In Vitro Comparison of the Accuracy of Conventional Impression and Four Intraoral Scanners in Four Different Implant Impression Scenarios

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Purpose: The aim of this study was to compare the trueness and precision of four intraoral scanners (IOSs) and splinted open-tray conventional implant impression (SOCI) in partial and total edentulism. Materials and Methods: Four gypsum models (Model A—implants at mandibular right second molar, right second premolar, and right canine; Model B—implants at mandibular right canine, left central incisor, and left canine; Model C—implants at mandibular right second molar, right second premolar, right canine, left central incisor, and left canine; and Model D—implants at mandibular right second molar, right second premolar, right canine, left central incisor, left canine, left second premolar, and left second molar) were prepared, and four different IOSs (Aadva IOS, CS 3600, Trios 3, and Emerald) and one polyvinyl siloxane (PVS) were used. Reference models were digitized with a high-resolution industrial scanner, and data were superimposed. Root mean square (RMS) values were calculated by software and defined as deviation values after superimposition. The one-way analysis of variance (ANOVA) test and Tukey honest significant difference (HSD) test were performed to analyze the data (P < .05). Results: For Models A and B, the truest impressions were made with Aadva, followed by CS 3600, PVS, Trios 3, and Emerald, respectively, while for Model C, the truest impressions were made with CS 3600, followed by Aadva, PVS, Trios 3, and Emerald, and for Model D, the truest impressions were made with Aadva, followed by CS 3600, PVS, Emerald, and Trios 3 (P < .05). There was no statistical difference between groups for precision in Models A, B, and C (P > .05); however, PVS showed lower precision values than other groups in Model D (P < .05). Conclusion: In partial edentulism, IOSs are true and precise as SOCI except Emerald. However, the trueness of IOSs is not favorable in total edentulism cases. SOCI with PVS in total edentulism treated with implants is less precise than IOSs. Int J Oral Maxillofac Implants 2022;37:39–48. doi: 10.11607/jomi.9172

Keywords: accuracy, conventional impression, digital impression, implant impression, intraoral scanner, trueness

The most current and preventive option for the treatment of partial or total edentulism is to provide the patient with dental implants.1 The passive fit of the restoration is crucial for long-term success.1,2 Therefore, accurate transfer of the three-dimensional implant position to the laboratory is a key factor in avoiding badly fitting restorations and achieving long-term success of the treatment.3–5

The accuracy of an impression is defined by means of trueness and precision.6–8 Trueness can be defined as the closeness of the impression to the reference, and precision can be defined as the repeatability or reproducibility of the impression, which means consistency in repeated impressions.6–8 In other words, trueness is the deviation amount between the test object and the reference object; precision is the repeatability of the deviation amount between repeated measurements. Therefore, an impression technique or material could be defined as follows: true and precise means the deviation amount between the test and the reference is not high and deviation amounts do not differ among repeated measurements; true but not precise means the deviation amount is not high but is not consistent in repeated measurements; not true but precise means the deviation amount is high but is consistent in repeated measurements; not true or not precise that means the deviation amount is both high and not consistent.8,9

With recent developments in technology, intraoral scanners (IOSs) have become more widely used.10 Current IOS devices have different working principles and are able to collect the data on shape and size of intraoral tissues through the emission of light beams.11–13 The captured data are processed on special 3D software, which then reconstructs a fully digital 3D model. Digital impressions have many advantages over conventional impressions, such as the possibility of immediate determination of the quality of the impression, that the procedure is rapid, that...
it causes less environmental residue, that it saves time and space, the ease of sending the models to the laboratory, and that they are well tolerated by patients, especially those with a gag reflex.8,9,14 Moreover, digital impressions have many advantages in implant impression, such as elimination of misfit of conventional impression copings or micromotion between the impression copings and analogs and elimination of the limitations due to dimensional stability of impression material or pouring material of the master model.8,15 Although IOSs are commonly available in daily practice, the limitations of these devices have not been fully defined.16

There are a limited number of studies in the literature that have investigated the trueness and precision of digital impression systems in different clinical situations.17–19 There are several studies that have evaluated the trueness and precision of IOSs and made comparisons with conventional implant impressions.16,20 However, the investigation of the trueness and precision of a digital impression system in different clinical situations is lacking. Most of the available studies have either evaluated first-generation IOSs,21–24 or the study was conducted on one16,25,26 or two master models8,10,27 simulating limited clinical situations. The behavior of different IOSs in different clinical situations, the effect of curvature presence, and the length of the edentulous area are still uncertain, and there is no evidence in the literature to clarify these points, as there have been no evaluations of the effect of curvature and length of impression area on digital or conventional impression methods for implant-supported prostheses.

