

GRADUATION PROJECT

Degree in Dentistry

EFFECT OF THE SCANBODY IN THE ACCURACY OF INTRAORAL IMPLANT IMPRESSIONS

Madrid, academic year 2025/2026

RESUMEN

Introducción: La prótesis implantosoportada han permitido rehabilitar a paciente parcial o completamente edéntulos. Para lograr una restauración exitosa, el ajuste pasivo es fundamental, y la precisión y exactitud de las impresiones digitales intraorales es clave. Los scanbodies de implantes (ISB) desempeñan un papel esencial en la transferencia de la posición de los implantes. Por lo tanto, es crucial comprender como el scanbody y sus características incluyendo geometría, altura, conexión y composición del material interactúan para influir en la precisión y la exactitud de las impresiones digitales intraorales. Entender esto para optimizar los procedimientos de escaneo de implantes.

Objetivos: Evaluar cómo los ISB influyen en la precisión y exactitud de las impresiones digitales intraorales en rehabilitaciones implantosoportadas de múltiples unidades y arcada completa.

Métodos: La búsqueda bibliográfica se realizó utilizando las bases de datos digitales Medline/Pubmed y Web of Science. **Resultados:** Se obtuvieron 846 artículos mediante operadores Booleanos entre las bases de datos, de los cuales 184 estaban duplicados. Tras la revisión de títulos, resúmenes y criterios de elegibilidad, finalmente se incluyeron 12 artículos en el estudio.

Conclusiones: Los ISB demostraron en los estudios mejorar la precisión y exactitud de las impresiones digitales intraorales para las rehabilitaciones fijas. Es importante considerar que su impacto es multifactorial. La geometría, el material y una adecuada exposición influyen en la precisión. Los diseños simples y los ISB fabricados en PEEK generalmente mostraron resultados más favorables. Los estudios actuales son en su mayoría in vitro, por lo tanto, se requiere más estudios in vivo para poder trasladar estos resultados a la práctica clínica y simular el entorno intraoral.

PALABRAS CLAVE

Odontología, Scanbody, Exactitud y precisión, Prótesis sobre implantes, Ajuste-pasivo.

ABSTRACT

Introduction: Implant-supported prosthesis have aided to rehabilitate partially or completely edentulous patients. To have a successful restoration passive-fit is fundamental. Accuracy of intraoral digital impressions is required to achieve passive fit. Implant scan bodies (ISB) play an essential role in transferring the position of the implants. Therefore, it is crucial understand how the scan body and its characteristics including geometry, height, connection, and material composition interact to influence the accuracy of intraoral digital impressions. Understanding these factors is essential for optimizing implant scanning procedures. **Objectives:** To evaluate how Implant scan bodies influence the accuracy (precision + trueness) of intraoral digital implant impressions in the context of multiple-unit and full-arch implant rehabilitations. **Methods:** The literature search was performed using the digital databases Medline/PubMed and Web of Science. **Results:** There were 846 articles obtained using Boolean operator between the databases of which 184 were duplicates and after review of titles, abstract and eligibility criteria 12 articles were finally included in the study. **Conclusions:** ISBs showed in studies to improve the accuracy of intraoral digital impressions for fixed rehabilitations. It is important to consider that its impact of ISBs are multifactorial. Geometry, material and adequate exposure influence precision. Simpler geometric designs and the ISB made of PEEK generally had more optimal outcomes. Current studies are mostly in-vitro. Therefore, to adapt these studies into clinical practice more in-vivo studies are required to simulate the environment intraorally.

KEYWORDS

Dentistry, Scanbody, Accuracy, Fixed-prosthetic, Passive-fit.

ABBREVIATIONS: see in
Annex 1

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1. INTRODUCTION

Dental implants are devices designed to replace the roots of missing natural teeth and are utilized in the rehabilitation of partially or completely edentulous patients. Their primary function is to transmit physiological loads to the surrounding supporting tissues (1). Unlike natural teeth, dental implants are rigid structures that lack periodontal ligaments and therefore do not possess physiological mobility or the capacity to accommodate minor discrepancies (2). As the bone–implant interface behaves as a single, immobile unit, exceptional accuracy in the production of implant-supported restorations and achieving passive-fit is essential to minimize biomechanical complications (1,3).

The accuracy of implant-supported restorations begins with the precise reproduction of implant position within the oral cavity. Traditionally, this has been achieved through conventional impression techniques. However, with the digitalization of dentistry and the intraoral scanners (IOS) have developed as an alternative method for capturing implant position. A key component that enables this process is the implant scan body (ISB) which is designed to transfer the three-dimensional (3D) position and orientation of the implant to the digital environment accurately. Therefore, understanding the design and functional factors of the scan body is fundamental to optimizing digital impression accuracy and ensuring long-term clinical success of the implant-supported prosthesis. Give the close relationship, it is essential to define the concept of accuracy within the context of digital implant impressions to better understand how the scan body influences the precision and reliability of the resulting digital model (4).

1.1 Definition of Accuracy (Trueness & Precision)

Accuracy is the simultaneous occurrence of 2 elements, trueness and precision (5). Therefore, when evaluating the accuracy of device or procedure we must understand each component. Trueness is defined as degree of conformity between the measured value and the reference value of the component being analyzed (6). It can also be described as the match between the test and the control model (7). Precision is defined as how close each repeated value is to the other or “consistency between values” (6,7). As accuracy governs the precise transfer of implant position and component relationships, it directly determines the ability to obtain a passive-fit, an essential requirement for clinical success of implant-supported prostheses (8).

