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REVIEW

Accuracy of various scanning strategies in partial edentulous with digital impression

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Keywords: Digital impression, Intra oral scanner, Precision, Strategy scanning, Trueness.

ABSTRACT

Digital impression of partial edentulous in removable partial denture requires special attention, based on Kennedy's classification, amount of tooth loss and position will affect the accuracy of digital impression. Factors affecting accuracy of intra oral scanner are handling and learning, powdering, lighting, scanning distance, and scanning strategy. The scanning strategy is a certain movement when scanning to improve the accuracy of the virtual model. The accuracy of the scanning strategy in digital impression can be assessed based on trueness and precision. This literature review aims to explain the various scanning strategies on partial edentulous on digital impression accuracy. Most IOS manufacturers recommend specific scanning strategies. In removable partial dentures, it was found that modified scanning strategies were more accurate than the manufacturer's recommended scanning strategies in some clinical situations. For cases in Kennedy Class IV and Class III maxillae the scanning strategy from occlusal to palatal and then to buccal proved to be more accurate. In Kennedy's Class I maxilla, the T-R (Teeth-Ridge) strategy was more accurate than the M (Manufactured) and R-T (Ridge-Teeth) strategies with reduced seesaw effect and high stabilization of the partial removable denture framework. This requires special strategies that depend on the IOS system. The scanning strategy affects the accuracy of digital impression, where the manufacturer's recommended scanning strategy is not necessarily better than the modified scanning strategy. In addition, the location and case of tooth loss also affect the scanning strategy. (IJP 2024;5(1):44-49)

INTRODUCTION

Since the eighteenth century, conventional impression techniques have been used to record the three-dimensional geometry of dental tissues. Problems with conventional impression are usually volumetric changes in impression materials and dental stone expansion caused by deficiencies and properties of impression materials, errors in storage of impression materials, errors during impression, and errors in the process chain (disinfection, storage, transport, model fabrication). To overcome these difficulties, impression with IOS (intra oral scanner) was developed for dental practice.[1,2]

Hassiny et al. surveyed 1072 respondents from 109 different countries. More than three-quarters of the survey group (78.8%) used IOS in their daily practice, while 21.17% did not. Regarding the period of IOS usage, of the 78.8% (n=845) respondents who used IOS daily, 17.9% (n=151) used IOS for more than 5 years, 12.9% (n=109) for 3 to 5 years, 34.3% (n=290) 1 to 3 years, 25.3% (n=214) less than 1 year, and 9.6% (n=81) less than 1 month.[3]

Impression of partial edentulous in removable partial denture manufacturing with digital impression (Intra Oral Scanner) requires special attention. Based on Kennedy's classification, tooth loss and position, and hard and soft tissue support will affect the accuracy of digital impression.[4] Factors affecting accuracy of intra oral scanner are handling and learning, powdering, lighting, scanning distance, and scanning strategy.[1] Scan strategy means that the scanner head is moved in a specific direction so as to improve the accuracy of the virtual model. Scan strategy means that the scanner head is moved in a specific direction so as to improve the accuracy of the virtual model.[1] A prerequisite for intraoral scanning is the accuracy of the resulting

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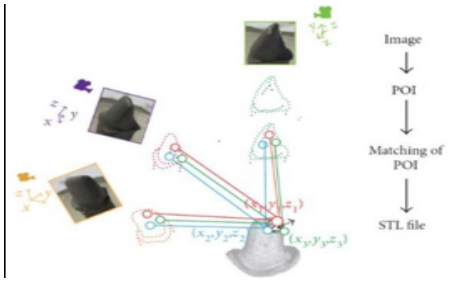

Figure 1. STL formation using IOS

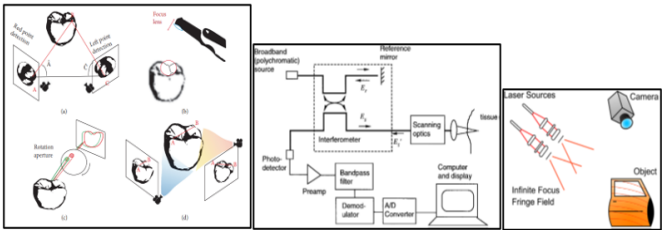

Figure 2. Determining the distance to an object. A. Triangulation: the distance BC can be determined based on the formula BC = AC × sin (Â) / sin (Â + Ĉ), B. Confocal: the distance to the object is determined according to the focal distance, C. AWS requires a camera and an off-axis that moves on a circular path around the optical axis and results in rotation of the points of interest, D. Stereophotogrammetry is a technology that generates files by algorithmically analyzing multiple images, E. OCT system diagram, F. AFI working principle.

