Comparison between digital superimposition and microcomputed tomography methods of fit assessment of removable partial denture frameworks

Article *in* The Journal of prosthetic dentistry · March 2023

DOI: 10.1016/j.prosdent.2023.02.002

6 authors, including:

Pedro Conceição
University of Lisbon

Jaime Portugal
University of Lisbon

Margarida Franco
Polytechnic University of Leiria

Nuno Alves
Instituto Politécnico de Leiria

THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Comparison between digital superimposition and microcomputed tomography methods of fit assessment of removable partial denture frameworks

Pedro Conceição, DMD, PhD,[a] Jaime Portugal, DMD, PhD,[b] Margarida Franco, DPharm, MSc,[c] Nuno M. Alves, MSc, PhD,[d] Duarte Marques, DMD, PhD,[e] and Cristina B. Neves, DMD, MSc, PhD[f]

ABSTRACT

Statement of problem. The fit of removable partial denture frameworks should be assessed to optimize clinical adaptation. Potential discrepancies between framework and supporting structures are typically precisely measured with negative subtracts and high-resolution equipment. The growth of computer-aided engineering technology allows the development of new methods for the direct evaluation of discrepancies. However, how the methods compare is unclear.

Purpose. The purpose of this in vitro study was to compare 2 digital methods of fit assessment based on direct digital superimposition and microcomputed tomography indirect analysis.

Material and methods. Twelve cobalt-chromium removable partial denture frameworks were fabricated by conventional lost-wax casting or additive manufacturing techniques. The thickness of the gap between occlusal rests and respective definitive cast rest seats (n=34) was evaluated by using 2 different digital methods. Silicone elastomer impressions of the gaps were obtained, and microcomputed tomography measurements were used as controls for validation purposes. Digitization of the framework, the respective definitive cast, and the combination was followed by digital superimposition and direct measurements with the Geomagic Control X software program. Because normality and homogeneity of variance were not verified (Shapiro-Wilk and Levene tests, $P<.05$), the data were analyzed with Wilcoxon signed rank and Spearman correlation tests ($\alpha=.05$).

Results. The thicknesses measured by microcomputed tomography (median=242 μm) and digital superimposition (median=236 μm) did not reveal statistically significant differences ($P=.180$). A positive correlation ($\rho=0.612$) was detected between the 2 methods of assessing fit.

Conclusions. The frameworks presented median gap thicknesses under the limit of clinical acceptability without differences between the proposed methods. The digital superimposition method was determined to be as acceptable as the high-resolution microcomputed tomography method for assessing removable partial denture framework fit. (J Prosthet Dent 2023;■:■-■)

Removable partial dentures (RPDs) are provided to replace teeth, improving mastication, phonetics, and esthetics, as well as patient quality of life, with an excellent cost-benefit ratio.[1-3] The correct fit to the supporting teeth is essential for treatment success. Poorly fitting RPDs can lead to poor function and patient dissatisfaction, resulting in an unused prosthesis.[4] Additionally, mechanical failures, such as denture deformation or fracture, or biological complications of the surrounding tissues, including ulcerations, tooth wear, dental caries, and periodontal disease, can arise.[1,2,5] Because of processing distortions,[5-7] up to 75% of frameworks require adjustment at the clinical

Funding: Supported in part by the Foundation for Science and Technology (FCT), Portugal (project UIDB/04044/2020).

[a]Invited Assistant Professor, Department of Dental Biomaterials, Biomedical and Oral Sciences Research Unit (UICOB), Faculdade de Medicina Dentária, Universidade de Lisboa, Lisbon, Portugal.
[b]Full Professor and Head, Department of Dental Biomaterials, Biomedical and Oral Sciences Research Unit (UICOB), Faculdade de Medicina Dentária, Universidade de Lisboa, Lisbon, Portugal.
[c]Laboratory Responsible, Material Characterization Laboratory, Centre for Rapid and Sustainable Product Development (CDRSP), Polytechnic Institute of Leiria (IPL), Marinha Grande, Portugal.
[d]Coordinator Professor and Director, Department of Biomechanics, Centre for Rapid and Sustainable Product Development (CDRSP), Polytechnic Institute of Leiria (IPL), Marinha Grande, Portugal.
[e]Associate Professor with Habilitation, Department of Oral Rehabilitation, Biomedical and Oral Sciences Research Unit (UICOB), Faculdade de Medicina Dentária, Universidade de Lisboa, Lisbon, Portugal.
[f]Assistant Professor with Habilitation, Department of Oral Rehabilitation, Biomedical and Oral Sciences Research Unit (UICOB), Faculdade de Medicina Dentária, Universidade de Lisboa, Lisbon, Portugal.

