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Conventional versus digital impression accuracy in maxillary and mandibular all-on-4 prostheses: An *in vitro* study

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Abstract:
Accurate impression making is essential for achieving passive fit and long-term success of All-on-4 implant-supported prostheses, and this study compared the accuracy of conventional and digital impression techniques for maxillary and mandibular All-on-4 restorations. Sixty impressions were allocated into four groups (n = 15 each): maxillary digital, maxillary conventional, mandibular digital, and mandibular conventional; conventional impressions were made using an open-tray splinted elastomeric technique, whereas digital impressions were obtained with the Medit i600 intraoral scanner and analyzed using Medit Design 2.1.4 software. Mean deviations ranged from −0.004 to 0.154 mm in the maxilla and from −0.069 to 0.225 mm in the mandible, with no significant difference in overall trueness between arches ($p > 0.05$). Digital impressions showed accuracy comparable to conventional impressions, with greater reproducibility in the maxillary arch and slightly higher variability in the mandibular arch. Thus, data shows the Medit i600 digital workflow proved to be a reliable alternative to conventional impression techniques for complete-arch All-on-4 implant-supported prostheses.

Keywords: All-on-4, digital impression, conventional impression, intraoral scanner, implant, prosthodontics

Background:
Full edentulism is a major functional and esthetic problem that impacts mastication, speech, and quality of life. Implant-supported fixed prostheses have become a dependable therapy technique for the rehabilitation of edentulous arches due to their better stability, comfort and patient satisfaction **[1].** One of the most extensively utilized treatment methods is the All-on-4 concept established by Maló *et al.* that allows the rehabilitation of completely edentulous arches with only four implants including two posterior slanted implants to optimize the available bone and minimize the need for grafting procedures **[2].** Accurate transfer of implant placements is required to fabricate passively fitting prostheses. An inaccurate imprint can cause a poor-fitting prosthesis, screw loosening, fracture of the framework, peri-implant bone loss and implant failure **[3].** Conventional elastomeric impressions are the clinical reference standard, but are subject to material distortion, polymerization shrinkage, tray deformation, and cast production mistakes **[4].** Development of intraoral scanners and CAD/CAM technology has revolutionized implant prosthodontics providing 3D virtual models without the use of impression materials or stone casts **[5].** Digital impressions also have many advantages, such as increased patient comfort, reduced chairside time, easier communication to the laboratory, and simplified digital operations **[6].** Digital impressions have shown good accuracy for single-unit and short-span restorations, but their usage in complete-arch implant prostheses is still problematic due to cumulative stitching mistakes, long scanning distances and few anatomic reference sites **[7].** The digital scan process becomes more challenging with posterior tilted implants in All-on-4 rehabilitations. Accuracy of digital and conventional implant impressions have been reported in various investigations. Ender and Mehl **[8]** found the complete-arch digital impression to be less accurate than a traditional impression. Recent studies by Amin *et al.* and Vandeweghe *et al.* shown that the clinical accuracy of full-arch implant rehabilitation with contemporary intraoral scanners is satisfactory in terms of trueness and precision **[9, 10].** The Medit i600 intraoral scanner is equipped with powerful optical technology and image-processing algorithms, although there is minimal proof of its accuracy for complete-arch All-on-4 implant-supported prostheses. Therefore, it is of interest to evaluate the accuracy of conventional and digital impression techniques for maxillary and mandibular All-on-4 implant-supported prostheses utilizing Medit i600 intraoral scanner and Medit Design 2.1.4 software.

Materials and Methods:
The present *in vitro* study was carried out for evaluating and comparing the accuracy of conventional and digital impression techniques for maxillary and mandibular All-on-4 implant-supported prostheses. A total of 60 samples were fabricated and randomly divided into 4 groups of 15 samples each. Group I consisted of maxillary digital impressions, Group II consisted of maxillary conventional impressions, Group III consisted of mandibular digital impressions, Group IV consisted of mandibular conventional impressions. The die stone was used to produce master casts of the edentulous maxilla and mandible. Four implant analogs with multiunit abutments (Alpha Bio-Tec Simplantology) were randomly placed in each master model simulating the All-on-4 configuration. Two anterior implants were placed axially, and two posterior implants were placed with distal inclination simulating clinical All-on-4 implant placement. The conventional impression groups used open tray impression copings attached to the implant analogs, which were splinted with ligature wire and pattern resin to minimize movement during impression making. Stock trays were selected appropriately, and adhesive was applied uniformly to enhance retention of the impression material. Impressions were taken