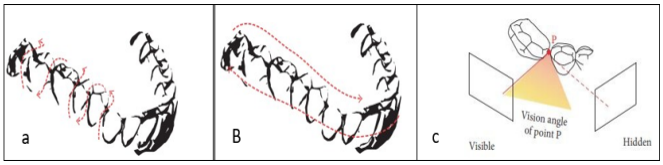

Figure 3. A. One-way scanning (S motion on vestibular, occlusal, and lingual surfaces, B. Linear movement on the occlusal-palatal surface followed by the buccal surface, C. Proximal surfaces cannot be scanned if the scanning strategy is not adjusted.

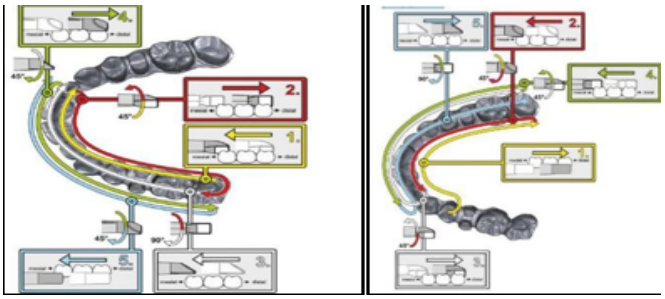

Figure 4. Scanning strategy Triangulation and Confocal (Omnicam) Technology A. Stage 1, B. Stage 2.

virtual impression. The accuracy of the scanning strategy in digital impression can be assessed based on trueness and precission.[5-7]

Various scientific analyses have shown the influence of scanning strategy on the accuracy of data capture, both in vitro and in vivo. Capturing structureless areas and areas with steep slopes, such as the anterior mandibular area, often proves difficult. This requires specialized strategies that are system-dependent. Rather than relying solely on technical specifications, it is also important for users to try out the scanning system they are interested in.[8]

The aim of this study was to elucidate various scanning strategies on partial edentulous on digital impression accuracy.

LITERATURE STUDIES

Intra Oral Scanner (IOS)

IOS is a device for recording the surface of tooth structures and surrounding tissues directly in the patient's mouth to obtain digital impressions.[9] IOS consists of a handheld camera, computer and software. IOS can record with precision the three- dimensional geometry of an object. The most widely used digital formats are open STL (Standard Tessellation Language) or locked STL-Like. These formats describe triangulated surfaces where each triangle is defined by three points and surface normals . However, there is a proliferation of other file formats that record the color, transparency, or texture of dental tissues (such as Polygon File Format, PLY files). Regardless of the type of scanning technology used by the IOS, all cameras require light projection to record individual images or videos and are compiled by the software after acquiring POIs (Points of Interest). The first two coordinates (x and y) of each point are evaluated on the image, and the third coordinate (z) is then calculated depending on the distance to the technological object of each camera, as described in figure 1.[1,10]

Indications and Contraindications of IOS

In the field of prosthodontics, IOS indications are: resin inlays/onlays, zirconia copings, single-tooth restorations in lithium disilicate, zirconia, all ceramic, frameworks and partial dentures in zirconia (4-5 elements), crowns with single implants, implant bridges (4-5 implants), implant-supported bars (≤4 implants), posts and cores, removable partial dentures, Digital Smile Design, and obturators.[11]

Contraindications of IOS in prosthodontics: long span/or full arch fixed partial denture (6-8 elements), implant supported partial fixed denture (6-8 elements), implant supported long span/or full arch fixed partial denture (6-8 implants), and removable full denture.[11]

Advantages and Disadvantages of IOS

Some of the advantages of using IOS in dental practice are real visualization, selective repetition, selective capture of relevant areas, no need to disinfect and clean dental impressions and impression trays, preparation/restoration analysis options, no model wear, rapid communication and availability, archiving, economical use of materials, chairside, virtual cutting tools, virtual follow-up, true-to-life representation, possibility of data fusion, and reduced patient discomfort.[8,11]

Besides the many advantages of using IOS, there are some disadvantages, including: Learning Curve, unable to obtain static and dynamic occlusion, high cost, difficulty in detecting marginal lines on prepared teeth, and requires a scanning strategy.[8,11]

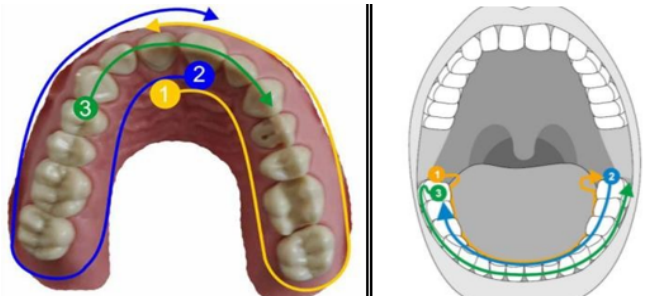

Figure 5. A. Procedure of the triangulation technology scanning strategy (Primescan) for the upper jaw, and B. For the lower jaw.