Clinical Implications

The fit of removable partial denture frameworks can be assessed in the dental laboratory with a high-precision digital superimposition method. The use of this quality control for framework production could reduce chair time for adaptation, prevent complications, and improve patient satisfaction.

evaluation appointment.[2] Thus, assessing frameworks in the dental laboratory could optimize clinical fit, decrease chair time, and ensure a successful prosthesis.[8,9]

Different methods have been proposed to assess RPD fit based on the measurement of the discrepancy between the framework and the supporting structures. Visual inspection and pressing tests have been the most described methods, as they are rapid and straightforward to apply in the dental laboratory or clinically.[2,3,10-17] However, they provide limited qualitative information and are prone to subjectivity and human error.[2,12-14] Other proposed direct analog methods, such as measuring with a calibrated wire scale or optical microscope, use low-resolution power or may lead to structural damage.[9,18-23]

A more detailed and objective evaluation can be obtained with an impression of the discrepancy followed by its quantitative analog measurement with calipers, a profile projector, or optical microscopy.[24,25] These sensitive techniques can lead to errors because of the low dimension and resilience of the impression materials.[8,9,12,26-33] Digital techniques, such as digital microscopy, can identify errors imperceptible to the human eye and overcome the limitations of analog methods.[19,32,34] Furthermore, image capture digital techniques, such as microcomputed tomography (μCT), have been used as high-precision and high-resolution techniques in various fields of biomedical analysis.[30,31,35-37]

The development of high-resolution scanners and computer-aided engineering software programs for dental laboratories has allowed new methods of directly measuring 3-dimensional (3D) discrepancies, such as digital superimposition, without an intermediate substrate.[29,31,32,38-44] However, studies validating the digital superimposition method of measuring the fit accuracy of RPD frameworks are sparse.[45]

The purpose of this in vitro study was to compare 2 digital methods of assessing the discrepancies between the occlusal rests of RPD frameworks and their respective cast rest seats. The null hypotheses were that the quantification of the discrepancy of RPD frameworks would not be affected by the method of assessment used and that no correlation between μCT and digital superimposition methods would be found in the RPD framework fit evaluation.

MATERIAL AND METHODS

Twelve different cobalt-chromium RPD frameworks were produced by conventional lost-wax casting or additive manufacturing techniques to fit 12 different definitive stone casts. The inclusion criteria were that the framework included both sides of the dental arch and at least 1 occlusal rest per quadrant. The RPD fit was assessed by measuring the gap between the occlusal rests of the 12 frameworks and their respective cast rest seats. Two methods were used to measure each gap: an indirect method through μCT measurement of silicone specimens (used as control) and a direct measurement after digital superimposition as proposed by the authors.

The sample size (n=34 occlusal rests) was estimated with a power analysis to provide statistical significance (α=.05) at a power of 80%, based on pilot study data.[46] The gap on each occlusal rest was evaluated once by using 2 assessment methods. For the μCT indirect method, an impression was made of the gap between each occlusal rest and the respective cast rest seat. The rest seat was cleaned with a prophylaxis brush (Prophylaxis Brushlet RA 060 Soft; Edenta AG) and filled with polyvinyl siloxane impression material (V-Posil Light Fast Set; VOCO GmbH). The metal framework was positioned and maintained until the complete polymerization of the impression material. After the removal of the framework, each silicone specimen was detached from the definitive cast, verified for the presence of surface pores and irregularities, and shaped with a scalpel blade (Aesculap blade #15; Aesculap, Inc) to remove excess material. The specimen was then positioned on the sample holder of a μCT system (Skyscanner 1174; Bruker SA/NV) with orthodontic wax (Protection wax; Dentaurum GmbH & Co KG) and scanned with the following parameters: 50 KV, 800 μA, 6.6-μm image pixel size, 5500 milliseconds exposure time, 0.9-degree rotation step, and no aluminum filter. Then, specific software programs were used to reconstruct (NRecon Server Local v1.7; Bruker SA/NV) and spatially position (DataViewer v1.5; Bruker SA/NV) the scanned grayscale image. The 9-point area defined in the digital superimposition method represented the volume of interest (Fig. 1). After performing the segmentation of the original reconstructed image, the mean thickness of the specimen was directly calculated in micrometer by a software program (CTAnalyser software, v1.18; Bruker SA/NV) and represented the thickness of the gap on each occlusal rest. Furthermore, the calculated thickness was confirmed through a 2-dimensional measurement of at least 3 transverse segments of the specimen (Fig. 2).

