Comparison of Accuracy Between Traditional and Various Digital Implant Measurements for Implant-Supported Complete Arch Prostheses

İmplant Destekli Tam Ark protezler İçin Geleneksel Ve Çeşitli Dijital İmplant Ölçüleri Arasındaki Doğruluğun Karşılaştırılması

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ABSTRACT

When a fixed prosthetic restoration is desired to be made on multi-unit implants for patients with complete edentulism; the accuracy of the impression process is very important for the passive compatibility of the prosthesis, its aesthetic, its ability to completely fulfill its function and to maintain its structural integrity during applicatıon.Today, the measurements required for the production of full arch fixed prostheses superstructures of multi-unit implants applied for total edentulism rehabilitatıon can be obtained by traditional and digital methods. While traditional impression-taking methods are time-consuming, invasive, lead to complications and impression errors, intraoral scanners shorten treatment times and increase patient comfort with fast digital scanning.The easy storage and transmission of the digital data enables more effective communication between dentists, laboratories and other healthcare professionals. However, intraoral scanners have their advantages but also some uncertainties.

In this review, models obtained with the traditional method and intraoral scanner used in the rehabilitation of multi-unit implant-supported full arch fixed prosthesis with complete edentulism are compared and their contributions to prosthetic success are presented.

Keywords: *Full arch implant impressions, conventional implant impressions, digital implant impressions*

ÖZ

Tam dişsizliğe sahip hastalara multi-ünit abutmentlar üzerine sabit protetik restorasyon yapılmak istenildiğinde; protezin pasif uyumluluğu, estetiği, işlevini tam olarak yerine getirebilmesi ve işlev sırasında yapısal bütünlüğünü korumasında ölçü işleminin doğruluğu oldukça önemlidir. Günümüzde multi-ünit abutmentlardan oluşan tam ark sabit protezlerin üst yapılarının üretilmesinde geleneksel ve dijital ölçü alma yöntemleri kullanılmaktadır. Geleneksel ölçü alım yöntemleri uzun süre alması, invaziv olması, komplikasyonlara ve ölçü hatalarına yol açması nedeniyle en başa dönülmesine neden olurken; ağız içi tarayıcılar hızlı dijital tarama yaparak tedavi sürelerini kısaltır ve hasta konforunu artırır. Elde edilen dijital verilerin kolayca depolanması ve iletilmesi, diş hekimlerinin laboratuvarlar ve diğer sağlık profesyonelleriyle daha etkili iletişimini sağlar. Fakat ağız içi tarayıcılar avantajlarıyla beraber bazı belirsizlikleri de beraberinde getirmektedir.

Bu derlemede tam dişsizliğe sahip multi-ünit abutment üstü tam ark sabit protez rehabilitasyonunda kullanılan geleneksel yöntem ve ağız içi tarayıcıyla elde edilen modeller karşılaştırılarak protez başarısındaki katkıları sunulmuştur..

Anahtar Kelimeler: *Tam ark implant ölçüleri, konvansiyonel implant ölçüleri, dijital implant ölçüleri*

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INTRODUCTION

Implant-supported fixed prostheses have become a routine procedure for the replacement of missing teeth to fulfill functional, biological, and aesthetic requirements.[1] A dental impression is a negative replica used to create a positive reproduction of the oral structures, serving either as a permanent record or utilized in the fabrication of a dental prosthesis.[2] Accurate indexing of implant positions from the patient's mouth to the dental laboratory is essential to minimize prosthetic misfit. Therefore, it is crucial to fabricate a prosthesis compatible with intraoral tissues based on a precise and accurate impression.[3] In implant-supported fixed full-arch prostheses fabricated as a single unit on multiple implants, precise impressions are unquestionably essential for the accuracy of the implant suprastructure and for achieving long-term clinical success.[4]

Traditional and digital implant impression techniques transfer the intraoral positions of dental implants to the working cast. Accurate transfer of each implant's position relative to adjacent implants or teeth is critical for the design and adaptation of implant-supported prostheses, thus ensuring long-term success of implant treatment by preventing mechanical and biological complications. Despite advancements in impression techniques and materials, outcomes in routine clinical practice frequently remain unsatisfactory, highlighting the ongoing need for further improvements.[5]

In conventional methods, implant analogs, impression copings, and impression materials are utilized. Any displacement of implant components during removal of the impression tray from the mouth and throughout laboratory procedures negatively affects the accuracy of the prosthesis.[6] Negative factors affecting impression accuracy can influence prosthetic components, potentially resulting in complications such as screw loosening, veneer fractures, and framework fractures.[7]

