ANALYSIS OF DIGITAL IMAGES CAPTURED BY INTRA AND EXTRAORAL SCANNERS IN PROSTHODONTICS

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ABSTRACT

Different techniques have been proposed to diminish the error that evolves the conventional dental impression techniques. Along with the evolution of technology a great amount of different extra and intraoral scanning systems have been created.

The main target of this investigation was to compare the accuracy of two dental scanning systems, using an industrial scanner as reference.

A modified model was built and scanned by an industrial scanner, followed by an intraoral scanner and an extraoral scanner. The image accuracy was analyzed through the comparison of the meshes obtained by the three scanners.

The three-dimensional comparison between the images captured by the industrial scanner and the intraoral scanner revealed positive and negative deviations.

Although intraoral digital impressions have given proof of precision and reliability in scanning a small number of preparations, they cannot be considered reliable when scanning a full-arch.

Keywords: Dental impressions, intraoral scanners, extraoral scanners, digital images.

INTRODUCTION

The impression of the teeth and soft tissues is a fundamental step to oral rehabilitation because it transfers the intraoral situation into a physical model where treatment plans, studies and orthodontic measurements can be done. It’s also where restorations and prosthesis can be made (Ender 2013, Logozzo 2014).

Different techniques and materials have been proposed to diminish the error that evolves the conventional impression techniques. Along with the modernization and evolution of technology a great amount of different extra and intraoral scanning systems have been created (Lee 2014, Seelbach 2013, Kachalia 2010, van Noort 2012).

The introduction of computer-aided design/computer-aided manufacturing (CAD-CAM) technology has demonstrated significant advantages, as it improves, enhances and simplifies some techniques that in the past were complicated and required a great amount of time. The techniques include automation of the production process and optimization of the quality of the restoration by using biocompatible materials especially high performance ceramics such as zirconia and lithium disilicate. The cost/benefit ratio is high because the time and effort
expended in the manufacture of prostheses are lower than in traditional techniques. Several studies reveal the high precision and accuracy of restorations when this technology is used (Yuzbasioglu 2014, Seelbach 2013, Correia 2006, Miyazaki 2009, Pradíes 2015).

Dental preparations can be scanned outside the mouth, on a plaster model or inside the mouth, using an intraoral scanning system (Correia 2006, Miyazaki 2009, Infante 2014). Currently, the most widely used procedure is still scanning the plaster model, a process that begins at the dentist's office with a traditional impression with trays and impression materials. The impression is sent to the laboratory where the technician transforms it into a 3D model of the dental arch. Afterwards, the prosthesis can be drawn in a CAD-CAM system and the file is sent to the milling machine. The milling machine produces the prosthesis, which is then placed and adjusted by the dentist in the patient's mouth (Logozzo 2014).

The ability to scan plaster models, or even the teeth directly from the mouth of the patient has been proved to be an asset for dentistry. The use of impression materials often introduces errors that can be made both by handling the materials and by the impression technique itself. The use of digital scanners for dental impressions can eventually eliminate the impression step with the use of trays, thus reducing errors in this process (Polido 2010, Yuzbasioglu 2014, Infante 2014). In addition, during the impression process, the dentist can immediately see the preparation and its relationship with the antagonistic teeth, and may correct the preparation or the impression, with no need to repeat the entire process (Pradíes 2015, Boeddinghaus 2015). In the laboratory it also saves time, because there is no need to pour the plaster impressions, to put pins and replicas, cut and shape dies or put models in articulation (Polido 2010, Boeddinghaus 2015).

Intraoral scanning is now a reality and the use of this technology is rapidly increasing throughout the world and represents a considerable change in the way the dental impressions are made (Logozzo 2014, Polido 2010, Correia 2006, Liu 2005). In this method, the dentist captures the image of the dental arch using a small camera and sends the image to the laboratory. In the laboratory the file is downloaded to a software where the margins of the preparations can be marked. The technician can then proceed to the completion of the restoration and send it to the dentist (Logozzo 2014, Schaefe 2014).

