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Accuracy of Partial and Complete-Arch Conventional Versus Digital Impressions: An In-Vitro Study

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ABSTRACT
Background: Digital impressions offering an alternative method that promises to enhance precision, reduce patient discomfort and streamline workflows. However, it is essential to compare the accuracy of both partial and complete arch impressions using conventional and digital techniques to provide evidence-based data that can guide dental professionals in selecting the most accurate and reliable method for different clinical scenarios. Ultimately, the goal is that these factors will lead to improved patient outcomes and advancing dental practices.
Objectives: To evaluate the accuracy of partial and complete arch impressions using conventional and digital techniques through an *in-vitro* 3D analysis.
Materials and Methods: Typodonts with zirconia crown preparation on tooth #19 along with grooves were prepared for alignment. Partial (PAS) and full (FAS) arch digital impressions were obtained using the intraoral scanner. Partial (PAC) and full (FAC) arch conventional impressions were made with vinyl polysiloxane (VPS) impression material, processed into a gypsum study cast and scanned with an intraoral scanner. A total of 120 STL files were superimposed and analyzed using three-dimensional analysis software.
Results: All experimental groups (PAS, FAC, and PAC) were statistically different from the control group (FAS). PAS demonstrated the least deviation (10.33 ± 29.00 µm) while PAC demonstrated the highest deviation (125.2 ± 81.88 µm) (Repeated ANOVA test, $p < 0.05$) with a deviation in the y-axis (occluso-gingival) contributing the majority of the deviations.
Conclusion: Within the limitations of this study, the accuracy of the partial arch digital impressions was comparable to complete arch digital impressions. Therefore, we would reject the null hypotheses of our study. The results indicated that the highest deviation appeared on the occluso-gingival axis.

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Partial arch; complete arch; scan; conventional impression; digital impression; intraoral scanner; 3D analysis; in vitro

Introduction

Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) were initially developed in the 1960s primarily for engineering and manufacturing industries. Early attempts utilizing CAD/CAM techniques in dentistry began in the 1970s by Altschuler and Duret.[1,2] In the 1980s, this technology was applied by Mormann and Brandestini in Germany, establishing the first CEREC chairside treatment, marking a significant advancement in dental care.[3] CAD/CAM systems enable dentists to create custom ceramic restorations, such as crowns, inlays, and onlays, within a single appointment. This technology has revolutionized the production of dental restorations, offering greater precision, efficiency, and improved patient outcomes.[4] In 2008, the Cadent iTero digital impression system was introduced, expanding the potential applications of digital impressions in dentistry. This system allows for full-arch intraoral scanning, providing more accurate and comfortable impressions for various dental procedures.

The advancements in intraoral scanning applications have not only led to the fabrication of fixed and removable prostheses but also improved diagnostics for orthodontics and treatment approaches in oral surgery.[2,5] Intraoral scanning has significantly enhanced patient comfort, streamlined treatment planning, reduced clinical chair time, and facilitated seamless collaboration between dentists and laboratories.[6]

The accuracy of dental impressions is quite crucial in restorative dentistry. To date, many investigations have addressed the impression accuracy between digital and conventional impressions.[7] Previous studies have concluded that digital impressions are just as clinically applicable and provide other benefits that conventional impression techniques lack.[8] While the accuracy of a dental impression is crucial in restorative dentistry, the extent of the scanned area for single crown scans can vary. This variation can range from an individual tooth, a single quadrant, to the complete maxillary or mandibular arch.[9] Despite the potential for alignment errors due to a larger scan area and the number of images stitched together, complete scans are commonly performed for a single prepared tooth.[10] This is due to conventional impressions, complete arch impressions that allow the practitioner to assess the entire

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occlusal plane. However, with the upcoming advancements in increased intraoral scanner accuracy, there is potential for capturing partial-arch scans with single-sided occlusal scans.[10] The accuracy of these partial-arch scans must be compared to the complete-arch standard to potentially increase the efficiency of a new emerging clinical standard of intraoral record taking.

