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# Dimensional Accuracy of Polyether Elastomeric Impression Materials After Using Chitosan as a Disinfectant: A Sustainable Approach to Dental Infection Control

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**Abstract:** Background: With the growing demand for sustainable dental practices, chitosan has evolved as an eco-friendly disinfectant for polyether impressions. Objectives: The present study investigated the disinfectant efficacy of chitosan on the dimensional accuracy of polyether (PE) impression material. Methods: A total of 63 polyether impressions (Impregum$^{TM}$, Penta$^{TM}$, 3M ESPE, Boca Raton, FL, USA) were prepared from the master 3D-printed model, each consisting of a single unit abutment facing two units' abutments. Three groups of these subjects were used, while each group comprised 21 impressions, respectively. Group 1 is used as a control group and is not subjected to chemical disinfection. Group 2 is spraying group, in which the PE impressions were sprayed with 0.5% chitosan with a high molecular weight. Group 3 is the immersion group, in which the impression was immersed for 15 min in 0.5% chitosan with a high molecular weight. The data collected were analyzed using SPSS 28.0 and the difference in dimensional accuracy between the groups was measured using a one-way ANOVA. Results: Both the intra-and inter-abutment measurements (MD and OG) showed no statistically significant differences in the dimensional changes between the control and the study groups, while the cross-arch distance showed a statistically significant difference in the dimensional change between control and immersion group, $p = 0.000$. Conclusions: While chitosan disinfection induced slight dimensional changes in polyether impressions, these alterations remained within clinically acceptable limits. The spray application method appeared to be preferable to immersion, as it resulted in less pronounced dimensional changes.

**Keywords:** disinfectant; chitosan; polyether; spraying; immersion; eco-friendly

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## 1. Introduction

Polyether impressions play a crucial role in prosthodontics and restorative dentistry, serving as the foundation for accurate dental prostheses and restorations. These impressions are valued for their ability to capture fine details of oral structures, their dimensional stability, and their hydrophilic nature, which allows for the excellent reproduction of subgingival margins [1]. The accuracy of these impressions is paramount, as even minor discrepancies can lead to ill-fitting prostheses, potentially compromising patient comfort and oral health outcomes. Recent advancements in digital dentistry have not diminished the importance of conventional impression materials [2]. While digital impressions show promise, conventional impressions still offer superior accuracy for full-arch restorations. This emphasizes the continued relevance of polyether impressions in modern dental practice [3,4].

The oral cavity is home to a diverse microbiome, and impression materials can become contaminated with potentially pathogenic microorganisms during the impression-taking process [5]. A study by Al Mortadi et al. 2019 found that 67% of dental impressions were contaminated with oral microorganisms, including *Streptococcus*, *Staphylococcus*, and *Candida* species. This contamination poses a risk not only to dental laboratory personnel but also to subsequent patients if proper disinfection protocols are not followed [6]. The COVID-19 pandemic has further emphasized the infection control setting in the dental practice. Impressions can potentially harbor SARS-CoV-2, the virus responsible for COVID-19, emphasizing the critical need for effective disinfection methods [7]. This increased focus on infection control has led to a re-evaluation of current disinfection practices and a search for more effective and sustainable alternatives [8].

Traditional disinfectants used in dentistry include sodium hypochlorite, glutaraldehyde, and quaternary ammonium compounds. These disinfectants have been widely used due to their broad-spectrum antimicrobial activity [9]. Sodium hypochlorite, for instance, is effective against a wide range of microorganisms and is relatively inexpensive [10]. Glutaraldehyde has been favored for its rapid action and compatibility with many dental materials [10,11]. However, these conventional disinfectants, when used with polyether impressions, are not without drawbacks. A study by Kotsiomiti et al. (2008) found that the immersion in 5.25% sodium hypochlorite for 10 min caused significant dimensional changes in polyether impressions [12]. Similarly, Yilamz et al. reported that glutaraldehyde disinfection led to surface changes in polyether materials, potentially affecting the quality of the resulting casts [13]. Moreover, these disinfectants pose potential health and environmental risks. Glutaraldehyde, for example, is known to cause respiratory irritation and skin sensitization in dental professionals with prolonged exposure [14]. Sodium hypochlorite can release chlorine gas when mixed with other chemicals, posing a respiratory hazard. The environmental impact of these chemicals is also a growing concern, with studies showing that they can contribute to the formation of harmful disinfection by-products in water systems [15]. Traditional disinfectants can have negative impacts on aquatic ecosystems when released into wastewater [16]. Several commonly used dental disinfectants demonstrated ecotoxicity [17]. In addition, the long-term exposure to chemical disinfectants has been associated with respiratory issues and dermatitis among dental professionals [18]. Furthermore, some disinfectants can adversely affect the properties of dental materials, including impression materials [19]. In response to these concerns, research has focused on developing more sustainable disinfection methods with a growing emphasis on environmentally friendly and biocompatible materials.