Intraoral impressions has been studied and some limitations have been reported regarding the difficulty of the technique. Because the systems available today only capture visible areas, the presence of adjacent teeth, gingiva, blood and saliva lead to technical difficulties, as the margin of the abutment teeth is hard to read in these conditions (Ender 2013, Logozzo 2014, Miyazaki 2009, Boeddinghaus 2015). Also, is often necessary to apply coating materials on the teeth surface and to rest the camera wand on a tooth to get a steady focus (Ender 2013, Logozzo 2014). However, there are some studies that show a better marginal adaptation of restorations when an intraoral impression is made in comparison to the conventional impression (Boeddinghaus 2015).

The main target of this investigation was to compare the accuracy of two dental scanning systems, using an industrial scanner as reference.

**MATERIALS AND METHODS**

In order to compare the extra and intraoral scanners a modified model was built. In the model, natural and acrylic teeth were placed, two of which were restored with amalgam and composite resin and another one was an abutment prepared to receive a full crown.
To allow the comparison of the images distortion, a reference system was placed. The reference system consisted of three calibrated metal balls with 4 mm of diameter fixed to the teeth 37, 41 and 47.

The model was coated with titanium dioxide particles, then scanned by an industrial scanner, followed by an intraoral scanner and an extraoral scanner. The image accuracy was analyzed through the comparison of the meshes obtained by the three scanners.

RESULTS

The three-dimensional comparison between the images captured by the industrial scanner and the intraoral scanner revealed positive and negative deviations that represent expansions and contractions (Figures 1 and 2).

The red areas reveal positive deviations of expansion while blue areas show negative deviations of contraction. In Fig 3 it is shown the deviations direction.

The comparison made between the images of the industrial scanner and the extraoral scanner didn’t reveal any significant discrepancies (Figs 4 and 5).
The last comparison made between the image captured by the intraoral scanner and the extraoral scanner revealed positive and negative deviations, representing contractions and expansions (Figs 6 and 7).

Visual analysis of the overlapping images revealed deviations in the horizontal plane, where the red areas show positive deviations of expansion, and blue areas show negative deviations of contraction of the intraoral images regarding the extraoral images. In Fig 8 we can observe the direction of the deviations found.
DISCUSSION

The main purpose of this study was to compare and analyze digital readings made by intra and extraoral scanners to see if there were differences between them.

For this study a model was built, in which natural and acrylic teeth with different materials and restorations were placed. Except for the study conducted by Akyalcin et al. (Akyalcin 2013) none of the studies analyzed had in consideration the error that may exist in the plaster casts made from conventional impressions. To eliminate this possible error, a model with the aforementioned characteristics was built, which could then be scanned in the same conditions in all scanners.

One way to minimize the error caused by highly reflective or translucent materials is to use a coating powder or spray covering all surfaces before being scanned (Boeddinghaus 2015, Holst 2015). Powder particles block glare and function as small “optical connectors”, which help the software to connect the images captured from different angles (Schaefer, 2014). The coating powder can be an additional source of secondary error, but comparative studies already carried out concluded that this error has absolute values of minor importance and its use brings more advantages than disadvantages (Flugge 2013, Holst 2015). The dusting with a coating powder prevented differences to be found between the different materials used. The model had materials such as enamel, acrylic, composite resin and silver amalgam but we cannot infer about their influence on the results. As the conditions of temperature, humidity and pressure were similar, it is more likely that there are no differences in readings, since any material is read in the same way since coated with the necessary coating powder.

Since the scanning with the intraoral scanner was done in vitro, it was not possible to evaluate the influence of intraoral conditions in this readings. However, this condition led to the scanning being done in the best possible conditions, without the interference of saliva, blood or unwanted head movements.

As mentioned in the results, in the first comparison made, it was observed that the buccal surfaces of the posterior areas of the image captured by the industrial scanner are extended horizontally regarding the image of the intraoral scanner. These results indicate that the buccal surfaces of the image captured by the industrial scanner describe a wider and shorter arc than the buccal surfaces of the image captured by the intraoral scanner. The lingual surfaces of the image captured by the industrial scanner had an inverse behavior. The posterior areas of the lingual surfaces have a negative deviation, being contracted horizontally and the anterior area shows positive deviations and therefore are extended horizontally (Fig 3).

