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Accuracy of Digital Impression Taking in Partial Dentures: an *in Vitro* Study on the Degree of Adaptation of Rests

Precisão da Tomada de Impressão Digital em Próteses Parciais: um Estudo *in Vitro* sobre o Grau de Adaptação de Apoios

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Abstract

The objective of the study is to assess the precision of digital impressions in removable partial dentures through an in vitro study on the degree of abutment adaptation. A Kennedy Class III model with a prosthetic space between elements 43 and 47, featuring niches in the mesio-occlusal and cingulum regions, respectively. Conventional impressions were performed in subgroups CONC and CONM, while digital scanning was conducted in subgroups DIGC and DIGM. Simplified cobalt-chromium alloy frameworks were manufactured using the lost-wax technique on plaster and resin models. The degree of adaptation of the structures was evaluated by impressing the niches with condensation silicone, qualitatively assessing perforations, and quantitatively measuring the mold thickness under a stereomicroscope after cross-sectioning. Regular adaptation was more prevalent among the experimental groups. CONC showed a higher mean degree of abutment adaptation, while CONM had a lower mean. The study factors, impression technique, and type of abutment seat, were not statistically significant, with no interaction among the variables. Occlusal and cingulum abutment measurement points, in both impression techniques, showed no statistically significant difference. Digital scanning yielded better results in terms of abutment adaptation, with smaller average gaps between the abutment seat and the metal structure, making it clinically acceptable. The type of abutment seat and the impression technique did not have a statistically significant impact on abutment adaptation. The impression technique does not represent a factor influencing the adaptation of occlusal and cingulum abutments at different measurement points.

Keyword: 3D Printing. Removable Partial Denture. Degree of Adaptation. Rest.

Resumo

O Objetivo do estudo é valiar precisão da impressão digital em próteses parciais removíveis, por meio de um estudo in vitro sobre o grau de adaptação dos apoios. Um modelo Classe III de Kennedy com espaço protético entre o elemento 43 e 47, nichos na região mésio-oclusal e na do cíngulo. Foram realizadas impressões convencionais nos subgrupos CONC e CONM, e digitalização nos subgrupos DIGC e DIGM, onde estruturas simplificadas de liga de Co-Cr foram fabricadas usando a técnica de fundição perdida nos modelos de gesso e resina. O grau de adaptação das estruturas foi avaliado pela impressão dos nichos com silicone de condensação, qualitativamente as perfurações e quantitativamente a espessura do molde em um estereomicroscópio após seção transversal. A adaptação regular foi mais prevalente entre os grupos experimentais. CONC maior média do grau de adaptação do apoio, enquanto CONM menor média. Os fatores do estudo, técnica de impressão e tipo de assento de apoio, não foram estatisticamente significativos, sem interação entre as variáveis. Pontos de medição de apoio oclusal e de cíngulo, em ambas as técnicas de impressão, sem diferença estatisticamente significativa. A digitalização mostrou melhores resultados em relação ao grau de adaptação dos apoios, com menores lacunas médias entre o assento de apoio e a estrutura metálica, sendo clinicamente aceitável. O tipo de assento de apoio e a técnica de impressão não interferem estatisticamente na adaptação dos apoios. A técnica de impressão não representa um fator que influencie a adaptação de apoios oclusais e de cíngulo em diferentes pontos de medição.

Palavras-chave: *Impressão 3D. Prótese Parcial Removível. Grau de Adaptação. Apoio.*

1 Introduction

The use of digital technology in removable partial dentures (RPDs) has been gaining clinical and laboratory space in the last decade, making it possible to perform digital impressions, fabrication of the structure, base of the prosthesis, artificial teeth, and registration of the maxillomandibular relationship.[1-9] Thus, with the application of digital technologies it is possible to simplify the clinical and laboratory steps, minimize errors, and reduce the risk of viral contamination.[1,6,7] Research that seeks to consolidate the use of digital flow in rehabilitation with RPD is desired, since a large number of partially edentulous patients requiring prosthetic rehabilitation are still identified.[10-12]