The superimposition technique is conducted by using reverse engineering software, and the software calculates the differences between two virtual models. There are many studies in the literature using this technique7,8,10,16; however, the color maps that are generated by software were not evaluated in any studies. The visuals of the color maps give many opinions about the behavior of the IOSs and their clinical appliance.

The aim of this study was to compare the trueness and precision of digital and conventional impressions in four clinical situations and observe the behavior of different IOSs. The null hypotheses of the study were as follows: (1) The presence of curvature and the length of the edentulous area do not affect the trueness and precision of conventional and digital impression techniques; (2) there is no difference between conventional and digital impression techniques in terms of trueness and precision of implant impression.

MATERIALS AND METHODS

Four different clinical situation scenarios were designed for the study, and each scenario was represented with a model. To create study models, a typodont mandibular model (Frasaco Study Model ANA-4, Frasaco) was used. The teeth related to the specific scenario were extruded from the typodont model, and the implant analogs (4.2-mm diameter, Bone Level Implant Analogos, Straumann) in all models were inserted with 2-mm gingival height and 0 degrees. Pontic areas were filled with polyvinyl siloxane silicone material that is used for gingival reproduction in the laboratory (GingiFast Rigid, Zhermack). After the typodont model was set, impressions were made with the open tray and splinted technique. Finally, four different gypsum models (GC Fujirock EP, GC Europe) inserted with implant analogs were poured (Fig 1). The first gypsum model was a partially edentulous mandible with three implant analogs inserted (4.2-mm diameter, Bone Level Implant Analogos, Straumann) at the posterior site in a linear positioning (right second molar, right second premolar, and right canine; Model A). The second model was a partially edentulous mandible with three implant analogs inserted at the anterior site in a curvature (right canine, left central incisor, and left canine; Model B). The third model was a partially edentulous mandible with five implant analogs containing both posterior and anterior zones with linear and curvature positioning (right second molar, right second premolar, right canine, left central incisor, and left canine; Model C). The fourth model was a fully edentulous mandible with seven implant analogs inserted (right second molar, right second premolar, right canine, left first incisor, left canine, left second premolar, and left second molar; Model D). Polyether-ether-ketone (PEEK) scanbodies (Scanbody, Straumann) were used for the master model digitization and digital impression procedures.

Four different IOSs (Trios 3, 3Shape; Aadva IOS, GC; CS 3600, Carestream; Emerald, Planmeca) were used for the digital impression groups (Table 1). Polyvinyl siloxane (PVS) impression material (Hydrorise Implant, Zhermack) was used for the conventional impression group. One operator (D.S.A.) performed all the impression-making procedures for digital and conventional impression groups.

Prior to digitization of the master models and impression making, small and superficial holes were made with a diamond bur and marked with a black pen to create borders for superimposition. To digitize the master models, scanbodies were inserted on each implant analog, and the models were scanned with a high-resolution industrial desktop scanner (Solutionix C500, MEDIT) with 1- to 6-µm accuracy.28 After calibration of the industrial scanner, each model was scanned, and the standard tessellation language (STL) files were imported into software (Geomagic Studio 2012, Geomagic) as the reference model.

During the digital impression making, the study models were scanned 10 times with each IOS. During
the scanning, one specific scan pattern was followed, as has been previously described in the literature, starting from the occlusal-palatal surfaces of the most distal tooth/scanbody, moving toward the other side of the arch and always including two surfaces, and returning from the buccal side. Four adjacent teeth were scanned for Models A and B, and two adjacent teeth were scanned for Model C to create more reference for superimposition. After all scans were completed, the data were saved as an STL file.