Digital systems utilizing optical scanners to capture implant positions and visualize them on virtual models represent a novel approach for impression-taking in implant-supported prostheses, and they are anticipated to gradually replace conventional impression techniques.[8] In digital systems, data acquisition is performed through direct and indirect approaches. In the indirect method, images are digitized by scanning conventional impressions or the resulting stone casts using laboratory scanners, whereas in the direct method, images obtained via intraoral scanners are utilized.[9] Compared to conventional methods, sufficient evidence regarding the accuracy of digitally fabricated working casts is still lacking. Furthermore, while the digital impression technique has been validated for single-unit restorations, its accuracy for full-arch prostheses remains controversial.[10,11]

Impression Techniques for Implant-Supported Prostheses

1. Conventional Impression Methods

Traditionally, three different techniques are employed for implant impressions:

1.1. Indirect Impression Technique (Transfer Technique/Closed Tray)

1.2. Direct Impression Technique (Pick-up Technique/Open Tray)

1.3. Snap-on (Press-fit) Impression Technique. [4]

While many authors report greater accuracy with the closed tray impression technique[12] others advocate splinting of impression copings[13] or the open tray technique without splinting.[14] Some studies have reported no difference between the open-tray and closed-tray impression techniques[15], nor between splinted and non-splinted techniques.[16] However, in a study evaluating implant impression accuracy, splinting of impression copings for internal connection implants resulted in higher accuracy, concluding that splinted impressions produced more accurate models than non-splinted impressions, especially when the number of implants was four or greater.[4]

Currently, elastomeric impression materials are commonly preferred in the fabrication of implant-supported prostheses.[17] Due to their high accuracy and dimensional stability, polyether (PE) and vinyl polysiloxane (PVS) impression materials are widely favored.[18] In conventional impression techniques applied to internally connected implants, the use of high-rigidity impression materials, such as polyethers, appears advantageous for achieving more accurate outcomes.Owing to their excellent properties, including high rigidity, polyethers are frequently utilized in implant prosthetics compared to polyvinyl siloxanes. With their superior hydrophilicity, polyethers reliably capture intraoral details and may serve as an alternative to other impression materials in partially or fully edentulous patients, particularly when saliva or blood is present.[6]

2. Digital Impression Techniques

Digital systems are classified into direct and indirect methods based on data acquisition techniques. The direct method utilizes images obtained through intraoral scanners, whereas the indirect method employs images derived from impressions or casts scanned using laboratory scanners.[9]

2.1 Direct Method:

Intraoral scanners (IOS) are medical devices based on three-dimensional (3D) measurement systems capable of capturing the shape and dimensions of dental arches and

reconstructing 3D models of teeth and soft tissues within the oral cavity, thereby enabling complete digitalization of intraoral anatomy.[19,20] The most commonly utilized operating principles for intraoral scanning systems include Triangulation, Confocal (Parallel Confocal), and Active Wavefront Sampling.[21]

2.1.1. Triangulation: This imaging method is based on the principle that the position of one point of an object can be calculated when the positions and angles of two other points are known. The two reference points of the triangle can be identified either by a single detector using a prism to obtain images from two different angles or by utilizing two separate detectors.[21] An example of this technology is the CEREC Bluecam (Sirona Dental System GmbH).[9] Generally, CEREC provides acceptable results.[22,23] However, its accuracy is comparable to that of conventional impression techniques. An in vitro study by Ender & Mehl concluded that the accuracy of digital impressions made with Cerec AC and Lava COS systems was similar to conventional method.[24] When using CEREC AC, the scanned surfaces must be treated with an anti-reflective matting agent to prevent reflections.[25]

2.1.2. Confocal: This imaging technique is based on acquiring focused and unfocused images at selected depths. Determination of the image's focal field depends on the lens's focal length and its distance to the object. A dental image can be reconstructed through successive images taken from different angles at varying focal points and depths. However, image clarity in this method may be affected by the clinician's hand movements.[21] The iTero scanner (Invisalign; Cadent Inc., Or-Yehuda, Israel) employs parallel confocal imaging technology to capture digital images and transform them into three-dimensional images (Andriessen, Rijkens, Van Der Meer, & Wismeijer, 2014). Similarly, the 3Shape TRIOS 3 scanner (Copenhagen, Denmark) utilizes parallel confocal microscopy, in which emitted light beams parallel to the scanned surface reflect back along the same optical pathway, producing images at different depths proportional to the distance from the focus to the object.[26] Both the iTero[25] scanner and TRIOS 3 do not require special surface preparations (powder, spray, etc.) of the teeth being scanned. Recent studies have indicated that TRIOS 3 is among the most accurate intraoral scanners when compared to other systems.[27]

