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REVIEW

Accuracy of intraoral scanner on subgingival finish line with gingival retraction

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ABSTRACT

The development of intraoral scanner (IOS) technology has brought about a significant transformation in dentistry, enabling more efficient and accurate digital workflows. Studies show that IOS provides clinically acceptable accuracy similar to conventional methods, especially for fixed prothesis. However, there are special challenges when impression subgingival finish line accurately. The use of gingival retraction methods is essential for easy access to these margins. This literature review aims to describe the accuracy of IOS in impression subgingival finish line with the aid of gingival retraction, and compare the effectiveness of mechanical and chemical retraction methods in digital impression of subgingival finish line. Mechanical methods, such as the use of retraction cord, provide stability to the sulcus but may cause discomfort and potential damage to the periodontium. Meanwhile, chemical methods using aluminum chloride-based pastes show good results in displacing gingival tissue with minimal side effects. Based on existing studies, the combined method of mechanical and chemical retraction provides the best results for impression accuracy in the subgingival area, taking into account patient comfort and quality of the final result. Thus, choosing the right retraction method can improve clinical outcomes and ensure the long-term success of digital- based prosthodontic restorations. (IJP 2025;6(1):50-54)

Introduction

The advent of intraoral scanners (IOS) that permit digital workflows has shifted dentistry's focus in recent years towards digital approaches. Thanks to its numerous benefits, IOS has found its way into everyday practice. For example, patients love it since it's less painful than traditional impression methods. Additionally, IOS may decrease mistakes caused by the dimensional instability of traditional impression materials, speed up clinical operations, and enhance communication between patients, dentists, and lab personnel. Many recent in vivo and in vitro research have shown that these devices have clinically acceptable accuracy, which is equivalent to that of traditional impression, and subsequent scientific studies have focused on analysing the accuracy of IOS.[1] When taking an impression of a tooth to use as a denture support, be sure to imprint not just the area directly below the completion line but also the full preparation line. The marginal fit of the prosthesis may be assured by the tooth structure above the finish line, and the suitable extension of the prosthesis, like the emergence profile, can be determined by the tooth structure below the finish line.[2]

To ensure a proper internal and marginal fit for the prepared tooth, it is crucial to make accurate digital impressions. Properly fitting prosthetic restorations, which should be positioned to seal all margin preparations, is essential for their long-term effectiveness. The abutment teeth have a low chance of survival due to marginal penetration, cement disintegration from oral agents, plaque buildup, and the subsequent caries and periodontal issues that result from these issues. When the finish line preparation is supragingival, equigingival, or subgingival relative to the gingival margin, complications could occur.[1] A normal expansion into the gingival sulcus should not surpass 0.5 mm to 1 mm, according to several prior research. A major mistake that might lead to gingivitis and damage to the epithelial attachment tissue is placing the finish line at a depth greater than 1 mm.[3] When IOS is located in the gingival sulcus, it might be challenging to make an imprint of the finish line, according to many studies. Research in the lab has shown that scanning preparations that go deep into the sulcus is not advisable, and that scanning at the supragingival finish line yields better results than scanning at the subgingival level. This is because there are other variables, including neighbouring teeth or the gingival sulcus, that influence the IOS's performance and block the light from reaching the preparation margin.[1] In their research, Keeling et al. used IOS to model a number of confounding variables that impact finish line quality. The findings revealed that subgingival finish line scans often exhibited readily deformable characteristics, such as rounded edges and blurry borders.[2]

The restriction of the line of sight is the primary challenge when producing digital prints. In order to make digital imprints with gingival retraction and scanning the finish line easier and more

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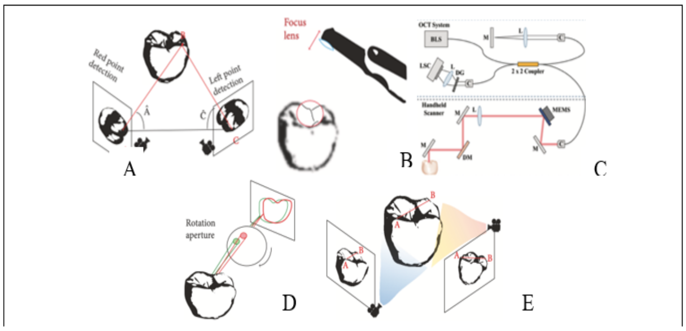

