Intraoral Scanners – A Review

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Abstract

Intraoral scanners (IOS) are the emerging digital technology in the field of dentistry. Introduction of IOS in dentistry has increased the use of digital technology in dental procedures. IOS are the devices used to capture optical impression directly inside the oral cavity. They are more accurate in reproducing the oral hard and soft tissues when compared with conventional impressions. Some of the IOS can also distinguish between soft and hard tissues by capturing colored impression images. Accuracy of the IOS has been evaluated based on their precision and trueness. The main aim of this review was to assess the characteristic features and the applications of various commercially available IOS. An electronic search was done using PubMed and Google scholar. Totally 308 articles were identified and 42 articles were included in the final analysis. Currently available IOS have wider indications for clinical use whereas the older one has fewer clinical indications.

Keywords: Accuracy, Digital impression, Precision, Trueness.

Introduction

Impression making procedure done routinely in dentistry to record the oral soft and hard tissues. The models or casts made from those impressions are used for diagnosis, treatment planning and fabrication of the prosthesis. A good impression must accurately record the oral tissues to enhance the fitting of the prosthesis. Revolution of digital dentistry reduced the difficulties encountered in today's dental practice with conventional impressions.

These commercially available scanners in the market today use various optical technologies for capturing the dental tissues. Intraoral scanners (IOS) system has improved the accuracy and convenience for the fabrication of the prosthesis. The use of these scanners has been increased in clinical practice because of its high degree of precision, accuracy and standardization.

Many IOS are available in the market with their own characteristics such as the working principle used, type of light source, imaging, and format of output. Hence, it is in dentist hands to carefully evaluate the performance of the IOS while selecting the scanner.

Clinical Indications and Contraindications

Indications[1-10]

- For Single tooth restorations.
- Resin inlays/onlays.
- Zirconia copings.
- Post and core.
- Removable partial dentures.
- Fixed partial dentures.
- Smile designing.
- Implant prostheses and
- Guided implant surgery.

Relative contraindications[11]

- Long span fixed partial dentures and implant prosthesis.
- Complete removable prosthesis.

Various IOS Used for Making Digital Impression are Discussed in Table 1

Accuracy of the IOS

Accuracy of the IOS can be measured in terms of trueness and precision. Trueness is how far the measurement is differing from the original dimension of the object. Precision will determine how far the repeated measurements are closer to each other.[12] For

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Table 1: Intraoral scanners for making digital impression

System	Scanning principle	Procedure	Standard triangle language-export
CEREC	Active Triangulation and single image shot	Buccal, occlusal, and oral image from every tooth, camera flip at midline	Direct via CEREC-connect portal
Itero	Confocal laser, single image shot	Guided scanning according to software instructions	After uploading to Cadent Center and central post-processing
LAVA	Active wavefront sampling, continuous images	Scan path: occlusal, buccal and oral direction of one quadrant, adding second quadrant	After uploading to 3M Connection Center and central post-processing
True definition	Active wavefront sampling, continuous images	-	Direct through 3 Shape communicate Portal
Trios	Confocal laser, continuous images	Scanning according to manufacturer's manual for complete-arch impression	Direct through 3 Shape communicate Portal

example, *in vitro* scanning of plaster model using extraoral scanner is taken as reference currently. However, it is difficult to compare the results with *in vivo* files.[13] Some studies compared the distance between the standard triangle language that is produced from the plaster model and those produced from IOS manually.

Other studies aligned two different files using an algorithm and measured the distance between them.[14,15] Kanazawa *et al*. reported that illumination and color temperature affects the trueness and precision of IOS.[16] The most appropriate lighting condition for making digital impression is 3900 K and 500 lux condition. The various conversion filters used are illustrated in Figure 1. Prudent *et al*. reported that the marginal discrepancy is influenced by powdering.[17] Many studies on IOS used models. However, the experimental environment is better than the actual environment.