Natural polymers like chitosan have gained attention for their antimicrobial properties and biocompatibility [20]. Chitosan is a linear polysaccharide derived from chitin, a component obtained from the exoskeletons of crustaceans and fungi cell walls. It is obtained through the deacetylation of chitin, resulting in a polymer with unique properties that make it attractive for various biomedical applications, including dental materials [21]. The antimicrobial activity of chitosan is attributed to its amino groups with a positive charge, which interact with microbial cell membranes which are negatively charged, leading to cell lysis [22]. This mechanism of action is particularly advantageous as it is less likely to induce microbial resistance. Chitosan has found various applications in dentistry, leveraging its unique properties. Chitosan scaffolds have been used in periodontal tissue regeneration and bone grafting [23]. Chitosan nanoparticles have been explored for the local delivery of antibiotics in periodontal pockets [24]. Chitosan-based materials have shown potential in promoting enamel remineralization [24]. Chitosan solutions have been investigated as alternatives to traditional disinfectants [25]. Manikyamba et al. (2020) [26] evaluated the antimicrobial activity of chitosan against common oral pathogens on alginate impressions. They found that a 0.2% chitosan solution effectively reduced microbial contamination without affecting the surface quality of the impressions [26]. A study by Ismiyati and Dipoyono (2019) [27] compared the antimicrobial efficacy of chitosan with conventional disinfectants on polyvinyl siloxane impressions. The results showed that chitosan was as effective as 2% glutaraldehyde in reducing bacterial contamination [27].

While chitosan shows promise as an effective disinfectant, its impact on the dimensional stability of polyether impression materials has not been investigated yet. The aim of this study was to evaluate and compare the dimensional accuracy of the polyether impression material when subjected to different disinfection procedures with 0.5% chitosan disinfectant solution, specifically comparing the spray and immersion techniques.

The study's null hypothesis is that there was no statistically significant difference in the dimensional accuracy of polyether dental impressions when disinfected with chitosan using either the spray and immersion techniques.

## 2. Materials and Methods

### *2.1. Ethical Approval*

This study was exempted from ethical approval by the Institutional Review Board of Imam Abdulrahman Bin Faisal University as it did not use patient-level data.

### *2.2. Sample Size*

Based on the previous study [11], the sample size was calculated with a confidence interval of 95% and 5% margin of error, and a sample power of 80%. A total of 63 samples were obtained.

This in vitro study was carried out in the College of Dentistry laboratory at Imam Abdulrahman bin Faisal University. In this study, 63 impressions were obtained from a 3D-printed typodont model designed for full veneer crown preparation to simulate oral conditions, and no human subjects or patients derived materials were involved (Figure 1). A customized acrylic tray (Vipi Flash; Vipi Industry, Pirassununga, São Paulo, Brazil) was fabricated to ensure reproducibility. The polyether impression material (Impregum$^{TM}$ Penta$^{TM}$, 3M ESPE, Mapplewood, MN, USA) was prepared in a single mix technique with both light- and heavy-body consistencies in the customized acrylic tray. Following this, impressions was poured using type IV gypsum (Glastone 2000, Dentsply, New York, NY, USA) to prepare the tested specimens. There were three groups of samples. The first group was a control group, and no disinfection was used, the second group was the spraying group, where impressions were sprayed with high molecular weight 0.5% chitosan, and the third group was a submersion/immersion group, where impressions were submersed in high molecular weight 0.5% chitosan for 15 min (Figure 2).