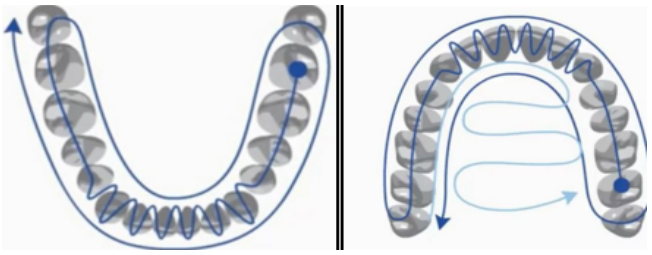

Figure 6. A. Scanning strategy of confocal technology (TRIOS) of the mandible, and B. Of the maxilla.

IOS Technology

There are various types of IOS technologies such as triangulation, confocal, Active Wavefront Sampling (AWS), Stereophotogrammetry, Optical Coherence Tomography (OCT), and Accordion Fringe Interferometry (AFI).[1,12] Triangulation is based on the principle that the position of a triangular point (object) can be calculated by knowing the positions and angles of two viewpoints. Confocal imaging is a technique based on acquiring focused and unfocused images of a selected depth so as to detect areas of image sharpness to infer the distance of the object correlated with the focal length of the lens. AWS is a surface imaging technique, which requires a camera and an off-axis aperture module, where the module moves on a circular path around the optical axis and produces POI rotation. Stereophotogrammetry estimates all coordinates (x, y, and z) through algorithmic analysis of the image. OCT is an interferometric imaging technique that provides cross-sectional images of the subsurface microstructure of a target object, such as biological tissue. AFI technology uses a laser beam and utilizes interference patterns created from multiple laser sources, to produce a perfectly focused and highly accurate fringe pattern on the target object.

rotation of the points of interest. (d) Stereophotogrammetry is a technology that generates files by algorithmically analyzing multiple images. (e) OCT system diagram (f) AFI working principle.[1,12]

IOS Accuracy

The accuracy of IOS scan results is measured based on trueness and precision. Trueness is defined as the ability of the IOS to capture the 3D geometry of an object that is closest to its original dimensions, while precision indicates the reproducibility of the IOS scanning results under the same conditions.[5-7] The accuracy and precision of digital impressions using IOS depend on the operator, the equipment used and calibration, the time elapsed between measurements, and the environment (temperature, humidity, etc.).[10]

Factors that affect accuracy

Handling and Learning

While digital impression is more convenient and faster than conventional impression, mastering the use of IOS technology takes time and experience. Each IOS has specific technology and different scanner head size and weight. For example, it has been reported that clinicians prefer to use Trios over iTero even though both IOSs use confocal technology.[1]

Shimmel et al conducted an in vitro study and determined: The accuracy of IOS for partially and fully edentulous arches is high, and experience with IOS has little influence on scanning accuracy.[13]

Powdering

Dental tissues such as enamel or restoration surfaces have many reflective surfaces that may interfere with POI matching due to overexposure. To solve the problem, the operator can change the orientation of the camera or install a polarizing filter to even out the light distribution. In addition, the use of 20-40 μm powder coating is sometimes required during the image capture process to avoid reflections. However, the use of powder can cause discomfort for the patient and the scanning time becomes longer due to saliva contamination, requiring cleaning and reapplication. So far, no significant difference has been found on the effect of powder on scanning accuracy.[1]

Lighting

Ambient lighting conditions affect IOS accuracy and the use of different IOS technologies results in different scanning accuracy. Therefore, lighting conditions need to be adjusted to the IOS technology system used. From research conducted by Revilla- Leon et al (2019), iTero IOS has better accuracy when using seat lighting of 10,000 lux and a room of 1003 lux. CEREC Omnicam has better accuracy with conditions without lighting, while TRIOS 3 is more suitable with room lighting conditions of 1003 lux.[14]