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with putty and light body addition silicone impression material (GC Flexceed). After taking the impression, the implant analogs were attached to the impression copings, and the impressions were filled in with a mixture of dental stone and die stone. The resulting casts were removed and scanned using the Upcera laboratory scanner with multiunit scan bodies attached to the implant analogs. The STL files generated from these scans were stored and classified according to the groups. For the digital impression groups, multiunit digital scan bodies were directly attached onto the implant analogs of the master casts. Then, digital impressions were acquired using the Medit i (60)0 intraoral scanner following the manufacturer's scanning protocol. Systematic full-arch scans were performed for continuity and to minimise stitching errors. Digital scan data were exported as STL files and labeled as such. All STL files obtained from conventional and digital impressions were imported into Medit Design 2.1.4 software for comparison. Superimposition of STL data set was done to compare conventional and digital impressions with the master model. The software gave quantitative measurements like mean deviation, median deviation, standard deviation, variation, minimum deviation and maximum deviation values. Statistical analysis was done to compare the dimensional accuracy between maxillary and mandibular arches and between digital and conventional impression techniques. Comparison was made using independent t-test and chi-square test, respectively. A p-value of less than 0.05 was considered statistically significant.

Results:

Table 1 presents the descriptive statistics of the comparison between conventional and digital maxillary impressions. The mean deviation values ranged from –0.004 mm to 0.154 mm, indicating a minimal dimensional difference between the two impression techniques. In all the comparisons the median values were close to zero, suggesting high reproducibility and consistency of the impressions. Standard deviation values ranged from 0.220 to 0.446, suggesting low variability among the samples. In general terms, digital impressions showed an equivalent dimensional accuracy to conventional impressions in the maxillary arch. **Table 2** presents the descriptive statistics of the comparisons between mandibular conventional and digital impressions. Mean deviations were between –0.069 mm and 0.225 mm, showing again a high dimensional accuracy. Mandibular impressions however showed relatively higher standard deviation and variation values than maxillary impressions, which means slightly more inconsistency between samples. Despite this variability, mean deviations were within clinically acceptable limits. The total statistical parameters of the maxillary and mandibular arches are presented in **Table 3**. Mean and median deviations were not significantly different between the two arches ($p > 0.05$), indicating similar overall trueness. Statistically significant differences were found in standard deviation and variation values ($p<0.001$) with higher variability in the mandibular arch than in the maxillary arch. The present study results showed that both digital and conventional impression techniques had high dimensional accuracy in reproducing implant positions for All-on-4 implant-supported prostheses. The deviations of digital impressions with the Medit i (60)0 scanner were comparable or slightly lower than those of conventional impression techniques. Excellent reproducibility was observed with minimal deviations of the maxillary arch. The low mean and median values show that the digital impressions captured the implant positions accurately with little distortion. Similarly, mandibular digital impressions showed clinically acceptable trueness, but the inter-sample variation was slightly higher. Comparison among arches revealed that although the mean dimensional accuracy was similar, mandibular impressions presented significantly higher variation and standard deviation values. This result suggests that there may be greater variability of mandibular scanning, possibly due to fewer anatomical landmarks and greater cumulative stitching errors. The results, in general, support the clinical applicability of digital impression systems for complete-arch implant-supported prostheses.