Figure 1. **A.Triangulation, B. Confocal, C. Schematic of OCT working principle, D. AWS working principle, E.Stereophotogrammetry**

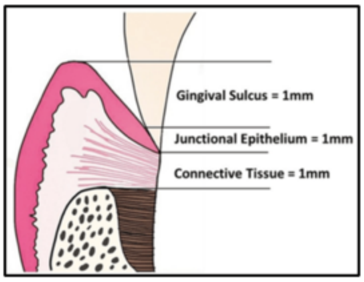

Figure 2. **Supracrestal tissue attachment (SCTA)**

accurate, a clean sulcus is a crucial need.[4] In its tenth edition, the Glossary of Prosthodontic Terms (GPT) provides the following definition of gingival retraction: "the displacement of the gingival margin away from the tooth."[5] In order to isolate and manage bleeding and fluid during impression formation, this technique atraumatically shifts the gingiva away from the abutment teeth. This improves visibility and accuracy.[6] A mix of mechanical, chemical, surgical, and/or all three approaches is often used.[7] Two metrics, Trueness and Precision, define accuracy in accordance with ISO 5725. Accuracy means consistently producing measurements under the same circumstances, while trueness means the IOS can record an object's 3D geometry as near as possible to its actual dimensions.[1]

According to Son et al.'s research, a subgingival finish line at a depth of 0.25 mm produced a trueness level below 100 µm when no retraction cord was used. However, when retraction cords were employed, the trueness level increased to 1 mm, and using gingival retraction cord increased the trueness level to 90%.[3] Manghani et al. found that physically pushing the retraction cable into the gingival sulcus resulted in more retraction than using retraction paste, which demonstrated proper margin retraction and allowed the IOS to record accurately. On the other hand, the patient may experience some pain or discomfort due to the retraction chord.[6] Research on the optimal retraction technique for digital impression subgingival finish line is still in its infancy. With the use of mechanical and chemical retraction techniques, this literature review aims to characterise the accuracy of digital impression on the depth of the subgingival finish line.

Literature Study

Intraoral Scanner (IOS)

A medical device called an intraoral scanner (IOS) uses a 3D measuring system to capture data on the size and structure of the dental arch. It then uses that data to create 3D models of the teeth and soft tissues in the mouth, allowing for a full digitalisation of the oral anatomy.[8] Using light, IOS is able to take optical imprints of implants and teeth. Projected light is necessary for the camera, regardless of the image method used by the IOS. A software program records each of these light beams as a distinct picture or video, and then it estimates where the objects of interest are.[9]

IOS Working Principle

The following is the process that iOS uses to capture an object's 3D geometry: Light Projection: In order to enlighten, IOS makes use of a light source, whether it a laser or structured light. Teeth and the tissues around them will be illuminated by this light;[10,11] Capturing images: the scanner's camera records photos of the tooth and its surrounding tissues as they reflect light. Information on the object's shape and features are included in this picture, which is taken in video or still form; Processing Data: The software that records the pictures is then used to process the data. A three-dimensional representation of the region that was scanned is created by combining the photos in the program; 3D coordinate recording: x, y, and z coordinates are used to record each point on the object's surface. The picture provides the x and y coordinates, while the distance from the item to the camera determines the z coordinate; Analyse and store: Create a digital format, such STL (Standard Testellation Language), to save the three-dimensional model.

IOS Technology

The idea behind the IOS approach known as triangulation is that two points of view may be used to determine the location of an item or triangle point. You can get these two perspectives by using two separate detectors, or by taking pictures at different times, or by putting a prism on one detector.[12] Using a combination of focussed and unfocused pictures taken at a predetermined depth, confocal imaging may pinpoint an object's precise location in relation to the lens's focal length. Subsequent photographs captured from various perspectives and with varying focus and aperture settings may then be used to recreate the item.[12,13] Utilising coherent light waves to generate three-dimensional (3D) pictures of oral and dental soft tissues is the fundamental idea behind Optical Coherence Tomography (OCT) at IOS. The method is based on reflecting infrared light from the different layers of oral tissues. Time and intensity measurements of the reflected light waves are used to produce a precise three-dimensional model. An off-axis aperture module, which rotates at the point of focus (POF) by following a circular route around the

