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Original Article

Effect of Inter-implant Distance on the Accuracy of Intraoral Scanner Following All on-4 Concept: An In-vitro Study

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Abstract

Aim: This study aimed to assess the accuracy of intraoral scanner (IOS) Medit i700 in scanning All-on-4 implant rehabilitation.

Subjects and methods: An edentulous mandibular model was designed with two straight anterior and two angulated posterior implants. The two test groups; were a short interimplant distance group (S) where the master model was fitted with two anterior and two posterior implants at the first premolar region. The second was the long interimplant distance group (L) two anterior and two posterior implants at the second premolar region. The model was scanned once with the extraoral scanner inEos X5, to obtain the reference scan and 10 times with the IOS, to obtain the test scans.

Results: Following statistical analysis it was evident that interimplant distance increase had no statistically significant influence on the accuracy of digital data obtained by Medit i700 wired.

Conclusion: Interimplant distance had no statistically significant effect on the accuracy.

Keywords: Optical imaging / instrumentation, Models, Dental Implants, Edentulous / rehabilitation

Introduction

Treatment of edentulous arches varies from removable to full arch fixed prosthesis. The All-on-4 concept is often used to restore edentulous mandibular arches with full arch fixed implant prosthesis. The All-on-4 concept provides the dental professional with the necessary implant number and distribution required to support a sound implant-supported restoration from the biomechanical point of view. The shift to complete digital implant prosthetic workflow has led to the development of digital data acquisition devices, that allow direct digitization, such as intraoral scanners (IOS) and intraoral scan bodies (ISB). Aided by specialized dental design software with dental implant component libraries that convert analog into virtual reality. The transfer of the intraoral situation to a virtual setting must be characterized by a high degree of accuracy. Recently, dental professionals have taken great interest in the complete digital workflow. Digital technologies have made it easier for dentists and the dental staff, regarding the elimination of technique sensitive impression making process and the transport of physical laboratory work to and from the clinic.[1]

The accuracy of conventional and IOS is comparable in short edentulous span situations. However, the trueness and precision of IOS for scanning full arch edentulous spans are still under scrutiny.[2,3] Few studies have investigated the effect of increased distance between the scan bodies on the accuracy of intraoral scans of completely edentulous arches.[4] Thus, there is great need for further studies investigating the most recent IOS systems specifically related to full arch implant rehabilitation.[2,4] Therefore, this research was conducted to assess whether IOS can accurately register implant 3D position in All-on-4 full arch cases with change in interimplant distance. The null hypothesis is that the inter-implant distance will have no effect on the accuracy of digital scan data.

Subjects and Methods

This was a non- randomized in-vitro study in which a 3D digital master model of an edentulous mandibular cast was designed by Blender for dental (Dental CAD software version 2.93.5, Australia) and printed one time. The master model was 3D printed with space for six implant analogs. Each intervention followed the All-on-4 concept, meaning that only four of the six analog spaces were used for each intervention. Scans obtained by the intraoral scanner were test scans and scans obtained by the reference bench top scanner were reference scans. Accuracy was evaluated using a superimposition software (Medit design software- Seoul, South Korea).

The model was designed to accommodate six bone-level virtual implant analogs (ROOTT, Implant analog, Digital AND). Anterior implant analogs were inserted straight in the lateral incisor area bilaterally. The two anterior virtual analogs were designed so that the flat surface is facial and the virtual analogs were almost parallel to the y-axis. Posterior implant analogs were inserted in the first premolar region bilaterally with a 25-degree angulation in relation to the y axis, which was the configuration of the short interimplant distance group. Implant analogs were placed in the second premolar region bilaterally with a 25-degree angulation in relation to the y axis, which was the configuration of the long interimplant distance group. The digital implant analog recess in the first and second premolar region was designed with an inclination in the y-axis of 25-degrees, almost parallel to each other contralaterally, and the digital-analog flat surface facing the facial surface of the model.

The virtual abutment replicas were imported from the digital library found on the Blender for dental Component module. The abutments required proper arrangement to fit in their specific position with the virtual implant analogs. The Stl file of the final master model was exported to a 3D slicer software (Chitubox version 1.9.4). The model was 3D printed using model resin (Proshape digital solutions, Turkey). 3D printing by digital light processing (DLP) was performed using Phrozen mini sonic 4k printer (Phrozen, Taiwan). The digital analogs were checked for fit into their recess, using frictional fit. The multiunit abutments were torqued to each implant analog.

