1. Introduction

In computer-aided design and computer-aided manufacturing (CAD/CAM), the clinical information of dental restorations can be transformed into a three-dimensional dataset by direct digitalization using intraoral scanners (IOSs). Intraoral digital impression making has evolved beyond single-tooth preparations and sextant scanning to include the ability to record complete arches and provide greater rehabilitation possibilities [1,3]. The first step of all digital work is to record the intraoral optical impression to capture a precise 3D image of the teeth (prepared or unprepared), dental implants, and/or any intraoral defect. The quality of the impressions can be immediately checked, and if necessary, the procedure can be repeated during the same appointment. These options contribute to a more efficient workflow [4]. Owing to the importance of this phase, manufacturers continuously improve and update the hardware and software of their scanners, resulting in increased accuracy [5,6].

CAD/CAM software allows the user to cut off existing cast areas and perform another scan of the same area, resulting in new 3D information, and this cut-off tool is helpful in many dentistry scenarios because it can be used to modify the digital intraoral scans, which can improve the workflow. Furthermore, new 3D information can be inserted into the existing intraoral digital scan. A prerequisite for adding new information to an existing digital scan is that the additional scan data must contain surface information corresponding to the existing 3D data set. Thus, the new scan can be virtually inserted into the original digital scan by superimposing the corresponding 3D surfaces.

Superimposition strategies differ depending on the scanning software used. If the anterior dentition has steep and structureless surfaces, the software algorithms may find it difficult to accurately superimpose the 3D structures of the two scans [7]. In contrast to the cut-off tool, the over scanning feature automatically substitutes the areas by rescanning the same areas until they are correct (superimposed). However,
it remains unclear whether cut-out–rescan or data exchange by over scanning using CAD/CAM software affects the accuracy of digital impressions. Therefore, this article describes and evaluates the trueness and precision of cut-out–rescan and data exchange by over scanning techniques in CAD/CAM software in complete arch digital impressions using two current IOS systems.

2. Materials and methods

A master cast was customized with teeth made from polymethyl methacrylate (Telio CAD (TC) - Low Translucency shade A3; Ivoclar Vivadent AG, Liechtenstein), which was selected because its refractive index (RI =1.49) lies between that of enamel (RI=1.63) and dentin (RI=1.54) (Fig. 1A) [8,9]. Three crown preparations [10] were prepared on different teeth; zirconia crowns (CEREC Zirconia, Dentsply Sirona, Germany) were prepared for the same teeth but were not cemented (Fig. 1B).

A master reference scan of the cast was obtained using an ATOS II Triple Scan (GOM Technologies, Metronic, Spain) digitizer and an industrial structured blue light 3D scanner complying with ISO 12836 (Fig. 2A) [2,8,11,12]. The two IOS setups, i.e., Omnicam with the CEREC v. 5.1.0 software (Dentsply Sirona) and Primescan with CEREC v. 5.0.2 software (Dentsply Sirona), were calibrated according to the manufacturer’s guidelines and used via an identical scanning strategy and a single experienced investigator [13] (Fig. 2B). Scans were repeated to obtain 60 digital files (n = 10 samples per group); three groups were established for each IOS system:

- Control group (CONTROL)

In this group the procedure consisted of scanning the cast through the described scanning strategy.

- Cut-out–rescan group (COR)

In this group, the procedure began by scanning the cast, and then three delimited areas were sequentially edited using the cut-off tool and then rescanned until the substitution of new images of these areas was complete (Fig. 3A-C). Digital casts were trimmed identically to avoid bias at the boundaries during superimposition for deviation analysis.

- Data exchange by over scanning group (OS)

The procedure began by scanning the cast with the three zirconia crowns positioned, individually; they were sequentially removed for rescanning until the substitute images of the crown areas were complete (Fig. 4A-B).

Each sample (scan file) was exported into a binary standard tessellation language (STL) file at high resolution. The STL files were then compared with the master STL file (ATOS II Triple Scan) using a 3D analysis software program (GOM Inspect 2018 Hotfix 6, Rev. 117418, Build 2019-04-11) that aligned the group scans with the master STL file using a best-fit alignment. The average distance values from the master STL file were recorded for each of the 10 samples per group.