Table 1: Descriptive Statistics of Maxillary Conventional versus Digital Impressions

Parameters	Mean Range (mm)	Median Range (mm)	S.D. Range	Variation Range
Maxillary Comparisons (n=15)	–0.004 to 0.154	–0.001 to 0.029	0.220 to 0.446	0.048 to 0.199

Table 2: Descriptive Statistics of Mandibular Conventional versus Digital Impressions

Parameters	Mean Range (mm)	Median Range (mm)	S.D. Range	Variation Range
Mandibular Comparisons (n=15)	–0.069 to 0.225	–0.012 to 0.051	0.406 to 0.684	0.165 to 0.467

Table 3: Comparison between Maxillary and Mandibular Conventional versus Digital Impressions

Parameters	Maxillary	Mandibular	p-value
Mean Deviation	0.0584	0.0405	0.599
Median Deviation	0.0105	0.0103	0.975
Standard Deviation	0.3174	0.4552	<0.001*
Variation	0.1094	0.2120	<0.001*

Discussion:

The present *in vitro* study was conducted to evaluate the dimensional accuracy of conventional and digital impressions in Maxillary and Mandibular All-on-4 implant supported prosthesis using Medit i600 intraoral scanner. Accurate impression making is important in implant prosthodontics as any discrepancy in implant position transfer may compromise passive fit and result in biological or mechanical complications **[11]**. The results showed that both conventional and digital impressions produced highly accurate reproductions of the master models. Mean deviations were within clinically acceptable limits in both arches. These results are consistent with previous studies reporting that modern intraoral scanners can achieve clinically acceptable accuracy for full-arch implant rehabilitation **[12, 13].** The mean deviations in the maxillary arch were between –0.004 mm and 0.154 mm indicating excellent trueness and reproducibility. Similar findings were reported by Amin *et al.* who concluded that digital full-arch implant impressions were comparable or superior to the conventional impressions **[9].** Pesce *et al.* reported that digital impressions could reliably create passively fitting frameworks in tilted implant configurations **[12].** The mandibular arch showed a slightly higher variability with standard deviation values from 0.406 to 0.684. This may be due to fewer anatomical landmarks and more cumulative errors in stitching during scanning. Similar increases in variability were observed by Vandeweghe *et al.* in mandibular scans due to longer scan times and fewer reference points **[10].** However, the deviations found in the present study were within clinically acceptable limits for implant supported prostheses despite the increased variability. Passive fit is generally considered acceptable if the discrepancy is less than 100–150 μm **[14].** Thus, it is unlikely that the dimensional differences observed in this study would have a negative effect on clinical outcomes. The mean deviation values between maxillary and mandibular arches were not significantly different statistically, suggesting that the overall trueness is similar. Mandibular impressions presented a significantly higher variation and standard deviation values indicating lower reproducibility. Drancourt *et al.* reported similar observations of increased variability of mandibular digital impressions **[15].** Conventional impressions have long been deemed the gold standard due to their clinical reliability. However, they are sensitive to technique and influenced by impression material shrinkage, tray deformation and stone expansion **[16].** In this study, open tray splinted impression techniques were used to minimize coping movement and increase accuracy. Digital impressions have a few advantages, including reduced patient discomfort, no impression materials, shorter clinical time and easier laboratory procedures **[17].** Digital workflows are especially beneficial in immediate loading protocols like All-on-4 rehabilitation, as they facilitate the rapid fabrication of prostheses. The Medit i600 intraoral scanner performed with good accuracy in this study. With the development of the scanner hardware and the software algorithms, the digital impression of the complete arch is now much more accurate. Conventional methods showed similar trueness as newer generation scanners, according to Mangano *et al.* **[18].** The accuracy of digital impression can be affected by a number of factors including type of scanner, experience of operator, scanning strategy and design of scan body **[19].** We conclude that careful scanning protocols and operator training are essential for improving reproducibility. The current study was performed under controlled *in vitro* conditions, excluding intraoral variables such as saliva, patient movement and soft tissue interference. But there may be inaccuracies added by clinical conditions. Therefore, the present findings should be confirmed in future *in vivo* studies. Within the limits of this study, the dimensional accuracy of the Medit i600 scanner was comparable to that of conventional impressions for All-on-4 implant-supported prostheses. Maxillary impressions were more consistent, whereas mandibular impressions showed a little more variability.

Conclusion:

Both conventional and digital techniques showed high dimensional accuracy for maxillary and mandibular All-on-4 prostheses. The Medit i600 scanner produced accuracy comparable to conventional impressions, with greater reproducibility in the maxilla and variability in the mandible. All deviations remained within clinically acceptable limits, supporting digital impressions as a reliable alternative for complete-arch implant rehabilitation.

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