REVIEW ARTICLE

DOI: https://doi.org/10.20453/reh.v34i1.5332

Dental digital impressions with intraoral scanners: a review of the literature

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Cite as:
Palomino-Granados RC, Solar C, Mas J. Dental digital impressions with intraoral scanners: a review of the literature. Rev Estomatol Herediana. 2024; 34(1): 67-72. DOI: 10.20453/reh.v34i1.5332

Received: October 21, 2023
Accepted: November 14, 2023
Online: March 31, 2024

Conflict of interest: The authors declare that they have no conflict of interest.
Funding: Self-funded.
Authorship contribution:
RCPG: conceptualization, data curation, investigation, resources, visualization, writing – original draft, writing – review & editing.
CSL: conceptualization, data curation, investigation, resources, visualization, writing – original draft.
JML: conceptualization, data curation, methodology, project administration, supervision, validation, writing – original draft, writing – review & editing.

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ABSTRACT

Computer-aided design and computer-aided manufacturing (CAD-CAM) has been applied in dentistry for the preparation and analysis of various dental treatments. It starts with capturing images through intraoral scanners, having different types of software and image export systems and technology. The advantages of this digital workflow are the following: better adjustment, shorter clinical time, and speed in dental treatments, in addition to providing greater practicality for dental surgeons. The accuracy provided is clinically acceptable in comparison with conventional methods, so there is sufficient evidence for their validity; however, it should be taken into account that several factors can alter the result, such as the operator's experience, the type of scanner, the type of software, the software update, the scanning principle of the scanner, the environment, the scanning sequence, and the oral structures. The present review article aims to analyze the literature on the different characteristics and properties that intraoral scanners present today and the evidence of the potential benefits and accuracy of digital impression techniques versus conventional impression techniques.

Keywords: dental impression technique, dental impression materials, computer-aided design.

INTRODUCTION

Since the beginning of dentistry, conventional impression techniques have been required and used to register the oral cavity of patients in a three-dimensional way (1). However, volume changes of impression materials and the expansion of dental plaster are sensitive to erroneous results. At the same time, with the advancement of technology applied to dentistry (1), in the early 1980s, computer-aided design and computer-aided manufacturing (CAD-CAM) were developed (2), which was the first system of the commercial brand Cerec (Sirona). This

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has become increasingly important in dentistry, and excellent results have been obtained in the preparation of restorations with various materials (2). The three main components of a CAD-CAM system are the data acquisition unit (intraoral or extraoral scanner), the program software, and the milling or 3D printing device (3). This way, the digital workflow starts with intraoral scanning, expanding the availability of various scanning systems in recent years, operating according to different principles, including active triangulation, parallel confocal imaging, active wavefront sampling and stereophotogrammetry. On the other hand, more recent systems present combined principles (3).

Digital impressions are a clinically acceptable alternative to conventional impression methods, as digital dental technology has evolved, and their application extends from single crowns to complete rehabilitations and even implant support (3). However, there are still limitations as the accuracy of intraoral scanning can be influenced by scanner technology, operating system, device calibration, scanning pattern, ambient light scanning conditions, cutting and rescanning procedures, extent of digital scanning, characteristics of the structures to be scanned as tooth preparation, implant-supported restorations, and partial or total edentulous jaws (4). Additionally, digital impressions present advantages such as efficiency of clinical time in the dental chair, greater patient comfort, real-time viewing, easy communication with dental laboratories, and the versatility of a smoother and more accurate workflow (5, 6).

The aim of this review article is to analyze the literature on the different characteristics and properties of current Intraoral Scanners (IOS) as well as to evaluate the evidence of the potential benefits and accuracy of digital impression techniques versus conventional impression techniques.

INTRAORAL SCANNERS

Imaging with intraoral scanners

IOS are devices used to capture direct optical impressions of the oral cavity (7). They perceive the surface structure of different tissues and capture this 3D image through a laser that projects a light source onto the dental arches, prepared tooth surfaces, and adjacent tissues, while images are captured by sensors (8).

IOS are composed of a *handheld wand* that generates a light projection (active technology) to capture the image by a static (photos) or dynamic (videos) method, which will be put together by the software after recognizing the triangulation of 3D images (9). Triangulation is a technique in which a light source is reflected onto an object, the x and y coordinates of each point are registered, and then the z coordinate is calculated, all based on various optical imaging technologies (10).

Active confocal microscopy

It is a technique for obtaining images of specific depths. It detects the different areas of image accuracy to be able to estimate the distance between the object to be scanned and the focal length of the lens. After that, a tooth can be reconstructed with consecutive images acquired with different focal lengths and diaphragm values from different angles of the object's periphery (11). The area of accuracy is clearly linked to the user's experience, since some type of motion blur may occur. Apart from that, this type of procedure requires a long head, which may cause difficulties in the clinical practice (12).