1.2 Passive-fit concept in implant-supported prostheses

Maintaining a high level of accuracy throughout the fabrication process is vital to ensure the passive fit of the final restoration. The definition of fit is the level of adjustment between two components (9). Acquiring passive-fit is essential to achieve osseointegration and maintain an optimal relationship between the bone and implant, critical to long-term success (4). Passive-fit can

be described clinically as a state where the prosthetic restoration does not cause tension and or static forces on the prosthetic component or surrounding tissues (3,9,10). Attaining a fully passive-fit is thought as clinically impossible due to the cumulative inaccuracies that may occur through the steps of prosthesis fabrication (11). However, the misfit level cannot surpass the clinically agreed 150 μm as it may produce complications (4,11). Mechanical complications may include loss of retention, screw loosening or fracture of the prosthesis (9,11). Additionally, biological complication such as mucositis and peri-implantitis can develop (9). Crestal bone loss can occur due to as a condition in which micro-movement at the implant-abutment connection or infiltration and plaque accumulation in the space between the implant and prosthesis (11,12). The complexity of achieving a passive-fit is influenced by factors such as the number of implants, the implant depth and angulation, connection type and inter-implant distance, as well as the expertise and proficiency of the clinician and dental technician (11). At present, digital impressions captured with IOS and ISB demonstrate higher accuracy in cases involving short edentulous spans and limited inter-implant distances, making them particularly suitable for single-implant restorations (13). Scanning accuracy tends to decrease as the distance between implants increases. Digital impressions involving greater inter-implant spans (40–50 mm) demonstrate reduced accuracy compared to those obtained over shorter distances (6–18 mm) (14). Therefore, it is vital to evaluate how accuracy can be improved in multi-unit and complete arch restorations. Ultimately, passive-fit is a key determinant of stability and longevity of implant-supported rehabilitations (3).

1.3 Conventional versus Digital Impressions

The accuracy of the impression is a fundamental prerequisite for achieving a passive fit in implant-supported restorations. Dental impressions constitutes a negative reproduction of the teeth, implants, and surrounding oral anatomy, serving as a critical step in the manufacturing of prosthetic restorations (15). An accurate impression allows the capture and transfer of inter-implant spatial relationship (16). Numerous factors can affect the accuracy of an impression, including the technique, method, as well as the implant level, depth and angulation (16). The conventional workflow for obtaining implant impressions requires screw-retained impression copings secured to the implant and impression trays filled with impression material (17). The most common elastomeric impression materials utilized are polyvinyl siloxane (PVS) and polyether (PE) due to their precision (18). These materials have the capacity to minimize positional distortion between implant analogues due to coping displacement (16). They exhibits exceptional dimensional stability, tear resistance and reliable reproduction. (18). The two most common techniques that are utilized to transfer implant position from the intraoral environment to the working cast are: the direct (open-tray/pick-up) technique or the indirect (closed tray) technique (19). Some studies conducted have shown that the

open-tray technique is more accurate than the close-tray (2,20). The most utilized technique is open-tray because it reduces the effect of implant angulation, minimizes the risk of impression material deformation, and eliminates the need to reposition the coping within the impression (2). The open tray technique is primarily indicated in cases involving multiple non-parallel implants, full-arch implant-supported prostheses, or implants positioned deeply within the soft tissues (21). Additionally, there is evidence from various studies that indicate that the use of splinted impression copings resulted in greater accuracy compared to non-splinted techniques. This effect is especially pronounced in cases involving angulated implants, where splinting enhances the stability of the impression assembly and reduces the risk of distortion during the procedure (22,23).

While conventional impression methods have long been considered the gold standard for capturing implant positions, the emergence of digital impression techniques has introduced a more efficient and patient-friendly alternative (17). Current evidence demonstrates that digital techniques for implant impressions provide accuracy comparable to traditional impression approaches (24).

Digital implant impressions represent a modern approach for capturing implant positions. Over recent years, the transition toward a fully digital workflow has gained momentum, motivated by the perception that it enhances efficiency, simplifies clinical procedures, and eliminates the necessity for multiple materials and conventional casts (17,25).

Implant scan body can be defined as an advanced device for transferring implant positioning (26). They are used in digital workflow of implant dentistry and connected to the implant or its laboratory analog (27). There are variable ISB designs available with distinct material, shape, size, surface connection, reusability, system compatibility and costs (28). ISBs are generally composed of three main parts: the base, the body, and the scan region. The scan region is the portion captured by intraoral scanners and registers the orientation and angulation of the implant, whereas the base serves as the connection to the implant. The body links the scan region to the base. During intraoral scanning the ISBs are positioned on the implants (28,29).

The implementation of IOS has enhanced the capability to digitally capture implants, teeth, and oral soft tissues in a single procedure, eliminating the need for multiple impression materials and trays (25). Digital impression techniques facilitate and expedite production of 3D computer-generated models reducing the number of steps and potential sources of error (30). Additionally, it increases patient comfort and decreases incidence of nausea (15). Computer-aided design and computer aided manufacturing (CAD/CAM) are technologies utilized to create the digital models. Within the CAD software, the actual image of the ISB is aligned with its corresponding digital counterparts from the virtual library through a best-fit algorithm that utilizes common reference points within the same region. Once this digital alignment is achieved, the prosthetic component is designed and produced

with CAD/CAM (14,27). Therefore, the accurate scanning of the scan body in intraoral impressions is crucial for adequately recording the position of the virtual implant in the CAD software (31).

1.4 Factors influencing scan body accuracy

The surface characteristics, geometry, size, contour, and base material of scan bodies are all factors that may influence the accuracy of digital scans. Each of these variable can affect how well the intraoral scanner captures the implant position and how accurately the data is transferred to CAD software for prosthetic fabrication (14).

1.4.1 Geometry

Surfaces that are perpendicular, sharp, deep, angled, or complex are more difficult to scan accurately and can lead to incomplete or missing regions within the image. Ultimately this reduces the precision of the scanned image. A study reported that ideally surface defects must be less than 10% due to there being an increase in linear and angular deviation in implant position transferred to the software as the number of scannable regions increased (31). Deviations can lead to decreased accuracy of digital impression and lack of passive-fit of the prosthetic. ISBs typically have a flat side which is added to have an asymmetrical shape which helps to identify their orientation improve recognition by the software (28). They are fabricated in a multitude of shapes which can range from spherical to cylindrical, with numerous intermediate variations. However, the optimal configuration in terms of geometry, dimensions, and surface features remains undetermined (32).

In addition to surface characteristics and geometry, another important factor influencing scanning accuracy is the vertical dimension or height of the ISB, which determines its visibility within the oral cavity (14).

1.4.2 Vertical dimension

The Vertical dimension of the scan region is another parameter that can affect scanning accuracy. The ISB can ranges from 3mm to 17 mm in height among those commercially available (33). Height chosen of the ISB is influenced by how deep the implant is positioned. Partially exposed scanbodies, resulting from higher gingival coverage, tend to produce larger angular deviations than fully visible ones, indicating that longer scanbodies are preferable for deeply placed implants (34). Beyond height, the stability of the scan body during scanning also plays a critical role in accuracy, which is influenced by anti-rotational design features (33).