Therefore, the aim of this in vitro study is to utilize 3D analysis for evaluation and comparison of the accuracy of both partial and full arch impressions using conventional and digital techniques. This study compares the accuracy between: Full-arch scan (FAS), Partial-arch scan (PAS), Full-arch cast (FAC), and Partial-arch cast (PAC) conventional and digital impressions. We hypothesize the following: 1) There will be no significant difference in deviation found when comparing a FAS to PAS, FAC, and PAC; 2) There will be no axis that is the major contributor to the deviations; 3) There will be no significant differences in the deviations found between digital and analog impressions.

Materials and Methods

Study Design

Ten fully dentate typodonts (ModuPRO®One M300, Acadental, Inc., Kansas, USA) were used in this study. Four different impressions were acquired from each of the ten typodonts: Full arch digital scan, Partial arch digital scan, Full arch conventional impression and Partial arch conventional impression (Figure 1). The full arch digital scan served as the control group. After typodont preparation, the digital scans were acquired directly from the typodont using the Trios 3 Scanner, capturing both full and partial arch scans. As for the conventional technique, a full and partial arch impression were casted, mounted and then scanned.

Typodont Preparation

Each typodont was articulated so that there were at least 2 points of contact on both arches when the teeth were in occlusion. A zirconia crown preparation was then performed on tooth #19 using a round-end taper diamond and coarse football diamond bur (BRIO6856.31.016, BRIO5368.31.023, Brasseler USA Dental, PA, USA). Four minor grooves were created on tooth #19 using a slow-speed round bur (4 RA Round CarbideH1.21.014 (Brasseler USA Dental, PA, USA), positioned on the mesial, distal, buccal, and lingual line angles of the crown preparation. On the adjacent teeth, #18 and #20, a minor groove was placed on the mesial and distal marginal ridges, respectively. Furthermore, three grooves were made on the occlusal surface of the opposing tooth #14 in accordance with the occlusal contacts marked by articulating paper prior to the crown preparation (Figure 2) to facilitate the alignment process for software analysis. A total of nine minor grooves were created, with three on the maxillary arch and six on the mandibular arch. The grooves were implemented for the dual purpose of proper alignment and deviation calculations during analysis. To minimize any possible variables, the same operator conducted all crown and groove preparations.

Digital Impression/Scan Acquisition

For the digital impression acquisition process, digital scans were directly captured three times on each typodont using an intraoral scanner (3Shape Trios 3; 3Shape Inc, NJ, USA; Food and drug registration ID 3015172511) capturing both the full arch scan (FAS) and partial arch scan (PAS). A standardized path was followed for all scans starting from the occlusal surface followed by the buccal and the lingual surfaces as well as opposing and bite scans according to the manufacturer's recommendation.

