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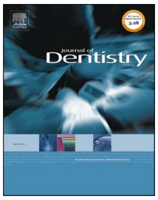

Original article

In vitro scan accuracy and time efficiency in various implant-supported fixed partial denture situations

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ABSTRACT

Objectives: To compare the accuracy and time efficiency of different digital workflows in 3 implant-supported fixed partial denture situations.
Methods: Three partially edentulous maxillary models with 2 implants (Model 1: implants at lateral incisor sites; Model 2: implants at right canine and first molar sites; Model 3: implants at right first premolar and first molar sites) were digitized (ATOS Capsule 200MV120, n=1) for reference scans. Test scans were performed for direct (Primescan (DDW-P) and Trios 3 (DDW-T)) and indirect (IDW) digital workflows (n=14). For IDW, stone casts (type IV) were obtained from vinylsiloxanether impressions and digitized (S600 Arti). The scan/impression and post processing times were recorded. Reference and test scans were superimposed (GOM Inspect) to calculate 3D point, inter-implant distance, and angular deviations. Kruskal-Wallis and Mann-Whitney tests were used for trueness and precision analyses (α=.05).
Results: Tested workflows affected trueness ($P \leq .030$) and precision ($P < .001$) of scans (3D point, inter-implant distance, and angular deviations) within models. DDW-P had the highest accuracy (3D point deviations) for models 1 and 3 ($P \leq .046$). IDW had the lowest accuracy for model 2 ($P < .01$). DDW-P had the highest accuracy (inter-implant distance deviations) for model 3 ($P \leq .048$). Direct digital workflow mostly led to lower angular deviations ($P \leq .040$), and higher precision for models 2 (mesiodistal direction) and 3 ($P < .001$). The time for direct digital workflow was shorter ($P < .001$), DDW-P being more efficient than DDW-T ($P = .008$).
Conclusion: Direct digital workflow was more accurate and efficient than indirect digital workflow in tested partial edentulism situations with 2 implants.
Clinical significance: Tested intraoral scanners can be recommended for accurate and efficient impressions of anterior and posterior 3- or 4-unit implant-supported fixed partial dentures.

1. Introduction

Incorporation of computer-aided design and computer-aided manufacturing (CAD-CAM) technologies has been one of the paramount advancements in dentistry [1–5]. These advancements have facilitated the use of intraoral scanners (IOSs) in various dental applications, including implant prosthodontics [6–8]. Direct digital impressions of implants minimize clinic- and laboratory-related shortcomings of conventional impressions [8–10]. In addition, digital impressions (scans) have the advantage of easy data transfer and communication [11], higher rate of patient acceptance [12, 13] and time efficiency [14]. Nevertheless, IOSs require an initial investment [15] and because indirect digital workflow, which is the digitization of a stone cast with laboratory scanners, is also an option [16, 17], conventional impressions are still used in implant dentistry.

Regardless of the method chosen, an implant impression must be accurate to prevent ill-fitting prosthetic structures, which may lead to biological or mechanical complications [18–20]. Trueness and precision

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are the components that establish accuracy [21]. Trueness is the closeness of a measurement to actual target/dimensions, while precision is the closeness of repeated measurements [22]. Currently available IOSs have different mechanisms to acquire data in point cloud form such as optical triangulation, confocal microscopy, active wave front sampling, interferometry, stereophotogrammetry structured light, laser, and video along with different algorithms to reconstruct the data [23]. The type of IOS was reported to affect scan accuracy [24, 25].

A recent systematic review on the accuracy of implant scans have reported that not only the type of IOS, but also various other factors may affect scan accuracy [26]. Among these factors, the extent of edentulous area is particularly critical, considering that scans of implants and conventional implant impressions have similar accuracy in short-span situations [27]. However, previous studies have reported that increased span length led to lower scan accuracy [8, 14, 16, 28, 29]. In addition, location of the implant might affect the scan accuracy [18, 23, 30], and to the authors' knowledge, no study has investigated the scan accuracy of anterior implants placed to support a fixed partial denture (FPD). Therefore, the aim of the present study was to evaluate the scan accuracy and time efficiency of different digital workflows (direct workflow with 2 IOSs and indirect workflow involving digitization of conventional impressions) in 3 different partially edentulous situations with 2 implants each. In addition, the time required for making impressions and processing durations for different impression techniques was also compared. The null hypotheses were that i) the type of digital workflow would not affect the trueness of implant scans within a partial edentulism situation, ii) the type of digital workflow would not affect the precision of implant scans within a partial edentulism situation, and iii) the type of digital workflow would not affect impression (digital or conventional) time efficiency within a partial edentulism situation with 2 implants.