Many studies have reported that the clinically valuable precision and trueness of currently used IOS both *in vivo* and *in vitro*. The mean trueness of various IOS technologies is between 20 and 48 µm. The precision value is between 4 and 16 µm.[18] Distortion is associated with the *in vivo* full arch scanning which involves triangulation, active wavefront sampling, and confocal technologies.[18-20]

Intermaxillary relationship registration

During prosthetic rehabilitation of the patients, it is necessary to take intermaxillary relationship. During this procedure, imprecision of bite registration material can occur. So during digital impression making using IOS, it will require a new acquisition of vestibular faces, when the patient in a state of occlusion.[21]

Alignment of maxillary and mandibular arches can be done using a matching process. For this, coincidental areas will be positioned under different planes. A study reported that, for the software alignment of maxilla and mandibular arch, we only need one left and one right occlusal record. It should be with a minimum dimension of 12 × 15 mm.[21,22]

Reproducibility of the IOS

Trueness and precision of the IOS should be verified to confirm the reproducibility of the scanner. With regard to the target site, some studies measured the partially edentulous areas and some studies measured the completely edentulous areas in models.

Figure 1: Conversion filters

Medina *et al*. used four IOS to measure the totally and partially edentulous models and concluded that the best trueness was produced by TRIOS (20.6 µm), followed by true definition (23.2 µm), itero (31.7 µm), and cerec (36.4 µm). For completely edentulous models, best trueness was obtained by true definition (32.1 µm), followed by TRIOS (55.3 µm), itero (94.5 µm), and cerec (98.3 µm).[23]

In implant dentistry, Imburgia *et al*. studied the trueness and precision in both edentulous and partially edentulous models. The best trueness was obtained when measuring the edentulous model using CS 3600 (50–81 µm), followed by Trios 3 (57–89 µm), Cerec Omnicam (63–87 µm), and True Definition (84–89 µm).[24] Mangano *et al*. used four IOS to validate both partially and totally edentulous models. In the study, the IOS showed similar results for both partially and totally edentulous models.[25]

From these studies, we can conclude that, if the scanning range is larger, then the error will be more. In many studies, they confirmed the trueness of <50 µm in a partially edentulous models. A significant amount of correction must be done while fabricating a cross arch fixed prosthesis. This is because IOS have a trueness of about 50–250 µm.[26]

Time efficiency of the IOS

The conventional impression making is considered as time consuming for the dentists and that makes the patient uncomfortable during the treatment. Patzelt *et al*. reported the time efficiency of different IOS based on three scenarios, that is, single abutment, short span fixed dental prosthesis, and full arch prosthetic preparation.[23] The time duration for making digital impression of scenarios 1, 2, and 3 was 5 min 57 s, 6 min 57 s, and 20 min 55 s. On contrary, conventional impression making took 18 min 15 s and 27 min 25 s for scenarios 1 and 2; for scenario 3, they ranged between 21 min 25 s and 30 min 25 s.

From the study, we can conclude that the computer-aided impression making provides more time efficient workflow than the conventional impression making. We can also reduce the actual chairside working time by sharing the steps among the dental team members.[27]

Handling characteristics

When compared to the conventional impression techniques, digital impression technique is more comfortable and faster.[28] It also makes the handling easy by the light weight wand head. IOS using confocal principle reported that it was more efficient technique with short preparation and retake time when performed by inexperienced 2nd year dental students. Handling time can be affected by the type of technology used in the scanner. It can also be affected by the scanning paths during impression making. It has been reported that the handling time lies between 4 and 15 min.[29]

Learning

Learning curves

A learning curve is a visual portrayal of rate of learning something over a period time or by repeated experience of an operator. Different types of learning curves are present. Among those, ascending sigmoid curve is a classic type. This curve starts from learning level zero.

The curve is divided into three segments. They are as follows:

1. Positive learning period.
2. Consistent period.
3. Negative growing period.

The learning rate will be constantly increased during the positive growing period. It will be followed by consistent uniform period which is represented by the middle section.