1.4.3 Connection type

Some scan body designs incorporate flat facets or beveled surfaces, to mimic the structure of the implant internal connection and enhance positional stability during scanning (35). Nevertheless, the most effective configuration of these components has yet to be determined (11,36). Finally, the

material composition of the scan body further affects scanning performance, influencing both optical detection and durability during repeated use (14).

1.4.4 Materials

The material composition and surface texture of ISBs are essential factors influencing the accuracy of digital scanning as they can influence their alignment within CAD software. While the scanning region often features a distinct surface design or texture compared to the main body, both parts are generally fabricated from the same base material (25). Most ISBs are manufactured from two primary materials, polyether ether ketone (PEEK) and titanium (14,29). The surface characteristics of the material of the scannable region influence optical detection by the intraoral scanner, for example PEEK is less reflective than titanium facilitating the ability to capture the scan body with the IOS. However, material utilized for the base requires wear resistance, particularly with repeated use as distortion from use can alter position and inclination. Titanium is more resistant and may be more advantageous for these circumstances. (14,28). The influence of material type (metal or polymer) and surface characteristics on scanning accuracy remains a topic of debate (28).

Although studies indicate that scan body characteristics affect the accuracy of intraoral impressions, there is no consensus on which features enhance accuracy and which contribute to deviations (14,25).

Overall, scan body characteristics including geometry, height, connection type, and material composition interact to influence the accuracy of intraoral digital impressions. Understanding these factors is essential for optimizing implant scanning procedures and ensuring the passive fit of the final prosthetic restoration (14).

1.5 Alternative technologies for implant position registration

In recent years, alternative technologies have been evaluated to improve the accuracy of implant position registration. Methods such as photogrammetry and extraoral scanning (EOS) have been evaluated to improve the transfer the position of ISB. It utilizes camera-based detection to determine directly the coordinates of the dental implants (37). IOSs are effective for obtaining rapid and precise digital records. However, accurately capturing the spatial relationship of multiple implants in completely edentulous arches remains challenging. Additionally, accuracy may be compromised in patients with severe mandibular resorption, mobile or excessive soft tissue, high salivary flow, postoperative bleeding, or limited mouth opening (38). The use of photogrammetry and EOS appears to overcome some of these limitations and show promising results. However, they are costly and not readily accessible and require further studies (37).

The motivation for this documentary research arose from the need to better understand how the scan body and its related factors affect accuracy.

2. JUSTIFICATION, OBJECTIVE AND HYPOTHESIS

2.1 Justification

The evaluation of how ISB influence the accuracy of intraoral digital impressions is advantageous for clinicians to obtain highly predictable outcomes and improve the passive-fit of implant-supported restorations for the patients. There is a lack of consensus in the literature regarding which characteristics of scanbodies provide superior accuracy, particularly in multi-unit and full-arch restorations. This systematic review aims to critically evaluate the effect of the scan body on digital impressions, while also identifying gaps and recommending further studies.

2.2 Objective

2.2.1 Main Objective

To evaluate the influence of implant scanbody characteristics, including geometry, material composition, connection and vertical exposure on the accuracy (trueness & precision) of intraoral digital implant impressions.

2.2.2 Secondary Objective

. To assess how these ISB factors influence accuracy in the context of multi-unit and full-arch implant rehabilitations.

2.3 Hypothesis

The use of scanbodies increases the accuracy (trueness & precision) of intraoral digital impressions in multi-unit and full-arch implant rehabilitations.

3. MATERIAL AND METHODS

3.1 PICO Question (Research Question)

To organize the methodological approach and discuss the objective developed in a systematical fashion the formulation of the following PICO question was established:

- Population (P): Adult patients who are partially or fully edentulous
- Intervention (I): Intraoral digital impressions using scanbodies
- Comparison (C): Reference model/reference dataset
- Outcome (O): Accuracy (precision & trueness) of the implant impression

In partially and fully edentulous patients undergoing multi-unit or full-arch implant rehabilitation, how do implant scanbodies used for intraoral digital impressions, compared with reference model or reference dataset, affect the accuracy (precision + trueness) of the resulting implant impressions?

3.2 Eligibility Criteria

Specific eligibility criteria were established to ensure that only studies relevant to the effect of scan body characteristics on the accuracy of intraoral implant digital impressions were included in this

systematic review. The inclusion and exclusion criteria applied during the article selection process are summarized in **Table 1** and **Table 2**.

Population	Multi-unit or full-arch implant restorations
Intervention	Use of ISB and IOS Studies evaluating the effect of scan body characteristics • Material • Geometry • Connection • Height (vertical dimension)
Comparison	Evaluation between intraoral scanning and reference model
Outcome	Studies reporting accuracy of implant impressions • Trueness and/or precision • Linear and/or angular deviations
Study design	Randomized control trials Prospective or retrospective studies In-vitro studies
Study Characteristics	Full text available Peer-reviewed Available in English

Table 1: Inclusion criteria

Population	Single-unit implants
Intervention	Studies evaluating extraoral scanning Studies using healing abutments
Outcome	Studies not reporting accuracy of implant impressions
Study design	Case reports, reviews, opinion papers
Study Characteristics	Non-peer reviewed Unavailable full text Other languages outside the inclusion criteria Studies older than 10 years

Table 2: Exclusion Criteria

3.3 Search Strategy & Joining Search Terms

The literature search was performed on the following digital databases:

Medline/PubMed and Web of Science. Only English language publications were included in this study.

A specific strategy search was conducted using MeSH terms and articles were selected based initially on their titles and abstracted and later discarded depending on the full text as seen in **Table 3**.