In this case, where there is a geometric distortion, we cannot infer the reason of the deviations in each individual tooth as all the teeth are geometrically distorted.

In the second comparison carried out, we analyzed the discrepancies between the images of the industrial scanner and extraoral scanner. No expansion or contraction was found, so there is no geometric aberration. These results were predictable since both machines use the same image acquisition system. Both use more than one lens and capture multiple images always having all the model in its field of view.

The comparison between the images of the intra and extraoral scanners provided positive and negative discrepancies similar to the comparison between the intraoral scanner and industrial scanner. Vestibular image captured by the intraoral scanner is contracted in posterior areas.
and expanded in the anterior area. On the contrary, the lingual surfaces are expanded in the posterior areas and contracted in the anterior area (Fig 8). These results were expected since the comparison between the extraoral scanner and the industrial scanner revealed no significant deviations. Given the results of the previous comparison and how the image was acquired, it is to assume that the image most similar to the reality is the one captured by the extraoral scanner.

The deviations found in the image captured by the intraoral scanner may be due to the fact that in intraoral scanning techniques, image acquisition is done incrementally. Both extraoral scanners make several continuous readings from different angles, with the model as a whole always in their field of view, so that when the software is to unite all these images captured, it is not difficult to find reference points to overlap them rigorously. In the case of the industrial scanner there are also scan markers placed in the model that are calibrated and coded and designed to help the software to recognize the connection points of the multiple images taken. In the case of the intraoral scanner, the size of the camera means that the optical lens is small and there is the need to read incrementally, capturing multiple images of each tooth and using an image superimposition process that can produce a systematic error (Flugge 2013). The intraoral scanner used reads the arch in three blocks. This requirement implies that when the software partially overlaps the acquired data of each block it only has some reference points in common between the three readings, which in this case lies in the area of the canines and premolars. It may be the explanation for the fact that in this area there is no significant distortion.

In addition to the errors related to software scanners, there is still the possibility of errors that are related to optics. The geometric aberrations can be corrected by increasing the number of degrees of freedom, using various lenses instead of one. Thus, by balancing the curvatures of the surfaces of each lens and by using different types of optical glasses, one can eliminate or reduce the geometrical aberrations (Courrol 2011). This is a solution that intraoral scanner can’t use because the small size of the camera limits the use of only one lens. This may be an explanation for the fact that the extraoral scanners do not have these aberrations, as they have more than one lens.

It is not possible to conclude whether the intraoral scanner is more or less accurate when scanning two or three teeth than the extraoral scanner, or if the shape of the teeth change somehow the results. In our study, the readings with the intraoral scanner of an entire dental arch presented geometric errors so it appears to be an unreliable instrument when an impression of an entire arch is required for rehabilitation purposes.

To fill this gap and reduce the geometric aberrations, digital impression systems will need to evolve and improve its optical systems and especially their software. The necessarily small size of the intraoral camera limits the possibility of using two lenses so they will have to evolve in another direction. Another limitation of optical systems is the need for a large approximation to the tooth. As space in the mouth is small and the camera must be very close to the object to read it, the focal length is very small and the distortion is bigger. Including more systems that complement themselves might be a way to improve these results.

Probably the most likely path to be followed to improve the performance of digital scanners will be the development of more complex software, more able to combine the meshes of the images with few reference points, since the space in the mouth restricts reading cameras in size and number of lenses.
CONCLUSIONS

Removing all physical impressions may be where technology is leading us on. Although intraoral digital impressions have given proof of precision and reliability in scanning a small number of preparations, they cannot be considered reliable when scanning a full-arch, as there are still geometric aberrations caused by small cameras, optical one-lens systems and the difficulty of the software to put together with precision the various readings that are needed.

To improve the performance of digital scanners it will be necessary to create more complex software.

REFERENCES


