracetic acid, which has a broad spectrum of antimicrobial activity and shorter soak time, and is active in presence of organic matter, environmentally friendly and safe for both the professional and the patient.

The main groups of available elastomeric materials differ significantly in rheological properties[12,18] and in their interaction and tolerance of moist surfaces according to their composition[4,13]. Polysulfides and polyethers are considered hydrophilic because they contain functional groups that attract and interact chemically with water molecules through hydrogen[18]. In polyethers, the hydrophilic groups

are the carbonyl (C==O) and ether (COC) groups, while polysulfide, the hydrophilic groups are the disulfide (—SS—) and mercapto (—SH) groups[18]. Our results showed that the 20-µm line was completely reproduced by all the elastomeric materials; however, although there was no change in the 20-µm line for the Light Bodied Permlastic (polysulfide) and Impregum Soft (polyether) elastomeric materials, their surfaces appeared porous when disinfected with sodium hypochlorite. Acceptable methods of measuring the dimensional accuracy of casts include measuring calipers[9,20], micrometers[21], dial gauges[22] and measuring microscopes[3]. A microscope was used in this study due to its high accuracy (0.0005 mm). An ideal impression material would be dimensionally accurate over time, and could therefore be poured at the operator's convenience[23]. One study found that the impression material polyvinylsiloxane presents ideal dimensional stability[23]. Another study found that polyether presented better dimensional precision than the polydimethylsiloxane and polysulfide materials[24], while in another[25], polyether presented intermediate behavior between polydimethylsiloxane and polyvinylsiloxane. Thus, although these studies used different methodologies, by analogy, polyvinylsiloxane appears to have the best dimensional accuracy, followed by polyether. In the present study, for non-disinfected molds, dimensional accuracy (Table 1) was statistically higher for Aquasil Ultra LV (polyvinylsiloxane) than for Oranwash L (polydimethylsiloxane), while Impregum Soft (polyether) and Light Bodied Permlastic (polysulfide) did not differ from the others. The lower dimensional accuracy for Oranwash L may be the result of ethanol being formed as a by-product during its polymerization reaction and being lost through evaporation from the surface of the material before disinfection.

Although polydimethylsiloxane has greater polymerization shrinkage, it is hydrophobic, being less susceptible to water sorption by immersion in disinfectant solutions[5]. Thus, the lower dimensional accuracy results for Oranwash L may be attributed to the time elapsed (15 min) during disinfection. Table 1 shows that the samples immersed in 2% sodium hypochlorite, 2% chlorhexidine digluconate or 0.2% peracetic acid showed no similar patterns after disinfection. The results of this study show no significant difference between the control group and the molds disinfected with peracetic acid for the elastomeric materials Impregum Soft (polyether) and Aquasil Ultra LV (polyvinylsiloxane). For Oranwash L (polydimethylsiloxane) and Light Bodied Permlastic (polysulfide), the significant difference between the control group and the molds disinfected with peracetic acid was probably related to leaching of alcohol or water in the disinfecting solutions. Thus, peracetic acid would be the material of choice for disinfection. As previously mentioned, polyethers can be considered hydrophilic, which was verified in the interaction Impregum Soft – sodium hypochlorite. However, dimensional accuracy of about 0.1 to 0.8% is compensated at some stages during the laboratory steps required in the preparation of the restorations[26]. Despite the diversity of results in the literature regarding the effect of disinfectant solutions on the dimensional stability of elastomeric materials[5], the dimensional variations observed in this study cannot be considered sufficient to create significant distortions which could compromise the accuracy of prosthetic restorations. Disinfection is an essential step which cannot be omitted.

Based on the results of this study, the first null hypothesis was accepted and the second was rejected, as there was no difference in [1] the surface detail reproduction, although [2] significant differences were found in the dimensional accuracy of elastomeric molds. The authors conclude that although there are differences in dimensional accuracy of elastomeric molds when they are disinfected, this change has no clinical affect. Moreover, peracetic acid only promoted a significant difference from the control group (dimensional accuracy) when compared to Oranwash L (polydimethylsiloxane) and Light Bodied Permlastic (polysulfide), which was probably not a result of the use of this disinfectant. Thus, the high-level disinfectant peracetic acid would be the material of choice for disinfection. Further studies are needed to prove its effectiveness in disinfection of elastomeric impression materials.

CONCLUSION

Under the conditions and within the limitations of the current study, it can be concluded that the high-level disinfectant peracetic acid would be the material of choice for disinfection.