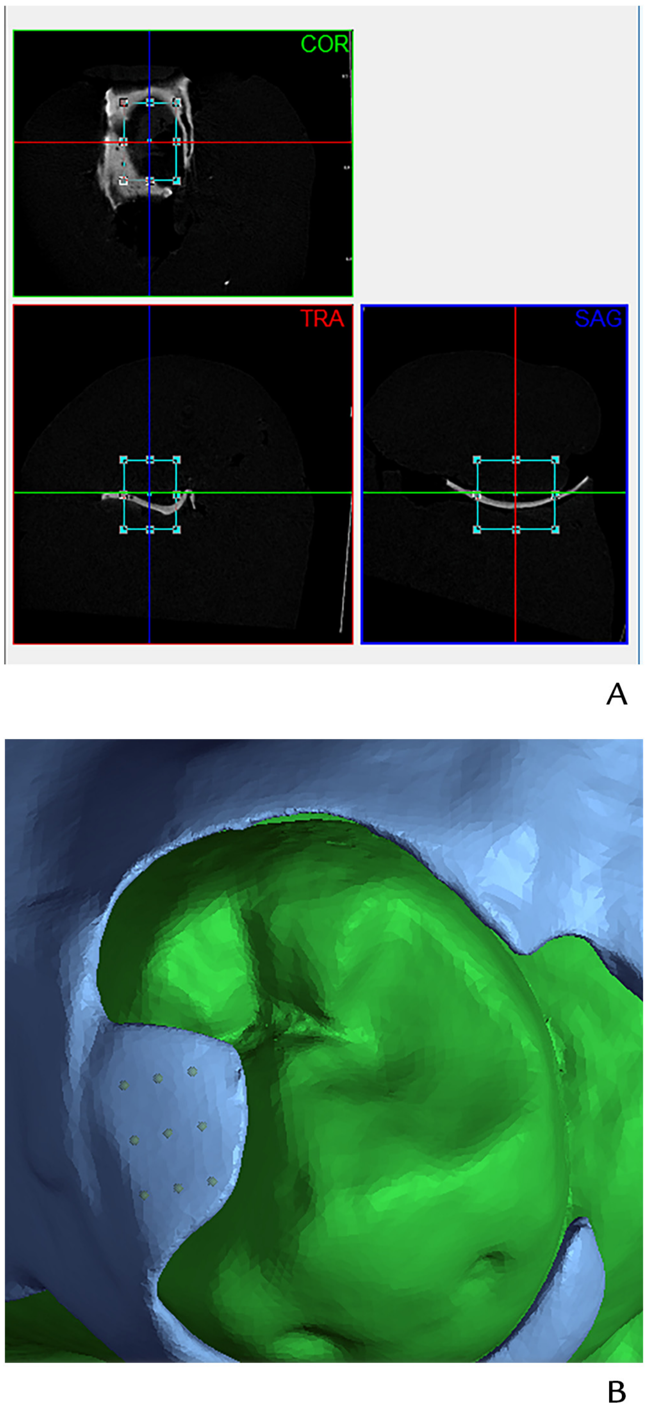

Figure 1. A, Volume of interest of silicone specimen digitized by microcomputed tomography in coronal (COR), sagittal (SAG), and transversal (TRA) planes. B, Nine points defined by Geomagic Control X software program.

For the digital superimposition method, the metal framework was coated with scanning spray (Zirko Scanspray; Zirkonzahn GmbH), and the definitive stone cast and the combination were digitized with an image assembly software program (Modellier; Zirkonzahn GmbH) installed in a scanner system (Arti S600; Zirkonzahn GmbH), producing 3 individual standard tessellation language (STL) files.[37,39] Each file was positioned with the best-fit tools of a software program (Geomagic Control X, v2018; 3D Systems Inc) by using the combined image as a reference (Fig. 3). A grid of 10 virtual planes was created by using the plane tool of the program and the 9 points identified where those planes intersected at each of the occlusal rest and rest seat surfaces. The distance of each pair of points was measured, and the mean of the 9 distances represented the thickness of the gap on each occlusal rest (Fig. 4).

A single researcher (P.C.) collected the data after training with experienced researchers (D.M. and M.F.) and tested for reproducibility at a 1-week interval. The distribution of the margin of error was 2.9% for the digital superimposition method and 4.3% for the μCT method.

The data were analyzed by using a statistical software program (IBM SPSS Statistics, v25; IBM Corp). The descriptive analysis was determined. Because normality and homogeneity of variance were not verified (Shapiro-Wilk and Levene tests, $P<.05$), the data were submitted to related-samples Wilcoxon signed rank and Spearman correlation tests with a scatter plot examination ($\alpha=.05$).

RESULTS

A total of 34 occlusal rests were present in the 12 RPD frameworks, with a mean of 2.8 occlusal rests, a minimum number of 2 rests, and a maximum number of 4 occlusal rests per framework. Similar distributions of the thickness data were obtained by digital superimposition (median=236 μm) and by μCT (median=242 μm) methods (Fig. 5), without statistically significant differences between methods ($P=.180$). A positive correlation ($\rho=0.612$) was observed between the 2 assessment methods, which was confirmed by examination of the scatter plot (Fig. 6).

DISCUSSION

This in vitro study aimed to compare 2 digital methods of assessing the fit of RPD frameworks based on digital superimposition and μCT analysis (control). Because a positive correlation was found, the digital superimposition method appeared to be acceptable for assessing the fit of RPD frameworks.

Assessment of fit is an essential step in controlling the quality of the framework production and ensuring the appropriate function of the prosthesis.[8,9] The fit is based on the intimate contact and residual discrepancies between the RPD framework and the supporting teeth.[12,45] Specifically, the design and fabrication standards of the RPD mean that stability and support of the framework are achieved when all rests are seated.[2,3,12,32] Therefore,

