

## RESEARCH WORKS



# Analysis of the scanning performance of dental implants using different intraoral scanners: Accuracy study.

Briza Letícia Almeida-Silva<sup>1</sup>, Sérgio Candido-Dias<sup>1</sup>, Geraldo Alberto Pinheiro de Carvalho<sup>1</sup>, Aline Batista Gonçalves-Franco<sup>1</sup>, Vanêssa Fazoli<sup>1</sup>, Kelly Maria Silva-Moreira<sup>1\*</sup>, Elimario Venturin-Ramos<sup>1</sup>

1. Área Prótese Dentária, Faculdade São Leopoldo Mandic, Brasil.

\* Corresponding author: Kelly Maria da Silva Moreira | Address: Faculdade São Leopoldo Mandic, Rua José Rocha Junqueira, 13, Swift, 13045-755, Campinas, SP, Brasil | Phone: ++55 19 98262-7151 | E-mail: kellynhaodonto@yahoo.com.br

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## ORCID

Briza Letícia Almeida-Silva:  
ORCID: 0000-0001-6705-7181

Sérgio Candido-Dias:  
ORCID: 0000-0003-2570-2167

Geraldo Alberto Pinheiro de Carvalho:  
ORCID: 0000-0002-6279-3558

Aline Batista Gonçalves-Franco:  
ORCID: 0000-0002-8793-0459

Vanêssa Fazoli:  
ORCID: 0000-0002-1748-1643

Kelly Maria Silva-Moreira:  
ORCID: 000-0002-1137-3908

Elimario Venturin-Ramos:  
ORCID: 0000-0001-7325-4093

## ABSTRACT

The accuracy of intraoral scanners in scanning dental implants in different clinical situations was verified. Models simulating single rehabilitation, multiple fixed partial dentures and protocol were scanned with each scanner by a single trained operator (n=10): iTero (Align Technology), Trios (3Shape), CEREC Primescan (Dentsply Sirona) and Ceramill 400 laboratory scanner (Amann Girrbach), as a control group. The engineering software R everse (Geomagic) was used for the analysis of the files obtained and SPSS for the statistics ( $p \leq 0.05$ ). In single-prosthesis rehabilitation, there was no difference between the intraoral scanners iTero, Trios and CEREC Primescan intraoral scanners. In the multiple fixed partial dentures, the Trios and CEREC Primescan scanners showed significantly smaller discrepancies than those found with the iTero, only the CEREC Primescan intraoral scanner did not differ significantly from the benchtop scanner. Simulating protocol-type prosthesis, in any region, all intraoral scanners resulted in significantly less accurate measurements than the benchtop scanner. Exceptions were found when the CEREC Primescan scanner was used in the regions of elements 13-23, 16-26 and 16-13, situations in which there was no significant difference in relation to the benchtop scanner. Therefore, different intraoral scanners and clinical situations can influence the accuracy of dental implant scanning.

## KEY WORDS

Dental implants; Digital dentistry; Scanner; Scanbody.

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## INTRODUCTION

Digital dentistry is an expanding field, and although it has high potential for technological growth, there are some issues that need to be addressed in the evolutionary process, such as accuracy and future operating costs. It contributes greatly to several areas, from the planning of the surgical treatment of implants to definitive prosthetic work<sup>(1,2,3)</sup>.

The dimensional accuracy of the digital models generated by intraoral scanning compared to the digitization of models obtained by conventional impressions and scanned with benchtop scanners has already been investigated. Studies report that intraoral scanners are highly accurate and that distance measurements obtained from digital images and plaster casts do not differ significantly<sup>(4,5,2)</sup>.

However, improvements to scanners are made from generation to generation. The digital impressions obtained are a valid alternative to conventional impressions for partial-arc segments. Full-arc impressions are still a challenge for scanners, but some devices have been shown to be within the range required for clinical quality<sup>(6,7)</sup>.

Comparative studies in dentate models support the concept that using different intraoral scanners, significantly different results can be obtained. The dentate model is believed to be the easiest to handle with intraoral scanners. In fact, the presence of occlusal surfaces with their peculiar geometry can help these devices to obtain a better result. It is important to investigate the feasibility and accuracy of partial and total digitization of edentulous archwires, especially in patients with dental implants<sup>(8,9,10,1)</sup>.