Active wavefront sampling

It is an image collection technique that uses a camera and an off-axis aperture. The module has a movement where it follows a circular path around the optical axis, which generates a rotational movement of the specific point of location to be scanned (POI). From the pattern produced by each evaluated point, depth and distance data can be obtained (13).

The images captured by different sensors are processed by the scanner software that generates a set of vertices (point clouds). These are then triangulated to create a three-dimensional mesh model (7). Performance can be influenced by several factors, including IOS type, intraoral conditions, scanning protocols, scanned object geometries and surface optical properties, processing software algorithms, and ambient light conditions (14).

Types of software and image export systems and technology

Digital print data transfer systems using IOS can be classified into open systems and closed systems.

Open systems

They are systems where IOS software allows digital printing to be sent directly through the export of source files, which can be a standard data transmission format for making elements in 3D (STL) Standard

Tessellation Language or Standard Triangle Language, a Polygon File Format (PLY) or an Object File Format (OBJ) to different laboratory units, which gives the desired flexibility and allows maximizing the investment potential with different options (15).

The STL file format is simple and small, so its processing is faster, but without color or texture representation. On the other hand, OBJ and PLY formats can store properties such as color and texture that benefit enhanced 3D printers (7).

Closed systems

In a closed system, digital impressions are sent to the manufacturing company for a subscription fee. The advantage is that, since the configuration, data collection, and manipulation are used by the same manufacturer, there is greater security, accuracy and a single place for delivery. Some scanners only allow data acquisition, which is then sent to the laboratory for further processing and manufacturing. On the other hand, there are scanners that, in addition to acquisition, can mill or print the same day, allowing the patient to have a dental restoration in a single session (7, 16).

Data collection methods, image transfer, tracking strategies, and scanner head size may vary between different types and brands, but each procedure produces a digital model of the patient's dentition (9, 16).

Patient acceptance of the use of intraoral scanners

In some of the studies using irreversible hydrocolloid impression, patients preferred conventional impression, compared to a previous IOS generation, due to the difficulties in optical impression, regarding operability, scanner size, scanning speed, etc. However, due to improved hardware technology, the scanning speed has improved, and the size of devices has been reduced, optimizing their ergonomics (1-6). Therefore, in recent research, many patients responded that IOS was more comfortable, especially when it is necessary to repeat some dental impression with the conventional technique, which would mean more time with the patient in the dental chair and the use of extra material. Furthermore, an additional benefit is that the gag reflex would be minimized. Some studies use irreversible hydrocolloid impressions as a comparison since they are easier to control than elastomeric impressions (3). As a result, when comparing IOS with conventional impressions, the first one presents superior qualities and results with respect to patient acceptance (1-7).

Operator satisfaction

Schlenz et al. (10) and Lam et al. (11) demonstrated that there was a significantly higher proportion of students who perceived that IOS require less armchair support and it is easier to master as a beginner. In addition, 60.2% of students had no difficulty to operate the scanner software, so the scanning process was manageable (11).

Accuracy of digital impressions made with intraoral scanners

Accuracy of impression methods is critical for the internal and external adjustment of indirect restorations. Accuracy is the difference between the quantitative values obtained from the measurement and the actual spatial values of the measured object, and, in turn, comprises trueness and precision. Trueness means how close the results of a measurement are to the actual values of the measured object, while accuracy is the variability of repeated measurements of the measured object (7). The higher the accuracy, the more reliable the measurement; and the higher the trueness, the closer the measurement is to the actual dimensions of the object. The methods for comparing the accuracy of digital and conventional impressions are linear measurement and 3D superimposition. Compared to linear measurement, 3D superimposition evaluates hundreds of measurement points, which may reflect the deformation of the entire dental arch (11).

The accuracy of a digital scan depends on the ambient light, the size of the scanner head, the scanning technology, whether reflective powder is required, the scanner software program, the scanning protocol, the limited space in the buccal opening, the length of the edentulous section, among others (5). Therefore, to evaluate the adjustment of restorations when using IOS systems, two-dimensional or three-dimensional indirect approaches can be used (4-6). Internal marginal discrepancies of less than 120 μm have been described as clinically sufficient for the fitting of single-tooth restorations (2). Despite this, the American Dental Association suggests that the thickness of cementation do not exceed 40 μm (2, 17). Hence, this acceptability limit is not yet defined, and inadequate marginal/internal adaptation may predispose to

restoration failure. When assessing the final fit, factors such as CAD design, CAM milling process and seating of the restoration, and preparation geometry should all be taken into account because the existing literature advocates that the more complex the scanned morphologies are, the more difficult it is to reproduce them in digital form and, consequently, there could be a detrimental effect on accuracy (3, 15, 18).