Search Strategy	Population Edentulous patients in need of full-arch or multi-unit rehabilitations	(((((Edentulous Mouth) OR (edentulous)) OR (fully edentulous)) OR (complete edentulism) OR (edentulous patients)) OR (toothless)) OR (Dental Implant)) OR (dental implant)) OR (implant-supported) (prosthesis)) OR (implant-supported rehabilitation)) OR (implant prosthodontics)) OR (full-arch rehabilitation)) OR (implant-supported restoration))
	Intervention: Digital impressions with intraoral scanner (IOS) and Implant scanbodies (ISB)	AND (Digital Impression)) OR (digital impression)) OR (intraoral scan)) OR (intraoral scanner)) OR (optical impression)) OR (digital intraoral impression)) AND (scan body)) OR (scan bodies)) OR (scanbody)) OR (scanbodies)) OR (implant scan body)) OR (implant scanbody)) OR (scan abutment)) AND (geometry)) OR (design)) OR (shape)) OR (configuration)) OR (material)) OR (PEEK)) OR (titanium)) OR (height)) OR (diameter)) OR (length)) OR (surface)) (connection))
	Comparison: Reference Model	AND (reference model)) OR (master model)) OR (reference cast)) OR (reference scan))
	Outcome: Accuracy (trueness & precision) of digital impressions	AND (Accuracy)) OR (accuracy)) OR (trueness)) OR (precision)) OR (dimensional accuracy)) OR (3D accuracy)) OR (deviation)) OR (linear deviation)) OR (angular deviation)) OR (scan accuracy)) NOT (Pet scan)) NOT (Photogrammetry)) NOT (systematic review))

Table 3: Search Strategy according to the PICO question

4. RESULTS

Prism flow chart with outcomes of the Boolean operators and filter application in **Figure 1**

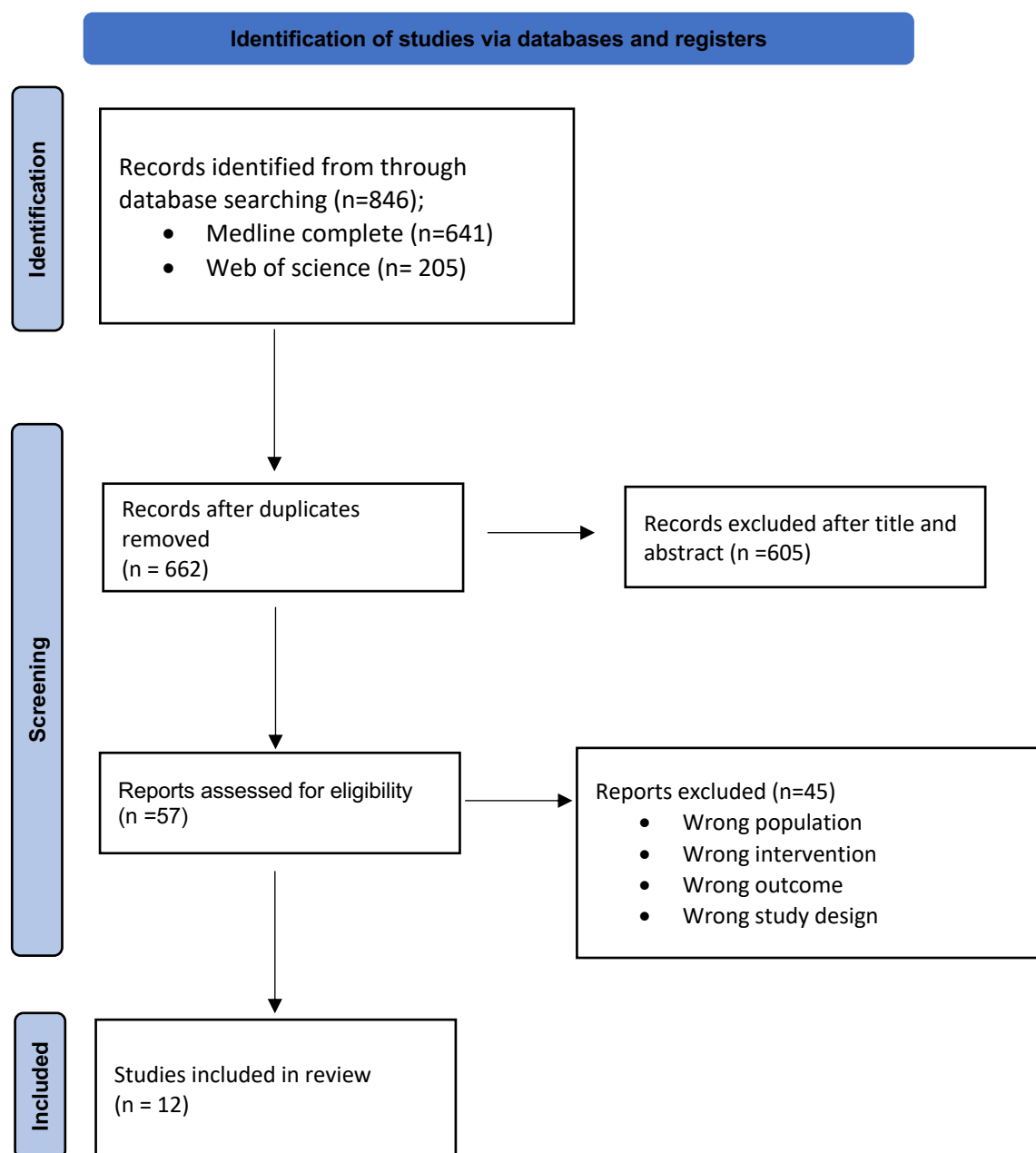


Figure 1: Modified Prisma 2020 flow diagram for new systematic reviews outlining the study identification process and results from the literature search through Medline complete database and Web of Science (39).

Articles which met the criteria and were selected from PubMed/Medline and Web of Science and summarized according to PICO Intervention subgroups (Geometry, Vertical dimension, connection type and material) see **Table 4, Table 5, Table 6, and Table 7**