For implant dentistry, implant printing is a crucial step. Inaccurate transfer of implant position can lead to an inadequate prosthesis, resulting in biological and mechanical complications. With the advent of CAD/CAM (computer aided design/computer assisted manufacturing) technology, it is possible to use the digital workflow in the manufacture of implant-supported restorations, which can be direct or indirect in nature<sup>(11)</sup> (Mizumoto, Yilmaz, 2018). The indirect method consists of performing

conventional implant transfer impression and scanning of the model in the laboratory, while the direct method scans the implant directly into the mouth using an intraoral scanner<sup>(12)</sup>. In both, the use of a scanbody is necessary to scan the implant. However, it is necessary to evaluate the accuracy of intraoral scanners in different clinical situations in implant dentistry.

Thus, the aim of this study was to analyze the accuracy of three intraoral scanners: CEREC Primescan (Dentsply Sirona, York, Pennsylvania, USA), iTero (Align Technology, San Jose, California, USA) and Trios (3Shape, A/S, Copenhagen, Denmark). As a control group, the Ceramill 400 benchtop scanner (Amann Girrbach, Koblach, Austria) was used to scan dental implants in order to verify its accuracy in accurately reproducing the position of the implants installed and to simulate different clinical situations in order to verify distortions as the distance between these implants increases. The null hypothesis postulates that the extension of the prosthesis and the different intraoral scanners do not influence the reproduction of the virtual models.

## METHODOLOGY

The research project for this study was submitted for evaluation by the Ethics Committee of Faculdade São Leopoldo Mandic and exempted from submission to the CEP (Research Ethics Committee) because it is a research that does not have a human being as a participant, according to the following protocol number: 2020-0451.

### Experimental design

In this study, the accuracy of dental implant scans using 3 intraoral scanners was evaluated. The study was composed of 12 groups simulating 03 different clinical situations in order to verify if there is a change in the scanning accuracy as the distance between dental implants increases, since some studies point out that there are distortions and others report



for high precision.

The scanners tested were: iTero (Align Technology, San Jose, California, United States), Trios (3Shape, A/S, Copenhagen, Denmark), CEREC Primescan (Dentsply Sirona, York, Pennsylvania, United States). The models were also scanned in the Ceramill 400 laboratory scanner (Amann Girrbach, Koblach, Austria) as a control group.

In each group, 10 scans ( $n=10$ ) were performed with each scanner, totaling 120 files<sup>(12,15)</sup>.

### Obtaining the models

A single operator made 03 models of Esthetic-base gold plaster (Dentona, Dortmund, Germany) obtained from the cloning of the dental mannequin (P-Oclusal, São Paulo) simulating 03 clinical situations with implants in different positions and distances in order to verify the accuracy of 03 intraoral scanners.

The PEEK scanbodies from EFF Dental (São Paulo, São Paulo) were installed on the implants and remained so for all scans.

### The models represented the following clinical situations:

**1. Unitary:** model with implants in the regions of dental elements 16 and 17 simulating rehabilitation for unitary prostheses (figure 1a);

**2. Fixed:** model with implants in the region of elements 14 and 17, with 15 and 16 missing teeth, simulating rehabilitation with partial fixed multiple prosthesis (Figure 1b);

**3. Edentulous:** model depicting a situation of total edentulism with 4 implants installed in the upper arch in the position of teeth 16, 13, 23 and 26, simulating rehabilitation with protocol-type prosthesis (Figure 1c).

In the model representing the Unitary situation, Straumann BLX implants (Basel, Switzerland) were used. For the Fixed and Edentulous models, components of the regular platform mini abutment type from the EFF Dental brand (São Paulo, São Paulo) were used.



**Figure 1:** a) Unit group model; b) Fixed group model; c): Edentulous group model

### Scans

Each group was first scanned on the Ceramill 400 laboratory scanner to generate the control group's files. After this procedure, the groups were scanned 10 times with each scanner in the following order: with the CEREC Primescan, iTero and Trios scanners, all scans were performed by the same previously trained operator.

The scanning strategy adopted was the experimental linear-continuum16, which in its study found that this scanning technique provides better precision and accuracy. The same technique was used for the 3 intraoral scanners.