For conventional impression making, splinted open-tray implant-level impression making with PVS (Hydrosi Implant) was preferred. Ten impressions for each model were made using PVS impression material at room temperature. Ten type IV stone casts (GC Fujirock EP, GC Europe) were created. All the stone casts were stored for 1 week at room temperature to complete delayed expansion and were then digitized with a high-resolution industrial scanner (Solutionix C500, MEDIT).

The trueness and precision assessment was made digitally with superimposition, using reverse engineering software (Geomagic Studio 2012, Geomagic) as described previously. All STL data were imported into Geomagic software, and the “mesh doctor” tool was used to remove any unexpected artifacts with no touch to the study model, such as the platform on which the models were placed during the scanning with the industrial scanner with the “cut by plane” tool. Then, the digital models were trimmed with the same tool and with the guidance of the small black dots created to standardize the surface area of superimposition. The superimposition process followed three steps: three-point registration on the scanbodies, also known as “rough alignment,” then application of the best-fit alignment function. Mean deviation values and SDs were calculated by root mean square (RMS) values that were reported by the software and defined as trueness value. For precision, the difference between the mean distortion value of the group and the individual scan was calculated and reported as the precision value of the scan.

To be able to visualize the trueness of the impression, a color-coded map was created with the “3D deviation” tool. Each color map was generated with a scale between red and dark blue and green at the center. According to the scale, a light green color means the ideal impression, and from light green to dark blue, the map

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**Table 1** Intraoral Scanners Used in the Study

<table>
<thead>
<tr>
<th>Intraoral scanner</th>
<th>Manufacturer</th>
<th>Working principle</th>
<th>Powder</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aadva IOS</td>
<td>GC</td>
<td>Confocal microscopy</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CS 3600</td>
<td>Carestream Dental</td>
<td>Structured light—Active Speed 3D Video</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Emerald</td>
<td>Planmeca</td>
<td>Red, green, and blue lasers—Projected Pattern Triangulation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Trios 3</td>
<td>3Shape</td>
<td>Structured light—Confocal microscopy and Ultrafast Optical Scanning</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Fig 1 Study models. (a) Model A with three implants in linear positioning. (b) Model B with three implants located in curvature. (c) Model C with five implants located linearly and in curvature. (d) Model D with seven implants in full arch.
shows the negative deviation areas that mean the test scan is dimensionally smaller than the reference scan. From light green to dark red colors, the map shows the positive deviation areas that mean the test scan is dimensionally larger than the reference scan. In the color mapping, the color scale ranged from ± 0.020 mm representing the ideal impression32 to ± 0.150 mm as the clinically acceptable limit.19 All the color-mapping visuals were observed by one operator, and noticeable results were noted.

Data obtained in the study were analyzed statistically using NCSS software (Number Cruncher Statistical Systems 2007). Descriptive statistical methods (mean, SD, frequency, percentage, minimum, and maximum) were used to evaluate the study data. The conformity of quantitative data to normal distribution was tested with the Shapiro-Wilk test. Two-way analysis of variance (ANOVA) was conducted to examine the effects of impression method and groups (models) variables on the general accuracy value. While the trueness and precision were included in the analysis as dependent, the main effects of the impression method and groups (models) variables and the interactions of these two variables (impression method*groups) were included as independent factors. One-way ANOVA and Tukey honest significant difference (HSD) tests were used to evaluate significant interactions. A value of $P < .05$ was accepted as statistically significant.

### RESULTS

It was determined that the two-way analysis obtained as a result of the evaluation performed was statistically significant and the independent variables could explain 77.6% of the variance of the dependent variable (F: 37.313, $P < .001$, R2adj: 0.776). The fact that the impression method*groups interaction was significant in the analysis shows that the difference observed between the groups in all impression methods is not the same. Similarly, it can be interpreted that the difference observed between impression methods in all groups is not the same. Therefore, post hoc evaluations were carried out to analyze the significance in interaction.