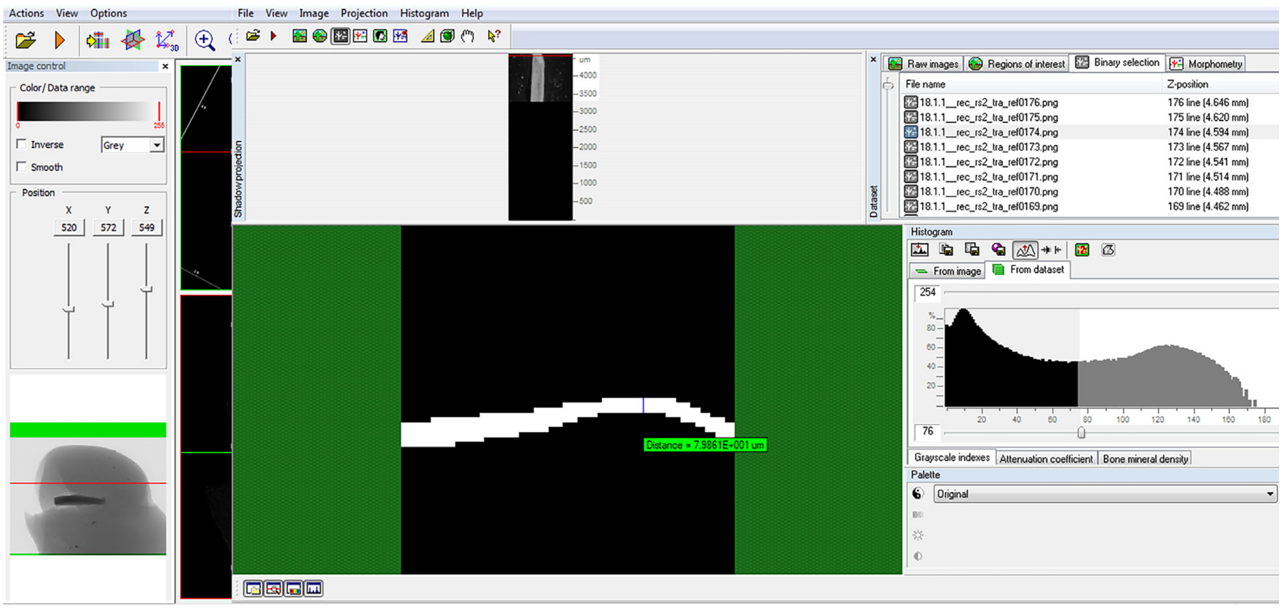

Figure 2. Two-dimensional thickness measurement of specimen transversal segment to confirm total mean thickness.

the present study focused on the discrepancy between the occlusal rests and the respective rest seats.[9-11]

In the present study, an impression of the gap between each occlusal rest and rest seat allowed an indirect quantitative assessment of the discrepancy. The impression material used was polyvinyl siloxane, a silicone elastomer material better than acrylic resin to reproduce details.[8,12,19,29] Furthermore, digital technology was used to analyze the impression specimens, as it permitted a complete and reproducible analysis by preserving the specimens.[8,12,24,26,34,37,43] Some digital techniques, with photography or microscopy, have shown limitations in the 360-degree analysis of the specimens, namely in measuring hidden locations.[8,24] Another technique based on digital superimposition of the specimens requires several scans to provide high-precision levels of measurement.[26,46] Therefore, the present study used μCT, the standard for analysis in various fields of biomedical science.[30,31,35] This high-precision and high-resolution technique provides a complete analysis of low-dimension specimens from a single scan.[30,31,35,37]

The direct measurement of the gaps avoids distortions of the impression materials used in indirect methods.[12,18] The most frequently used direct method has been based on visual inspection but provides unreliable qualitative information, is limited to the border of the framework structures, and is prone to subjectivity and human error.[2,12-14] The development of the digital design and production of restorations in the dental laboratory have expanded the direct methods of assessing the quantitative gap. Previous studies[1,32,41,42] compared the digitized framework with the STL design but did not consider the relationship with the supporting structures, which is essential for a successful prosthesis.

The present study proposed a method that applied the digital principles of a triple scan,[39] followed by digital superimposition with a specific software program. A precise evaluation of discrepancies was made possible by measuring the selected distances between 2 points in a defined axis. In addition, this method avoided impingements of the RPD framework on the definitive cast because of incorrect overlap, as with techniques that evaluate a range of distances in a color map.[25,32,44]

The null hypothesis that the quantification of the discrepancies of RPD frameworks was not affected by the assessment method could not be rejected because no differences were found between the 2 methods. However, a moderate positive correlation between the digital superimposition and the μCT techniques rejected the null hypothesis that no correlation between μCT and digital superimposition methods would be found. The results indicated that digital superimposition by using the available digital laboratory hardware and software equipment is an acceptable method of quantifying discrepancies during the quality control of the RPD framework production.[19,26,32,39] Nevertheless, this direct method should be used with caution in intraoral evaluations of discrepancies, as it requires a high-resolution scanner and a precise technique.[38,40]

Limitations of this study were related to the scanning and best-fit alignment of the structures in the superimposition method. Because of its complex shape, fewer RPD frameworks had to be repositioned for a second scan to digitize the complete information on the upper