2. Material and methods

2.1. Reference model acquisition

Three different maxillary models simulating different partial edentulism situations were digitally designed by using a CAD software (Zirkonzahn.Modellier; Zirkonzahn GmbH, Gais, Italy). Each model had 2 implant spaces, which were designed with threads to screw the implants 2 mm submucosally. Holes were included in palate's design to confirm impression post seating. The models were milled from cobalt-chromium-molybdenum alloy [31] by using a heavy metal computerized numerical control milling unit (M5; Zirkonzahn GmbH, Gais, Italy) (Fig. 1). Model 1 simulated an anterior 4-unit implant-supported FPD situation (Kennedy class IV) with 2 implants at right and left lateral incisor sites and 2 pontic sites inbetween. Model 2 simulated a posterior 4-unit implant-supported FPD situation (Kennedy class II), 2 implants at right canine and right first molar sites with 2 pontic sites inbetween. Model 3 simulated a posterior 3-unit implant-supported FPD situation (Kennedy class II) with 2 implants at right first premolar and right first molar sites and 1 pontic site inbetween. Tissue level titanium implants (Straumann S RN 4.1 × 10 mm; Straumann AG, Basel, Switzerland) were screwed into implant sites in models and further fixated with a dental metal adhesive (Adesso Split Justierkleber; Baumann Dental GmbH, Remchingen, Germany). Brand new 1-piece cylindrical polyetheretherketone scan bodies (SBs) (CARES Mono Scanbodies 4.8 × 10 mm; Straumann AG, Basel, Switzerland) were unpacked and tightened to the implants with 15 Ncm torque.Each model was digitized with an industrial-grade optical scanner (ATOS Capsule 200MV120; GOM GmbH, Braunschweig, Germany) to obtain reference datasets in standard tessellation language (STL) format. An anti-reflective scan spray (IP Scan Spray; IP-Division, Haimhausen, Germany) was used before scans.

2.2. Direct digital workflow (DDW)

Prior to the study, a sample size analysis was done by using Welch-tests for the outcomes trueness and precision based on the results of previous studies [12, 32]. Since there is no closed power function for the test used, the power was approximated by using 5000 simulations. With a significance level (α) of 5% and a power (1- β) of above 80%, 10 scans for trueness and 13 scans for precision were deemed sufficient to detect differences between digital and conventional impressions. Therefore, 14 full-arch scans were performed for each model-scanner combination, resulting in a total number of 84 scans.

Two IOSs (Primescan; Dentsply Sirona, Bensheim, Germany (DDW-P) and Trios 3; 3Shpae, Copenhagen, Denmark (DDW-T)) were used in the present study. Both scanners were equipped with the most recent versions of software and calibrated before scans. All scans were performed by one operator (A.M.), who had in situ experience for two years. Prior to test scans, the operator performed 10 trial scans with both IOSs following recommended scan strategies. All scans were performed at room temperature and under approximately 1.000 lux illuminance [24]. All models were mounted to a phantom head with artificial skin by using two-sided adhesive tape and its surface was sprayed with the same anti-reflective spray. The model surfaces were not contacted until all scans were performed, which ensured a standardized layer thickness. A dentate typodont mandibular model was also mounted as the opposing jaw. DDW-P was determined as the first IOS to be used with the help of a coin-flip. After all models were scanned once using both IOSs, the scanning procedures were repeated 13 times. All tests scans were exported in STL format and imported into a CAD software (Zirkonzahn. Modellier; Zirkonzahn GmbH, Gais, Italy).

2.3. Indirect digital workflow (IDW)

Stock impression trays (Disposable impression trays; 3M ESPE, Saint Paul, Minnesota, USA) were perforated at implant locations for non-splinted open-tray impressions. Screw-retained impression posts (Straumann AG, Basel, Switzerland) were tightened to the implants with 15 Ncm torque. After impression post seating was verified evaluating through preparedholes, a 2-phase vinylsiloxanether (Identium Light and Identium Heavy; Kettenbach GmbH, Eschenburg, Germany) impression material was used to make 14 conventional impressions of each model.

Fig. 1. Occlusal view of reference models.

The sequence for the impressions was similar to that of digital impressions and these impressions were made under the conditions the intraoral scans were made.

After relaxation time of 2 hours, type IV dental stone (Dentalgips Typ 4; Kulzer GmbH, Hanau, Germany) was poured in impressions by an experienced dental technician to obtain stone models with implants. The same SBs that were used for reference and test scans were tightened to the implants in stone models with 15 Ncm torque. Only one set of SBs was used to eliminate any issues related with manufacturing tolerances of SBs [33]. SB orientations on models were identical to those on reference scans.