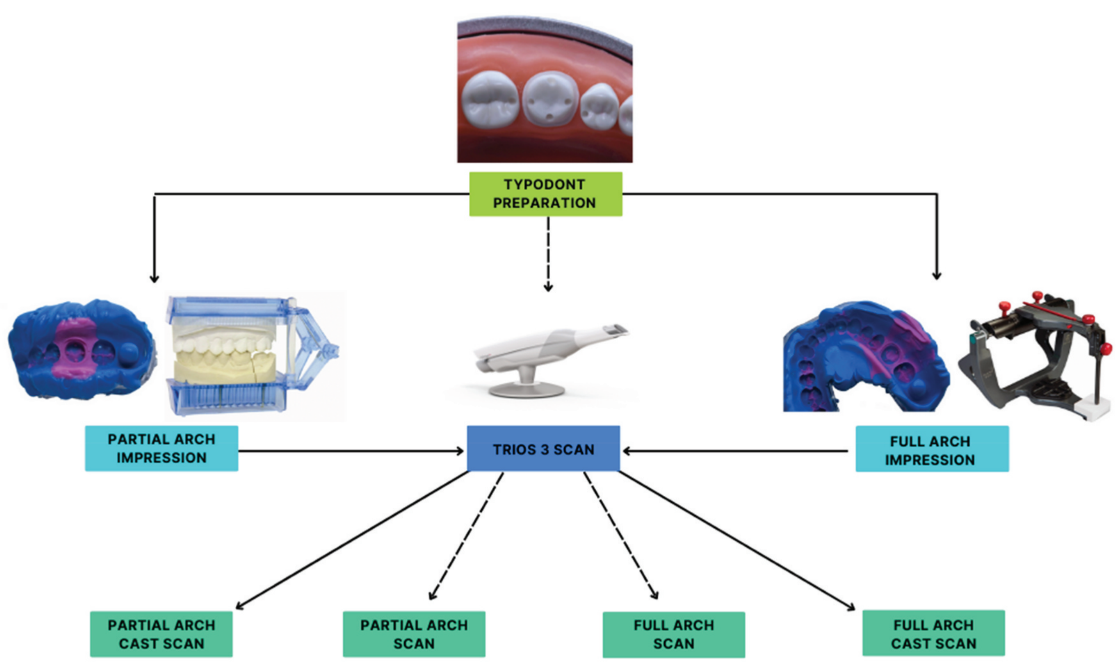

Figure 1. Flowchart of experimental design.

Figure 2. Typodont of the prepared quadrants.

Conventional Impression Acquisition and Scanning

Partial arch impressions were taken with dual arch trays (Quad-Tray Xtream, Clinician's choice dental product Inc, Canada) and complete arch impressions were taken with a full arch plastic trays (COD Spacer Tray#4D, Henry Schein Inc, NY). A two-step impression technique was utilized, taking an initial impression with heavy body vinyl polysiloxane (VPS) Impression Material (3 M™ Imprint™ 4, MN, USA) and then a light body PVS layer added over once the first impression was set. This was done for both arches of a single typodont.

Subsequently, a cast was poured and made using the Green Die Stone (Die-Keen®, Scott's Dental Supply, WA, USA), a Gypsum product line of Modern Materials. Each partial arch cast (PAC) was mounted using segmental Artimax articulators (Artimax Dental Products Inc., IL, USA), and each full arch cast (FAC) was mounted using a semi-adjustable articulator (Denar Mark 330, Whip Mix Corporation, Louisville, KY, USA) (Figure 3).

A total of 20 casts (maxillary and mandibular for each typodont) were each scanned three times using the same scanning technique as acquiring the digital scans. The same operator performed all the impression techniques and casts in standardized temperature and humidity conditions. Each scan data was exported as a stereolithography (STL) file. This brings a single typodont to have eight STL files: 1 FAS, 1 PAS, 3 FAC scans, 3 PAC scans.

3D Scan Analysis

A total of 120 STL files were imported into a 3D analysis software (Geomagic Control X 2020.0.1 3 D systems, Geomagic Control Inc, NC, USA). The world axes were first established such that the bucco-lingual correlated with the x-axis, occluso-gingival the y-axis, and mesio-distal the z-axis. The FAS control group was then aligned with these axes. Each experimental group, FAC, PAS, PAC were superimposed onto their respective control group using the nine grooves that were prepared on the typodont as reference points of alignment. Alignment was initially conducted with the manual alignment tool using the corresponding grooves. Then, the best-fit alignment tool was used in Geomagic to minimize possible user errors. Once aligned, the 3D comparison tool was used to measure the deviation in each groove and compare them between FAS, PAS, FAC and PAC. Deviation measurements within each groove were calculated using a surface area mapping tool within Geomagic between the two superimposed models; total deviation as well as deviation along each axis were computed. Each measurement was repeated three times to enhance the data reliability. The 3D comparison tool also computed a color map to visualize any large deviations. Any deviation within ±300 µm was considered negligible and displayed in green. Any area with a negative change would trend toward blue, and areas with positive changes would trend toward red in the color spectrum. The calculated deviation values were measured in the x, y, and z axes in a total of 2,880 deviation points (Figure 4a-c).