2.1.3. AWS (Active Wavefront Sampling): This imaging method utilizes a camera equipped with an off-axis aperture capable of continuous oscillation. The optical module follows a circular path around the optical axis, capturing sharp images to determine surface topography. Distance and depth data are calculated for each point, thus creating the model.[21] An example of this method is the Lava Chairside Oral Scanner (Lava C.O.S., 3M ESPE, St. Paul, MN). Lava C.O.S. is a 3D video system capturing real-time images at 20 three-dimensional frames per second. Following the scanning procedure, a post-processing cycle is necessary to recompute the recorded data and correct potential errors, resulting in a high-resolution digital model uploaded to 3M.[25]

2.2. Indirect Method:

Laboratory scanners can also be referred to as extraoral scanners, model scanners, impression scanners, and desktop scanners.[29] Laboratory scanners are utilized to convert conventionally produced plaster casts into digital files.[30] Consequently, indirect extraoral digitization procedures can inherently include errors related to conventional methods, such as impression-taking, model fabrication, and impression distortion.[31] Some researchers have reported that direct scans obtained using intraoral scanning devices result in accuracy equivalent to or even superior to models digitized indirectly via extraoral scanning of plaster casts.[29]

Digital impression constitutes the first step of a fully digital protocol, and its accuracy depends on multiple factors including the optical system of the intraoral scanner, image processing software, algorithms used for aligning, merging, and resolving triangulation networks, readability of scan bodies, compatibility with virtual design libraries, scanning pathway, patient-related factors (e.g., salivary flow rate, tongue size and position, mouth opening), as well as operator experience.[25,32]

Advantages of Digital Impression Systems

Digital impression scanners eliminate the need for conventional impression trays, the intraoral placement of impression materials, disinfection, and shipment of impressions to the laboratory.[20] Other claimed advantages include improved accuracy[33] by minimizing operator-dependent variability and eliminating material-related dimensional changes (e.g., impression and cast materials), as well as enhanced patient comfort.[34]

Digital impressions obtained with intraoral scanners have demonstrated satisfactory outcomes for single crowns and short-span bridges fabricated on both natural teeth[35] and dental implants.[36]

Disadvantages of Digital Impression Systems

The limited adoption of intraoral scanners among dental professionals can be attributed to several factors, including their high cost, complexity of equipment, the requirement for training and practical experience for proper use, limitations similar to conventional methods in capturing subgingival areas, sensitivity to the oral environment (presence of moisture, saliva, or blood), comparable accuracy results obtained in comparative studies between conventional and digital impression techniques, and high susceptibility to operator and patient movements.[37]

Summary of Studies on Digital Impression Accuracy and Precision:

Marques et al.[38] , in their study comparing the accuracy and precision of dental arches during single-implant digitization using partial or full-arch scans, utilized a partially edentulous maxillary model with one implant (4.0 × 11 mm; Proactive Straight Implant, Neoss, Woodland Hills, CA, USA) and an intraoral scan body (Intra-Oral Scanbody, Neoss, Woodland Hills, CA, USA) positioned in the region of the left central incisor. Partial arch scans from the distal of the left second molar to the distal of the right canine were performed using an IOS with 6.9 μm precision (TRIOS 3 v 1.4.7.5; 3Shape, Copenhagen, Denmark). The accuracy of intraoral scans was significantly influenced by whether scans were partial or full-arch. Partial arch scans demonstrated higher accuracy than full-arch scans, though their precision was found to be similar. Considering accuracy across different regions of the arch, anterior regions exhibited greater accuracy compared to posterior regions for both partial and full-arch scans.

Vandeweghe et al.[11] and Imburgia et al.[39] compared several intraoral scanners and concluded that accuracy levels varied among different devices, indicating that not all intraoral scanners are sufficiently accurate for full-arch implant impressions.