Models were digitized by using a laboratory scanner (S600 Arti; Zirkonzahn GmbH, Gais, Italy), which had a precision of ≤10 µm [34] and the STL data were imported into the same CAD software.

2.4. Accuracy analysis

Before accuracy analyses, all STL files were trimmed approximately 2 mm below the gingival zenith of remaining teeth by using a software (Meshmixer; Autodesk Inc, San Rafael, USA) for standardization. After trimming, all STLs were imported into a metrology-grade 3-dimensional (3D) analysis software (Pro 8.1, GOM GmbH, Braunschweig, Germany) for superimpositions. Initial superimposition of test scan STL over reference scan STL was performed by using automatic prealignment, which was followed by global best-fit, excluding only the SB surface data (Fig. 2). After superimposition, 8 points were defined on each SB in reference model scan (Fig. 3), and their coordinates were recorded. This protocol allowed standardized selection of points throughout the analyses. The points were projected onto the test scan, and 3D point deviations between the reference and the test scans were automatically calculated. The deviation of inter-implant distance was calculated by measuring the distance between 2 of the previously defined points (one on each SB) for reference and test scans. In addition, a mesiodistal and a buccopalatal vector passing through 2 points on each SB were generated (Fig. 3). These vectors were used to calculate mesiodistal and buccopalatal angular deviations between the reference and the test scans.

2.5. Time efficiency

For DDW-P and DDW-T, the time needed for scans, data processing, exporting data from the IOS, importing data into the CAD software, and data processing in CAD software until the design could be started were recorded by using a stopwatch.

For IDW, the time needed for tray perforation, impression making, tray removal, setting of impression material, model fabrication, digitization of the models, and data processing in CAD software until the design could be started were recorded by using the same stopwatch. However, relaxation time of impression material and time for transportation to dental laboratory were not considered, given that they mostly coincide and transportation time might change depending on the presence of an in-house laboratory.

2.6. Statistical analysis

For trueness (distance between test and reference scans) and precision (variance between scans) analyses, median values and interquartile ranges for 3D point-deviations, distance deviations, and angular deviations were calculated. The median working times and interquartile ranges were also calculated. Group data for some variables were skewed and thus, assumption of normality was violated. Therefore, the workflows were compared by using Kruskal-Wallis tests. In situations the Kruskal-Wallis test showed significant effects, exact Mann-Whitney tests were conducted post hoc to detect local differences. In addition, median working times and interquartile ranges were calculated. Throughout, p-values less than 0.05 were considered statistically significant. All post hoc tests were corrected for multiple comparisons using the method of "Holm". All analyses were performed with the statistics software R, version 4.0.2.

3. Results

3.1. Trueness

Significant differences were found among workflows when 3D point deviations were concerned ($P \leq .004$). For models 1 and 3, DDW-P had lower deviations than DDW-T ($P \leq .046$) and IDW ($P \leq .004$), while differences between DDW-T and IDW were nonsignificant ($P = .026$ for model 1 and $P = .015$ for model 3). For model 2, DDW-P and DDW-T had lower deviations than IDW ($P = .010$), while the difference inbetween was nonsignificant ($P = .770$). Fig. 4 illustrates the box-plot graphs of 3D distance deviations in each workflow-model pair, while Table 1 shows the descriptive statistics.

When distance deviations were considered, significant differences were found among workflows only in model 3 ($P = .003$). DDW-P had lower deviations than DDW-T ($P = .048$) and IDW ($P = .006$), while the difference between DDW-T and IDW was nonsignificant ($P = .110$) (Table 2).

When angular deviations were considered, significant differences were found among workflows in mesiodistal direction for all models ($P \leq .030$) and for models 2 and 3 in buccopalatal direction, ($P \leq .001$). All workflows had similar angular deviations in buccopalatal direction for model 1 scans ($P = .10$). In mesiodistal direction, DDW-P ($P \leq .040$) and DDW-T ($P \leq .020$) had lower deviations than IDW for models 1 and 3. In buccopalatal direction, DDW-P had lower deviations than IDW in model 2 ($P = .001$), while DDW-P and DDW-T had lower deviations than IDW in model 3 ($P \leq .030$). All other comparisons were found to be statistically nonsignificant ($P > .05$) (Table 2).