Scanning distance

The distance between the scanner head and the scanned object surface affects impression accuracy. According to Rotar et al (2022), a scanning distance of less than 5 mm or more than 15 mm will negatively affect the impression accuracy with the IOS used (Medit i700). A scanning distance of 10 mm between the object and the scanner head produces the best accuracy.[15]

Scanning strategy

Scan strategy means that the scanner head is moved in a specific direction so as to improve the accuracy of the virtual model. The scanned object should be positioned in the center of the acquisition area to depict the optimal scope around the object. The operator should also maintain a trajectory of movement, always keeping a stable distance and the gear centered during recording. The camera should be held between

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5 and 30 mm away from the scanned surface depending on the scanner and technology.[1,16]

For IOS using confocal technology, when scanning the entire arcade is required, different strategies are described by the manufacturers. One is a linear motion on the entire palatal occlusal surface followed by the buccal surface. The other procedure consists of S-movements on the vestibular, occlusal, and lingual surfaces of each tooth in sequence. The first strategy seems to limit spatial distortion by completing the image capture at the starting position, thus avoiding the overall one-way error, but the linear movement of the vestibular scanning may not be precise on the interproximal area. These technical observations lead practitioners to adjust their clinical protocols in difficult areas such as the interproximal zone, tooth preparation, central incisors with high arches, and axis changes around canines. However, imaging areas with steep slopes, such as the anterior mandibular area, is often associated with difficulties in image processing.[1]

Effect of Scanning Strategy

Different IOS manufacturers have proposed different scanning strategies based on the technology used. The scanning strategy refers to the specific path followed by the IOS head along the scanned object. Although the actual impact of the scanning strategy is not fully understood, variations in accuracy have been reported depending on the scanning strategy used. In addition, the effect of scanning strategy on the accuracy of digital scanning is reported to vary depending on the IOS used.[5,17-21]

Most IOS manufacturers recommend specific scanning strategies for their systems, but those strategies are usually described for dentate arches. Different scanning strategies and techniques for scanning edentulous and partial edentulous arches have been described, but accuracy analysis is still lacking.[5]

Strategy Scanning Recommendations from the Manufacturer

There are several recommended scanning strategies from several IOS technologies, namely: triangulation and confocal technology (Omnicam), triangulation technology (Primescan), and confocal technology (TRIOS).[22]

Triangulation and Confocal (Omnicam) Technology[22,23]

The following scanning strategy is divided into two stages.

Stage 1, : (1) Start as shown above, on the occlusal surface of the right terminal tooth, and scan occlusally. Tilt the scanner by 45° in the palatal (oral) direction and aim from distal to mesial. (2) Tilt the scanner another 45° in the palatal (oral) direction and move it distally. (3) Tilt the scanner by 90° to the occlusal surface and move it mesially. (4) Tilt the scanner 45° buccally and move it back distally. (5) Then tilt the scanner another 45° buccally to a total of 90° and move it mesially again.

Stage 2, namely: (1) Start by placing the device on the occlusal surface of the premolar tooth, which has already been scanned, and point the scanner in the palatal (oral) direction with a mesial tilt of up to 90° across the lingual surface of the front teeth in a distal direction towards the terminal premolar tooth. (2) Tilt the scanner slightly by 45°, so that the scanner is only tilted by 45° in the palatal (oral) direction moving from the distal and posterior parts mesially to the front teeth. (3) Once you reach the front tooth area, point the scanner 45° to the buccal side and tilt the scanner by 45° from mesial to distal direction. (4) When you reach the distal part, tilt the scanner by another 45° (90° in total) to the buccal side and point the scanner from the distal part back to the mesial direction. (5) Once you reach the front tooth area, tilt the scanner in the occlusal direction and point the scanner mesial to the occlusal surface right to the rear distal molars.

Triangulation Technology (Primescan)[24,25]

The triangulation technology scanning strategy (primescan) was divided into maxilla and mandible. Procedure 1 for the maxilla includes: (1) Start with the mouth surface of the anterior teeth and move the scanner toward the mouth along the quadrant. Move the scanner past the distal teeth to the vestibular side and trace the first quadrant to the anterior teeth. Gently tilt the scanner by approx. 30° in the coronal- apical direction. (2) Move the scanner as shown under (1) for the second quadrant. (3) Then scan the anterior teeth from cuspid to cuspid in the coronal apical direction. Ensure that both the labial surface and the oral surface are visible. Extend this third scan to a location where you can see the scanning hole.