The mean and SD values of the groups of trueness analysis are summarized in Table 2. For Model A, there was a statistically significant difference between the impression groups in terms of precision values ($P = .005$). As a result of Tukey tests, the values of Aadva were determined to be statistically higher than those of Trios 3 ($P = .032$), Emerald ($P = .012$), and PVS ($P = .010$). For Models B and C, there was no statistically significant

<table>
<thead>
<tr>
<th>Trueness</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>aP</th>
<th>bP (A–B)</th>
<th>bP (A–C)</th>
<th>bP (A–D)</th>
<th>bP (B–C)</th>
<th>bP (B–D)</th>
<th>bP (C–D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trios</td>
<td>0.12 ± 0.06</td>
<td>0.09 ± 0.03</td>
<td>0.14 ± 0.02</td>
<td>0.21 ± 0.02</td>
<td>&lt; .001**</td>
<td>.300</td>
<td>.739</td>
<td>&lt; .001**</td>
<td>.039*</td>
<td>&lt; .001**</td>
<td>.001**</td>
</tr>
<tr>
<td>Aadva</td>
<td>0.05 ± 0.02</td>
<td>0.05 ± 0.01</td>
<td>0.09 ± 0.03</td>
<td>0.17 ± 0.06</td>
<td>&lt; .001**</td>
<td>.988</td>
<td>.093</td>
<td>&lt; .001**</td>
<td>.045*</td>
<td>&lt; .001**</td>
<td>.001**</td>
</tr>
<tr>
<td>CS 3600</td>
<td>0.06 ± 0.01</td>
<td>0.06 ± 0.01</td>
<td>0.06 ± 0.01</td>
<td>0.18 ± 0.03</td>
<td>&lt; .001**</td>
<td>.933</td>
<td>.966</td>
<td>&lt; .001**</td>
<td>.999</td>
<td>&lt; .001**</td>
<td>.001**</td>
</tr>
<tr>
<td>Emerald</td>
<td>0.18 ± 0.05</td>
<td>0.23 ± 0.03</td>
<td>0.22 ± 0.04</td>
<td>0.20 ± 0.03</td>
<td>.096</td>
<td>.090</td>
<td>.255</td>
<td>.776</td>
<td>.947</td>
<td>.464</td>
<td>.791</td>
</tr>
<tr>
<td>PVS</td>
<td>0.08 ± 0.02</td>
<td>0.09 ± 0.02</td>
<td>0.09 ± 0.02</td>
<td>0.19 ± 0.05</td>
<td>&lt; .001**</td>
<td>.761</td>
<td>.567</td>
<td>&lt; .001**</td>
<td>.988</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
</tr>
<tr>
<td>aP</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>.333</td>
<td></td>
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<tr>
<td>bP (1–2)</td>
<td>0.02**</td>
<td>.01**</td>
<td>.002**</td>
<td>.347</td>
<td></td>
<td></td>
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<tr>
<td>bP (1–3)</td>
<td>0.007**</td>
<td>.075</td>
<td>&lt; .001**</td>
<td>.594</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>bP (1–4)</td>
<td>.004**</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>.995</td>
<td></td>
<td></td>
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<tr>
<td>bP (1–5)</td>
<td>.095</td>
<td>.999</td>
<td>.005**</td>
<td>.770</td>
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<td></td>
<td></td>
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<tr>
<td>bP (2–3)</td>
<td>.991</td>
<td>.399</td>
<td>.194</td>
<td>.994</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>bP (2–4)</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>.583</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>bP (2–5)</td>
<td>.589</td>
<td>.001**</td>
<td>.997</td>
<td>.954</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>bP (3–4)</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>&lt; .001**</td>
<td>.825</td>
<td></td>
<td></td>
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<tr>
<td>bP (3–5)</td>
<td>.851</td>
<td>.076</td>
<td>.094</td>
<td>.998</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

*One-way analysis of variance.

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difference between the groups in terms of precision ($P = .833$, $P = .149$). For Model D, the values of Trios 3 were lower than those of CS 3600 ($P = .048$; Table 3).

A statistically significant difference in precision was determined between the study models for each impression group. For Aadva, CS 3600, Emerald, and Trios 3, there was no statistically significant difference between the models in terms of precision values ($P = .056$, $P = .077$, $P = .383$, $P = .081$; Table 3). A statistically significant difference was determined between the models in terms of precision values for PVS ($P = .001$). As a result of Tukey tests, Model A and C values were found to be statistically significantly lower than the Model D values ($P = .046$, $P = .003$; Table 3).