Impression is a critical step in making the RPD, during conventional impression it seems difficult to avoid errors due to deformation of the impression, especially tensile stress in the cervical region during the impression removal .[2,13] Therefore, the use of digital impression is a way to capture the image of the dental arch, safely and comfortably for patients.[14] It is also a viable option to reduce the number of clinic visits, lab work, patient anxiety, improve comfort and allow any errors to be corrected relatively easily.[3,15]

Additionally, the digital method can also help eliminate operator caused variation and improve quality control in the dental laboratory.[16] So far, there is a promising increase in evidence on the use of digital impression integrated into the production of RPDs,[2-4,15-18] and the literature findings show a prevalence of studies on framework fabrication techniques in RPDs using computer-aided design and computer-aided manufacturing (CAD-CAM).[6,7,19-21] However, framework fabrication by laser sintering, for example, is still a high-cost and laboratory-specific process that is not accessible to the entire dental community.[19]

The studies published from comparative data between digital and analog flow, do not present evidence on digital impression taking in the fabrication of RPD associated with the lost-wax technique.[2-4] That is, there is a gap in the literature whether digital impressions obtained using an intraoral scanner are accurate enough for use in the fabrication of frameworks in RPDs.[2] Challenges in taking digital impressions still need to be resolved in order to extend these indications.[1]

Based on the above, the aim of this study was to verify the accuracy of digital impression in removable partial dentures through an in vitro study on the degree of adaptation of rests. The expected results for this research are: Null Hypothesis (H0): There will be no statistically significant differences between impression techniques and rest seat types on the degree of adaptation of the rests; Alternative Hypothesis 1 (H1): There will be statistically significant differences between impression techniques and rest seat types in the degree of adaptation of the rest.

2 Material and Methods

2.1 Reference model

For the study, a partially edentulous Class III Kennedy clinical case was simulated on a dental manikin (PD100 manikin; Pronew). The mandibular partially edentulous arch had a prosthetic space between two abutment teeth, right mandibular canine and right mandibular second molar. Prior to making the rest seats in the artificial teeth, the parallelism between the abutment teeth was observed and the direction of prosthetic insertion was defined with the aid of a Delineator (Model B2; Bioart) and transfer guide on the plaster model of the partially edentulous arch. In the absence of guide planes in the abutment teeth, a red acrylic resin guide crown (Self-curing Acrylic Resin; Dencrilay) was made on the diagnostic cast to perform the proper wear on the manikin.[23]

Next, the rest seats were made in the artificial abutment teeth of the manikin, in the right mandibular second molar in the mesio-occlusal region with a triangular shape and an apex facing the center of the tooth. The angles were rounded, this preparation covered 1/3 of the distance between cusps in the bucco-lingual direction and 1/4 in the mid-distal direction. The rest seat depth was 1.5 mm, this preparation was performed with a high rotation pen with constant water flow, using a diamond tip #2131 (KG Sorensen) positioned parallel to the long axis of the dental element. In the right mandibular canine, the rest seat was made in the cingulum region, which presented a step shape with rounded angles (mesio-distal). The rest depth was 1.5 mm, and this preparation was also performed with a high rotation pen with constant water flow, using a diamond tip #2130 (KG Sorensen) positioned parallel to the long axis of the dental element.[23]

2.2 Experimental design

After the partially edentulous arch in the manikin, already presenting the proper rest seats preparations, the different impression techniques were performed according to the experimental groups, which are segmented into subgroups in Table 1.

Table 1 - Subgroups, satisfactory adaptation (%), regular adaptation (%), maladaptation (%), mean (SD), minimum and maximum value of rest adaptation (µm)

Subgroups	Satisfactory Adaptation	Regular Adaptation	Maladaptation	Mean (SD*)	Minimum	Maximum
CONC	20%	80%	-	326.975 (203.13)	96.466	549.648
CONM	20%	40%	40%	132.480 (24,36)	105.219	164.574
DIGC	-	40%	60%	161.096 (58.47)	104.870	244.047
DIGM	60%	40%	-	162.402(82.42)	74.294	280.446

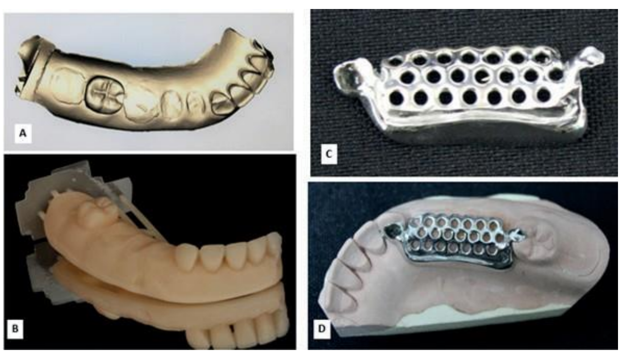
* SD - Standard Deviation.
Source: research data.