While intraoral scanner (IOS) systems can provide predictable and accurate digital scans for partially edentulous patients, certain difficulties have been reported, including operator experience, file size limitations, and the absence of reliable hard tissue references under edentulous conditions. Currently available IOS systems cannot yet reliably scan completely edentulous jaws due to the lack of distinct anatomical reference structures, complicating the software's ability to integrate individual images accurately.[40] According to Lee et al.[41], digital implant impression accuracy was influenced by implant angulation regardless of IOS type, achieving highest accuracy when the distal terminal implant was inclined mesially. In contrast, Menini et al.[6] reported that angulation of tilted posterior implants did not affect the accuracy of the digital technique. Due to such factors, transforming scan bodies into implant analogs using a digital library may result in linear and angular displacement errors; therefore, the conventional open-tray impression technique is recommended at the implant level for full-arch, single-unit implant-supported prostheses.[42]

Rutkūnas et al.[40] , in their study evaluating digital scanning accuracy of partially and fully edentulous jaws using five different intraoral scanners (IOS) with and without additional artificial reference points, fixed polymerized glass ionomer cement (Fuji Plus; GC) reference objects using adhesive (Super Moment Glue; Henkel) at specific locations: one centrally positioned in the edentulous area, six distributed among the scan bodies, and three on the palate of a partially edentulous model. Subsequently, five IOS systems—Primescan v5.0.1 (Dentsply Sirona), TRIOS 3 v1.18.2.10 (3Shape A/S), TRIOS 4 v19.2.2 (3Shape A/S), CARESTREAM 3600 v3.1.0 (Carestream Dental), and Medit i500 v2.0.3 (Medit)—were utilized for digital scanning. Their findings revealed that, except for vertical displacement accuracy observed with Medit i500 and CARESTREAM 3600, additional artificial reference points did not significantly influence accuracy parameters in partially edentulous scans. However, when employing different IOS devices, fully edentulous regions showed variable accuracy and precision: Medit i500 displayed variation for distance, PRIMESCAN and TRIOS 4 for angle measurements, and all systems except TRIOS 4 exhibited variations for vertical displacement precision. Ultimately, the study concluded that additional artificial reference points have limited effects on scanning accuracy parameters for partially edentulous cases, whereas their use significantly improves scanning accuracy in fully edentulous arches.

In an in vitro study by Kim et al.[42] , to compare the accuracy and precision of linear and angular displacement of implant analogs, an epoxy resin master cast was fabricated by replicating an edentulous maxillary gypsum model containing six implant analogs positioned at the right first molar, right first premolar, right lateral incisor, left lateral incisor, left first premolar, and left first molar regions. While the conventional method employed a splinted open-tray impression technique using medium-viscosity polyvinyl siloxane impression material (Aquasil Monophase; Dentsply Sirona), the digital method involved intraoral scanning utilizing the TRIOS 3 scanner (3Shape) combined with scan bodies (TruScan body; TruAbutment). The study reported that intraoral digital scanning resulted in lower accuracy compared to the conventional splinted open-tray impression technique. The conventional open-tray impression technique demonstrated greater precision across all implant analog positions compared to intraoral digital scanning. Additionally, conventional open-tray impressions produced significantly smaller angular deviations than intraoral digital scans; however, this difference was not considered clinically significant.

In an in vitro study conducted by Menini et al.[6] evaluating the accuracy of various impression techniques on multi-unit abutments, eight impression techniques were tested on a master cast simulating a four-implant jaw designed for full-arch rehabilitation, in which four low-profile implant analogs were embedded into a gypsum cast at canine (positions 13 and 23) and first molar (positions 16 and 26) locations. Seven conventional impression methods were selected, including the open-tray technique with polyether [Impregum Penta, 3M ESPE, Saint Paul, MN, USA]; open-tray polyether technique with impression copings

splinted by acrylic resin; closed-tray technique with polyether; open-tray technique with polyether [Ramitec Penta, 3M ESPE]; open-tray polyether technique with acrylic resin-splinted impression copings; closed-tray polyether technique; and open-tray technique with plaster impression material [BF Plaster, Dental Torino, Torino, Italy]. Additionally, five digital impressions (DIs) of the master cast were taken using a True Definition Scanner [3M ESPE]. Prior to scanning, four polyetheretherketone (PEEK) scan bodies were screwed into the implant analogs on the master cast to digitally capture implant positions. Subsequently, a homogenous layer of matting powder [3M High-Resolution Scanning Spray, 3M ESPE] was applied to the master cast for digitization procedures. The intraoral scanning procedure commenced at implant position 26 and proceeded in a continuous mode around all scan bodies. After reaching implant position 16 to complete an initial general scan, an additional circular scanning pattern was performed around each scan body. The study concluded that intraoral scanners could serve as an alternative to conventional impression techniques for fabricating full-arch implant-supported prostheses with satisfactory passive fit; however, it was noted that digital impressions showed reduced angular deviations when the inter-implant distances were shorter.