To measure the trueness within each group, the average distance among the 10 samples was compared to the master STL file,
which represents the reference (or true) cast. To measure the precision within each group, the average distance of the 10 samples was evaluated using the centroid of each group. The differences between the CONTROL group and the COR and OS groups were statistically analyzed in terms of trueness and precision indices using Welch’s unequal variances t-test (n = 10) for each IOS system. All analyses were performed using Microsoft Excel, version 16.16.11.

3. Difference from conventional methods

The novelty of the proposed technique is that it aims to simplify the CAD/CAM image acquisition workflow. Currently, the addition or removal of image catalogs is carried out instantly by the operator, and, if necessary, the cut-out–rescan procedure [7] can be performed for correction and/or replacement of images. However, with the evolution of camera hardware and software, new possibilities and advantages related to data exchange have emerged, which allows for the model accuracy to be preserved and for the previous occlusal registrations to be retained. Thus, this technique facilitates the capture of images and the maintenance of correlations previously established by the software, resulting in reduced time.

4. Effect or performance

The proposed technique maintains the accuracy of the models and previously established relationships with image catalogs. This efficiency leads to reduced time; however, it is important to note that it is only effective in subtractive OS strategy. The software’s image processing during over scanning considers the area of the initial image obtained. Thus, if the image to be exchanged is larger than that obtained initially, the software will not perform the exchange, thereby maintaining the initial image. If the image to be replaced is smaller, the software will process and replace it.

Statistically, the p-values of the experiment, for both trueness and precision, show that with the Primescan IOS, the COR group was significantly different from the CONTROL group (p < 0.01), whereas the OS group was not. In contrast, using the Omnicam IOS, the p-value, for both trueness and precision, showed that the COR group was not significantly different from the CONTROL group (p = 0.01), whereas the OS group was (Table 1). Figures 5A and B show the boxplots of trueness and precision data.

Logically, it can be said that a software update that improves the manner in which the acquired data are managed can improve the accuracy of a scanner. This statement is true in principle, and in this technique, data exchange by over scanning improved the result of the Primescan IOS. For the Omnicam IOS, cut-out–rescan cast areas remain a suitable choice. However, as the Omnicam and Primescan IOSs employ entirely different cameras, this comparison can only be confirmed if testing is performed using different software versions with the same type of scanner, which was not the case in this study. Furthermore, it is noteworthy that from a clinical point of view, the operational application of both IOSs is valuable if the user does not wish to delete the entire image catalog simply because of the need for partial correction (or replacement).

It is essential to note that, in this study, cut-out–rescan cast areas required delimiting the areas that had to be cut to standardize the
cutting area and avoid variations. For data exchange by over scanning, the finished zirconia crowns, which were removed after being scanned established the standardization necessary to repeat the procedure.

It is important to quantify these results for each specific application, as the differences might constitute a problem for some applications. Despite modeling several variables using the master reference cast, this study did not replicate a clinical situation and was limited by lack of simulations of saliva, soft tissues, patient movement, humidity in the oral environment, and multiple substrates, including amalgam, ceramic, cast metal, composite resin, dentin, and enamel [2]. Further research is necessary to determine whether these different variables affect the accuracy in terms of the influence of the extension of areas delimited for the cut-out–rescan cast areas and the influence of those subjected to data exchange by over scanning.

5. Conclusion

The proposed technique provides statistical evidence that for trueness and precision in complete arch scans, data exchange by over scanning results in higher accuracy than cut-out–rescan cast areas when using a Primescan IOS. However, the opposite is true when using an Omnicam IOS, with cut-out–rescan cast areas providing scans with higher accuracy. This technique simplifies the workflow and saves time with a Primescan IOS when correctly applied and should be used with an awareness that future research is required to provide robust evidence regarding its accuracy compared to current clinical best practices.

Acknowledgements

The authors thank Vtech Consulting LTDA, especially Ms. Isabela Quadros, for her help and assistance with ATOS Triple Scanner.
The authors did not receive support from any organization for the submitted work. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

**Conflicts of interest**

The authors declare to have no conflict of interest.

**References**


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