Firstly, an adhesive (Polyether Adhesive, 3M ESPE, USA) was applied on the trays, followed by the application of the polyether impression material with a constant pressure of 2 kg/cm$^2$ over a period of 5 min on the loaded custom tray. The impressions were then poured after 24 h (stored at room temperature) and mixed with stone gypsum (water/powder: 50 mg/11 mL). A vibrator was used during the gypsum mix preparation to avoid having air trapped inside the model [11]. Afterward, each group was exposed to 0.5% chitosan disinfectant according to the prescribed application method. The inclusion criteria of samples included impressions with excellent detail reproduction, and impressions with no distortion, whereas the exclusion criteria of samples included impressions with poor margin details, impressions with internal bubbles, impressions with a marginal tear, impressions with inadequate material mixing, and impressions with poor adhesion of the impression material to the tray. A total of 4 distances was measured twice by two different examiners based on the data obtained from eight reference points (Figure 3). The retrieved cast was positioned in the Ceramill transfer kit (Ceramill Map 400, Amanngirrbach GmbH, Mäder, Austria). This assembly was then inserted into a 3D laser scanner (Ceramill Map 400, Amanngirrbach GmbH, Austria) for digitization. The resulting scan was saved as an STL file. The STL file was subsequently analyzed using the Ceramill Mind software (V2.4-7437, Amann Girrbach AG, Mäder, Austria, Ceramill Mind, Amanngirrbach GmbH, Austria) for precise measurements. The reference points were identified for the intra-, inter-abutment and cross-arch distances. To ensure accuracy, each reference point was selected using a cursor and magnified by 150×. The measurements were recorded with a precision of 0.001 mm. The standard measurements for the reference points were as follows: mesiodistal dimension (MD): 4.22 mm, occluso-gingival dimension (OG): 5.34 mm, inter abutment distance: 16.07 mm, and cross-arch distance: 45.48 mm. This measurement protocol was consistently applied to all of the subsequent casts, with each cast being scanned and analyzed using the same method as the master cast.