The learning rate will be decreased during the negative growing period. After this phase, the curve will end in a flat phase.[30]

Inverse learning curve

If the repeated experience is represented on a X-axis and resource cost is represented on a Y-axis, the resultant curve is an inverse learning curve. Example: Time and number of images required.[30]

Powdering

Dental tissues contain number of reflective surfaces such as enamel crystals and polished surfaces. It will affect the scanning procedure. Due to overexposure they will disrupt the target area by the software. It can be prevented by changing the orientation of the camera to increase the diffuse light. It can also be prevented using cameras with polarizing light.[31]

There should be 20-40 μm thickness of powder coating is required to minimize the reflectivity during procedure. The thickness of powder coating will vary between the operators. However, the IOS should be capable of taking the average thickness.[32]

Partial impressions can be made more accurate using powder based IOS.[27] However, sometimes it will make the patient uncomfortable due to contamination with saliva. To overcome this, it requires frequent cleaning and reapplication of the powder.[33]

For full jaw scanning, powder free technology is used. Because of the difficulty in maintaining the powder in all the teeth during the entire procedure.[29] Even though powder is not very comfortable for patients, no clear difference was found in recent articles about the effect of powdering on scan accuracy. The powder spraying of the tooth during scanning is illustrated in Figure 2.

Scanning paths

The IOS had specific movement to increase the scanning accuracy.[29] Recent *in vivo* and *in vitro* studies reported the influence of scanning path on the accuracy of the data captured especially with confocal technologies.[34] Linear or rough movement of the vestibular scans will make the image imprecise mainly on the interproximal areas. This will enable the dentist to adapt their clinical protocol in difficult areas such as interproximal areas, tooth preparation zone, high curvature of incisors, and change of axis around the canines.[34,35] Ideally, the camera should be held at a distance range between 5 and 30 mm of the scanned surface. However, it will depend on the type of scanner and technology used during scanning.[31,36,37]

Discussion

Imburgia *et al.* compared four IOS with regard to trueness and precision in a partially edentulous model with three implants and in a fully edentulous model with six implants. From the

Figure 2: Powder spraying tooth

study, there were significant differences in trueness and were found among different IOS.[24] Arakida *et al*. studied the influence of illuminance and color temperature of ambient light for trueness, precision, and scanning time of a digital impression at 0 lux, 500 lux, and 2500 lux with a light-emitting diode. Using a high-accuracy coordinate-measuring machine master data were acquired.

The reference model was scanned under each condition for 5 times by an IOS. He concluded that the 3900 K and 500 lux condition is the most appropriate lighting condition for taking a digital impression. High illuminance ambient light increased the scanning time.[38] Park *et al*. designed an intraoral environment simulator and to assess the accuracy of two IOS using the simulator. An intraoral environment simulator was designed in a box-shape to simulate two specific intraoral environments. Ten times the cast was scanned using Identica Blue, TRIOS, and CS3500 scanners in the two simulated groups.

The distances between the left and right canines, first molars, second molars, and the left canine and left second molar were measured. The results showed that the differences in intraoral environments were not statistically significant. Statistically significant differences were seen in regard to D3 and D6 between the IOS. She concluded that no difference due to the intraoral environment was revealed. The simulator will contribute to the higher accuracy of IOS in the future.[39] Sotomayor *et al*. evaluated and compared the accuracy of four IOS on a complete dental arch and on prepared teeth digitally in terms of trueness and precision. Their accuracy was evaluated using 3D software to compare the test models with a highly accurate reference model. He stated that, both long-span scans of the complete dental arch and isolated prepared teeth, the True Definition scanner had the greatest accuracy followed by TRIOS.[23] Sawase *et al*. accessed whether the IOS can be used in implant prosthetic work. The accuracy and operating time with IOS, as well as safety and patient perception, were evaluated from the clinical aspect. He stated that for single or partial prostheses, accuracy of digital scans with IOS was dependent on the optical scanning devices and software used.[40]

Conclusion

IOS are becoming integral part for the modern dental office. It improves the clinical efficiency of the dentists and patient comfort in office when compared to conventional impressions. It provides better communication with the dental technician and the patient by eliminating the need for plaster models.

Moreover digital impressions are time efficient by simplifying the clinical procedures. Also with the repeated use, scanning time will tend to decrease. Even though it has many advantages, it has several disadvantages also. It includes difficulty in detecting the deep marginal lines in prepared teeth and incase of bleeding, purchasing and managing costs.

Currently available IOS have wider indications for clinical use whereas the older one has fewer clinical indications. This should be considered before selecting the scanner in addition to other features such as powdering, scanning speed, wand size, and possibility of obtaining color images.

Nowadays, IOS closed system can also be made opened using CAD software. It is not only used in fixed partial dentures but also used in dental implantology for guided surgery and in orthodontics.

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