The conventional impression technique was performed with the use of a partial aluminum stock tray (Industry and Commerce Ltda) and irreversible hydrocolloid (Hydrogum Alginate Type I; Zhermack), which was manipulated according to the manufacturer's recommendation. The impression material was loaded onto the tray and rest seat areas, and finally the impression was made in the area of interest of the case. Type IV plaster (Type IV Special Stone Plaster; Durastone) was manipulated according to the manufacturer's recommendations to fill the mold with the aid of a plaster vibrator. After the plaster set, the cast was removed from the mold and then trimmed using a plaster trimmer.

The scanning of the reference model (manikin) was performed by the study operator and when necessary, assisted by a trained operator using an intraoral scanner (iTero Element 2; Align Technology) according to the manufacturer's recommendations. That is, starting with the buccal region, then occlusal and lingual, applying the Chair

Side scanning option. The reference model was scanned five times and the Standard Tessellation Language (STL) files were obtained and processed in software (Exocad; Align technology). Then, the slicing software (Photon Workshop, version V2.1.21.; Anycubic) was applied and the 3D printed models (Photon S; Anycubic) were obtained. The printing of the models in resin (Prizma 3D Model Beige; Makertech Labs) was conducted in the 90° position with 0.05 mm layers, followed by a cleaning and curing process. The cleaning was done with Isopropyl Alcohol and absorbent paper, followed by a 6-minute post curing in a 120W UV cabin, the removal of the supports was done with a bench motor and diamond disc cutter, finishing with a flame shaped carbide cutter and polishing brush (Polishing Brush pm - Scotch Brithe 22mm extra fine; American Burr), and finally surface cleaning with paper soaked in isopropyl alcohol. A single operator took the impression of the models (Figure 1).

Figure 1 - A, Scan of the hemi-arch corresponding to the reference model. B, Printed cast of the hemi-arch under study. C, Modified metal structure. D, Metal structure positioned on the plaster model



Source: the authors.

The working casts were sent to the fabrication of the metallic structures. Such structures prepared for this study were simplified, as they presented only rests, minor and major connectors, and saddle as constituent elements of the removable partial denture, based on similar literature.[6] The metallic structures were the specimens of the research, as through them the adaptation of the rests on the reference model was evaluated. The sample size of this study was calculated in the Minitab (version 17 for windows) based on the standard deviation of similar research, the study by Ichi[22], thus the N=5 exceeds the sample power of 80.0% in relation to the maximum ones.

2.3 Making of the metallic structure

The metal frameworks for both impression strategies were made of cobalt-chromium alloy (CoCr DeguDent alloy; Dentsply Sirona) by the lost-wax technique and made by a dental technician, according to the simplified design. After the frameworks were finished and polished in the dental laboratory.

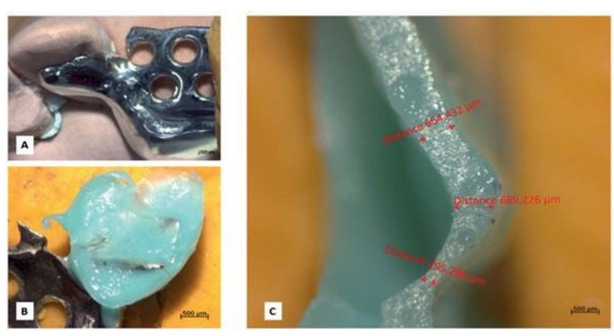
2.4 Degree of support adaptation

At first, the frameworks were subjectively evaluated in terms of design and suitability for the arch.[6] The adaptation of the rests was conducted by influence of the methodology described in some studies.[23-25] The impression material (Flex-sil consistency condensation silicone; Maquira) was applied over the rest seats of the abutment teeth and internally to the rests, and then the metal framework was positioned on the manikin, according to its insertion path until final seating, digital pressure was applied until the polymerization of the impression material, similarly to other studies.[23-25] After polymerization, the framework was removed together with the silicone.