The groups were identified by the initial letter of the name of the scanner used followed by the clinical situation represented, so the groups were then identified:

G1 - GCU: Unit Control Group, scanning of the model representing the clinical situation of unit implants using a Ceramill 400 scanner;

G2 - GCF: Fixed Control Group, scanning of the model representing the clinical situation of implants for partial fixed prosthesis using a Ceramill 400 scanner;

G3 - GCE: Edentulous Control Group, scanning of the model representing the clinical situation of implants for rehabilitation with total fixed prosthesis using a Ceramill 400 scanner;

G4 - GPU: Unitary Primescan Group, scanning of the model representing the clinical situation of unit implants using a Primescan scanner;

G5 - GPF: Fixed Primescan Group, model scan representing clinical situation of implants for partial fixed prosthesis using Primescan scanner;

G6 - GPE: Primescan Edentulum Group, model scan representing the clinical situation of implants for rehabilitation with total fixed prosthesis using a Primescan scanner;

G7 - GIU: iTero Unitary Group, scanning of the model representing the clinical situation of unitary implants using an iTero scanner;

G8 - GIF: iTero Fixed Group, scan of the model representing the clinical situation of implants for partial fixed prosthesis using an iTero scanner;

G9 - GIE: iTero Edentulum Group, scan of the model representing the clinical situation of implants for rehabilitation with total fixed prosthesis using an iTero scanner;

G10 - GTU: Unitary Trios Group, scanning of the model representing the clinical situation of unitary implants using a Trios scanner;

G11 - GTF: Trios Fixed Group, scanning of the model representing the clinical situation of implants for partial fixed prosthesis using a Trios scanner;

G12 - GTE: Trios Edentulum Group, scan of the model representing the clinical situation of implants for rehabilitation with total fixed prosthesis using a Trios scanner.

### Measurements in software

After obtaining the files, they were analyzed in reverse engineering software Geomagic (Morrisville, NC, USA). The files of the scanned models were superimposed on the file of the control group scanned by the benchtop scanner. The discrepancies in the files were then analyzed taking into account the positioning of the implants, so precise values were obtained to assess whether or not there was distortion between the study and control groups. The measurements were performed by means of a point in the center of the scanbodies, evaluating the distance between them in comparison to the control group.

In the unit group, only a distance between the Scanbodies located on implants 17 and 16, as exemplified in Figure 2a. In the fixed group, only a distance was measured between the scanbodies located in implants 17 and 14 (Figure 2b). In the edentulous group, five distances were measured between the scanbodies located in implants 13 and 23, 16 and 26, 16 and 13, 23 and 26, and between implants 13 and 26, as shown in figure 2c.

The results obtained were sent for statistical analysis and submitted to the appropriate tests.



**Figure 2:** a) Geomagic software file referring to the unit group. b) Geomagic software file showing the distance between the scanbodies relative to the fixed group. c) Geomagic software file showing all measurements regarding the distances between the scanbodies of the edentulous group.

### Statistical analysis

To compare the three intraoral scanners regarding the discrepancy in the models simulating rehabilitation with a single prosthesis, with a partial fixed multiple prosthesis, and with a protocol-type prosthesis, whether the data adhered to normality and homoscedasticity, analysis of variance and Tukey's test were used. Since these assumptions were violated, the comparison between the scanners was performed using the Kruskal-Wallis and Dunn tests. In addition, by means of Student's t-test for one sample, each of the intraoral scanners was contrasted with the benchtop scanner (Ceramill 400). Statistical calculations were performed using SPSS 23 (SPSS INC., Chicago, IL, USA) and BioEstat 5.0 (Mamirauá Foundation, Belém, PA, Brazil), with a significance level of 5%.

### FINDINGS

In the model simulating rehabilitation with a single prosthesis, there was no statistically significant difference between the iTero, Trios and CEREC Primescan intraoral scanners ( $p = 0.117$ ; Table 1) regarding the discrepancy measured by the overlap with the file of the control scanner group (Ceramill 400). Comparing each of the three intraoral scanners with the benchtop scanner, it was found that the Trios ( $p = 0.171$ ) and CEREC Primescan ( $p = 0.748$ ) equipment did not differ significantly from the Ceramill 400, while the iTero had significantly less accurate values (Table 2).

In the case of a simulation of rehabilitation with a partial fixed multiple prosthesis, the one-way analysis of variance indicated a statistically significant difference between the intraoral scanners ( $p < 0.001$ ). Identifying the differences using Tukey's test, it was found that with the Trios and CEREC Primescan scanners, discrepancies were significantly lower than those found with the iTero (Table 1). Only the CEREC Primescan intraoral scanner did not differ significantly from the benchtop scanner. The others (iTero and Trios) provided significantly less accurate

**Table 1:** Arithmetic means, standard deviations, medians and minimum and maximum values of discrepancies (mm) in models simulating rehabilitation with single prosthesis and with multiple fixed partial prosthesis, according to the intraoral scanner.