According to color-mapping analyses, in the Aadva group, there are higher distortion areas color coded with red and dark blue on scanbodies, especially on their mesial, distal, and occlusal surfaces (Figs 3 and 4). CS 3600 showed higher distortion at the last scanned area of the scan, the mesial, distal, and occlusal surfaces of the scanbodies. However, the edentulous areas between the scanbodies and teeth surfaces look

---

**Table 3**  **Mean ± SD Values of Precision (mm)**

<table>
<thead>
<tr>
<th>Precision</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>$^aP$</th>
<th>$^bP$ (A–B)</th>
<th>$^bP$ (A–C)</th>
<th>$^bP$ (A–D)</th>
<th>$^bP$ (B–C)</th>
<th>$^bP$ (B–D)</th>
<th>$^bP$ (C–D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Trios</td>
<td>0.05 ± 0.02</td>
<td>0.08 ± 0.03</td>
<td>0.05 ± 0.03</td>
<td>0.09 ± 0.04</td>
<td>.081</td>
<td>.796</td>
<td>.999</td>
<td>.482</td>
<td>.602</td>
<td>.996</td>
<td>.077</td>
</tr>
<tr>
<td>2 Aadva</td>
<td>0.18 ± 0.08</td>
<td>0.08 ± 0.04</td>
<td>0.08 ± 0.07</td>
<td>0.13 ± 0.07</td>
<td>.056</td>
<td>.305</td>
<td>.101</td>
<td>.652</td>
<td>.998</td>
<td>.647</td>
<td>.144</td>
</tr>
<tr>
<td>3 CS 3600</td>
<td>0.13 ± 0.05</td>
<td>0.07 ± 0.02</td>
<td>0.09 ± 0.06</td>
<td>0.14 ± 0.06</td>
<td>.077</td>
<td>.577</td>
<td>.766</td>
<td>.988</td>
<td>.924</td>
<td>.198</td>
<td>.147</td>
</tr>
<tr>
<td>4 Emerald</td>
<td>0.03 ± 0</td>
<td>0.09 ± 0.07</td>
<td>0.07 ± 0.06</td>
<td>0.09 ± 0.06</td>
<td>.383</td>
<td>.576</td>
<td>.676</td>
<td>.346</td>
<td>.964</td>
<td>.999</td>
<td>.862</td>
</tr>
<tr>
<td>5 PVS</td>
<td>0.03 ± 0</td>
<td>0.06 ± 0.02</td>
<td>0.04 ± 0.02</td>
<td>0.12 ± 0.07</td>
<td>.001**</td>
<td>.891</td>
<td>.988</td>
<td>.046*</td>
<td>.942</td>
<td>.290</td>
<td>.003**</td>
</tr>
</tbody>
</table>

$^aP .005** | .833 | .149 | .012* |
$^bP (1–2) | .325 | .989 | .427 | .048* |
$^bP (1–3) | .964 | .998 | .859 | .999 |
$^bP (1–4) | .936 | .949 | .973 | .455 |
$^bP (1–5) | .548 | .974 | .981 | .999 |
$^bP (2–3) | .012* | .999 | .999 | .132 |
$^bP (2–4) | .010* | .911 | .396 | .890 |
$^bP (2–5) | .132 | .937 | .946 | .083 |
$^bP (3–4) | .110 | .999 | .152 | .796 |
$^bP (3–5) | .999 | .844 | .506 | .595 |

*One-way analysis of variance.

**Tukey HSD.

$^*P < .05.$

$^{**}P < .01.$

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mostly green or yellow (Figs 3 and 4). In the Emerald group, most of the specimens showed high distortion areas color coded with red and dark blue on almost every surface of the scanbodies. In addition, a halo-shaped dark blue area can be noticed in the center of the scanbodies (Figs 3 and 4). The trueness of the impression taken with Emerald does not appear to be favorable, as it is hard to find continuous green-yellow areas. Trios 3 showed higher distortion areas at the occlusal surfaces of the scanbodies. However, teeth surfaces and edentulous areas were mostly green in partially edentulous models (Figs 3 and 4). In the conventional impression group, only occlusal surfaces of the scanbodies appeared to be in dark blue in some specimens (Figs 3 and 4). In addition, all the digital impression groups showed red and dark blue color-coded areas at the interface areas between the scanbody and adjacent tooth (Figs 3 and 4).