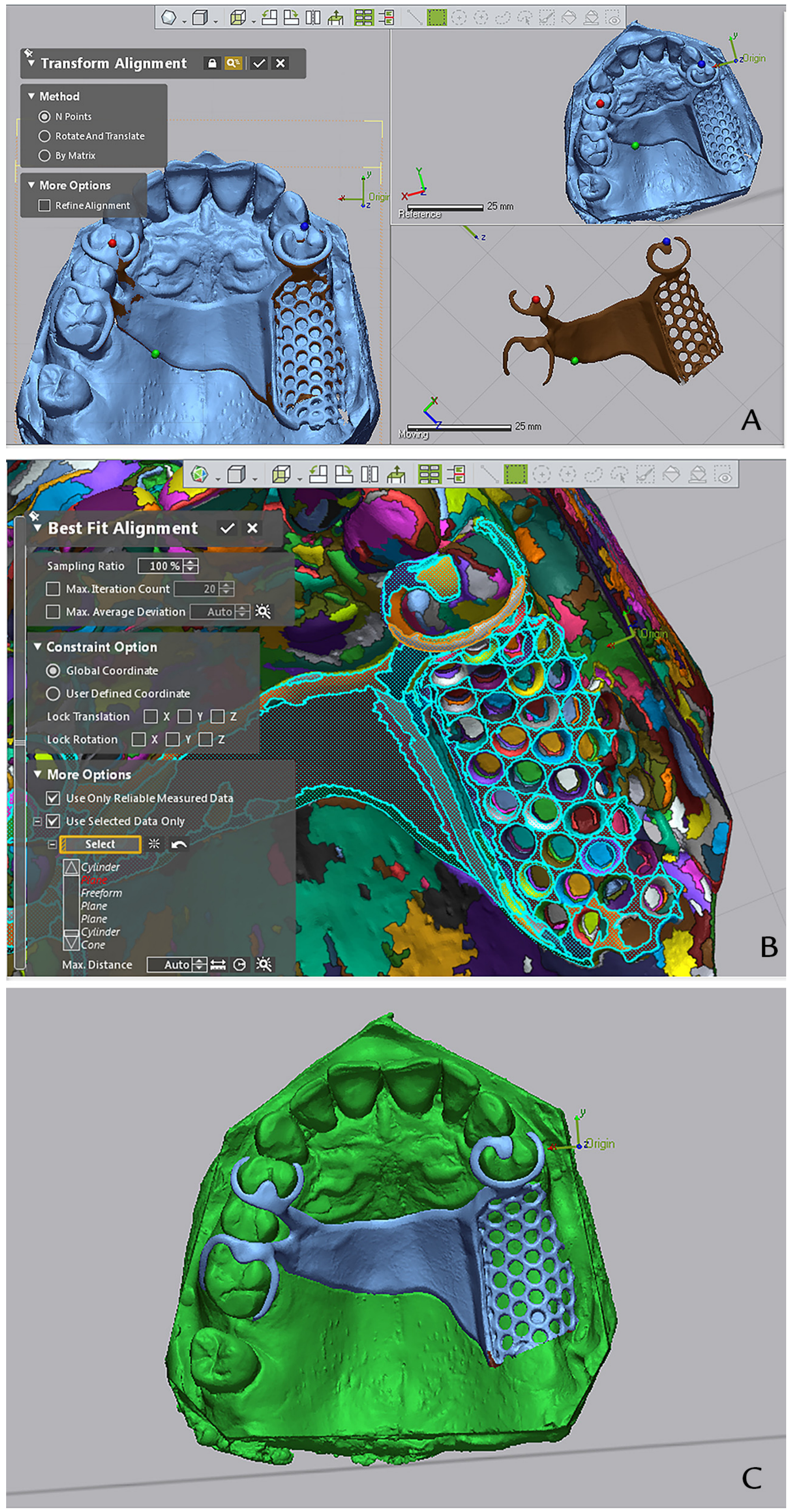

Figure 3. Digital superimposition of framework, definitive cast, and combination images by using Geomagic Control X software tools. A, Point selection to transform alignment. B, Selection of areas to make best fit. C, Image of combination after superimposition.