| Model simulating         | Scanner                                |                                        |                                        |
|--------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
|                          | iTero                                  | Trios                                  | CEREC Primescan                        |
| Single prosthesis        | -0,02 (0,03) A<br>-0,02 [-0,09; 0,00]  | +0,01 (0,02) A<br>+0,02 [-0,03; +0,03] | -0,01 (0,10) A<br>-0,03 [-0,12; +0,14] |
| Partial fixed prosthesis | -0,10 (0,02) B<br>-0,10 [-0,12; -0,05] | +0,01 (0,02) A<br>+0,01 [-0,01; +0,04] | 0,00 (0,04) A<br>0,00 [-0,06; +0,06]   |

Arithmetic means and standard deviations (in parentheses) are in the first row of each model. Medians and minimum and maximum values (in brackets) are in the second row of each model. Considering each model separately (comparisons within each row), arithmetic means followed by distinct capital letters indicate significant differences between scanners.

**Table 3:** Arithmetic means, standard deviations, medians and minimum and maximum values of discrepancies (mm) in models simulating rehabilitation with protocol-type prosthesis, according to the intraoral scanner and the region.

| Region | Scanner                                 |                                          |                                         |
|--------|-----------------------------------------|------------------------------------------|-----------------------------------------|
|        | iTero                                   | Trios                                    | CEREC Primescan                         |
| 13-23  | -0,07 (0,04) Ba<br>-0,08 [-0,16; -0,01] | +0,04 (0,03) Aab<br>+0,04 [0,00; +0,11]  | +0,01 (0,06) Aa<br>+0,02 [-0,10; +0,13] |
| 16-23  | -0,03 (0,03) Aa<br>-0,03 [-0,09; +0,02] | +0,17 (0,05) Bc<br>+0,17 [+0,07; +0,25]  | +0,04 (0,06) Aa<br>+0,03 [-0,05; +0,19] |
| 16-13  | -0,06 (0,02) Ba<br>-0,06 [-0,08; -0,02] | +0,02 (0,02) Aa<br>+0,03 [-0,02; +0,07]  | -0,05 (0,09) Ba<br>0,00 [-0,21; +0,05]  |
| 23-26  | -0,07 (0,03) Aa<br>-0,07 [-0,11; -0,03] | +0,14 (0,02) Bbc<br>+0,14 [+0,09; +0,17] | +0,03 (0,03) Aa<br>+0,03 [-0,01; +0,08] |
| 13-26  | -0,05 (0,04) Aa<br>-0,06 [-0,10; +0,01] | +0,23 (0,03) Bc<br>+0,22 [+0,18; +0,27]  | +0,06 (0,05) Aa<br>+0,08 [-0,02; +0,12] |

Arithmetic means and standard deviations (in parentheses) are in the first row of each model. Medians and minimum and maximum values (in square brackets) are in the second row of each model. Considering each region separately (comparisons within each row), arithmetic means followed by distinct capital letters indicate significant difference between scanners. Considering each scanner separately (comparisons within each column), arithmetic means followed by distinct lowercase letters indicate significant difference between regions.

**Table 2:** Results of comparisons between intraoral and benchtop scanners, in models simulating rehabilitation with single prosthesis and with multiple fixed partial prosthesis.

| Model simulating         | Scanner   |           |                 |
|--------------------------|-----------|-----------|-----------------|
|                          | iTero     | Trios     | CEREC Primescan |
| Single prosthesis        | p = 0,027 | p = 0,171 | p = 0,748       |
| Partial fixed prosthesis | p < 0,001 | p = 0,037 | p = 0,936       |

P-value of comparisons between each intraoral scanner and the benchtop scanner.

values in relation to the benchtop scanner (Table 2).

In the condition simulating rehabilitation with protocol-type prosthesis, considering the measurements made in the region formed between elements<sup>(13-23)</sup>, the Trios and CEREC Primescan intraoral scanners were associated with significantly smaller discrepancies than that found for the iTero scanner. In the regions between elements 16-26, between 23-26 and also between 13-26, the iTero and CEREC Primescan scanners proved to be significantly more accurate than the Trios. In the region of elements 16-13, the opposite was observed, i.e., there was significantly greater precision with the Trios scanner compared to the other intraoral scanners, which did not differ from each other (Table 3).