The two main groups were short interimplant distance group, and long interimplant distance group. The short interimplant distance subgroups were given the following codes, S0, S15, and S30.The long interimplant distance subgroups were given the codes L0, L15, and L30.The first subgroup is S0 or L0 received a 30-degree angled multiunit abutment (ROOTT Abutment MxA30), while S15 and L15 received 15-degree angled multiunit abutment (ROOTT Abutment MxA15). The S30 and L30 subgroups received the straight multiunit abutment (ROOTT Abutment Mx). The multiunit abutments were torqued into position using hand tightening (10-15 Ncm). Over the straight and angled multiunit abutments an intraoral scan body (ISB) (ROOT, SPCOMIO) was screwed into place by hand tightening. Once a group was assembling the component parts were not replaced until scanning with both the extraoral and intraoral scanners was completed. The scanning of a single group took place in the working hours of one day.

The master model was then scanned with a laboratory scanner inEos X5 blue light scanner (CEREC inLab, Sirona Dental Systems, Germany). The inEos X5 was used to obtain a reference scan for each group. The reference scan was the Stl file upon which alignment and superimposition of the scans by the intraoral scanner (IOS). Thus, six reference scans were obtained by the inEos X5. Extraoral scanning was followed by, intraoral scanning by Medit i700 wired IOS. Each group was scanned ten times by the Medit i700 wired IOS. Environmental conditions for scanning was room temperature 21 ºC, with blinds closed and, room lighting. The scanning strategy was similar for all scans performed using the Medit i700 IOS (Fig. 1).

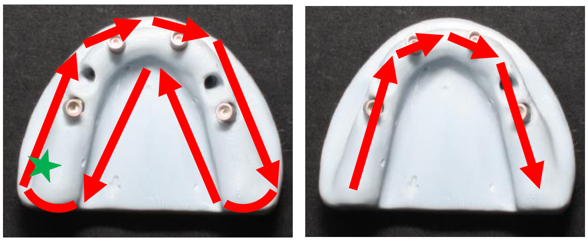

Figure (1): IOS Medit i700 wired. Scanning strategy green star indicates the starting position to scan.

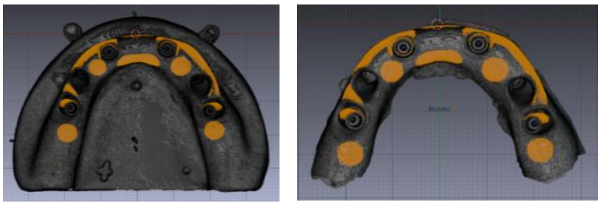

Figure (2): Alignment was performed on Blender for dental using the alignment module. Top view of surface matching area selection, highlighted in orange.

Blender for dental software (Dental CAD software version 2.93.5, Australia) was used to perform alignment of the ten intraoral scanner scans to the reference scan by inEos X5 of each subgroup. The alignment was used to align the 10 intraoral scans to the reference extraoral scan of a single group. Alignment was achieved using surface matching. Specific areas were selected for surface matching. These areas were selected for both the reference and intraoral scan (Fig. 2, 3).

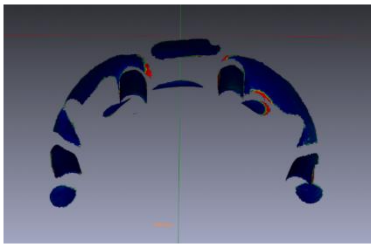

Figure (3): Color map feature used to evaluate correct alignment between the scans. Blue color= 0 mm and Red color= 0.05 mm.

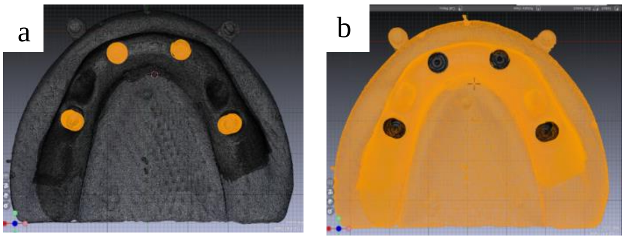

Figure (4): All scans were selected to use the fast edit feature to obtain the scan body region for the superimposition phase (a). The Ctrl I keys were used to maintain the SB region of the scans (b).