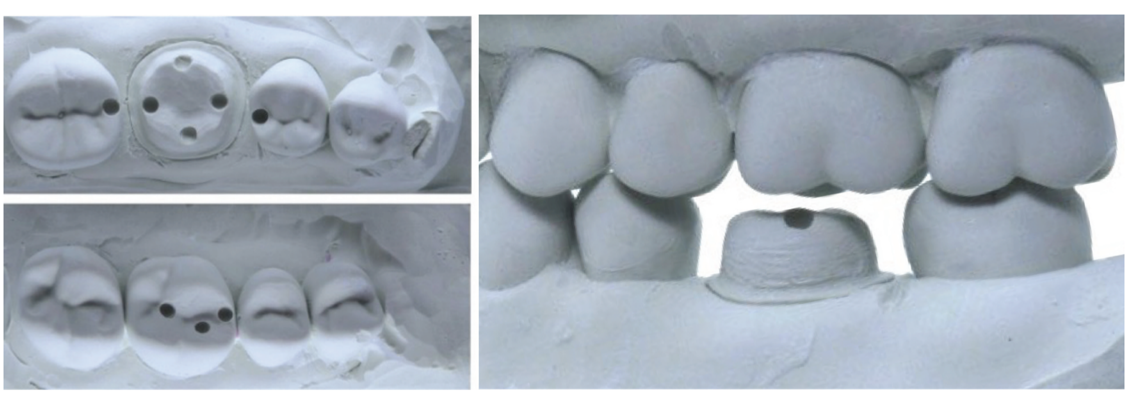

Figure 3. Die-Keen Green cast of prepared quadrants.

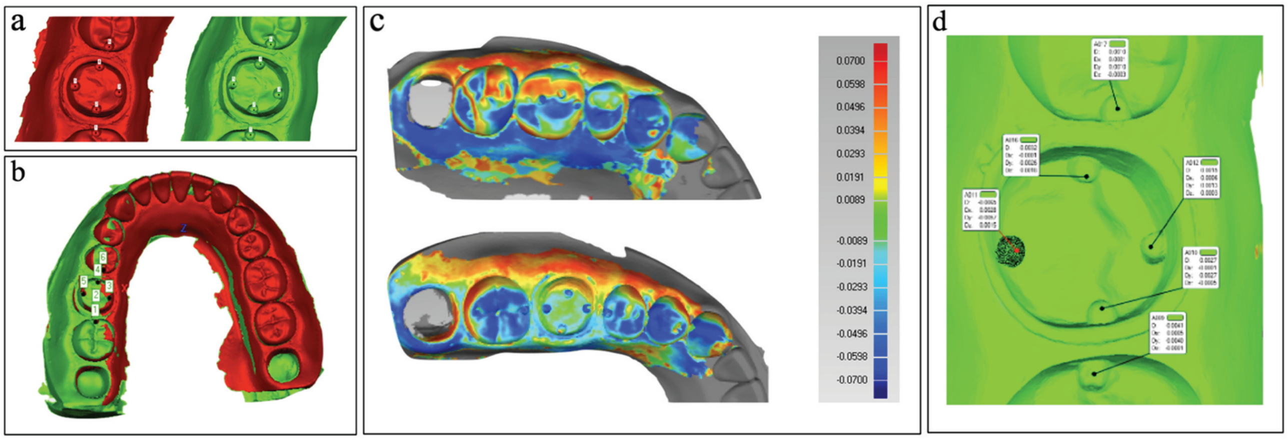

Figure 4. 3D analysis using Geomagic software. (a) Two separate scans of different impression techniques (b) Superimposition of the two scans. (c) Color map revealing dimensional differences between two impression techniques. (d) Obtaining deviations from each groove.

Statistical Analysis

Shapiro–Wilk test was used to determine if the data was normally distributed. The Wilcoxon signed rank test was used to determine if the deviations were statistically significant. ANOVA test was performed with $\alpha = 0.05$ to compare each variable group against each other. Jamovi statistical software (Jamovi, (Version 2.5) [Computer Software], Sydney, Australia) was used to compute all statistical measurements.

