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Influence of the impression techniques on the accuracy of dental restorations

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Abstract

In recent years we have seen rapid development of digital technologies in dental medicine. The use of CAD / CAM technology and 3D printing is increasing. Digital impression techniques are used to improve the quality and accuracy of dental restorations – directly via an intraoral scanner or indirectly through a laboratory scanner. The purpose of this review is to present the literature data on the impact of different impression methods on the accuracy of dental constructions.

Keywords: intraoral scanner, laboratory scanner, digital impression, marginal fit, internal fit

Background

The use of digital technology in dental medicine is constantly increasing. Digital devices for the needs of dental practices and dental laboratories are being improved. CAD/CAM systems were first introduced in 1970 by F. Duvet (1). This technology is related to the process in which digital images or object models are created and used to produce different types of restorations. The system consists of three main parts: an intraoral scanner or a laboratory scanner that transfers physical data to a digital image; software that converts the received data into a digital model, and a milling machine that changes the set digital data into a dental construction (2).

One of the most critical moments in the preparation of the indirect restorations is taking a precise and accurate copy of the operative field. Nowadays, this could be done using standard or digital impressions. 3D scanners are electronic devices through which information from the prosthetic field is received and processed so as to reconstruct a 3D model of the scanned object. They could be classified on the basis of different features: scanner type and image capture mode; type of light transmitted from the scanning device; architecture (open or closed / locked) (1), single scanner or complete scanning system, 3D image modeling and milling machine. The choice of a scanner is influenced by the following factors: intraoral wand size, benchtop scanner size, the need for a covering agent, the scanning method, the ability to capture colors and creating video.

There are two possibilities for three-dimensional reconstruction of images: directly through an intraoral scanner or indirectly through a laboratory scanner. Thus, the digitalization of the sample is of two types: **direct** or **indirect**. Direct digitalization avoids some inaccuracies related to the deformation of the impression material and pouring gypsum models (3), and some mistakes during cavity preparation (undercuts, sharp line angles) and they could be corrected without any material waste. Other advantages of this technique are increasing the comfort of patients during dental treatment (especially in patients with increased gag reflex), visualization, motivation and the ability to clarify the case with the patient and reducing manipulation time (4, 5, 6). However, mainly the high cost of intraoral cameras and the insufficient data in the literature on their qualities and advantages are the reasons for the limited application of this method (7). When using a laboratory scanner, it is necessary to take a standard impression, which then becomes a digital model. This method does not eliminate the problems associated with the deformation of the elastomer material.

Milled dental restorations present with great precision and adaptation to the prosthetic field. Nowadays, there is a difference in the accuracy of scanning devices - intraoral and laboratory scanners.

Aim

The aim of this study was to carry out a literature review on the impact of different impression methods on the accuracy of dental restorations.

Laboratory scanners (benchtop)

There are two types of laboratory scanners depending on how the image is obtained: contact (tactile) and contactless (optical). The first receive information about the object through mechanical contact between the scanner and the gypsum model. They are characterized with extreme accuracy - in the order of 1-2 µm. The main drawback is the long image acquisition time and the ability to distort the model in mechanical contact. The second type of laboratory scanners is contactless (optical). They use electromagnetic waves, usually light, to capture the information of the models. Scanning is significantly faster and does not compromise the integrity of the scanned objects as it does not touch their surface.

Depending on the type of radiation used for scanning, laboratory scanners are of three types: using structured light; laser beams; confocal.

Scanners using structured light consist of a centrally localized projector, opposite the object. The light source sends to the object a series of templates consisting of vertical and horizontal parallel light and dark streaks generated by a special software. The designed templates are deformed based on the different surface characteristics of the scanned object. Then a photosensitive camera, located on a line with the projector (but away from it), receives the signal. Then the object is reconstructed based on the information

received. When the rays pass through the object without being reflected, the latter must be inclined at an angle to allow its surface to be illuminated and to receive the reflected light. Scanners of this type are: Cara Scan (Kulzer, Hanau, Germany), D2000 (3Shape, Copenaghen, Denmark), inEos X5 (Dentsply / Sirona, Bensheim, Germany), Evolution Plus (Zfx, Munich, Germany). Object scanning accuracy with these devices varies from 2.1 µm for inEos X5 (Dentsply / Sirona, Bensheim, Germany), 9 µm Evolution Plus (Zfx, Munich, Germany) to 15 µm for Cara Scan (Kulzer, Hanau, Germany) (8).

Laser scanners based on the projection of a point of light record its position through a set of cameras. The software creates a 3D object based on the principle of triangulation. To reduce operating time, line of laser light is used instead of single points. The disadvantage of these scanners is that less light is reflected and this reduces the accuracy of the scanned object. Examples of such devices are ConoScan 4000 (Optimet, Jerusalem, Israel), OpenScan 100 (LaserDenta, Berghain, Germany), Zeno scan S 100 (Wieland, Pforzheim, Germany). The accuracy of these scanners is significantly lower - 15 µm for the ConoScan 4000 (Optimet, Jerusalem, Israel) and 50 µm for the Zeno scan S 100 (Wieland, Pforzheim, Germany).