4.1 Geometry

Author/Year	Motel et al., 2020 (40)
Study Design	<i>In vitro</i> experimental study
Sample	Titanium model with 3 implants (1 angled 15° and 2 parallel) 3 ISB systems
Variables	- Group 1 (ELOS A/S) - Group 2 (NT- trading) - Group 3 (TeamZiereis) Independent Variable: Geometry of ISB - Group 1 (ELOS A/S): Flat cylindrical design with partially beveled top. - Group 2 (NT- trading): Cylindrical cervically and slightly oval coronally. - Group 3 (TeamZiereis): Cylindrical geometry with a retraction and enlarged coronal diameter Dependent Variable: 3D deviation
Outcomes	Axis deviations: x (oro-vestibular), y (mesio-distal), z (vertical) 3D deviation: - ELOS: 41 µm (best trueness) - NT-Trading: 112 µm (highest deviation) - TeamZiereis: intermediate accuracy. Axis deviations: x-axis: - ELOS 0.015 mm - NT-Trading 0.076 mm - TeamZiereis 0.035 mm z-axis: - ELOS 0.015 mm - TeamZiereis 0.014 mm - NT-Trading 0.040 mm y-axis: no significant differences.
Author/Year	Alvarez et al., 2022 (41)
Study Design	<i>In vitro</i> experimental study
Sample	Polyamide master model with 6 implant analogs (36, 34, 32, 42, 44, 46) 4 ISB designs made of PEEK were scanned with 2 intraoral scanners (Cerec Omnicam and TRIOS 3)
Variables	Independent Variables: ISB Geometry - SB1(ELOS): 1-piece design with milled angulated sides - SB2(Mozo Grau "MG"): pyramidal milled side, 2-piece clip system and geometric complexity - SB3(Ticare MG): multiple milled sides with 12 surfaces and larger flat areas - SB4(Talladium): milled side, magnetic placement, two-piece design Dependent Variables: - Distance error (mm), Angulation error (°), Height error (mm)
Outcomes	Distance error (mm): - ELOS: 0.083 ± 0.072 mm - MG: 0.082 ± 0.065 mm - Ticare MG: 0.050 ± 0.039 mm - Talladium: 0.041 ± 0.024 mm

	Angulation error (°): • ELOS: $0.836 \pm 0.804^\circ$ • MG: $0.371 \pm 0.272^\circ$ • Ticare MG: $0.185 \pm 0.189^\circ$ • Talladium: $0.221 \pm 0.186^\circ$ Height error (mm): • ELOS: 0.082 ± 0.070 mm • MG: 0.089 ± 0.066 mm • Ticare MG: 0.039 ± 0.051 mm • Talladium: 0.055 ± 0.078 mm
Author/Year	Meneghetti et al.,2023 (42)
Study Design	<i>In vitro</i> experimental study
Sample	Conducted on 3D-printed edentulous maxillary model with 6 parallel implants with multi-unit abutments
Variables	7 scan body designs Independent Variables: Geometry, Height, Material • SB1: - Design: Cylindrical body with a trapezoidal top and multiple flat surfaces - Height: 14 mm - Material: PEEK with metal connection • SB2: - Design: Cylindrical with one angled flat surface - Height: 9 mm - Material: PEEK • SB3: - Design: Cylindrical with diamond-shaped surfaces - Height: 12 mm - Material: PEEK • SB4 - Design: Cylindrical with rounded top - Height: 7 mm - Material: 3D-printed grey resin • SB5 - Design: Cylindrical with three flat surfaces angled at the top - Height: 7 mm - Material: 3D-printed grey resin • SB6 - Design: Bar-shaped scanbody (16 mm length) with convex half-circle ends - Length: 16 mm - Material: 3D-printed grey resin • SB7 - Design: Cylindrical with one angled flat surface - Height: 7 mm - Material: PEEK Dependent Variables (accuracy/trueness) • 3D deviation (μm) • Angular deviation (AD) (degrees) • Linear distance deviation (LDD)

Outcomes	SB1 • 3D deviation: 118.47 μm • AD: 0.45° • LDD: 120.95 μm SB2 • 3D deviation: 72.27 μm • AD: 0.25° • LD: 64.44 μm SB3 • 3D deviation: 158.23 μm • AD: 0.63° • LDD: 94.17 μm SB4 • 3D deviation: 165.08 μm • AD: 0.77° • LDD: 80.65 μm SB5 • 3D deviation: 190.29 μm • AD: 0.89° • LDD: 162.86 μm SB6 • 3D deviation: 182.51 μm • AD: 0.71° • LDD: 205.27 μm SB7 • 3D deviation: 93.31 μm • AD: 0.51° • LDD: 55.17 μm
Author/Year	Anitua et al., 2025 (43)
Study Design	In vitro experimental study
Sample	Three 3D printed implant models with three ISB designs tested 6-implant edentulous model 4-implant partially edentulous model 2-implant short span
Variables	Scans performed with TRIOS 5 intraoral scanner by 5 experienced operators producing 540 scans and 1620 deviation analyses Independent variables: Scan body geometry • Group 1: standard design with two flat surfaces • Group 2: reduced-length design with 50% height reduction • Group 3: reduced length with three flat surfaces Number of implants (6, 4,) (operator and 2-implant excluded from review) Dependent variable: • Trueness measured as 3D Euclidean deviation (μm)
Outcomes	6-implant model: • Group 1: 102 μm mean deviation • Group 2: 87 μm (highest trueness) • Group 3: 149 μm (lowest accuracy)

	4-implant model: • Group 1: 153 μm • Group 2: 104 μm (best performance) • Group 3: 166 μm (highest deviation)
Author/Year	Lawand et al., 2024 (44)
Study Design	<i>In vitro</i> experimental study
Sample	Completely edentulous maxillary cast with 4 implant analogs • 2 anterior parallel and 2 posters tilted 17° Three groups of PEEK ISB's were used: 15 digital scan per group
Variables	• Nonmodified (NM) • Subtractively modified (SM) • Additively modified (AM) with PEEK bead Independent variables: • Scan body geometry modification (NM, SM, AM) Dependent variables: • 3D surface deviation (RMS error, mm) • Linear discrepancy between scanbodies (LD) (mm) • Angular deviation (AD) (degrees) (Scanning time was excluded from this review)
Outcomes	NM • 3D surface deviation (RMS): 0.092 $\pm$ 0.015 mm • AD: 1.266 $\pm$ 0.074° SM • 3D surface deviation (RMS): 0.100 $\pm$ 0.004 mm • AD: 0.993 $\pm$ 0.062° AM • 3D surface deviation (RMS): 0.266 $\pm$ 0.030 mm (P<0.001) • AD: 1.273 $\pm$ 0.120° (p < .001) LD: Varied on implant pairs, but SM group showed the smallest deviation overall

Table 4:Summary of Studies Evaluating the Effect of Scan Body Geometry on Intraoral Scan Accuracy