Results

Differences in accuracy were seen between the digital and conventional impression techniques. The least difference in total deviation was between PAS and FAS (10.33 ± 29.00 µm). The highest significant difference in total deviation was between the conventional and digital techniques with the FAC and FAS (123.6 ± 97.23 µm) and between the PAC and FAS (125.2 ± 81.88 µm) (Table 1). Considering all the axes, the y-axis demonstrated the highest deviation with relatively the same average total deviation values in all three experimental groups (7.3 ± 6.5 µm for PAS, 120 ± 93.8 µm for FAC and 121 ± 76.8 µm for PAC) (Table 1). Additionally, the y-axis displayed the most influence on the overall deviation across all technique types (Figure 5a-c). All three experimental groups (PAS, FAC, and PAC) were found to be statistically different from the control group (FAS) as confirmed by the repeated ANOVA test ($p < 0.05$) (Table 2).

Discussion

The use of intraoral scanners in dentistry offers an effective alternative for obtaining intraoral records.[11–13] However, clinicians often resort to conventional impressions when the finish lines of tooth preparations are undetectable with the digital impression. Previous studies indicate that partial arch scans became less accurate as the scan area increased but was never directly compared to the accuracy of any varying arch length conventional impression technique.[14,15] It is imperative to compare the accuracy of different impression techniques in varying arch lengths. However, this present study found PAS to have the least number of total deviations, which conformed to the previous studies.[16,17] It cannot be directly concluded that one impression technique is clinically superior, as the term "clinical acceptability" is solely subjective to the clinician. A study determined that the crown margin gap "clinical acceptability" ranges between 50 and 120 µm.[18] Since the total deviations of both the FAC and PAC are just slightly above 120 µm, we can infer that digital and conventional impression techniques can be used interchangeably during the crown fabrication process. However, clinicians must determine the most appropriate impression technique for overall impression accuracy.[19] Factors include, but are not limited to, the placement of the finish line (supra/equigingival or subgingival), moisture and saliva control, ability of image capture of the intraoral scanner, and lighting conditions.[20] Although it is implied that partial arch scans are a better option for patients with complex dental restorations, it is to note that there is no specific scanning strategy that is significantly more accurate or inaccurate for intraoral scanners.[21–23] The overall accuracy of impression acquisition would be impacted by the clinician's skill, the type of conventional impression trays, materials, and the type of scanner used.

Considering partial arch conventional impression with dual arch tray, Cox (2005) conducted a study evaluating occlusion and marginal fit of full crown made following conventional partial double arch and complete arch impressions in 10 patients.[24] They found that the conventional double arch impression method revealed comparable margin accuracy, superior occlusal accuracy and less patient discomfort when compared to complete arch impression. However,

Table 1. Summary of deviations (mean ± SD in µm).

	Total dev	dx dev	dy dev	dz dev
PAS	10.33 ± 29.00	0.907 ± 1.080	7.320 ± 6.500	1.030 ± 1.040
FAC	123.6 ± 97.23	15.89 ± 19.03	120.13 ± 93.79	19.41 ± 2.430
PAC	125.2 ± 81.88	16.62 ± 25.59	121.06 ± 76.86	19.03 ± 20.22