The qualitative analysis of the adaptation of the rests was performed under a stereomicroscope (Discovery V20; Zeiss), regarding the integrity of the silicone copies, still on the metal framework.[24,25] The presence of perforations in the silicone copies was an indication that there was contact of the rest with the rest seat, while the absence of perforations demonstrated its maladaptation.[26] The parameters for this analysis were: maladaptation - no perforations; Satisfactory adaptation - perforations on the edge and center of the support; Regular adaptation - perforations on the border or center of the support.[26]

For the quantitative analysis, the silicone copies were removed from the framework and sectioned in the deepest region of the preparation for rest seat. The thickness of the sectioned material showed the adaptation between rest and support tooth with the aid of a stereomicroscope (Discovery V20; Zeiss) through three measuring points. From the fitting values (μm) of these points, an average was obtained for the canine abutment tooth and the molar abutment tooth in each subgroup. For the canine abutment tooth, the measurement points were from the center of the support to the deepest region of the preparation, as to its edge with point in incisal and cervical direction. For the Molar abutment, the measurement points were the center of the abutment, the mesial point near the minor connector, and the occlusal point toward the end of the rest on the occlusal surface (Figure 2).

Figure 2 - Stereomicroscope images of the CONC subgroup. A, Image of the rest positioned over the rest seat in the plaster model in 1x magnification. B, Representative image of regular adaptation with perforation in rest edges (arrow) in 1x magnification. C, Representative image of the measurement of the degree of rest adaptation in 1x magnification.



Source: the authors.

The measurements of the degree of adaptation were performed under a stereomicroscope (Discovery V20; Zeiss) immediately after polymerization of the impression material.[23-,25] The larger the gap between the rest and the rest seat, the lower the degree of adaptation of the rest, and vice versa.

The procedures reported in the research methodology were performed by two operators (LOA and VMGF).

2.5 Analysis of the results

The results were tabulated and analyzed in Minitab (version 17 for windows), with a significance level of 5%. Quantitative data on the degree of adaptation of the rests were submitted to the 2 Factor Anova statistical test ($p< .05$), to evaluate the effect of the impression strategy and rest type on rest adaptation. Qualitative data were exhibited based on descriptive statistics. The 1 Factor Anova test ($p < .05$) was applied to measure point values of rest adaptation between the impression techniques. Previously, the Komolgorov Smirnov Normality Test was applied to the data and showed a significance level greater than 1% between the experimental groups and analyses performed.

3 Results and Discussion

The structures were subjectively adequate in terms of design on the manikin. Regular adaptation was the most prevalent category among the groups; the DIGM subgroup presented the highest percentage of satisfactory adaptation, while the DIGC group had the highest percentage of maladaptation. The experimental group CONC presented the highest mean of the degree of adaptation of the rest, that is, the greatest gap between rest and rest seat, while the subgroup CONM presented the lowest mean.

The two-factor analysis of variance (ANOVA) examined the influence of impression technique and rest seat type on the adaptation of prostheses. The results indicate that the impression technique was not statistically significant, with a p-value of 0.201. Similarly, the rest seat type also showed a non-significant p-value of 0.077. Furthermore, the interaction between the impression technique and abutment tooth type was also not statistically significant, with a p-value of 0.073. Overall, these results suggest that both the impression technique and rest seat type did not have a statistically significant impact on prosthesis adaptation.

No statistically significant difference was observed for the measurement points of the occlusal and cingulum rests in both impression techniques (Table 2 and 3). Figure 3 show representative images of the qualitative and quantitative data on the adaptation of the rests.