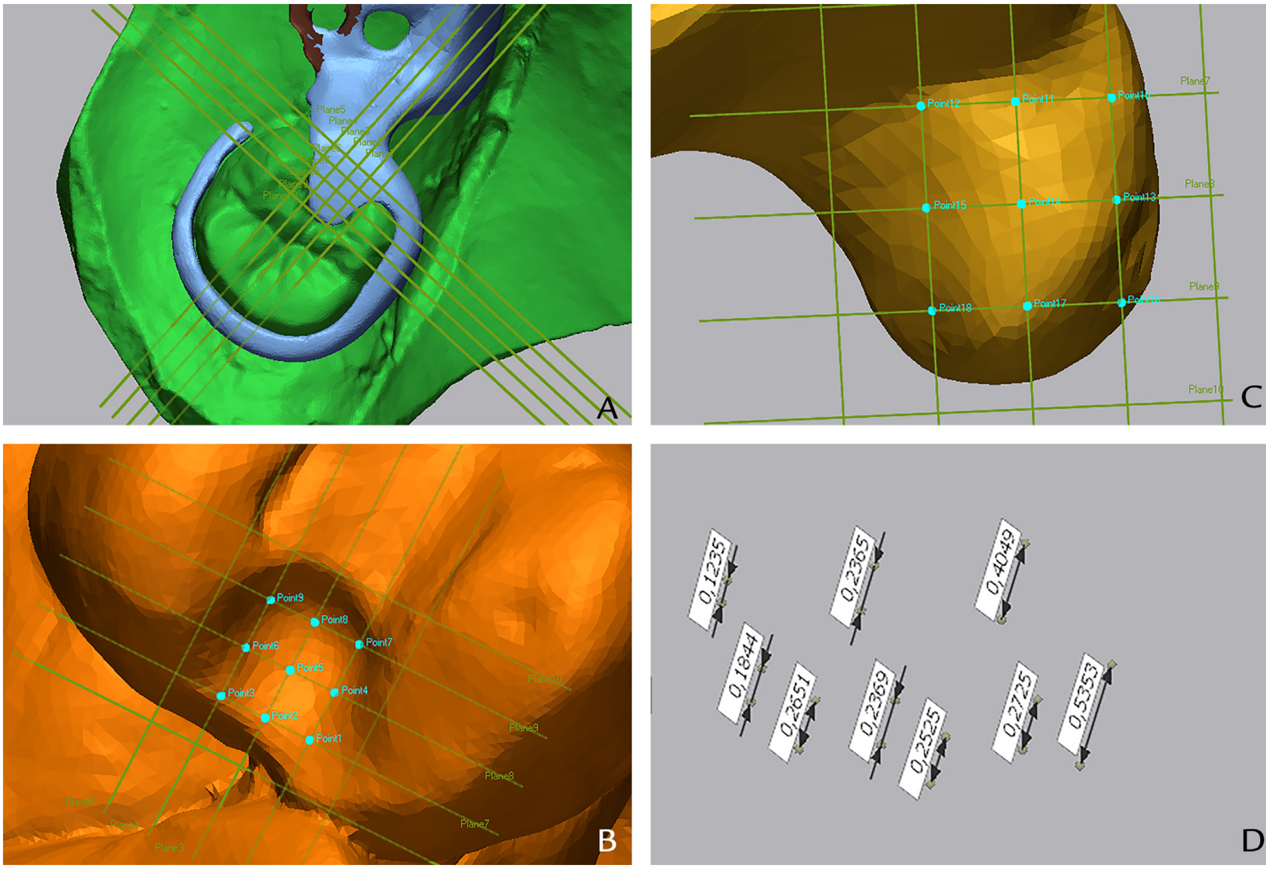

Figure 4. Fit assessment method after digital superimposition. A, Grid resulting from 10 built planes with overlapping of 9 points projected on each structure surface. B, Nine points projected on cast rest seat. C, Nine points projected on lower surface of occlusal rest. D, Distance (mm) between each pair of points projected on each structure.

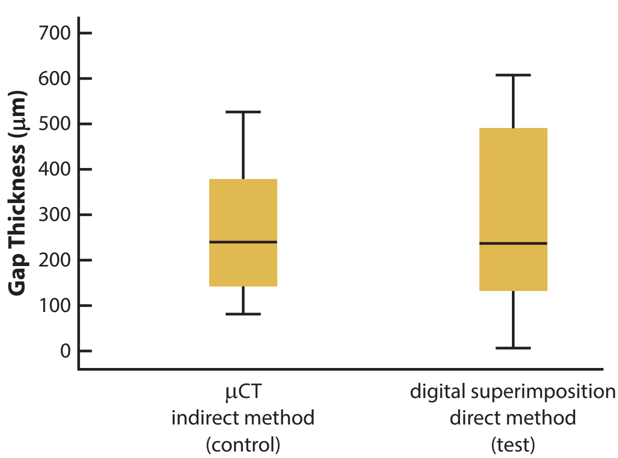

Figure 5. Box plot representation of gap thicknesses (µm) measured by assessment methods under study.

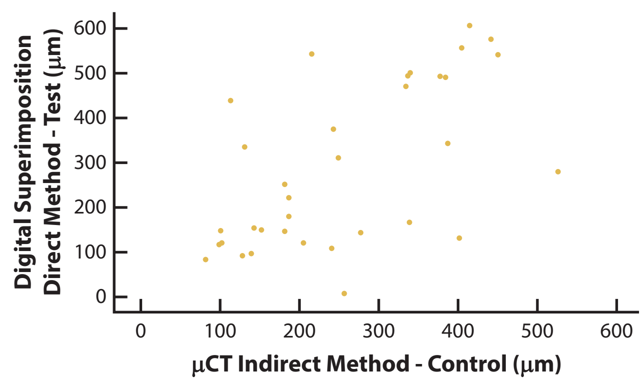

Figure 6. Scatter plot of thicknesses (µm) of gaps between occlusal rests and respective cast rest seats obtained by assessment methods under study.

and lower surfaces of the occlusal rest. In those situations, the final image was achieved by using the scan and match tool of the scanning program. Also, only frameworks with at least 1 occlusal rest per quadrant were included in the study to minimize errors caused by undesirable inclinations. The 3D image acquisition and the value selection in the µCT morphometric analysis are also sensitive techniques. All the procedures were made by the same researcher (P.C.), who was trained and calibrated by experienced researchers (D.M., M.F.) to prevent bias. Furthermore, the mean thickness of each silicone specimen was confirmed by a 2D measurement in at least 3 transverse segments with the tools of

CTAnalyser software, v1.18 (Bruker SA/NV) (Fig. 2). Further studies with larger sample sizes are required to verify the validity of these results.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The digital superimposition method of quantifying discrepancies between the occlusal rests and their respective cast rest seats had results similar to those of the μCT analysis.
2. The positive correlation between the methods determined that the digital superimposition method was as acceptable as the high-resolution μCT method for assessing the fit of removable partial denture frameworks.