The aligned scans of each group were imported into the Medit design app feature for superimposition. After editing the scan data, the export file consisted of the aligned and trimmed ISB of the 11 scans (Fig. 4, 5). Once the STL file formats for each group were imported into the Medit design software, superimposition of the lab scan and each individual IOS scan was performed. Medit for clinics software was used, and the color-coded deviation map was available using the Medit Design app. A color-coded map for accuracy was visualized. Each color in the color map translates into a specific numerical value. The color maps indicated the displacements between overlapped structures. The same colorimetric parameters were set for all groups; the maximum deviation ranged from 1000 µm to -1000 µm (Fig. 6).

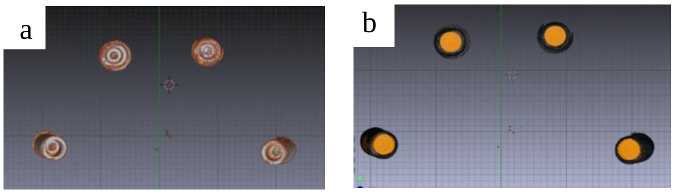

Figure (5): SB data remaining after gross trimming of the scan data (a). Screw access channel selected for digital trimming using the fast edit feature (b).

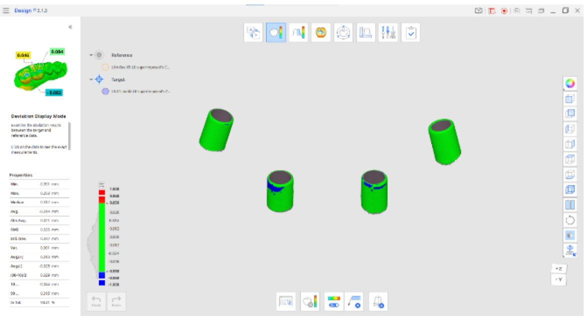

Figure (6): The color-coded deviation map.

Results

The effect of inter-implant distance

The comparison between the short and long inter-implant distance was performed using independent sample t-test. Comparison between S & L revealed insignificant difference between them for all subgroups 0, 15 and 30 as P>0.05. (Figure. 7)

For S0 and L0 the mean difference between the groups was statistically insignificant (Mean diff=1.4±1.21 μ, P=0.28).

For S15 and L15 the mean difference between the groups was statistically insignificant (Mean diff=3.8μ, P=0.12 ns).

For S30 and L30 the mean difference between the groups was statistically insignificant (Mean diff=2.2μ, P=0.66ns).

For the collective data of both groups total S versus total L irrespective of scan body inclination the mean difference was statistically insignificant (Mean diff=1.53μ, P=0.60 ns).

In the present study, the statistical analysis revealed insignificant differences between scans made with short versus longer inter implant distance. The mean difference in the value of the scan discrepancies between groups was less than 4 microns and was statistically insignificant.

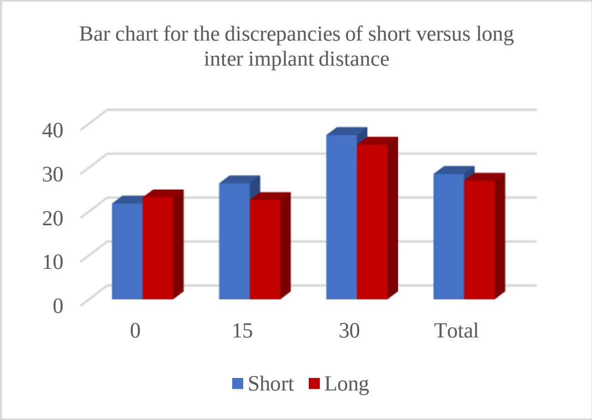

Figure (7): bar chart showing comparison between short and long interimplant distance groups at 0, 15, 30-degree inclination and the total, in microns.