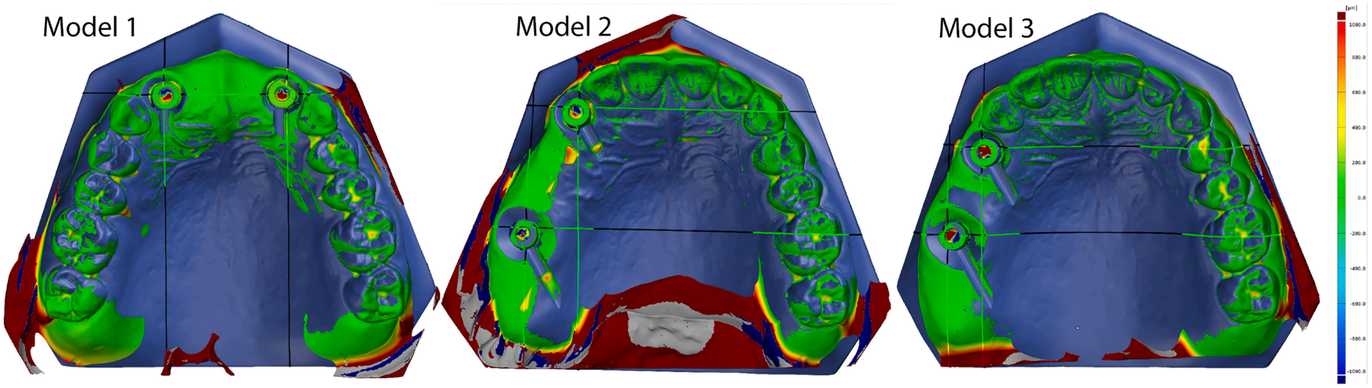

Fig. 2. Color maps generated by superimposing test scans over reference scan and planes generated for angular deviation analyses.

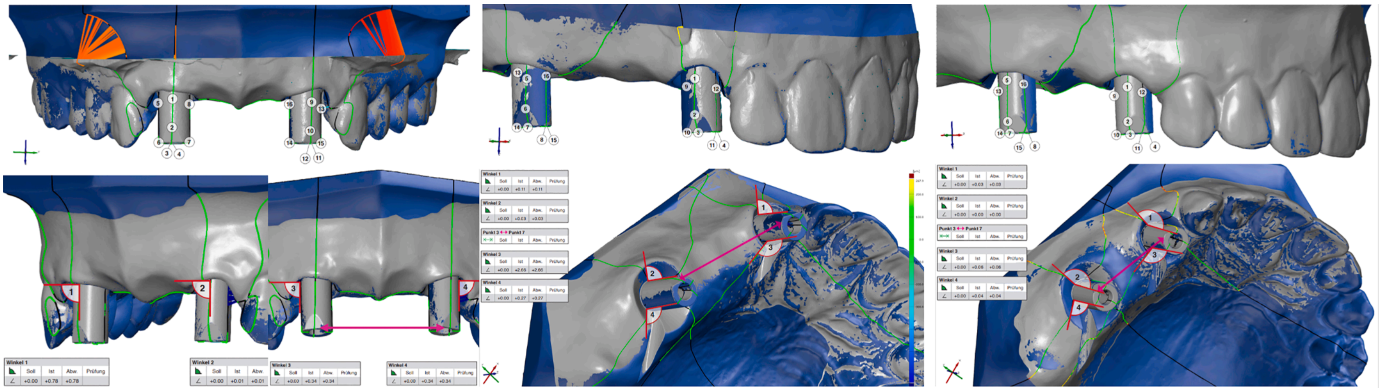

Fig. 3. Overview of points 1-16 (upper images), and angles (lower images) used for the trueness and precision analyses. Angles 1 and 2 were used for buccopalatal, and angles 3 and 4 for mesodistal deviation analyses. Analyzed distances are demonstrated by the violet vector.