REFERENCES

1. Almufleh B, Emami E, Alageel O, et al. Patient satisfaction with laser-sintered removable partial dentures: a crossover pilot clinical trial. *J Prosthet Dent*. 2018;119:560–567.
2. Frank RP, Brudvik JS, Leroux B, Milgrom P, Hawkins N. Relationship between the standards of removable partial denture construction, clinical acceptability, and patient satisfaction. *J Prosthet Dent*. 2000;83:521–527.
3. Etman M, Bikey D. Clinical performance of removable partial dentures: a retrospective clinical study. *Open J Stomatol*. 2012;2:173–181.
4. Bohnenkamp DM. Removable partial dentures: clinical concepts. *Dental Clin North Am*. 2014;58:69–89.
5. Schweiger J, Güth JF, Erdelt KJ, Edelhoff D, Schubert O. Internal porosities, retentive force, and survival of cobalt-chromium alloy clasps fabricated by selective laser-sintering. *J Prosthodont Res*. 2020;64:210–216.
6. Xie W, Zheng M, Wang J, Li X. The effect of build orientation on the microstructure and properties of selective laser melting Ti-6Al-4V for removable partial denture clasps. *J Prosthet Dent*. 2020;123:163–172.
7. Anan M, Al-Saadi M. Fit accuracy of metal partial removable dental prosthesis frameworks fabricated by traditional light curing modeling material technique: an in vitro study. *Saudi Dent J*. 2015;27:149–154.
8. Bajunaid SO, Altwaim B, Alhassan M, Alammari R. The fit accuracy of removable partial denture metal frameworks using conventional and 3D printed techniques: an in vitro study. *J Contemp Dent Pract*. 2019;20:476–481.
9. Williams RJ, Rafik T, Al-Hourani Z. An electronic method for measuring the fit of removable partial denture frameworks to dental casts. *J Eng Res*. 2009;6:15–20.
10. Tasaka A, Shimizu T, Kato Y, et al. Accuracy of removable partial denture framework fabricated by casting with a 3D printed pattern and selective laser sintering. *J Prosthodont Res*. 2020;64:224–230.
11. Williams RJ, Bibb R, Rafik T. A technique for fabricating patterns for removable partial denture frameworks using digitized casts and electronic surveying. *J Prosthet Dent*. 2004;91:85–88.
12. Ye H, Ning J, Li M, et al. Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques. *Int J Prosthodont*. 2017;30:348–353.
13. Tregerman I, Renne W, Kelly A, Wilson D. Evaluation of removable partial denture frameworks fabricated using 3 different techniques. *J Prosthet Dent*. 2019;122:390–395.
14. Chen GX, Zeng XY, Wang ZM, Guan K, Peng CW. Fabrication of removable partial denture framework by selective laser melting. *Advanced Mater Res*. 2011;317–319:174–178.
15. Keltjens HM, Mulder J, Käyser AF, Creugers NH. Fit of direct retainers in removable partial dentures after 8 years of use. *J Oral Rehabil*. 1997;24:138–142.
16. Carneiro Pereira AL, Bezerra de Medeiros AK, de Sousa Santos K, Oliveira de Almeida É, Seabra Barbosa GA, da Fonte Porto Carreiro A. Accuracy of CAD-CAM systems for removable partial denture framework fabrication: a systematic review. *J Prosthet Dent*. 2021;125:241–248.
17. Wu J, Cheng Y, Gao B, Yu H. A novel digital altered cast impression technique for fabricating a removable partial denture with a distal extension. *J Am Dent Assoc*. 2020;151:297–302.
18. Arnold C, Hey J, Schweyen R, Setz JM. Accuracy of CAD-CAM-fabricated removable partial dentures. *J Prosthet Dent*. 2018;119:586–592.
19. Soltanzadeh P, Suprono MS, Kattadiyil MT, Goodacre C, Gregorius W. An in vitro investigation of accuracy and fit of conventional and CAD/CAM removable partial denture frameworks. *J Prosthodont*. 2019;28:547–555.
20. Gowri V, Patil NP, Nadiger RK, Guttal SS. Effect of anchorage on the accuracy of fit in removable partial denture framework. *J Prosthodont*. 2010;19:387–390.
21. Stern MA, Brudvik JS, Frank RP. Clinical evaluation of removable partial denture rest seat adaptation. *J Prosthet Dent*. 1985;53:658–662.
22. Murray MD, Dyson JE. A study of the clinical fit of cast cobalt-chromium clasps. *J Dent*. 1988;16:135–139.
23. Abdelfatah M. Clinical and laboratory evaluation of the fit accuracy of metal frameworks of removable partial denture fabricated from two different pattern materials. *Oral Health Dent Manag*. 2019;18:1–4.
24. El-Khamisy NE, Habib AH, El-Mekawy NE, Emera RM. Digital versus conventional design for mandibular distal extension RPD: A study of passivity of RPD components and principal abutment alveolar bone height changes. *Mansoura J Dent*. 2017;4:6–13.
25. Alabdullah SA, Hannam AG, Wyatt CC, McCullagh APG, Aleksejuniene J, Mostafa NZ. Comparison of digital and conventional methods of fit evaluation of partial removable dental prosthesis frameworks fabricated by selective laser melting. *J Prosthet Dent*. 2022;127:478.e1–478.e10.
26. Chen H, Li H, Zhao Y, Zhang X, Wang Y, Lyu P. Adaptation of removable partial denture frameworks fabricated by selective laser melting. *J Prosthet Dent*. 2019;122:316–324.
27. Saad AS, Abbas FS, Elgharabawy SH. Clinical evaluation of removable partial denture constructed from 3D printed resin pattern designs using CAD CAM technology. *Alexandria Dent J*. 2019;44:15–21.
28. Dunham D, Brudvik JS, Morris WJ, Plummer KD, Cameron SM. A clinical investigation of the fit of removable partial dental prosthesis clasp assemblies. *J Prosthet Dent*. 2006;95:323–326.
29. Diwan R, Talic Y, Omar N, Sadiq W. The effect of storage time of removable partial denture wax pattern on the accuracy of fit of the cast framework. *J Prosthet Dent*. 1997;77:375–381.
30. Ram SM, Ranadive NM, Nadgere JB. Microcomputed tomography a noninvasive method to evaluate the fit of a restoration as compared to conventional replica technique. *J Indian Prosthodont Soc*. 2019;19:233–239.
31. Han SH, Sadr A, Tagami J, Park SH. Non-destructive evaluation of an internal adaptation of resin composite restoration with swept-source optical coherence tomography and micro-CT. *Dent Mater*. 2016;32:e1–7.
32. Tasaka A, Okano H, Shimizu T, Kato Y, Higuchi S, Yamashita S. Influence of reinforcement bar on accuracy of removable partial denture framework fabricated by casting with a 3D-printed pattern and selective laser sintering. *J Prosthodont Res*. 2021;65:213–218.
33. Lee JW, Park JM, Park EJ, Heo SJ, Koak JY, Kim SK. Accuracy of a digital removable partial denture fabricated by casting a rapid prototyped pattern: a clinical study. *J Prosthet Dent*. 2017;118:468–474.
34. Muehlemann E, Orzcan M. Accuracy of removable partial denture frameworks fabricated using conventional and digital technologies. *Eur J Prosthodont Restor Dent*. 2022;30:76–86.
35. Jackson N, Assad M, Vollmer D, Stanley J, Chagnon M. Histopathological evaluation of orthopedic medical devices: the state-of.the art in animal models, imaging, and histomorphometry techniques. *Toxicol Pathol*. 2019;47:280–296.
36. Vasconcelos I, Franco M, Pereira M, Duarte I, Ginjeira A, Alves N. 3D-printed multisampling holder for microcomputed tomography applied to life and materials science research. *Micron*. 2021;150:103142.
37. Conceição PR, Franco M, Alves N, Portugal J, Neves CB. Fit accuracy of removable partial denture metal frameworks produced by CAD-CAM – clinical study. *Rev Port Estomatol Med Dent Cir Maxilofac*. 2021;62:194–200.
38. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. *J Prosthet Dent*. 2016;115:313–320.
39. da Silva Marques DN, Marques Pinto RJ, Alves RVAA, Baratieri LN, da Mata ADSP, Caramês JMM. Soft tissue replication in single unit implant impressions - A three dimensional clinical study. *J Esthet Restor Dent*. 2019;31:359–368.
40. Lee S, Kim S, Lee J, Cheong C. Comparison of intraoral and extraoral digital scanners: evaluation of surface topography and precision. *Dent J (Basel)*. 2020;8:52.
41. Peng PW, Hsu CY, Huang HY, Chao JC, Lee WF. Trueness of removable partial denture frameworks additively manufactured with selective laser melting. *J Prosthet Dent*. 2020;127:122–127.
42. Hwang S, An S, Robles U, Rumpf RC. Process parameter optimization for removable partial denture frameworks manufactured by selective laser melting. *J Prosthet Dent*. 2023;129:191–198.
43. Oh KC, Yun BS, Kim JH. Accuracy of metal 3D printed frameworks for removable partial dentures evaluated by digital superimposition. *Dent Mater*. 2022;38:309–317.