Poor marginal fit can promote biofilm buildup and cause complications, such as secondary caries and periodontal disease, and poor internal adaptation can lead to periodontal loss of axial retention, lack of rotational stability, reduced fracture toughness and positioning inaccuracies, which lead to interproximal and occlusal interferences (3-8).

Scanner (Brand name)	Scanning principle	Size	Price	Integrated screen	Open system
Trios 4 (3Shape)	Confocal microscopy	Small	💲💲💲	No	Yes
Trios 3 (3Shape)	Confocal microscopy	Small	💲💲	No	Yes
PrimenScan (Dentsply Sirona)	Active triangulation and confocal microscopy	Medium-sized	💲💲💲	Yes	Yes
Omnicam (Dentsply Sirona)	Active triangulation	Medium-sized	💲💲	Yes	Yes
Cs3600 (Carestream)	3D active speed video	Medium-sized	💲💲	No	Yes
Cs3500 (Carestream)	Optical triangulation	Medium-sized	💲💲	No	Yes
iTero Scanner (Align Technology)	Parallel confocal microscopy	Medium-sized	💲💲💲	Yes	Yes
i500 (Medit)	Active triangulation	Medium-sized	💲💲	No	Yes
i700 (Medit)	3D motion video technology / Fullcolor 3D broadcast capture	Medium-sized	💲💲	No	Yes
Virtuo Vivo (Dental Wings)	*"Orthographic projection"*	Small	💲💲	No	Yes

Figure 1. Comparison of intraoral scanners according to their characteristics

In addition, the manufacturer of each scanner specifies a scanning strategy, although for each full arch it does not mention the starting quadrant. In general, newer scanners, Trios 4 and Primescan provide more accurate data for full-arch digital impressions. However, up to the moment there is no evidence of relevant differences in performance between the various digital scanners that are clinically relevant. This, on the one hand, may be due to continuous advances in hardware development and/or software upgrades. For the Cerec systems, the software version had a significant impact on IOS accuracy. And for the Trios scanner, the hardware also has a significant influence on the transfer accuracy of full-arch scans (1, 17).

Comparison between digital impressions and conventional impressions

Dental impressions can be conventional or digital. Conventional impressions refer to the negative impression of the tooth surface and adjacent structures. Nowadays, the most used materials for this type of impressions are irreversible hydrocolloids and elastomers (1, 5, 16).

With the advent of IOS, interest in digital impressions obtained directly from intraoral scanning has been increasing (4, 5). Compared to conventional impressions, digital impressions generated by IOS have several advantages. However, conventional

impressions and plaster models have always been considered the gold standard (9-12). Hasanzade et al. (13) demonstrated that, for partial-arch impressions, digital impressions were so —or even more— accurate than polyether and polyvinylsiloxane impressions in the fabrication of single-unit, short-span fixed dental prostheses. In addition, digital scans have demonstrated clinically acceptable impressions of one or two contiguous implants (6-8, 10).

As for full-arch impressions, the results of accuracy and trueness are ambiguous. In this regard, Kong et al. (19) demonstrated in a systematic review that the veracity of digital impressions and full-arch irreversible hydrocolloid impressions were similar, and both showed high accuracy. This coincides with Sfondrini et al. (14), who reported that accuracies of digital and alginate impressions were the same. However, Tomita et al. (15) stated that digital impressions showed higher accuracy compared to alginate and polyvinylsiloxane impressions. At the same time, Duvert et al. (16) found that digital impressions were less accurate than polyvinylsiloxane impressions. And Atieh et al. (18) concluded that digital impressions showed lower accuracy compared to polyvinylsiloxane impressions.

On the other hand, full-arch impressions are essential for diagnosis in some dental specialties, such as orthodontics, restorative dentistry, oral rehabilitation, as well as in preoperative evaluation in orthognathic surgery (15-20). Therefore, several *in vitro* studies have concluded that digital impression provides higher accuracy for marginal fit values than the conventional technique, since it avoids possible deformations due to material properties caused by incomplete polymerization. However, one should not exclude the different factors such as saliva, sulcular fluid, blood and patient motion, which could affect the accuracy of the impression in *in vivo* conditions that do not exist in the *in vitro* method (1, 6, 17, 19, 20).

Nowadays, digital impressions, compared to conventional impressions, show excellent accuracy and versatility, and provide a faster workflow, so they are considered acceptable for clinical use. However, consideration should be given to the various causes that may alter the result, such as operator experience, type of scanner, type of software, environment, scanning sequence and oral structures. For these reasons, it is essential to be aware of the factors that can decrease scanning accuracy to maximize precision.

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