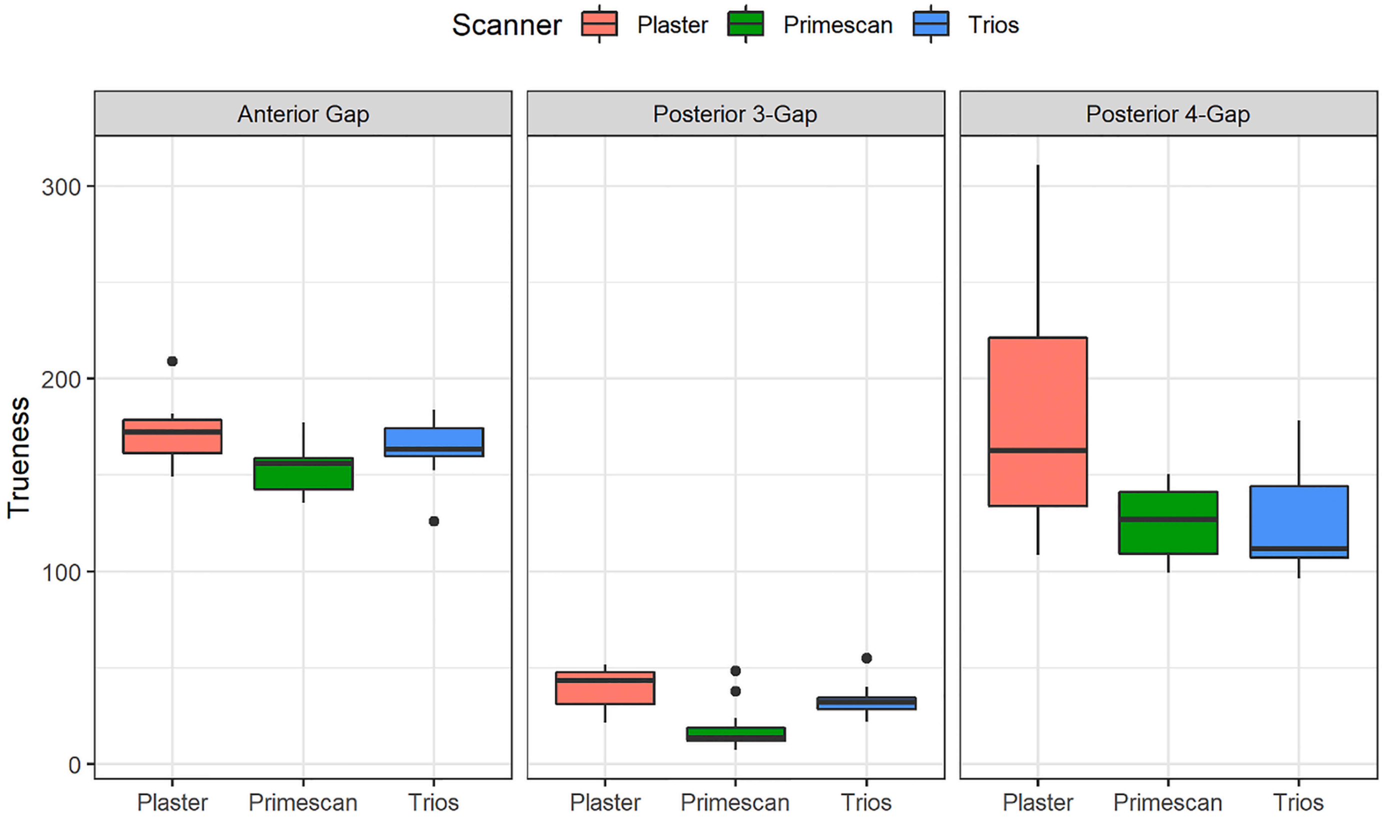

Fig. 4. Trueness analysis: 3D point deviations [μm] between reference and test scans for all workflow-model pairs.

3.2. Precision

When 3D point deviations were concerned, significant differences were found among the precision of workflows of all models (P<.001). DDW-P and DDW-T had higher precision than IDW for models 2 and 3 (P≤.003), while DDW-P also had higher precision than DDW-T (P<.001). For model 1, scans of DDW-P had the highest precision (P<.001) and the difference between DDW-T and IDW was nonsignificant (P=.130) (Table 1).

When distance deviations were concerned, precision significantly differed among workflows in only model 3 (P<.001). IDW had the lowest precision (P<.001), while DDW-P resulted in higher precision than DDW-T (P<.001) (Table 2).

When angular deviations were considered, precision significantly differed among workflows in mesiodistal direction for models 2 and 3 (P<.001), and in buccopalatal direction for model 3 (P<.001). In mesiodistal direction, IDW had the lowest precision (P<.001). In addition, the scans of DDW-P had higher precision than DDW-T for model 3 (P=.005). In buccopalatal direction, DDW-P had the highest precision (P<.001), while DDW-T had higher precision than IDW (P<.001) (Table 3).

3.3. Time efficiency

The type of workflow significantly affected impression and processing durations for all models (P<.001). DDW-P required the least amount of time to complete the entire procedure up to the CAD stage (P≤.008), while DDW-T required lesstime than IDW (P<.001), regardless of the model (Fig. 5).

Table 1

Median and interquartile range (IQR: 25% - 75%) values for 3D point deviations (μm). IDW: Indirect digital workflow; DDW-P: Direct digital workflow by using Primescan; DDW-T: Direct digital workflow by using Trios 3.