Fig 3  Color-mapping visuals of Models A: (a-1) Aadva, (a-2) CS 3600, (a-3) Emerald, (a-4) Trios 3, and (a-5) conventional impression. Color-mapping visuals of Models B: (b-1) Aadva, (b-2) CS 3600, (b-3) Emerald, (b-4) Trios 3, and (b-5) conventional impression.
DISCUSSION

Due to the lack of knowledge about the effect of length of edentulous area and presence of curvature in different models, the aim of the present study was to investigate the behavior of conventional impression and IOSs in different situations and define the trueness values in four different clinical situations. According to the results of the present study, presence of curvature did not affect the trueness and precision between PVS and IOSs; however, length of the edentulous area affected trueness and precision (Tables 2 and 3). Therefore, the first null hypothesis was partially rejected. A statistically significant difference was determined between digital and conventional impression techniques in implant impression (Tables 2 and 3). Therefore, according to the results of this study, the null hypotheses were partially rejected.

Fig 4  Color-mapping visuals of Models C: (a-1) Aadva, (a-2) CS 3600, (a-3) Emerald, (a-4) Trios 3, and (a-5) conventional impression. Color-mapping visuals of Models D: (b-1) Aadva, (b-2) CS 3600, (b-3) Emerald, (b-4) Trios 3, and (b-5) conventional impression.
The present study may be identified as unique in terms of leading the clinical effectiveness of the IOSs and conventional impression in implant impressions, as until the present study was designed and conducted, no study existed that investigated the effect of presence of curvature and length of edentulous area with various models. Therefore, it is not easy to compare the results of the study with others in terms of the effect of curvature and length. Nevertheless, there are some that evaluated the accuracy of digital and conventional impression techniques in implant impression.\(^7,8,10,33–35\)

Recently, Mangano et al\(^8\) published a comparative in vitro study about the trueness and precision of five IOSs in the impressions of single and multiple implants. In their study, two models were prepared for partial and total edentulism, simulating three different clinical conditions: single crown, three-unit prosthesis, and full-arch implant impression. The models were scanned with five different IOSs (CS 3600, DWIO, Omnicam, and Trios 3). The reference models were digitized with an industrial scanner, and superimposition was conducted by reverse-engineering software for true-ness and precision measurements. At the end of their study, CS 3600 had the best trueness and precision results, followed by Trios 3, DWIO, Omnicam, and Emerald in the single crown group. In the three-unit prosthesis group, CS 3600 had the best trueness and precision results, followed by Trios 3, Omnicam, Emerald, and DWIO. In the full-arch group, CS 3600 had the best trueness and precision results, followed by Trios 3, Emerald, Omnicam, and DWIO. Significant differences were found between the IOSs; a significant difference in trueness was found between the contexts (single crown vs three-unit prosthesis vs full arch). Three IOSs (CS3600, Emerald, and Trios 3) were in both their study and in the present study, and the authors think it is a good chance to review the results comparatively. The relationship between the common groups (CS3600, Emerald, and Trios 3) were similar in both studies.

In another in vitro study, two stone models were prepared, representing a partially and a totally edentulous maxilla, with three and six implant analogs, respectively.\(^7,8,10,33–35\) The study models were digitized with an industrial scanner (JScan D104I) used as a reference, and with four IOSs (Trios, CS 3500, Zfx Intrascan, and Planscan). All datasets were superimposed with the reference model, and the deviations were calculated using the RMS values. In both partially and totally edentulous models, CS 3500 showed the lowest distortions, followed by Trios, Zfx Intrascan, and Planscan, respectively. In the present study, the three newest versions of the IOSs in that study were used (CS 3600, Trios 3, and Emerald). The relationship between similar groups with different versions was also similar, and the results of the previous study supports the results of the present study.

Imburgia et al\(^11\) compared the accuracy of four different IOSs in two different study models and reported that the deviation values of the three implanted models with partial edentulism were obtained at the lowest with CS 3600, followed by Trios 3, Cerec Omnicam, and True Definition, respectively. In the present study, Aadva showed the truest impression group from Model A, followed by CS 3600, Trios 3, and Emerald, respectively. The relationship between common groups was similar in both studies.