Discussion

Biologic tolerance makes room for a certain degree of error, linear error of 100 um, and angular error 0f 0.2-0.5 degrees.[4] The minimum acceptable values of trueness and precision of IOSs are 50 um and 10 um respectively .[3] The null hypothesis was rejected, as the interimplant distance had no statistically significant effect on the accuracy of digital scan data. Limitations of this study include the invitro setting that does not fully represent the intraoral clinical situation. Mouth temperature, humidity, illumination, mouth opening, saliva, soft tissue movement, and patient movement are influencing factors that represent challenges during scanning IO scanning of full arch implant rehabilitations.

Reich et al. (2023) stated that printed full arch casts have the necessary accuracy for implication in orthodontics, and that deviation from the actual object less than 300 um is clinically acceptable. Also, that a trueness threshold of less than 100 um is sufficiently accurate and indicated for fixed and implant prosthodontic procedural steps.[5] Consequently, in this research, a digitally designed and fabricated master model was utilized. This offered a representation of digital technology application in the field of implant dentistry.

Factors that influence accuracy are the scanning hardware and software used, the method of alignment and surface matching between the test and reference scans and the software used to analyze the deviation from the reference scan. Thus, a true comparison with similar studies is difficult.[4,6] Accordingly, in this body of research, the measurement of accuracy was performed using alignment, surface matching, and deviation from the reference obtained using a 3D color coded deviation map. The method and technical skills required had a steep learning curve and applicable using the already available software such as Blender for Dental and Medit link.

The effect of interimplant distance

The placement of implants in full arch cases is demanding from the biomechanical point of view. When placing as few as 4 implants there is a greater need to spread the implants as far anteroposterior as possible to improve the mechanical resistance and decrease the posterior cantilever length. The original All-on-4 concept places the implants in the lateral incisor and second premolar region aiming to achieve this mechanical goal. As the implants become widely separated a problem might occur during digital scanning. Many authors including **Kim et al. (2017)**, **Braian and Wennerberg (2019)**, **Schmidt et al. (2020), Albayrak et al. (2021), and Schmlaz et al. (2023)** reported in their studies that as the implants became more widely spread the scanning accuracy is reduced.[7-11] They refer this to the increased error in stitching the recorded frames as the span length increases.

In the present study the span difference between the short and long interimplant distance groups was a single unit. The effect of changing the interimplant distance might have been insignificant due to the relatively small increase in the span length. A longer span might cause larger errors due to lack of distinctive landmarks between the scan bodies, making the frame stitching less reliable. The increase of interimplant distance seems non-practical as implant frameworks should not contain more than 2 posterior pontics. The presence of longer pontic beam is associated with increased prosthetic complication due to flexure of the long beams.

The present result is different from the results obtained by **Ahlholm et al. (2018)** and **Kong et al. (2022)** they found larger scan discrepancies when scanning full arch cases with long spans.[12,13] The contradiction might be due to the difference in the IO scanner used. The newer scanner hardware and software have greatly improved the scanning accuracy when scanning full arch cases. **Mangano et al. (2020)** reviewed the trueness and precision of 12 intra oral scanners in full arch implant cases. The test scanner included some of the older and the newer scanner versions. The newer scanner versions as the Prime scan, Trios 3, CS3700 and Medit I500 yielded lower discrepancy values (38.4 µ, 36.4µ, 30.4, and 32.2µ respectively), compared to higher discrepancy values reported with older versions as Omincam, Emerald and DWIO (79.6µ, 76.1µ, and 98.4µ respectively).[14] In the present study Medit i700 scanner was used which is an upgraded hardware compared to the Medit i500. The improved accuracy of the used scanner might have reduced the effect of the longer span between scanbodies rendering the difference between the short and long group insignificant.

Conclusion:

Within the limitations of the present in vitro study, we could conclude that:

1) The accuracy of intra oral scanning of All-on-4 cases is not affected by the interimplant distance.
2) The use of intra oral scanners in All on 4 cases is a promising approach. The means of the reported scanning discrepancies are within the acceptable limits.

Conflict of Interest:

The authors declare no conflict of interest.

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Ethics:

This study protocol was approved by the ethical committee of the faculty of dentistry- Cairo university on: 05/04/2021, approval number 5-4-21.

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