Model	Scanner	Trueness (IQR)	Precision (IQR)
Model 2	DDW-P	155.94^{B} (142.4-158.88)	35.21^{b} (29.14-43.87)
	DDW-T	163.48^{A} (159.87-174.32)	57.21^{a} (46.71-86.37)
	IDW	162.78^{A} (133.79-221.33)	100.89^{a} (80.85-124.34)
Model 3	DDW-P	127.03^{B} (108.99-141.07)	47.79^{c} (33.13-59.41)
	DDW-T	111.66^{B} (107.23-144.06)	69.32^{b} (50.38-79.28)
	IDW	43.36^{A} (31.06-47.66)	26.84^{a} (22.39-30.89)
	DDW-P	13.66^{B} (12.15-18.75)	9.18^{c} (6.85-31.33)
	DDW-T	32.05^{A} (28.35-34.34)	21.79^{b} (13.9-31.36)

*Different superscript letters indicate significant differences among impression techniques within each model (Uppercase letters for trueness, lowercase letters for precision) (*P*<.05).

Table 2

Median and interquartile range (IQR: 25% - 75%) values for interimplant distance deviations (μm). IDW: Indirect digital workflow; DDW-P: Direct digital workflow by using Primescan; DDW-T: Direct digital workflow by using Trios 3.

Model	Scanner	Trueness (IQR)	Precision (IQR)
Model 2	DDW-P	20.15^{A} (8-39.28)	21.06^{a} (10.45-45.85)
	DDW-T	11.50^{A} (4.14-34.44)	15.08^{a} (6.45-35.98)
	IDW	33.7^{A} (16.02-36.1)	18.99^{a} (5.2-34)
Model 3	DDW-P	20.58^{A} (1.86-36.17)	29.34^{a} (1.6-34.62)
	DDW-T	21.84^{A} (5.34-36.4)	28.30^{a} (2.54-31.68)
	IDW	6.92^{A} (5.24-11.5)	5.47^{a} (3-9.69)
	DDW-P	2.04^{B} (1.07-3.32)	1.54^{c} (0.8-2.39)
	DDW-T	3.86^{A} (2.98-6.24)	3^{b} (1.11-6.32)

*Different superscript letters indicate significant differences among impression techniques within each model (Uppercase letters for trueness, lowercase letters for precision) (*P*<.05).

Table 3

Median and interquartile range (IQR: 25% - 75%) values for angular deviations. IDW: Indirect digital workflow; DDW-P: Direct digital workflow by using Primescan; DDW-T: Direct digital workflow by using Trios 3.

Model	Scanner	Mesiodistal Direction Trueness (IQR)	Mesiodistal Direction Precision (IQR)	Buccopalatal Direction Trueness (IQR)	Buccopalatal Direction Precision (IQR)
Model 2	DDW-P	0.23^{B} (0.11-0.34)	0.21^{a} (0.11-0.67)	0.33^{A} (0.28-0.4)	0.12^{a} (0.06-0.23)
	DDW-T	0.21^{B} (0.13-0.34)	0.16^{a} (0.07-0.71)	0.21^{A} (0.12-0.29)	0.16^{a} (0.1-0.33)
	IDW	1.26^{A} (0.56-1.99)	0.98^{a} (0.47-1.69)	0.68^{A} (0.62-0.91)	0.36^{a} (0.14-0.54)
Model 3	DDW-P	0.58^{A} (0.36-0.8)	0.37^{b} (0.18-0.68)	0.11^{B} (0.06-0.52)	0.40^{a} (0.06-0.49)
	DDW-T	0.37^{A} (0.18-0.96)	0.44^{b} (0.16-1.03)	0.21^{AB} (0.11-0.58)	0.38^{a} (0.09-0.8)
	IDW	0.34^{A} (0.25-0.45)	0.14^{a} (0.07-0.26)	0.18^{A} (0.13-0.29)	0.12^{a} (0.06-0.17)
	DDW-P	0.06^{B} (0.04-0.09)	0.04^{c} (0.02-0.06)	0.04^{B} (0.03-0.06)	0.03^{c} (0.01-0.04)
	DDW-T	0.08^{B} (0.07-0.16)	0.06^{b} (0.03-0.11)	0.06^{B} (0.04-0.10)	0.04^{b} (0.01-0.12)

*Different superscript letters indicate significant differences among impression techniques within each model and direction (Uppercase letters for trueness, lowercase letters for precision) (*P*<.05).

4. Discussion

Significant differences were observed in scan trueness and precision of tested workflows. Therefore, the first and the second null hypotheses were rejected.

Even though making conventional impressions and subsequent cast fabrication have been considered as standard for the fabrication of FPDs [5, 11], IDW generally had lower accuracy in the present study. Despite the fact that recommended relaxation time of the impression material was followed, stiffness of the metal models might have led to the distortion of the impression [19], which could explain large deviations with digitized casts. Another reason might be the preliminary steps; implant analogs had to be screwed on impression posts, the impressions had to be poured, and SBs had to be manually mounted to the implant analogs [35] before digitizing implant models as these steps are prone to operator-induced error. Considering relatively small effect of impression post splinting for parallel implants on the impression accuracy [20], splinting was not performed.