Ciocca et al.[32], in their in vitro study evaluating the accuracy of digital scanning using a single intraoral scanning system, placed six implants in a completely edentulous arch. They reported that the error values associated with scan bodies progressively increased with the distance between them. Particularly, the increased inter-implant distance in the most posterior regions of the edentulous arch significantly contributed to higher error values.

Papaspyridakos DDS et al.[43] compared the three-dimensional deviations between full-arch digital scans and conventional implant impressions in edentulous maxillae and mandibles. In their study, a total of 204 implants were placed across patients, ranging from four to six implants per arch, using a prosthetically driven surgical approach. For digital impressions planned at the multi-unit abutment level, SRA scan bodies for the Straumann system and Elos and Neodent scan bodies for the Nobel Biocare system (due to their interchangeability) were employed using a TRIOS 3 (3Shape A/S, Copenhagen, Denmark) intraoral scanner. For conventional impressions, a splinted open-tray technique at the abutment level using polyether impression material was implemented. The results indicated three-dimensional deviations between full-arch digital scans and conventional models as 85 ±25 μm for the maxillary group and 92 ±23 μm for the mandibular group.In another in vivo study by Chochlidakis et al.[44], comparing digital and conventional implant impressions in 16 patients with edentulous maxillae, the mean three-dimensional deviation (mean ± SD) between virtual models obtained from intraoral full-arch maxillary digital scans and digitized models from conventional implant impressions was found to be 162 ±77 μm. These findings were within the clinically acceptable threshold and consistent with previously reported values.[43]

In an in vitro study conducted by Kosago et al.[11] , the three-dimensional deviation accuracy of conventional and various intraoral scanner impression methods was compared to stereophotogrammetry (PIC - Precise Implant Capture) for a fully edentulous mandibular arch containing five implants (three straight and two 17° angled screw-retained abutments). The conventional method utilized the splinted open-tray technique with polyether impression material, whereas digital methods involved intraoral scanners TS (Trios 4), IT (iTero Element 2), and PS (Primescan). Results indicated that PIC exhibited the lowest three-dimensional deviation, achieving the highest accuracy (48.74 ± 1.80 μm) and precision (5.46 ± 1.10 μm), followed respectively by Trios 4, Primescan, iTero Element 2, and the conventional method. The conventional method demonstrated the highest three-dimensional deviation in terms of accuracy (141 ± 5.58 μm) and precision, significantly differing from the others. Among different intraoral scanners, Trios 4 and Primescan provided greater accuracy compared to iTero Element 2. Consequently, the study concluded that conventional methods utilizing splinted open-tray impression techniques were less accurate than digital impressions and stereophotogrammetry techniques.

In a clinical study by Chochlidakis et al.[44] comparing the accuracy of digital and conventional maxillary implant impressions in completely edentulous patients, a total of 16 patients underwent implant treatment. Four patients received maxillary fixed complete dentures (FCD) supported by 4 implants, five patients received FCDs supported by 5 implants, and seven patients received FCDs supported by 6 implants. In the conventional method, an open-tray impression technique at the abutment level using high and low viscosity vinyl polysiloxane (VPS) impression materials (3M Imprint, 3M, St. Paul, MN) was employed, whereas a True Definition intraoral digital scanner was used for the digital method. In this study, the average three-dimensional deviation between full-arch models generated by conventional and digital techniques was found to be 162 μm. This deviation is within the previously reported clinically acceptable threshold (up to 200 μm). It was also observed that three-dimensional deviations increased with a greater number of implants in the arch; however, this increase was not clinically significant.

CONCLUSION

Digital models obtained through intraoral scanners have shown promising results compared to conventional methods. However, in completely edentulous cases,

implant positioning may not yield consistent results for each operator due to inherent variations in scanning characteristics and the physical dimensions of intraoral scanners. This situation underscores the necessity of specialized operator training for digital techniques. Fixation of the scan body to a cast model typically results in fewer positioning errors compared to in vivo procedures, as in vitro studies lack factors such as mucosal mobility, saliva, and tongue movements that influence the precision of in vivo measurements.[32] Nevertheless, further clinical studies are require.

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