Table 2 - Impression technique and mean (SD*) in µm of the measurement points of the occlusal rest adaptation

Impression Technique	Border (Mesial Point)	Center	Border (Occlusal Point)	p-Valor
Conventional	113.5126 (26.6)	121.6096 (27.2)	162.3194 (23.4)	0.643
Digital	173.8802 (108.7)	152.9092 (55.8)	160.4182 (94.8)	

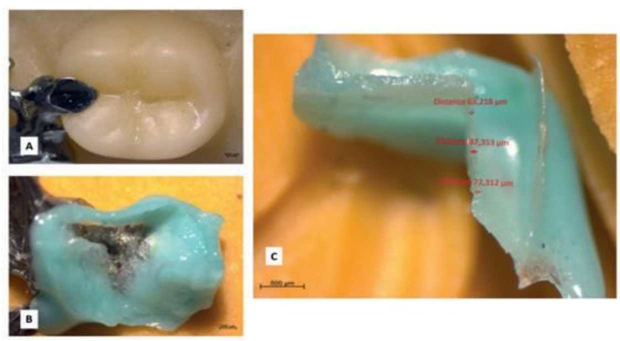
* SD - Standard Deviation.
Source: research data.

Table 3 - Impression technique and mean (SD*) in µm of the measurement points of the cingulum rest adaptation

Impression technique	Border (point in incisal direction)	Center	Border (point in cervical direction)	p-Valor
Conventional	368.0 (236.0)	367.0 (251.0)	245.9 (189.6)	0.140
Digital	181.0 (62.4)	170.7 (90.8)	131.6 (56.4)	

* SD - Standard Deviation.
Source: research data.

Figure 3 - Stereomicroscope images of DIGM subgroup. A, Image of the rest positioned on the rest seat in 1x magnification. B, Representative image of satisfactory adaptation with perforation in edges and center of the rest (arrow) in 1x magnification. C, Representative image of the measurement of the degree of adaptation of the rest in 1x magnification



Source: the authors.

This study qualitatively and quantitatively evaluated the degree of adaptation of rests in removable partial dentures, through metal structures fabricated in casts obtained by conventional and digital impression techniques. The findings of this research show that there was no statistical difference between the impression techniques and rest seat types in the degree of adaptation of the rests, thus the null hypothesis was accepted. The research findings can be compared to the data from the studies of Tregerman et al[3] and Soltanzadeh et al.[4], however it is in agreement with the results of Hayama et al.[2]

Clinical research performed on partially edentulous Kennedy Class I, II, and III arches showed that the completely digital method (intraoral scanning + selective laser fusion) was significantly better than the analog method ($p < .001$) and the combined method (analog casting + selective laser fusion) ($p < .001$) of fabricating the RPD. Finally, the analog method showed better performance of rest adaptation, larger connector, and proximal plate than the combined method (p = .008).[3]

The in vitro study on accuracy and fit of the frameworks in Kennedy's Class III arch modification 1 revealed distinct discrepancies when observed on color maps. Conventionally cast RPD frameworks fabricated on plaster cast or printed resin casts showed a significantly better fit (p < .05) than 3D printed frameworks. There was no significant difference in the fit of the framework between the groups that adopted the lost-wax technique using plaster cast (conventional impression) and printed resin cast (intraoral scanner impression) (p = .68). The mean adaptation values for rests, posterior bar of the larger connector and proximal plate in the study were < 50 µm, and were considered as close contacts.[4]

The accuracy data between Kennedy's Class I and III partially edentulous arches obtained by conventional and digital impression observed that digital impressions had lower accuracy (100-121 µm) compared to conventional impressions (52-119 µm) (p < .05). The intraoral scanner with the larger scan head showed better veracity and accuracy than the scanner with the smaller scan head, and on average required fewer scanned images of the digital moldings (p < .05). The color maps showed a distribution of deviation in the gingival area around the coronal portion and mucosal area for conventional impression and for digital impression there was a tendency for positive and negative deviations in buccal and lingual regions, respectively for both scanners. However, in this study the extraoral scanner was used to convert the reference model and the plaster cast into STL data, which possibly included a greater error than those using a higher accuracy scanner (intraoral scanner).[2]

The results of this research are due to the use of an intraoral scanner, which has higher copy accuracy compared to the extraoral scanner, which can generate replicas of plaster cast with intrinsic errors and thus promote failures in the framework fabrication, and some of them can present an error rate of 50 µm.[2,3,29] And the discrepancy in results can be explained by the variation in the types of scanners adopted in research, as significant differences have been reported between some scanner systems with regard to accuracy and precision, the software used and the level of experience of the professional operator possibly influence the quality of the RPD.[2,21,27] Also, the scanning of only the hemi-arch, because even if the reference model is a Kennedy Class III, the structure was modified and limited to the edentulous region, that is, the arch was not scanned in its entirety. Thus, it seems that scanning was not affected by the position of the scanner head, which is more difficult in the lingual region. Different angles of the scanner head during scanning can generate shading and cause errors.[2]