4.2 Vertical Dimension

	Sicilia et al., 2024 (45)
Study Design	<i>In vitro</i> experimental
Sample	2 partially edentulous maxillary casts with 2 implants in 1 st premolar and 2 in 1 st molar each (Positioned at 3 supramucosal ISB exposures):
Variables	2 Groups: Group P: Parallel implants (P-3mm, P-5mm, P-7mm) Group A: 18° distal angulated implants (A-3mm, A-5mm, A-7mm_ Independent variables: • Implant angulation (P Vs A) • Scan body supramucosal height (3 mm, 5 mm, 7 mm) Dependent variables: • Linear discrepancy (LD) (μm) • Angular discrepancy (AD) (°) • RMS error (μm)
Outcomes	Group-P: • 3mm - LD: 70-75 μm - AD: 1.0° • 5mm

	- LD: 65-70 μm - AD: 1.0° • 7mm - LD: 88.3 $\pm$ 33.9 μm - AD: 1.05° Group-A: • 3mm - LD: 55.3 $\pm$ 21.1 μm - AD: 0.90 $\pm$ 0.22° • 5mm - LD: $\sim$ 60-65 μm - AD: 1.12 $\pm$ 0.14° • 7mm - LD: 65-70 μm - AD: 0.95–1.0°
Author/Year	Jannati et al., 2025 (46)
Study Design	<i>In vitro</i> experimental study
Sample	Three maxillary partially edentulous models with 3-implants (63 scans) placed: • Lower (2 mm below occlusal plane), Equal (at occlusal plane), Higher (2 mm above occlusal plane).
Variables	They were compared to desktop scanner reference Independent variables: Scan body height • Lo: 2 mm below occlusal plane • Eq: at occlusal plane • Hi: 2 mm above occlusal plane Dependent variables: • Distance deviation • Angular deviation • Axis deviations (μm)
Outcomes	Distance deviation: affected by implant position ($p < .001$) but height had no significant effect overall ($p = 0.126$). Significant pairwise differences: • Sin-Hi vs Sin-Eq ($p = 0.03$) • Sin-Hi vs Sin-Lo ($p < 0.001$). Angular deviation: significantly affected by scan body height ($p < 0.0001$). • Highest deviation: Sin-Eq = 3.51° $\pm$ 0.36 • Lowest deviation: Sin-Hi = 0.54° $\pm$ 0.59 Axis deviations (μm): • lowest ΔX Adj-Lo = 0.04 $\pm$ 0.03, • lowest ΔY Sin-Lo = 0.01 $\pm$ 0.00, lowest ΔZ Adj-Eq = 0.02 $\pm$ 0.01, • lowest rotational deviation ΔR Adj-Eq = 0.07 $\pm$ 0.02.

Table 5: Summary of Studies Evaluating the Effect of Scan Body Height and Supramucosal Exposure on the Accuracy of Intraoral Implant Digital Impressions.

4.3 Connection type

Author/Year	Arcuri et al., 2022 (47)
Study Design	<i>In vitro</i> comparative study
Sample	Edentulous mandibular PMMA model with 4 implants (15, 12, 22, 25) 76 intraoral scans:
Variables	• 38 Screw retained ISB 38 Snap-on ISB Independent variables • Scan body type: screw-retained vs. snap-on Dependent variables • Linear deviations (LD) (ΔX, ΔY, ΔZ) • 3D deviation
Outcomes	Angular deviation (AD) 3D deviation: • Snap-on: $99.9 \pm 42.5 \mu\text{m}$ • Screw-retained: $107.6 \pm 40.8 \mu\text{m}$ No significant difference ($P = .097$). Angular deviation: • Snap-on: $0.35 \pm 0.23^\circ$ • Screw-retained: $0.41 \pm 0.23^\circ$ Snap-on more accurate ($P = .033$)
Author/Year	Park et al., 2024(48)
Study Design	<i>In vitro</i> experimental study
Sample	2 epoxy resin mandibular casts with 3 implants (PM1, M1, M2) Two internal conical connection implants (ICCI) tested:
Variables	• 7° conical angle (07) and 11° conical angle (11) 4 Groups (10 scans each) • Without vertical stop (conventional) - nS07 - nS11 • With vertical stop (experimental) - S07 - S11 Independent variables: • Implant internal conical connection angle (7° vs 11°) • Scan body connection design (with vertical stop vs without vertical stop) Dependent variables: • Linear displacement (Δx, Δy, Δz, Δd) • Angular displacement ($\Delta\theta_{XY}$, $\Delta\theta_{YZ}$, $\Delta\theta_{ZX}$)
Outcomes	Effect of implant connection angle: • 11° implants showed significantly greater linear displacement than 7° implants in ΔY, ΔZ, and ΔD ($P < .05$). Effect of scan body connection design: • Vertical stop scan bodies reduced displacement in implants with 11° (smaller ΔY, ΔZ, ΔD; $P < .05$). • No significant difference between scan body types in 7° implants.

Table 6: Summary of Studies Evaluating the Effect of Scan Body Connection Type on the Accuracy of Intraoral Implant Digital Impressions.

4.4 Material

Author/Year	Baranowski et al., 2025 (49)
Study Design	In vitro experimental study
Sample	Conducted on a cast metal edentulous jaw 9 Implants: 5 parallel/ 2 angled anterior/ 2 angled posterior 8 groups of scan body characteristics (9 implants in each)
Variables	Controlled variable PEEK (control): Independent variables • Material • Titanium blasted • Titanium polished • Height • Short (30% shorter than control) • Long (50% longer than control) • Geometry • Concave top (CO) Dependent variables • Depth deviation (DD) (μm) • Angular deviation (AD) ($^{\circ}$) • Rotational deviation (AD) ($^{\circ}$) (Scanning time and Screw holes size were excluded from this review)
Outcomes	• Control (PEEK) ○ DD: $149 \pm 131 \mu\text{m}$ ○ AD: $0.31 \pm 0.21^{\circ}$ ○ RD: $0.38 \pm 0.31^{\circ}$ • Material - Titanium blasted: ○ DD: $89 \pm 86 \mu\text{m}$ ○ AD: $0.31 \pm 0.21^{\circ}$ ○ RD: $0.36 \pm 0.28^{\circ}$ - Titanium polished: ○ DD: $80 \pm 72 \mu\text{m}$ ○ AD: $0.38 \pm 0.23^{\circ}$ ○ RD: $0.44 \pm 0.35^{\circ}$ • Height - Short (30% shorter than control): ○ DD: $172 \pm 143 \mu\text{m}$ ○ AD: $0.64 \pm 0.70^{\circ}$ ○ RD: $0.53 \pm 0.49^{\circ}$ - Long (50% longer than control): ○ DD: $143 \pm 130 \mu\text{m}$ ○ AD: $0.44 \pm 0.27^{\circ}$ ○ RD: $0.68 \pm 0.82^{\circ}$ • Geometry - Concave top (CO) ○ DD: $107 \pm 82 \mu\text{m}$ ○ AD: $0.39 \pm 0.28^{\circ}$ ○ RD: $0.30 \pm 0.25^{\circ}$