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optical axis, is necessary for the AWS surface imaging method, which employs a camera. Stereophotogrammetry relies only on computational picture processing to provide all three coordinate estimations (x, y, and z). Smaller, more user-friendly, and less expensive cameras are used since this technology depends on passive light projection and software rather than active projection and hardware.[12]

Indications and Contraindications

Digital impressions are utilised in prosthodontics for a variety of purposes, including but not limited to: designing and fabricating single tooth crowns, endodontic crowns, veneers, fixed partial dentures, removable partial denture frameworks, digital smile design (DSD), and implant bridge posts and cores. Furthermore, guided implant surgery may be developed using IOS as well. Certain types of dentures, such as long-span implant-supported fixed partial dentures, full removable dentures, and long-span fixed partial dentures, are not recommended. The patient's incapacity to remain still, a small mouth opening, an excessively big head scanner, interference from the tongue, or the use of an orthodontic device are all examples of common contraindications. Furthermore, to ensure sufficient pictures are obtained during scanning, it is crucial to prevent bleeding beforehand.[14,15]

IOS Accuracy

The effectiveness and durability of the prosthesis depend on its precision.[13] Two metrics, Trueness and Precision, define accuracy in accordance with ISO 5725. Accuracy means consistently producing measurements under the same circumstances, while trueness means the IOS can record an object's 3D geometry as near as possible to its actual dimensions. For prints to pass muster as realistic reproductions, they must exhibit the utmost degree of accuracy and precision.[1,16] The minimal accuracy when scanning the complete dental arch is 60 µm, and while scanning prepared teeth it is 23 µm, according to a systematic study that looked at the average accuracy of digital technology, including intraoral scanners. The accuracy of scans on implants ranged from 19 to 112 µm, whereas scans on a single prepared tooth showed a range of 20 to 40 µm.[17]

Other investigations have also stressed the significance of precise digital impression production in ensuring a proper internal and marginal fit for the prepared tooth. Properly fitting prosthetic restorations, which should be positioned to cover all margin preparations, is essential for their long-term effectiveness. Despite extensive study on the topic, scientists still lack a definitive upper limit for the adaptability of fixed prostheses with respect to the marginal space between crowns and abutment teeth. Hence, the clinically acceptable gap value of up to 120 µ m, established by McLean (1971), is still used as a benchmark by other writers. Newly available IOSs have shown clinically acceptable accuracy in horizontal and vertical finish line designs, independent of the shape of the abutment teeth, according to current research.[1]

Factors Affecting Scan Accuracy

Operator: The operator's proficiency with the device, the scan's distance and angulation, and the operator's pattern or sequence are three operator-dependent elements that substantially impact IOS's accuracy. The effect of operator experience on scan accuracy has been shown in several studies. Lim et al. found that trueness after several scans, particularly in the maxillary arch, was much improved with longer clinical experience. Operator experience is a key factor in mistake reduction, according to Revell et al.'s research. Scanners with less experience are more likely to make deviations.[18]

Scanner: Light, heat, scanner head size, and software are just a few of the scanner-related factors that have been the subject of several research as they relate to IOS accuracy. The accuracy of IOS may be affected by ambient illumination conditions, however the optimal circumstances differ for each form of IOS. According to research by Revilla-Leonet al., certain scanners might yield varied findings depending on the illumination. Accuracy is improved in both natural and artificial illumination, similar to the iTero Element (Align Technology). Accuracy was maximised in low-light settings using the CEREC Omnicam (Densply Sirona). Under typical indoor lighting, TRIOS 3 (3shape) had the best accuracy. Furthermore, the research conducted by Hayama et al. revealed that bigger IOS scanner heads resulted in improved accuracy and precision with a decrease in the number of scanned pictures needed. Consistent with the findings of An et al., smaller scanner heads provide lower trueness but quicker scan rates, demonstrating that the size of the scanner head has a substantial impact on trueness.[18]

Intra oral conditions: The accuracy of intraoral ultrasound is greatly impacted by the patient's intraoral circumstances. Among these important considerations are the features of the scanned oral cavity region, including the edentulus's position, intraoral moisture, and the tooth's finish line preparation design.[18] Results indicated that preparation of the supragingival end resulted in superior accuracy, but preparation of the subgingival end resulted in incorrect accuracy, according to the location of the finish line. In light of these findings, it seems that the finish line preparation site could influence the IOS's precision.[16] Digital imprints need a clean sulcus for gingival retraction to be conducted and for scanning the finish line to be easy and error-free.[6] Gingival retraction cord use promotes truthfulness by 90%, according to Son et al.[3]