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REFERENCES

1. Vitti RP, Correr-Sobrinho L, Sinhoreti MA. Dimensional accuracy of stone casts made by a monophase impression technique using different elastomeric impression materials. Braz J Oral Sci 2011; 10:175-179.
2. Perakis N, Belser UC, Magne P. Final impressions: a review of material properties and description of a current technique. Int J Periodontics Restorative Dent 2004;24:109-117.
3. Guiraldo RD, Borsato TT, Berger SB, Lopes MB, Gonini-Jr A, Sinhoreti MA. Surface detail reproduction and dimensional accuracy of stone models: influence of disinfectant solutions and alginate impression materials. Braz Dent J 2012; 23:417-421.
4. Petrie CS, Walker MP, O'mahony AM, Spencer P. Dimensional accuracy and surface detail reproduction of two hydrophilic vinyl polysiloxane impression materials tested under dry, moist, and wet conditions. J Prosthet Dent 2003; 90:365-372.
5. Carvalhal CI, Mello JA, Sobrinho LC, Correr AB, Sinhoreti MA. Dimensional change of elastomeric materials after immersion in disinfectant solutions for different times. J Contemp Dent Pract 2011; 12:252-258.
6. Kimondollo PM. Guidelines for developing a dental laboratory infection-control protocol. Int J Prosthodont 1992; 5:452-456.
7. Adabo GL, Zanarotti E, Fonseca RG, Cruz CA. Effect of disinfectant agents on dimensional stability of elastomeric impression materials. J Prosthet Dent 1999: 81:621-624.
8. Taylor RL, Wright PS, Maryan C. Disinfection procedures: their effect on the dimensional accuracy and surface quality of irreversible hydrocolloid impression materials and gypsum casts. Dent Mater 2002; 18:103-110.
9. Casemiro LA, Pires-de-Souza FC, Panzeri H, Martins CH, Ito IY. In vitro antimicrobial activity of irreversible hydrocolloid impressions against 12 oral microorganisms. Braz Oral Res 2007; 21:323-329.
10. Salvia AC, Teodoro GR, Balducci I, Koga-Ito CY, Oliveira SH. Effectiveness of 2% peracetic acid for the disinfection of gutta-percha cones. Braz Oral Res 2011; 25:23-27.
11. ISO 4823 "Dentistry: elastomeric impression materials" Geneva Switzerland, 2000.
12. Guiraldo RD, Moreti AF, Martinelli J, Berger SB, Meneghel LL, Caixeta RV, Sinhoreti MA. Influence of alginate impression materials and storage time on surface detail reproduction and dimensional accuracy of stone models. Acta Odontol Latinoam 2015; 28:156-161.
13. German MJ, Carrick TE, McCabe JF. Surface detail reproduction of elastomeric impression materials related to rheological properties. Dent Mater 2008; 24:951-956.
14. Melilli D, Rallo A, Cassaro A, Pizzo G. The effect of immersion disinfection procedures on dimensional stability of two elastomeric impression materials. J Oral Sci 2008; 50:441-446.
15. Omidbakhsh N. A new peroxide-based flexible endoscope-compatible high-level disinfectant. Am J Infect Control 2006; 34:571-577.
16. Ramer MS, Gerhardt DE, McNally K. Accuracy of irreversible hydrocolloid impression material mixed with disinfectant solutions. J Prosthodont 1993; 2:156-158.
17. Fernandes FH, Orsi IA, Villabona CA. Effects of the peracetic acid and sodium hypochlorite on the colour stability and surface roughness of the denture base acrylic resins polymerised by microwave and water bath methods. Gerodontology 2013; 30:18-25.
18. Berg JC, Johnson GH, Lepe X, Adan-Plaza S. Temperature effects on the rheological properties of current polyether and polysiloxane impression materials during setting. J Prosthet Dent 2003; 90:150-161.
19. Chong YH, Soh G, Setchell DJ, Wickens JL. Relationship between contact angles of die stone on elastomeric impression materials and voids in stone casts. Dent Mater 1990; 6:162-166.
20. Woodward JD, Morris JC, Khan Z. Accuracy of stone casts produced by perforated trays and nonperforated trays. J Prosthet Dent 1985; 53:347-350.
21. Rueggeberg FA, Beall FE, Kelly MT, Schuster GS. Sodium hypochlorite disinfection of irreversible hydrocolloid impression material. J Prosthet Dent 1992; 67:628-631.
22. Millstein PL. Determining the accuracy of gypsum casts made from type IV dental stone. J Oral Rehabil 1992; 19:239-243.
23. Donovan TE, Chee WW. A review of contemporary impression materials and techniques. Dent Clin N Am 2004; 48:445-470.
DOI dx.doi.org/10.1016/j.cden.2003.12.014.
24. Shah S, Sundaram G, Bartlett D, Sherriff M. The use of a 3D laser scanner using superimpositional software to assess the accuracy of impression techniques. J Dent 2004; 32:653-658.
25. Lacy AM, Fukui H, Bellman T, Jendresen MD. Time-dependent accuracy of elastomer impression materials Part II: polyether, polysulfides, polyvinylsiloxane. J Prosthet Dent 1981; 45:329-333.
26. Johnson GH, Chellis KD, Gordon GE, Lepe X. Dimensional stability and detail reproduction of irreversible hydrocolloid and elastomeric impressions disinfected by immersion. J Prosthet Dent 1998; 79:446-453.