**Figure 1.** A 3D-printed typodont model.

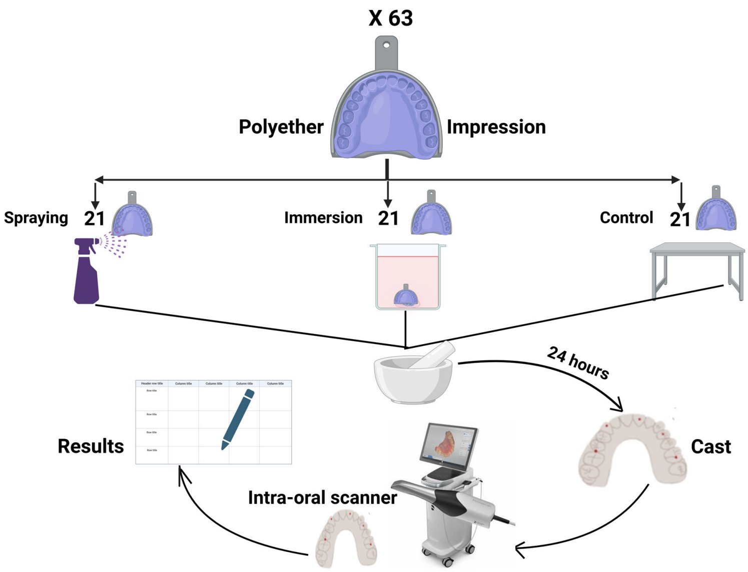


**Figure 2.** Study workflow.

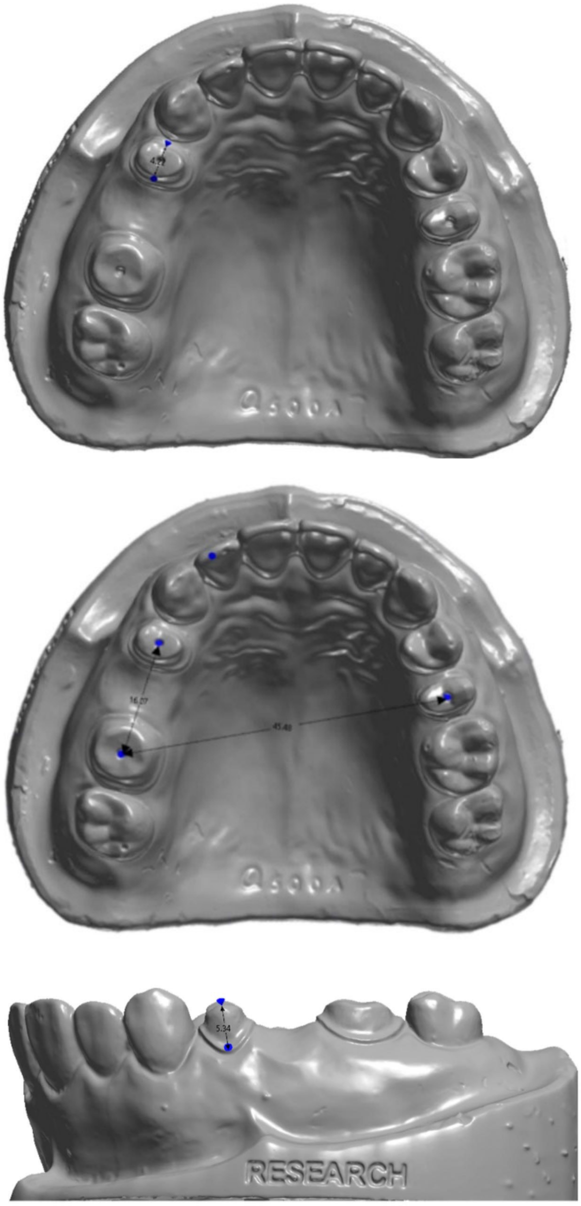


**Figure 3.** Illustration of the 4 dimensions on a digitally scanned model cast.

For all of the measurements, the absolute value of the difference from the master model was calculated. Two experienced evaluators performed all the measurements [11]. The intra- and inter-examiner reliability for dimensional accuracy was assessed using the kappa coefficient, yielding values of 0.90 and 0.86, respectively, indicating an excellent agreement between the examiners.

### *2.3. Statistical Analysis*

The data were analyzed using Statistical Package for the social sciences (SPSS), Version 28.0. The difference in dimensional accuracy between the groups was analyzed using the one-way analysis of variance (ANOVA) and Tukey post hoc tests. A $p$-value of $\leq$0.05 was considered statistically significant.

## 3. Results

The intra-abutment measurements (MD and OG) showed that the dimensions of the abutments produced from spraying and immersion showed the least shrinkage, with a maximum shrinkage of 0.56% shown in immersion. Moreover, the difference between the groups was statistically insignificant in OG ($p$ = 0.01) between the control and immersion groups ($p$ = 0.01). Furthermore, the percent change among all of the groups is clinically acceptable (±0.5%) (Table 1).

**Table 1.** Comparison between control group and study groups on the mean difference, the standard deviation of dimensions (in mm), and the percentage of dimensional changes.

| Dimensions (mm) | Master Model (mm) | Control | % | Spraying | % | Immersion | % | *p*-Value |
|---|---|---|---|---|---|---|---|---|
| MD (Mean ± SD) | 4.22 | 4.23 ± 0.09 | 0.24 | 4.21 ± 0.06 | −0.24 | 4.20 ± 0.04 | −0.47 | 0.257 |
| OG (Mean ± SD) | 5.34 | 5.35 ± 0.04 $^{a}$ | 0.19 | 5.32 ± 0.02 $^{a,b}$ | −0.37 | 5.31 ± 0.05 $^{b}$ | −0.56 | 0.051 |
| Inter-abutment (Mean ± SD) | 16.07 | 16.12 ± 0.09 | 0.31 | 16.06 ± 0.05 | −0.06 | 15.99 ± 0.32 | −0.50 | 0.099 |
| Cross-arch (Mean ± SD) | 45.48 | 45.59 ± 0.08 | 0.24 | 45.35 ± 0.27 $^{a}$ | −0.29 | 45.29 ± 0.27 $^{a}$ | −0.42 | 0.000 * |

*: statistically significant at $p \leq 0.05$. Horizontally, groups with similar superscript small letters indicate no statistically significant difference ($p$ > 0.05).

Regarding the inter-abutment distance, spraying and immersion showed slight shrinkage; however, the dimensional change percentages were 0.06% and 0.50%, respectively. The changes were statistically not significant ($p$ = 0.099), and the percentage change was less than ≤0.5% (Table 1).

Regarding the cross-arch distance, spraying and immersion showed minimal shrinkage; however, the dimensional change percentages were 0.29% and 0.42%, respectively. The changes were statistically significant ($p$ < 0.001) between the control and spraying groups ($p$ = 0.003); and control and immersion groups ($p$ < 0.001). Furthermore, the percentage change was less than <0.5% (Table 1).

## 4. Discussion

This study investigated the dimensional accuracy of polyether impressions after disinfection with chitosan, a promising antimicrobial agent derived from natural sources. Consequently, the null hypothesis was partially rejected, as significant dimensional changes were observed in the cross-arch dimension between the immersion group and the control. However, the percentages of dimensional change for both disinfection groups were remarked to be within the clinically acceptable limit (±<0.5%) [11].