In the present study, DDW-P and DDW-T had deviations that were either similar to or lower than those with IDW. Even though conventional impressions were reported to have higher accuracy than IOSs for implant-supported FPDs and particularly for large inter-implant distances [36], variations in methodologies may lead to different results as superimposition algorithms affect measured deviations [37]. Previous studies investigating scan accuracy of implant-supported FPDs digitized with IOSs, by using global best-fit algorithm for superimpositions, reported smaller deviations than those measured in the present study [8, 38]. Studies on single implants, which used a methodology similar to that in present study [7, 17, 25] also support this hypothesis, as in Yilmaz et al's [25] study, reported greatest mean 3D point deviation was 178 μm for IOSs and 197 μm for digitized casts. In the same study [25], mean mesiodistal angular deviations were 0.27° for IOSs and 0.91° for digitized casts. Considering that IOSs have already been recommended for the fabrication of implant-supported single crowns [36], and digitized casts mostly led to higher deviations in the present study, the authors believe that tested IOSs may be alternatives to digitized casts for 2 implant-supported FPDs.

It has been shown that the extent of the edentulous area affected scan accuracy as large edentulous areas led to greater deviations [4, 28, 29]. The results of the present study are in line with this finding as, even though no statistical analysis was performed, Model 3 had lower deviations than other models for each impression technique. Nevertheless, given that the greatest median inter-implant distance deviation measured was 33.7 μm, it can be speculated that implant-supported FPDs fabricated by using tested impression techniques would have clinically acceptable fit, as reported misfit value for implant-supported restorations varied from 10 μm to 150 μm [39, 40]. However, the authors are unaware of a longitudinal clinical study on maximum misfit, and there could be deviations at proximal or occlusal contacts [6], which should be tested clinically.

Along with scan accuracy, present study also focused on the time needed beginning from the impression to when CAD can be started. DDW-P had the shortest combined impression and processing duration followed by DDW-T and digitization of casts. Therefore, the third null hypothesis was also rejected. DDW-P and DDW-T had favorable results when compared with IDW. Previous studies on time efficiency of IOSs have mostly focused on the impression time and the time spent in the laboratory [9, 12, 41]. However, the time required for data post-processing, data export, and import were mostly not considered. Although DDW-P had higher time efficiency compared with DDW-T, it