Procedure 2 for the mandible includes: (1) Start occlusally at the distal tooth, tilt the scanner approx. 60° towards the mouth and move it orally along the dental arch to the opposite distal tooth. (2) Move the scanner occlusally from the distal tooth across the entire dental arch back to the other side. (3) To complete scanning, tilt the scanner approx. 60° buccally and move it buccally along the entire dental arch.

Confocal Technology (TRIOS)[25,26]

The confocal technology scanning strategy (TRIOS) is divided into the mandible and maxilla. The lower jaw starts from the occlusal, lingual and buccal surfaces. The maxilla starts from the occlusal, buccal, lingual and then palatal surfaces (if required).

Modification of Scanning Strategy in Some Studies

Jamjoom et al. conducted an in vitro study with six scanning strategies and two ios on maxillary and mandibular edentulous arch typodonts. The six scanning strategies were a). BOP (Buccal-Occlusal-Palatal), b). POB, c). OBP, d). OPB, e). ZZ-P, and f). ZZ. The POB scanning strategy produces a virtual model with the highest accuracy and the ZZ strategy the lowest compared to others.[5] Chang et al. suggested that the recommended scanning strategy for maxillary Kennedy Class I is the TR (Teeth-Ridge) strategy due to the reduction of the seesaw effect and high stabilization of the RPD frame compared to the M (Manufactured) and RT (Ridge-Teeth) strategies.[16] Muller et al. suggested that scanning strategy B (occlusal-palatal first, buccal return) might be recommended because it provides the highest trueness and precision in full-arch scanning and therefore minimizes inaccuracies in the final reconstruction compared with strategy A (buccal surface first, occlusal-palatal return) and strategy C (one-way S-type).[27] Saidan et al. recommended a scanning strategy for Kennedy Class IV maxillary jaws from occlusal to palatal then finally to buccal because it produced the highest trueness value compared to the other seven groups (Kennedy Class I, Class II, Class I modification 2, Class II modification 1, Class III, Class III, and Class III modification 1).[28]

DISCUSSION

Muller et al investigated scan strategies influence accuracy digital impression. Saidan et al said that different partially edentulous conditions affected the trueness of the scan generated from the selected intra oral scanner.[28] Digital impression of partial edentulous in removable partial denture requires special attention; Kennedy classification, amount of tooth loss

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and position, and hard and soft tissue support will affect the accuracy of digital impression. Therefore it is necessary special scanning strategies for Kennedy Classification Class I,II, III, and IV.

In some studies, it was determined that the scanning plane affects the accuracy of IOS. Mizumoto et al in their study found that the accuracy and precision of digital scanning of the non-toothed maxillary arch, regardless of the suturing or unsuturing of the palate and the position of the implant had a significant effect on its trueness.[19] Various scientific analyses have shown the influence of scanning strategy on the accuracy of data capture, both in vitro and in vivo.[8] Different IOS manufacturers have proposed different scanning strategies based on the technology used. Most IOS manufacturers recommend specific scanning strategies for their systems, but those strategies are usually described for dentate arches. Different scanning strategies and techniques for scanning edentulous arches have been described, but accuracy analysis is still lacking.[5] Zarone et al investigated the effect of different scanning strategies on the accuracy of intraoral scanning in vitro and concluded that scanning strategy has a significant impact on scanning accuracy, in particular, when anatomical landmarks are well-defined.[18] The scanning strategy also depends on the IOS system used, Medina et al. investigated the impact of scanning strategy on the accuracy of four IOS systems and different results for other systems.[29]

Some studies explained digital impression in edentulous partials is only indicated in Kennedy Classifications III and IV, but some studies have been conducted in Kennedy Classifications I and II with modified scanning strategies and the impression accuracy is not significantly different from other classifications. In the Kennedy Class I maxillary condition, the modified scan strategy is better than the recommendations, in the Chang et al study suggesting that the recommended scan strategy for Kennedy Class I maxillary is the TR (Teeth-Ridge) strategy due to the reduction of seesaw effect and high stabilization of the maxilla. The RPD framework was compared with the M (Manufactured) and RT (Ridge-Teeth) strategies.[16] Saidan et al. recommended a scanning strategy for Kennedy Class IV maxillary jaws from occlusal to palatal then finally to buccal because it produced the highest trueness value compared to the other seven groups (Kennedy Class I, Class II, Class I modification 2, Class II modification 1, Class III, Class III, and Class III modification 1).[28]

CONCLUSION

The scanning strategy affects the accuracy of digital impression, where the manufacturer's recommended scanning strategy is not necessarily better than the modified scanning strategy. In addition, the location and case of tooth loss also affect the scanning strategy.

SUGGESTIONS

Further research is needed on scanning strategies in partial

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