Author/Year	Soltan et al., 2025(50)
Study Design	<i>In vitro</i> experimental study
Sample	4 implants placed in an all-on-4 configuration: 2 parallel implants (0°) and 2 angled implants (30°)
Variables	Independent Variables • Material • Peek • Titanium • Angulation: 0°/ 30° Dependent Variables (measured in mm) • Trueness (Root mean square (RMS) deviation vs reference model) • Precision (RMS deviation within group comparisons)
Outcomes	Pairwise comparison (Trueness): Bonferroni (PEEK vs Ti: $p < 0.001$) Pairwise comparison (Precision): Bonferroni (PEEK vs Ti: $p < 0.001$) PEEK • 0° - Trueness (Mean RMS mm): 0.030 – 0.054 mm - Precision (Mean RMS mm): 0.019 – 0.036 mm • 30° - Trueness (Mean RMS mm): 0.030 – 0.054 mm - Precision (Mean RMS mm): 0.026 – 0.045 mm Titanium • 0° - Trueness (Mean RMS mm): 0.041 – 0.083 mm - Precision (Mean RMS mm): 0.027 – 0.064 mm • 30° - Trueness (Mean RMS mm): 0.037 – 0.092 mm - Precision (Mean RMS mm): 0.024 – 0.048 mm
Author/Year	Lee et al., 2021 (51)
Study Design	<i>In vitro</i> experimental study
Sample	3 partially edentulous mandibular models with simulated soft tissue 2 implants in the 15 and 17 6 groups: Implant angulation x material 3 intraoral scanner = 180 total scans
Variables	Independent variables: • ISB material Dependent variables: • Trueness (RMS deviation μm) • Within-tolerance percentage ($\pm 100 \mu\text{m}$ deviation) (Angulation and type of scanner was excluded)
Outcomes	PEEK ISB • 349.9 (77.3) μm RMS • 72.37 (11.59) % Titanium ISB • 222.1 (152.3) μm RMS • 65.70 (29.20) %

Table 7: Summary of Studies Evaluating the Effect of Scan Body Material on the Accuracy of Intraoral Implant Digital Impressions.

5. DISCUSSION

The aim of this study was to assess how implant scanbody characteristics influence the accuracy of intraoral digital implant impressions. Accurate replication of implant position is critical for the fabrication of implant-supported prostheses and the achievement of long-term clinical success in order to achieve clinical success (8,11). Errors in digital impressions may compromise passive fit, potentially leading to mechanical complications, biological issues and ultimately failure of the implant-supported restoration (3,9,11,12). This study evaluated factors associated with the ISB that may influence its ability to reproduce implant position during intraoral scanning, including scan body geometry, vertical exposure, connection interface and the material composition.

5.1 Geometry

The geometric design of the ISB have shown to considerably affect the quality of digital surface reconstruction (28,40). Well-defined geometric landmarks and identifiable surfaces have shown to improve the ability of the scanner to recognize the ISB and improve digital alignment (25,28). Past studies have indicated that objects which have greater number of surfaces may be interpolated more accurately when the IOS detects individual data points and are more prone to errors in areas with pronounced angles (52,53).

Motel et al. evaluated 3 ISB designs and found that scanbodies with less complex and flatter designs had significantly smaller deviation in digital implant impressions. ELOS ISB had the lowest 3D deviation (0.041 mm or 41 μ m), whereas NT-Trading ISB had a greater deviation (0.112 mm or 112 μ m). This emphasizes the importance of geometric design to reduce errors during scanning (40).

Similarly, Alvarez et al. reported that scanbodies with multiple milled surfaces showed lower errors in digital impressions. In their study, the Talladium ISB had the lowest distance error (0.041 ± 0.024 mm), followed by Ticare MG (0.050 ± 0.039 mm), in contrast ELOS had a higher angular deviation ($0.836 \pm 0.804^\circ$). However, these three designs which were flatter and simpler performed better than MG ISB which had a very complex pyramidal design with 2 side. These findings suggest that ISB with multiple flat surfaces and limited pronounced angles may facilitate higher accuracy in intraoral impressions (41).

Lawand et al. conducted a study which assessed the effect of modifying geometrically the ISB on the trueness of the scan achieved. The study aimed to create modifications which would permit sufficient surface detail to be used as a georeferencing. It was found that the additively modified (AM) group had the highest discrepancy with an angular accuracy of ($1.273 \pm 0.120^\circ$) comparatively to the subtractively modified (SM) ISB which showed an angular accuracy ($0.993 \pm 0.062^\circ$). The authors infer that this may be because AM create additional angles which may increase the difficulty for the IOS to detect all surfaces (44).

A study conducted by Meneghetti et al. found a significant difference in the overall trueness of complete-arch digital impressions when different ISB designs were used. The two implant scan body designs that demonstrated the lowest linear deviation exhibited similar geometric features, specifically a cylindrical shape with a single beveled surface. Overall, they found that ISB geometry significantly affected the accuracy of the digital impression ($p < 0.001$) (42).

Contrarily, Anitua et al. found that although there was a trend in deviation that was impacted by ISB geometry the differences were not statistically significant (43). Both these studies also suggested that other factors beyond geometric configuration such as size and exposure may influence scanning accuracy. These findings suggest that aside from geometric configuration, the vertical dimension of the scan body may also play a role in the accurate transfer of implant position during digital impression acquisition (42,43).

5.2 Vertical Dimension

Meneghetti et al. highlighted that in addition to geometric design the extent of scan body surface available also impacted the accuracy of the scan. As discussed in the previous section the two ISB with the least deviation also had a reduced height compared to the other scanbodies evaluated. This observation suggests that the amount of scan body surface available for scanner detection may play a role in digital impression accuracy (42).