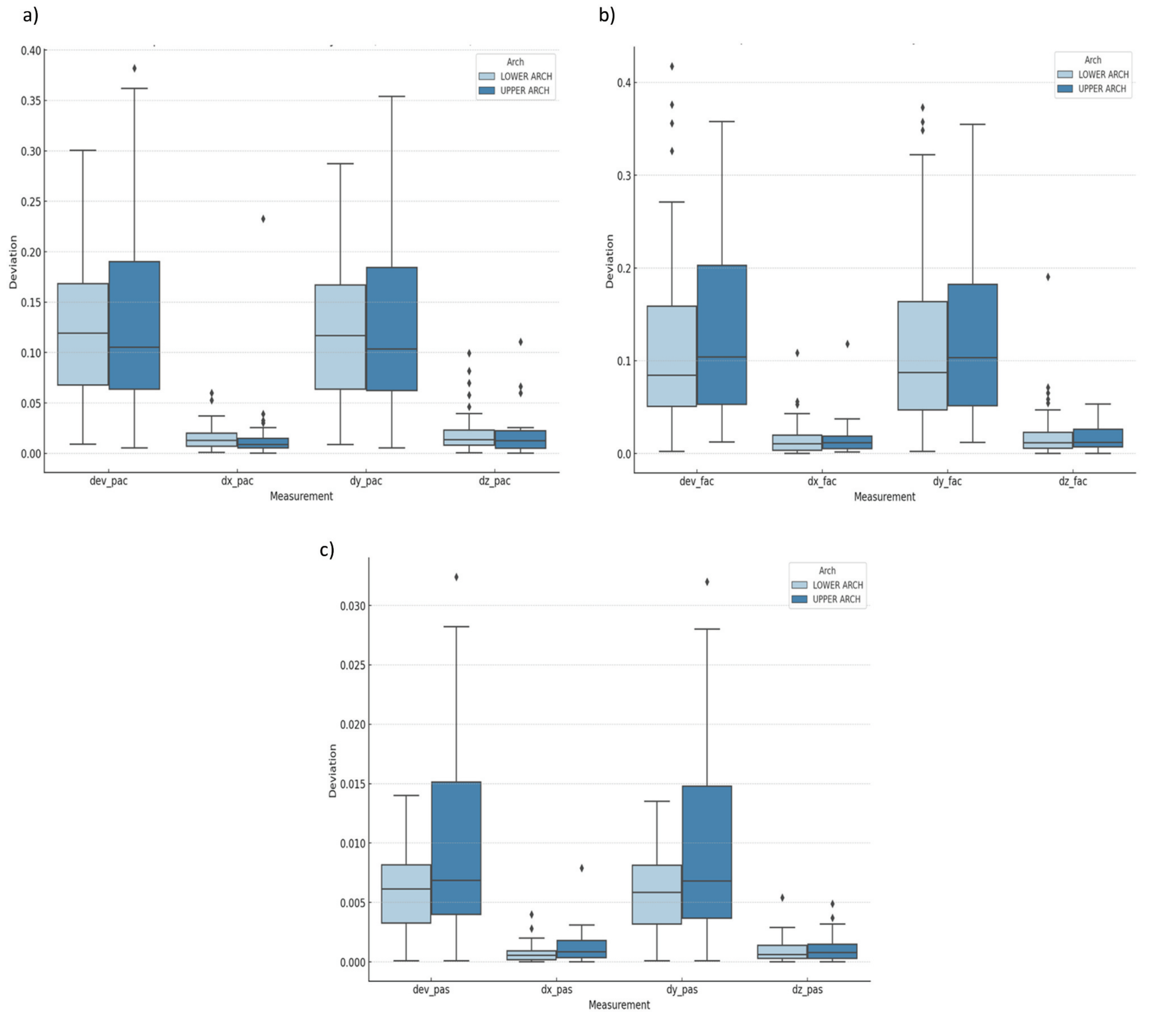

Figure 5. (a) Deviation between PAS when compared to FAS. (b) Deviation between PAC when compared to FAS. (c) Deviation between FAC when compared to FAS.

Table 2. *p*-Values when comparing techniques.

	Total dev	dx dev	dy dev	dz dev
PAS vs FAC	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
PAS vs PAC	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
FAC vs PAC	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$

Larson et al. (2002) evaluated the accuracy of partial dual arch impressions.[25] They concluded that the accuracy of conventional partial dual arch impressions was comparable to custom trays impressions and the accuracy was reduced when the trays were flexed during closure of the arch. This flex can be caused by the high side wall on the dual-arch tray hitting the anatomical structures such as maxillary tuberosity or retro molar area. Additionally, the high viscosity of impression material can cause the dual arch tray to flex away from the tooth preparation.[26] The discrepancies of conventional dual-arch tray impression can reveal up to 180–210 μm[27] which corresponds to the results of this presented study (the total deviation between the PAC and FAS was 125.2 ± 81.88 μm).