The control group (no disinfection) exhibited the smallest dimensional changes, with a mean change of 0.19–0.24%. This finding is consistent with the inherent dimensional stability of polyether materials when they are not subjected to any disinfection procedures [28].

The results demonstrated that both disinfection methods (spraying and immersion) led to slight dimensional changes in polyether impressions, with the immersion group generally showing greater dimensional alterations, compared to the spraying group. This trend is particularly evident in the cross-arch measurements, where statistically significant differences were observed. The slightly higher dimensional changes seen in the immersion group, compared to the spray group, may be related to the duration and extent of PE material exposure to the chitosan solution, allowing for more extensive interactions [29]. The immersion for 15 min allows for greater penetration and interaction between the solution and the impression material, potentially leading to a slightly more pronounced dimensional response. This finding aligns with previous studies on other disinfectants, where immersion often results in more pronounced dimensional changes, compared to spray techniques [13,30].

The observed smaller dimensions of casts retrieved from PE impressions after chitosan disinfection could be explained by PE's hydrophilic nature, which led to the absorption of water, causing slight shrinkage [31]. Additionally, the amine and hydroxyl groups in chitosan could potentially interact with the functional groups in polyether, leading to a rearrangement of polymer chains and a more compact structure [32]. The observed dimensional changes can be attributed to the specific properties of the chitosan-based disinfectant solution. Unlike traditional disinfectants, such as sodium hypochlorite or glutaraldehyde, chitosan is less reactive and has a more compatible molecular structure with polyether materials [33,34]. This reduced chemical interaction could minimize the disruption of the polymer network and limit the osmotic pressure changes that can lead to significant dimensional alterations [35].

From a clinical perspective, while the dimensional changes observed in the immersion group were statistically significant in some measurements, the magnitude of these changes (ranging from $-0.56\%$ to $0.31\%$) is considered clinically acceptable, as they fall within the generally accepted clinical range for dental impressions ($\pm$<0.5%) [11], suggesting that both techniques can be considered suitable for having dimensional accuracy of polyether impressions.

Comparable results were observed in previous studies investigating the dimensional accuracy of disinfected polyether impression materials. Gounder and Vikas 2016 reported that the immersion disinfection of polyether impressions in various chemical agents resulted in dimensional changes, with the magnitude varying depending on the disinfectant used [12,36]. Martins et al. investigated long-term storage combined with disinfection and found that polyether impressions exhibited minimal shrinkage ($0.42 \pm 0.19\%$ with hypochlorite and $0.52 \pm 0.28\%$ with autoclave treatment), remaining within acceptable limits after six months [28]. However, most of the previous studies focused on traditional disinfectants, such as sodium hypochlorite or glutaraldehyde. Our study contributes a novel approach into the effects of chitosan, a more biocompatible and eco-friendlier alternative, on polyether impressions.

Therefore, further research should explore alternative methods or concentrations of chitosan application to optimize the balance between effective disinfection and dimensional stability.

## 5. Conclusions

The results of the current study indicate that the disinfection of polyether dental impressions using a 0.5% chitosan solution, applied either by spraying or immersion, can effectively maintain the dimensional accuracy and stability of the impressions within the clinically acceptable range. The use of this biocompatible and less reactive disinfectant offers a promising alternative to traditional disinfectants, providing dental practitioners with a reliable method to ensure the dimensional stability of polyether impressions and the subsequent accuracy of prosthetic restorations. Additionally, utilizing a larger sample size would enhance the reliability of the findings. Furthermore, incorporating additional groups that evaluate classical disinfectants, such as glutaraldehyde or sodium hypochlorite solutions, would provide a more comprehensive comparison and improve the overall efficiency of the study.

## 6. Clinical Implications

Chitosan has the potential to improve disinfection and reduce the microorganisms in polyether impression materials. However, the immersion in chitosan resulted in a larger dimensional shift, showing that immersion had an adverse effect on the dimensional accuracy and stability of the polyether impression material.

## 7. Recommendations

Using chitosan as a disinfectant for polyether dental impressions offers several potential benefits. Here are some recommendations. Using 0.5% chitosan by weight in cooperation with spraying techniques on each impression can be particularly beneficial in reducing the risk of infections and dimensional stability of the material, and it is important to consider a 15 min duration after spraying chitosan to optimize performance. To maximize these benefits, it is recommended to optimize and maintain the chitosan concentration, and proper storage can prevent degradation and maintain performance.

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