Preparation of Finish Line

The preparation of finish line can be placed above the gum (supragingival), parallel to the gum (equigingival), or below the gum (subgingival). Supragingival and equigingival finish line are easier to prepare, impression, and polish for a smooth surface. This makes it easier to clean plaque and maintain healthy gums. However, in some cases, such as when there are old restorations, caries, aesthetic needs, or the need for retention, subgingival finish line are required. Restorations have exposed and rough margins that easily harbor plaque when compared to natural tooth surfaces. The higher the margin of the restoration (near the gum surface), the easier the access for plaque removal, resulting in healthier gum tissue. Therefore, subgingival margins should be avoided if possible as they are often problematic. In terms of periodontal health, subgingival finish line almost always cause an inflammatory response in the gums. The degree of inflammation can vary from mild, invisible inflammation to severe inflammation with symptoms of swelling, redness, pain, bleeding and even bone destruction.[19]

The most crucial biological metric for gum health is the location of the finish line preparation, which allows for better patient and dentist-led hygiene management and a longer restoration life. Dentists need to be familiar with supracrestal tissue attachment (SCTA), also known as biologic width, in order to properly place finish line preparations. All of the connective tissue around the teeth, including the junctional epithelium and the supracrestal layer, form this connection. Microorganisms are unable to infiltrate the periodontium due to the barrier action of the SCTA. Inflammation of the gingival edge, faster bone loss, and deeper sockets are all possible outcomes of rupturing this connection. Incorrectly positioned repair margins, which promote persistent inflammation, are a common cause of SCTA breaches. When it comes to periodontal health, nothing is more important than keeping the SCTA proportions correct. Figure 2 shows the optimal dimensions for the SCTA width, which are 1 mm for the depth of the sulcus, 1 mm for the junction epithelium, and 1 mm for the attachment of the supracrestal connective tissue.[20] There are three guidelines that can be used in the placement of finish line preparations based on the depth of the gingival sulcus, including if the depth of the gingival sulcus is ≤1.5 mm, the edge of the preparation is placed below the gingival crest, the depth of the gingival sulcus is >1.5 mm. To make a 1.5 mm deep gingival sulcus, the edge of the preparation is positioned 1.5 mm below the gingival crest, which is 1½ times the depth of the gingival sulcus. If the depth of the sulcus is >2 mm, particularly in the facial aspect, it is evaluated whether a gingivectomy can be done on the tooth. Following that, the first guide is repeated.[21]

Gingival Retraction

The tooth must undergo gingival retraction after the pretreatment step prior to taking an imprint. An explanation for gingival retraction is given in the 10th edition of the Glossary of Prosthodontic Terms (GPT) as "the displacement of the gingival margin away from the tooth." The goal of this atraumatic displacement of the gingiva away from the abutment teeth is to improve accuracy and visibility during impression formation by isolating and regulating fluid and haemorrhage.[5,6] In order to capture the precise contours of the prepared tooth borders on the imprint, this technique aids in the transient vertical and lateral displacement of the gingival tissue. Common techniques for retraction of the gingiva include mechanical, chemical, surgical, and hybrid approaches. When using mechanical procedures, tools like retraction cords and rubber dams are used to compress the gum tissue. In chemical-mechanical approaches, the sulcus is kept dry and bleeding is reduced by combining retraction cord with medicines like epinephrine, aluminium chloride, and aluminium sulphate. For inflammatory gingival disorders, a surgeon with specialised expertise may use rotary curettage, electrocautery, or a laser to temporarily remove or relocate gingival tissue. This procedure is helpful, but it does need careful attention to prevent tissue damage.[4]