The fact that the methodology between the mentioned studies\(^7,8,10\) and the present study is similar and the relationship between the IOSs is similar strengthens the reliability of the results of the present study. Besides, the authors think that the difference between these devices is due to their different working principles.

Alsharbaty et al\(^35\) compared digital (Trios 3) and conventional impression groups in 36 patients with two implants placed in the posterior region. The results of the study showed that the deviation values obtained from Trios 3 were significantly higher than those of conventional impression.\(^35\) The relationships between the groups in the present study were similar to the findings of them. However, the deviation values in their study were much higher than the results of the present study. This difference may be attributed to the fact that the distortion obtained from in vitro studies may become greater in intraoral situations.\(^36\)

According to the trueness data (Table 2), only the PVS and Emerald groups showed an increase in distortions in presence of curvature; however, the difference was not statistically significant. On the other hand, the length of edentulous area had a negative effect on all the groups. In addition, total edentulism had a negative effect on the trueness of the conventional impression.

According to the precision values (Table 3), the results were consistent for all IOSs, at least for the models that simulate partial edentulism. However, it must be noted that the length of the edentulous area affected the precision negatively.

In the color-mapping point of view, it was possible to observe the general behaviors of the IOSs used in this study. The color-mapping visuals showed that Aadva has limitations in the impression making of implant–natural tooth interference, which means that the axial walls of the tooth surface and scanbody surface were facing each other, and the discrepancies increased at the distal walls of scanbodies. In addition, the longer the scanning area, the more discrepancies occurred at the last abutment, irrespective of tooth or scanbody. CS 3600 showed increased discrepancies at the top of scanbodies in many impressions, color coded in red. Also, the lingual walls of the scanbodies located in the anterior zone resulted in more discrepancies than the rest. Emerald showed circular artifacts in the center of many
Discrepancies up to 30 to 150 μm between frameworks and abutments have been stated as clinically acceptable to prevent biologic and technical complications. The conventional impression group and four out of five digital impression groups (except Emerald) showed clinically acceptable discrepancies in partial edentulism (Models A, B, and C; Table 2 and Fig 2). However, the trueness deviations of Emerald were higher than the acceptable limits in all the models. Recently published studies are working on the mesh quality of the IOSs and evaluating the results with different superimposition methods. IOSs used in the present study were chosen with different working principles rather than being repetitive of one another. Therefore, the authors believe that the difference between the IOSs may be related to the different working principles the devices have or the data processing software. However, there is either not enough evidence about the mesh quality of the scans or more than one superimposition method that can conclude the results about the difference among IOSs.

There are some limitations of this study. First, as it was an in vitro study, it was not possible to simulate the oral situation, including the effect of saliva and the lack of light in the oral cavity, which may have a direct effect on digital impressions. The conditions were optimal for impression making, and the experiments were conducted at room temperature. However, the PVS material may behave differently at intraoral temperature. Second, the study models were prepared from gypsum and compared with transparent tooth surfaces or soft tissue surfaces; the scan data on plaster surfaces may reflect a different behavior of the scanners. In addition, the only parameter that was evaluated was the accuracy and the different scenarios. To evaluate the effect of the implant positioning, no other clinical parameter was included, such as gingival depth, connection type, or implant angulation. There is no evidence in the literature about which scanning strategy is better for partial edentulism. No statistically significant differences were found between the groups in precision for partial edentulism. IOSs showed high deviation values in Model D. Therefore, the digital impression technique using IOSs for full-arch implant-supported restorations is not still favorable. The Emerald group showed unfavorable deviations in all models.

CONCLUSIONS

Under the limitations of this study, it is concluded that in partial edentulism situations treated with implants, digital and conventional impression techniques can be preferred. Aadva, CS 3600, and Trios 3 showed similar deviations as conventional impression with PVS in Models A, B, and C. Presence of curvature and length of the edentulous area did not affect the trueness of PVS in partial edentulism. No statistically significant differences were found between the groups in precision for partial edentulism. IOSs showed high deviation values in Model D. Therefore, the digital impression technique using IOSs for full-arch implant-supported restorations is still not favorable. The Emerald group showed unfavorable deviations in all models.

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REFERENCES