44. Rokhshad R, Tehrani AM, Nahidi R, Zarbakhsh A. Fit of removable partial denture frameworks fabricated from 3D-printed patterns versus the conventional method: an in vitro comparison. *J Prosthet Dent*. 2022. https://doi.org/10.1016/j.prosdent.2022.03.027. [Epub ahead of print.].
45. Lang LA, Tulunoglu I. A critically appraised topic review of computer-aided design/computer-aided machining of removable partial denture frameworks. *Dent Clin North Am*. 2014;58:247–255.
46. Conceição PR, Pinto R, Marques D, et al. Fit accuracy assessment of RPD metal framework by digital superimposition. In: Belinha J, et al., eds. *Advances and current trends in biomechanics*. Leinden: CRC Press/Balkena. 2022:331–334.

Corresponding author:
Dr Cristina Bettencourt Neves
Rua Professora Teresa Ambrósio
Lisbon, 1600-277
PORTUGAL
Email: mneves@edu.ulisboa.pt

Acknowledgments
The authors thank VOCO GmbH (Cuxhaven, Germany) for the donation of the impression material and Dr. Ricardo Pinto (FMDUL) for digital support.

CRediT authorship contribution statement
Pedro Conceição: Conceptualization, Data curation, Formal analysis, Investigation, Software, Visualization, Writing – original draft. **Jaime Portugal:** Supervision, Visualization, Writing – review & editing. **Margarida Franco:** Data curation, Investigation, Methodology, Software, Validation. **Nuno M. Alves:** Resources, Supervision, Funding acquisition. **Duarte Marques:** Methodology, Software, Resources, Validation. **Cristina B. Neves:** Conceptualization, Project administration, Supervision, Writing - review & editing.

https://doi.org/10.1016/j.prosdent.2023.02.002