Based on the presented 3D analysis, the y-axis (occluso-gingival) displayed a higher deviation than the x- (bucco-lingual) and the z-axis (mesio-distal). This suggests that the occlusal gingival dimension may require the most adjustment, whether reducing or adding crown fabrication material. However, most fabricated crowns would still be clinically competent due to the increased volume between the intaglio surface and ferrule. It is important to note that this study does not provide a definitive conclusion on which impression technique is the best, highlighting the need for further research and exploration in this area.

Limitations

This in-vitro research study was conducted using available materials, such as 3 M VPS impression material and Die Keen Green Stone. A major limitation was the use of the 3Shape Trios 3 Intraoral Scanner.

Conclusion

Within the limitations of this study, the accuracy of the partial arch digital impressions was comparable to complete arch digital impressions. Therefore, we would reject the null hypotheses of our study. The results indicated that the highest deviation appeared on the occluso-gingival axis.

Future Studies

We would like to explore in more detail the accuracy of impression techniques by utilizing a wider variety of intraoral scanner models (TRIOS 5, CEREC PrimeScan, iTero, etc.), measure clinical discrepancies after crown fabrication, and measure discrepancies in other aspects of the crown such as the marginal fit, intaglio surfaces, etc.

To better compare digital and conventional impression techniques, the use of a laboratory or industrial extraoral scanner to obtain the STL file for the conventional impression groups should be considered. This implementation would better replicate how impressions are clinically processed and possibly eliminate any discrepancies from scanning a cast with an intraoral scanner.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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Notes on Contributors

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References

1. Logozzo S, Franceschini G, Kilpela A, Governi L, Caponi M, Blois L. A comparative analysis of intraoral 3D digital scanners for restorative dentistry. *Internet J Med Technol*. 2011;5:0–0.
2. Ashtiani RE, Khanlar LN, Mahshid M, Moshaverinia A. *Comparison of Dimensional Accuracy of Conventionally and Digitally Manufactured Intracoronal Restorations*. 2018. doi:10.1016/j.prosdent.2017.03.014.
3. Moörmann WH. The evolution of the CEREC system. *J Am Dent Assoc*. 2006;137(Suppl 1):7S–13S. doi:10.14219/jada.archive.2006.0398.
4. Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J. CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data. *J Prosthet Dent*. 2012;107(1):34–46. doi:10.1016/S0022-3913(12)60015-8.
5. Baheti MJ, Soni UN, Gharat NV, Mahagaonkar P, Khokhani R, Dash S. Intra-oral scanners: a new eye in dentistry. *Austin J Orthopedics & Rheumatol*. 2015;2(3):1023.
6. Al-Omari M, Al-Omari WM, Al-Omari AM. Digital impressions in dentistry: a review. *Int J Clin Dent*. 2019;12(1):1–7.
7. Al-Omari M, Al-Omari WM, Al-Omari AM. Comparison of accuracy between digital and conventional impressions for full-arch denture fabrication: an in-vitro study. *J Contemp Dent Pract*. 2023;14(3):232–238.
8. Kim K, Seo K, Kim S. *Comparison of the Accuracy of Digital Impressions and Traditional Impressions: Systematic Review*. 2018. doi:10.7759/cureus.51537.
9. Patel I, Patel B, Patel R. *Digital Impressions - a Review of Latest Technology in Dentistry*. June 12, 2015. doi:10.5866/2015.7.10142.
10. Alkadi L. A comprehensive review of factors that influence the accuracy of intraoral scanners. *Diagnostics*. 2023;13(21):3291. doi:10.3390/diagnostics13213291.
11. Robles-Medina M, Romeo-Rubio M, Salido MP, Pradíes G. Digital intraoral impression methods: an update on accuracy. *Curr Oral Health Rep*. 2020;7(4):361–375. doi:10.1007/s40496-020-00285-z.
12. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: a systematic review and meta-analysis. *J Prosthet Dent*. 2016;116(2):184–190. doi:10.1016/j.prosdent.2015.12.017.
13. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. *Clin Oral Investig*. 2016;20(7):1495–1504. doi:10.1007/s00784-015-1641-y.
14. Onbasi Y, Abu-Hossin S, Paulig M, Berger L, Wichmann M, Matta RE. Trueness of full-arch dental models obtained by digital and conventional impression techniques: an in vivo study. *Sci Rep*. 2022;12(1):22509. doi:10.1038/s41598-022-26983-5.
15. Waldecker M, Rues S, Behnisch R, Rammelsberg P, Bömicke W. Effect of scan-path length on the scanning accuracy of completely dentate and partially edentulous maxillae. *J Prosthet Dent*. 2022. doi:10.1016/j.prosdent.2022.02.016.
16. Marques VR, Çakmak G, Yilmaz H, Abou-Ayash S, Donmez MB, Yilmaz B. Effect of scanned area and operator on the accuracy of dentate arch scans with a single implant. *J Clin Med*. 2022;11(14):4125. doi:10.3390/jcm11144125.
17. Ender A, Zimmermann M, Mehl A. Accuracy of complete-and partial-arch impressions of actual intraoral scanning systems in vitro. *Int J Comput Dent*. 2019;22(1):11–19. PMID: 30848250.
18. Demir N, Ozturk AN, Malkoc MA. Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography

(micro-ct) technique. *Eur J Dent*. 2014;8(4):437–444. doi:10.4103/1305-7456.143612.
19. Donmez MB, Mathey A, Gäumann F, Mathey A, Yilmaz B, Abou-Ayash S. Scan accuracy and time efficiency of different implant-supported fixed partial denture situations depending on the intraoral scanner and scanned area: an in vitro study. *J Prosthet Dent*. 2023;131(6):1198–1207. doi:10.1016/j.prosdent.2023.01.029.
20. Revilla-León M, Lanis A, Yilmaz B, Kois JC, Gallucci GO. Intraoral digital implant scans: parameters to improve accuracy. *J Prosthodontics*. 2023;32(S2):150–164. doi:10.1111/jopr.13749.
21. Moon YG, Lee KM. Comparison of the accuracy of intraoral scans between complete-arch scan and quadrant scan. *Prog Orthod*. 2020;21(1):1–6. doi:10.1186/s40510-020-00337-1.
22. Morsy N, El Kateb M. Accuracy of intraoral scanners for static virtual articulation: a systematic review and meta-analysis of multiple outcomes. *J Prosthet Dent*. 2022;2022: doi:10.1016/j.prosdent.2022.09.005.
23. Medina-Sotomayor P, Pascual MA, Camps AI. Accuracy of four digital scanners according to scanning strategy in complete-arch impressions. *PLOS ONE*. 2018;13(9):e0202916. doi:10.1371/journal.pone.0202916.
24. Cox JR. A clinical study comparing marginal and occlusal accuracy of crowns fabricated from double-arch and complete-arch impressions. *Aust Dent J*. 2005;50(2):90–94. doi:10.1111/j.1834-7819.2005.tb00346.x.
25. Larson TD, Nielsen MA, Brackett WW. The accuracy of dual-arch impressions: a pilot study. *J Prosthet Dent*. 2002;87(6):625–627. doi:10.1067/mpr.2002.125180.
26. Cho GC, Chee WW. Distortion of disposable plastic stock trays when used with putty vinyl polysiloxane impression materials. *J Prosthet Dent*. 2004;92(4):354–358. doi:10.1016/j.prosdent.2004.07.020.
27. Carrotte PV, Johnson A, Winstanley RB. The influence of the impression tray on the accuracy of impressions for crown and bridge work–an investigation and review. *Br Dent J*. 1998;185(11):580–585. doi:10.1038/sj.bdj.4809870.