The mean adaptation values of the rests, whose structures were obtained by printed casts, are lower than the findings of clinical research by Chia et al.[24] (242.2 ±44.5 µm) and Lee et al.[25] (274.34 ±135.94 µm), which are considered clinically acceptable adjustments. These data also reflect the higher prevalence of rests with satisfactory and regular adaptation, in agreement with the study of Souza et al.[26] and Ye et al.[20] who observed 78% and 72.5% of the evaluated copies with some perforation, respectively. Regarding the points of adaptation of the rests, the research results corroborate with those of Lee et al.[25] and Ye et al.[20] for the occlusal rest values (P= .821) and (P= .948), respectively. However, it disagrees for the findings of the cingulum rests (P < .01), this statistical difference found in the study of Lee et al[25] and not observed in the present study may be due to the use of extraoral scanning of the plaster cast and the rapid prototyping technique for fabrication of the structure, which has shown high values of internal discrepancy.[4,6,20,24]

Sample size and method of fitting evaluation are factors that may hinder comparison of results on digital RPD fitting.[8,9] This study adopted an even larger sample size compared to other studies, even though it is still small, a factor that may influence data variability.[6,8] As for the method of adaptation evaluation, in vitro or in vivo impression material, software application, microscopy, visual inspection were observed in the literature to measure the adaptation of the rests.[2,20,23-26] However, many of these evaluations seemed somewhat subjective and failed regarding the evaluation of the cutouts of the framework on a model or distortion.[9]

In this research an association of methods was performed using the impression material and optical microscopy, as adopted in other studies.[23-25] The use of silicone to measure the gaps between the rest and the rest seat may not be as accurate as three-dimensional analyses due to the limiting characteristics of elastomers.[19] However, it is the most prevalent method among studies of adaptation in RPD, favoring comparisons between results.[9]

Satisfactory clinical results with the use of digital impression for partially edentulous arches are reported in the literature and have proven to be a viable option to reduce clinic visits and simplify laboratory procedures, relieve patient anxiety and improve comfort in wearing the prosthesis.[1,7,15,17,18] However, the literature reports a limited indication of fully digital RPDs (digital impression + fabrication of the framework) to patients with Kennedy Class III or IV arches with several missing teeth, because there is no interference of the mucosa condition as it is present in Kennedy Classes I and II.[1] Although the current research did not present different Kennedy Classes as a variable in study, research shows clinically acceptable results in arches with free ends when adopting digital impression.[2,3]

The adaptation of the RPD is considered good when visually all the rests are well adjusted in the position according to their corresponding rest seats.[28] Even with the limitations of this study, the mean values of rests adaptation when adopting digital impression are clinically acceptable and thus the use of this impression technique seems to be applicable for daily clinical use in partial dentures. In the future, the clinical application of digital technologies would benefit RPD treatments not only in the dental office, but also in the patient's home, which is important in an advanced society.[1] The combination of improved materials, digital design, research and education regarding the care of patients with partial edentulism promises to improve the quality of life of patients.[12]

Limitations of this research include a one-sided framework and absence of the clamps, small sample size, and comparison with other framework fabrication techniques. Further developments are needed to facilitate soft tissue impression, and clinical research needs to be conducted to validate the use of digital impression techniques in removable dentures, including other Kennedy classification arches in partially edentulous patients.[13] Scientific evidence comparing methods of adaptation assessment with larger sample numbers through in vitro and in vivo studies is desired.

4 Conclusion

Within the limitations of this study, the following conclusions were presented: the digital impression technique showed better results regarding the degree of adaptation of the rests, with lower mean gaps between the rest seat and the rest, which were clinically acceptable.

1. The rest seat type and impression technique do not statistically
   interfere in the adaptation of rests.
2. Satisfactory and regular fit were most prevalent among the Co-Cr alloy framework rests in the study.
3. The impression technique is not a factor that influences the adaptation of occlusal and cingulum rests at different measurement points.

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