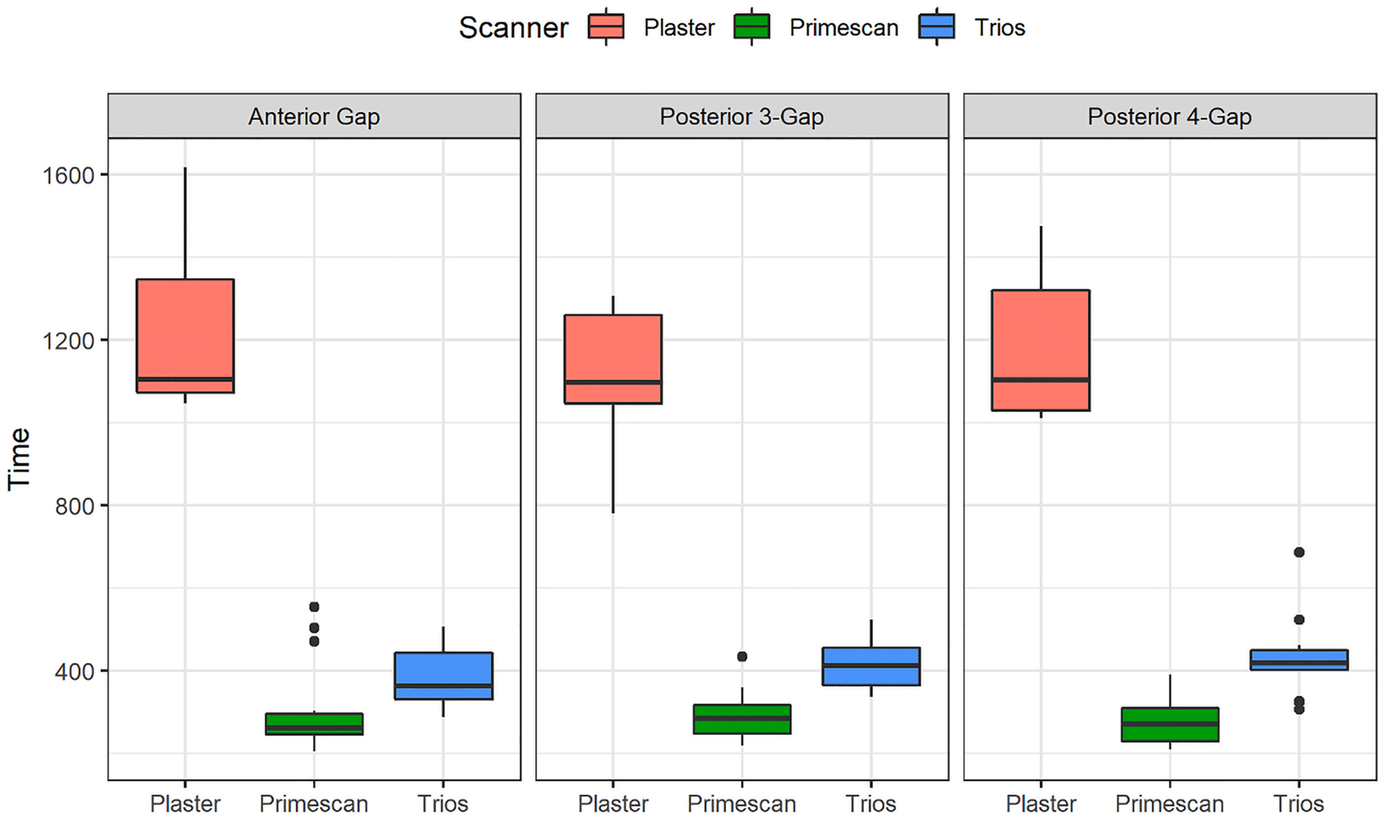

Fig. 5. Time analysis: Time elapsed [seconds] during digitization and subsequent import into computer aided design (CAD) software for all workflow-model pairs.

should be noted that this result cannot be extrapolated to different test arrangements. In situations, where the data do not have to be exported from IOS and later imported into the CAD software, the results could be different.

Superimpositions were performed by using a metrology-grade 3D analysis software and global best-fit algorithm without including the SB surface data. This software-algorithm pair has been recommended for accuracy analyses [1, 2]. In addition, global best-fit algorithm has higher repeatability as local-best fit algorithm involves manual selection that is prone to errors [1]. Given the fact that SBs were screwed only once for IOSs and for more than once for the digitization of casts, the inclusion of SB surface data during superimpositions could have been disadvantageous for the IDW group.

The in vitro setup of the present study has limitations. Scans performed by using tested IOSs were standardized and the conditions of the room in which these scans were performed corresponded to previously described ideal conditions [24]. The scans were performed on a phantom head with an opposing jaw to simulate intraoral conditions as accurately as possible. However, potential patient-related factors that could affect the scan accuracy could not be fully simulated [17]. The results of the present study are limited to 2 IOSs tested. Even though these IOSs are commonly used and their accuracy has been shown to be high [10, 13, 21], IOS type may affect scan accuracy [8]. Conventional impressions were made by using stock impression trays, yet, custom trays may lead to different results. Implants were placed parallel to each other in the present study. Because implant angulation may affect the accuracy of an impression, results may differ when implants are not placed parallel to each other [20]. Metal models were used considering their dimensional stability [31]. Even though a scan spray had to be used to facilitate the scans of reflective metal surfaces [3] and sprayed surfaces were not touched until all scans were completed, an inconsistent powder thicknesses might have affected the results. In addition, the results may change when a scan spray is not used or a different material is used for model fabrication. The results of the present study should be substantiated with future in vivo studies, in which implant-supported FPDs fabricated by using tested impression techniques are evaluated for their fit, and occlusal and proximal contacts.

5. Conclusions

Within the limitations of this in vitro study, it can be concluded that scans performed by using direct digital workflows had trueness and precision that were either similar to or higher than when indirect digital workflow was used. In addition, scan accuracy of DDW-P was either similar to or higher than that of DDW-T. DDW-P had the highest time efficiency, whereas, IDW had the lowest, regardless of the model.

Author contributions

Samir Abou-Ayash: Conceptualization, Data curation, Formal analysis; Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Drafting initial manuscript, reviewing and confirming final version

Amber Mathey: Investigation, Visualization, Drafting initial manuscript, Reviewing and confirming final version

Fabio Gäumann: Investigation, Visualization, Drafting initial manuscript, Reviewing and confirming final version

Ayse Mathey: Conceptualization, Funding acquisition, Methodology; Reviewing and confirming final version

Borga Donmez: Validation, Visualization, Drafting initial manuscript, Reviewing and confirming final version

Burak Yilmaz Conceptualization, Project administration, Methodology, Validation, Visualization, Reviewing and confirming final version

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Declaration of Competing Interest

The authors declare no conflict of interest. The authors do not have any financial interest in the companies whose materials are included in this article.

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