Confocal scanners are subtype of scanners using structured or laser light. They allow the reproduction of small details of an object and the use an optical technique that increases resolution and contrast. They are characterized with high precision - 1-2 µm for Procera Forte (Renishaw, Gloucestershire, UK).

Intraoral scanners

Intraoral scanners were first introduced to the market by Mormann and Brandestini in 1980 (9). Nonetheless, F. Duret introduced the idea of CAD / CAM systems in 1971. These devices eliminate the need to use impression trays, reduce inaccuracies associated with dispensing and setting material, disinfection and transferring the impressions to the laboratory. The collaboration on the line doctor-patient-dentist (10, 11) is improved due to their utilization.

Intraoral scanners can be divided into two groups: using a coating agent (powder) and no coating agent (powderless). The former are monochromatic and the latter may be colored. Intraoral scanners use different technologies for 3D imaging: confocal microscopy, optical coherence tomography, active and passive triangulation, active wavefront technology, photogrammetry, interferometry (12, 13). According to the type of the light source, they can operate with laser, structured, visible and LED light. All of these mode of action can influence the acquisition and construction of the image, and hence the modeling and accuracy of the future restorations.

Intraoral scanners using coating agents are the first introduced in the market. Typically, titanium oxide spray is used to reduce the reflection of light from the tooth surface and soft tissues, thus enhancing the image precision. These types of scanners are based on two principles of image capturing - through active triangulation or active wavefront technology. They are extremely accurate, but their main disadvantages are the unpleasant feeling and side effects for the patient by the covering agent, as well as the errors caused by the lack or accumulation of more powder on the scanned surface. Today, there are new generations of scanners that do not require coating of the scanned object.

Scanners that use active wavefront technology refer to image capture by a lens system. If the subject is in focus, the distance to it is related to the focal point. Otherwise, mathematical formulas are used to calculate it.

Active triangulation is based on the principle of designing models of lines on the object. It is the most commonly used method for intraoral scanners and shows the highest precision (14).

Recently created intraoral scanners recreate an image from a scanned object without the need to be covered with powder. The resulting 3D copies can also be colored. These intraoral scanners are based on

the principle of confocal microscopy, ultrafast section technology and passive triangulation and are extremely accurate because they do not require a specific focusing distance (14, 15).

The scanning process is very sensitive to a number of factors (16, 17, 18), such as manipulation of an intraoral scanner. Studies have shown that the accuracy of the obtained 3D image is increasing with the experience of the dentist (16). Scanning accuracy is strongly influenced by factors such as saliva and soft tissue around the subject. In order to avoid errors, it is necessary to isolate the operative field from the lips and cheeks, and to place a retraction cord in the gingival sulcus. The presence of saliva and / or blood is among the most common causes of inaccuracies in scanning. Therefore, special attention should be paid to the isolation of operating field. The use of intraoral scanners still has difficulties in obtaining an accurate image from the subgingival margins of the prosthetic field, especially in the distal region. This is another reason for placement of retraction cord (19).

Studies on the accuracy of structures

A number of studies have been conducted to compare the accuracy of different methods for obtaining a digital copy of the prosthetic field. According to Malaguti et al, marginal and internal adaptations provide information on the accuracy of indirect restorations (20).

Pedroche et al evaluated the marginal and internal adaptation of zirconium crowns made by scanning with a Trios 3Shape intraoral scanner (Copenhagen, Demark) based on confocal microscopy, and with a laboratory 3Shape D700 (Copenhagen, Denmark) (21). Restorations made through direct digitalization demonstrated statistically better results for marginal and internal adaptation. Similar results regarding the accuracy of intraoral and laboratory scanners are found by Ahrberg et al. and Shimizu et al (5, 22). Their studies concluded that there are statistically significant benefits of intraoral scanners regarding the accuracy and precision of the image obtained.

Hack and Patzelt found that Trios are the most accurate scanners compared to four other devices (True definition, ITero, CS3500, Omnicam, and Planscan) for single-tooth (23) images.

An et al. investigated the accuracy of zirconium crowns after a fully digital impression and scan of a plaster model using iTero (Cadent) (24). They found no statistically significant difference in the size of the marginal gap in the two studied groups.

Other authors reported lower marginal gap values when using a laboratory scanner compared to an intraoral (25). Shembesh et al reported better marginal discrepancy results using a 3M True Definition Scanner lab scanner compared to iTero (Cadent).

Despite the numerous results from in vitro studies, they are difficult to compare because of some differences in the methods of testing.

Conclusion

The data from the current literature review yields conflicting results regarding the accuracy of the impression obtained by an intraoral scanner and a standard impression digitalized with a lab scanner. Therefore, further studies are needed.

Acknowledgment

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