Continuing with the analysis of the data related to the simulation of rehabilitation with protocol-type prosthesis (Table 3), specifically focusing on the iTero (p = 0.071) and CEREC Primescan (p = 0.279) intraoral scanners, the discrepancy values were not significantly affected by the location of the measurement, i.e., there was no difference in the values of discrepancies measured in the regions between elements 13 and 23. 16-26, 16-13, 23-26 and 13-26. On the other hand, for the Trios scanner, the discrepancy value was significantly influenced by the region (p < 0.001). Specifically, it was found that the discrepancy in the region between elements 16-13 was significantly smaller than that found in regions 23-26, 16-26 and 13-26, with no significant difference between the discrepancies in these last three regions. In the 13-23 region, the discrepancy did not

differ significantly from that observed in the 16-13 region.

Still focusing on the condition of simulated rehabilitation with protocol-type prosthesis, in any of the regions where the measurement was performed (13-23, 16-26, 16-13, 23-26 or 13-26), all intraoral scanners resulted in significantly less accurate measurements than the benchtop scanner (Ceramil 400). The only exceptions were found when using the CEREC Primescan scanner in the regions of elements 13-23, 16-26 and 16-13, situations in which there was no significant difference in relation to the benchtop scanner (Table 4).

## DISCUSSION

**Table 4:** Results of comparisons between intraoral and benchtop scanners, in models simulating rehabilitation with protocol-type prosthesis, according to the region.

| Region | Scanner   |           |                 |
|--------|-----------|-----------|-----------------|
|        | iTero     | Trios     | CEREC Primescan |
| 13-23  | p < 0,001 | p = 0,003 | p = 0,552       |
| 16-26  | p = 0,031 | p < 0,001 | p = 0,101       |
| 16-13  | p < 0,001 | p = 0,016 | p = 0,161       |
| 23-26  | p < 0,001 | p < 0,001 | p = 0,007       |
| 13-26  | p = 0,002 | p < 0,001 | p = 0,005       |

p-value of comparisons between each intraoral scanner and the benchtop scanner.

The use of intraoral scanners has expanded in recent years for dental implant scanning, and this practice is justified due to the proven satisfaction and preference of patients over the use of conventional impressions<sup>(3,17,18)</sup>. However, some technical aspects can influence the

quality of the examination: the selection of the scanbody and the material used for its manufacture, the distance between the implants, as well as their angulation and, mainly, the scanner used, which is the object of study of this research.

Thus, in this study, we opted for the use of a Poly-ether-ether-ketone (PEEK) scanbody, observing a maximum limit of repetitions with the same piece, based on the study by Sawyers et al.<sup>(19)</sup>, in which it was demonstrated that with up to ten replicates the accuracy of the scanbody in the PEEK was not affected. In addition, the choice of the PEEK scanbody is justified, since for some authors<sup>(11,20)</sup> the design of the scan interferes with the quality of the scan and the best results were obtained when the scan material was PEEK<sup>(21)</sup>.

When evaluating the distance between the implants, some authors found results similar to those of this study, the greater the distance between the implants, the greater the distortions found, thus interfering with the accuracy of the scanners tested<sup>(12,15,22,23)</sup>. In the research by Mangano et al.<sup>(1)</sup>, there was no difference in the accuracy of the scanners evaluated when the distance between the implants was increased.

Imburgia et al.<sup>(24)</sup>, Tan et al.<sup>(25)</sup> and Canullo et al.<sup>(26)</sup> obtained similar results, noting that the best performance of the scanners tested was in clinical situations of partial rehabilitation and not total rehabilitation. In the studies by Pesce et al.<sup>(27)</sup> the results obtained from the scanners tested proved to be effective for the rehabilitation of the complete arch, as found by Mangano et al.<sup>(28)</sup> and Bilmenoglu et al.<sup>(29)</sup>. For Sami et al.<sup>(30)</sup> found no difference in accuracy between the scanners tested for full-arch rehabilitation.

The use of intraoral scanners has some disadvantages, such as the

high cost of the equipment and the long clinical time required for scanning. However, with technological evolution, there is no doubt that in a short time it will be possible to obtain sufficiently accurate intraoral examinations in vivo, even with different equipment and brands. The great influence caused by the environment in which these tests are performed, in the most diverse clinical situations, is the most challenging for researchers.

It is important to consider that, due to the limitations of this in vitro study, it is necessary to perform in vivo studies to validate the results obtained, since the clinical conditions cannot be fully replicated in vitro.

## CONCLUSION

Intraoral scanners and different clinical situations can influence the accuracy of dental implant scanning.

## CONFLICT OF INTEREST STATEMENT AND SOURCE OF FUNDING

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