Gingival retraction most commonly uses retraction cord. The retraction cord physically compresses the gingiva, while the chemical controls the fluid in the gingival sulcus from the sulcus wall. Errors in the selection of retraction cord and chemicals used can lead to irritation of the gingival tissue and inaccurate results. The selection of retraction cord depends on the shape of the gingiva, the thickness of the gingiva and the depth of the gingival sulcus. The deeper the gingival sulcus and the thicker the gingiva, the larger and more retraction cord are used. Usually patients will complain of pain and discomfort with the use of retraction cord, which can even cause permanent damage to the gingiva.[22] This has led to innovations in recent developments, several new materials and technologies have been introduced, such as retraction paste and foam, which are claimed to be more atraumatic and easy to use. The use of aluminum chloride-based retraction materials or injectable kaolin matrix can effectively open the sulcus without damaging the gingival tissue.[4]

Discussion

There are three possible places to prepare the gingival border for a fixed denture: supragingival, equigingival, and subgingival. According to studies conducted by Son K et al., scan accuracy varies depending on where the finish line preparation is located, and subgingival finish lines are particularly inaccurate. The marginal and internal fit of the temporary crowns were shown to be altered by the positioning of the finish line, according to another research by Son et al. The findings obtained by marginal fit were most favourable for the supragingival finish line and the least favourable for the subgingival finish line. Although this research has its limitations, the findings indicate that the placement of the finish line during preparation may impact the final dental prosthesis manufactured using IOS.[23] The According to Son YT et al., there were notable variations in IOS trueness at the subgingival finish line at depths of 0 mm, 0.25 mm, 0.5 mm, 0.75 mm, and 1 mm. At a depth of 0.5 mm, the marginal portion of the subgingival finish line had a trueness more than 100 μm in this research, and at a depth of 1 mm, the marginal zone had the worst trueness (>200 μm). The scan accuracy that is clinically suggested is less than 100 μm, according to Brawek et al. and Shim et al. While prior study has validated IOS's correctness, there is a lack of studies that assess its veracity in relation to the finish line's position.[3]

When taking impressions for a permanent denture, it is crucial to isolate the region around the finish line and treat the tissue carefully. Particularly for equigingival and subgingival finish lines, this is essential to ensure accurate scanning and a clear final product. Hence, it is essential to retract the gums.[6] Methods might be mechanical, chemical, surgical, or a mix of these.[7] To retract the gingiva, the mechanical technique is most often utilised. This technique entails inserting a cable soaked with medication into the sulcus depth in a non-traumatic manner. The lack of systemic adverse effects has led to aluminium chloride's rise to the position of most-used medication.With a maximum retraction of 0.61 mm and a retraction efficiency that was consistent across various kinds of knitting cord (#000, 00, 0), the

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clinical trial conducted by Zeena et al. indicated that knitting cord is superior than braided cable. Furthermore, due to the mechanical pushing of the cord into the gingival sulcus, Manghani et al. discovered that retraction cord caused a larger gingival displacement than non-cord.The benefits of a method without a retractable cable include greater preservation of gingival health, less pressure, less time spent on the procedure, and more patient comfort.[6]

There are a number of cordless retraction systems on the market that work much like cord, including pastes, foams, and gels. Materials like kaolin paste, silicone foam that cures in an addition, and kaolin paste mixed with aluminium chloride are common choices. Gingival retraction accuracy and impression accuracy are both compromised by retractor fibres that remain in the sulcus (retraction cord fibres.[6] Cleaning the sulcus and reducing impression mistakes may be achieved by adding 15% aluminium chloride to the kaolin matrix.[4] The amount of gingival displacement with retraction cord and paste was compared by Choudhary et al., who found that the cordless method was more effective and that the retraction cord could cause discomfort and periodontal damage if not used carefully.[24] Furthermore, Manghani et al. found that sulcus breadth and depth could be adequately achieved using either retraction cord or retraction paste; however, retraction paste was superior in terms of clinical handling convenience.[6]

Conclusion

The accuracy of intraoral scanners (IOS) in capturing subgingival finish lines depends significantly on the gingival retraction method used. While IOS offers clinically acceptable accuracy, subgingival finish lines pose challenges due to restricted visibility and access. Mechanical retraction, such as retraction cords, provides stability but may cause discomfort and potential periodontal damage, whereas chemical retraction using aluminum chloride-based pastes effectively displaces gingival tissue with minimal side effects. Research suggests that combining mechanical and chemical retraction yields the best results in terms of both impression accuracy and patient comfort.

Thus, more studies are required to determine the precision of digital impression on the subgingival finish line, particularly at depths of 0.5 mm and 1 mm, using mechanical gingival retraction cord retraction and chemical retraction paste.

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