Sicilia et al. evaluated the effect of supramucosal exposure on the accuracy of the digital impression and found that at 3 mm exposure of the ISB resulted in lower linear deviation ($55.3 \pm 21.1 \mu\text{m}$) compared with 7 mm exposure ($88.3 \pm 33.9 \mu\text{m}$). However, most comparison found no statistical significance ($p > 0.05$). This suggests that as soon as the scanners can detect the ISB, increasing its height or exposure may not significantly improve overall scanning accuracy (45).

In contrast, Jannati et al. found that ISB positioned above the occlusal plane exhibited significantly ($p < 0.0001$) lower angular deviation than those at or below. Unlike other investigations this study included the presence of adjacent teeth, which could partially obstruct the ISB during scanning. Therefore, in those conditions having a greater height could improve scanner visibility and improve accuracy of detection (54).

These findings indicate that although it is not always necessary to increase the vertical dimension of the ISB because it does not consistently improve accuracy, there are certain clinical situations where it is advantageous. In addition to the visibility of the ISB the stability of the interface should also be considered to assure accurate transfer of the implant position (25).

5.3 Connection Type

The connection between the ISB and implant may also impact the accuracy of the digital impression by affecting the stability of the implant- scanbody interface (36).

A study conducted by Arcuri et al., compared snap-on and screw-retained ISB utilized to scan a complete-arch. They measured accuracy outcomes by 3D and angular deviations. The angular deviation of the snap-on scanbodies was better than that of the screw-retained with $P=0.33$. However, there was no significant difference in 3D deviation, $P=0.097$) (47). These results suggest that although the mechanism of the interface may influence the angular accuracy, it has limited effect on the accuracy of the intraoral implant impression.

Park et al. studied the ISB interface by comparing ISB with and without vertical stop with 7° and 11° internal conical connections. Implants with a 7-degree conical connection showed no significant difference in linear displacement between scan body-designs. In comparison 11-degree ISB showed significantly reduced displacement when a vertical stop was used ($P<0.001$). These findings suggest that implants with a larger internal conical angle are more susceptible to axial displacement, which can be reduced by incorporating a vertical stop (48).

Collectively, these studies suggest some degree of influence between connection type and accuracy of impression. However, current studies available are limited and require further investigation to determine their overall impact. Beyond connection stability, the ISB material may also influence accuracy through its optical interactions with the intraoral scanner.

5.4 Material

Material is also considered an important factor when evaluating the effect of the scanbody on the accuracy of implant impressions some evidence suggest that the reflectiveness of the surface may impact the ability of the scanner to register the ISB (55).

A study conducted by Lee et al. evaluated the effect of the material on the accuracy of digital impressions by comparing the most common utilized titanium and PEEK. To avoid other factors influencing the result they utilized ISB from the same manufacturer. Although similar design, they differed that the PEEK ISB had a single bevel and the titanium two. The deviation analysis conducted showed that the material affected the trueness of the impressions ($P<0.001$). The titanium ISB showed a better trueness value RMS deviation ($222.1 \pm 152.3 \mu\text{m}$) than PEEK ($349.9 \pm 77.3 \mu\text{m}$). However, PEEK showed to be more constant in its results with a narrower interquartile range and a higher within tolerance percentage. The author suggests titanium may have had a better trueness more due to its design. However, the reflectiveness of titanium may cause optical interference and reduce precision and increase result variability. Therefore, although titanium scanbodies have improved trueness they may cause difficulties scanning under certain conditions (51).

Alternatively, Soltan et al. reported significantly improved trueness and precision when PEEK ISB were used compared to titanium ($P<0.001$). PEEK, which is a matte material, appears to enhance

scanner detection due to its non-reflectiveness which reduces light-scattering(50). Comparable results in which PEEK out performed titanium are seen in studies by Arcuri et al. and Karthhik et al. (11,56).

Similarly to Lee, Baranowski et al. detected that the titanium ISB had a lower mean deviation ($80 \pm 72 \mu\text{m}$) than PEEK ($149 \pm 131 \mu\text{m}$). However, there is variability among the results depending on other present factors such as vertical dimension and geometry (49).

Analysis of these indicates that although material may influence scanner ability to capture the ISB, results remain variable. This indicates that the effect the ISB has on the accuracy of intraoral implant impression is multifactorial as seen in systematic reviews (25,36).

5.5 Other Factors affecting accuracy

Although this review focuses on ISB characteristic, other factors have been shown to significantly influence the accuracy of intraoral digital impressions. The number of implants and inter-implant distance has shown to have a large impact as an increased edentulous span has been associated with lower accuracy. This is mainly due to the absence of stable landmarks which can result in cumulative stitching errors, especially in multi-unit and complete-arch scans (7).

The extent of the scanning area also contributes to this limitation. Larger spans have more complex scanning paths and changes in angulation, increasing the risk of distortion (7,57). Implant angulation may also influence accuracy, as tilted implants can complicate the scanner access and alignment, potentially increasing deviation (58).

Operator-related variable remain critical, as IOS is technique sensitive. Differences in scanning strategy and clinician experience can significantly affect outcomes. This highlights the importance of standardized protocols (7,11,59). In addition, scanner-related factors such as device design, technology and scanner head size may influence accuracy, particularly in posterior or areas which are difficult to reach (58).

It is important to also consider clinical intraoral conditions including saliva, soft tissue mobility, and limited access may interfere with optical data capture and reduce scan quality(58). Overall, intraoral scanning accuracy is multifactorial and should not be attributed solely to ISB characteristics.

5.6 Limitations

A common limitation among the literature included in this study is that most investigations were conducted under *in vitro* conditions, which does not replicate the oral cavity. The presence of saliva, mobile soft tissue and humidity are absent and therefore may influence the accuracy of the intraoral impression and limit clinical applicability (31,42,46,50,51).

Additionally, there is notable variation in study design between the investigations included. The studies evaluated distinct number of total implants and their position within the arch, angulation, scan body system, scanners utilized and measurements used to analyze accuracy. This limits direct

comparison between studies and makes it difficult to establish relationships and draw conclusion on the effect of ISB on the accuracy of digital impressions (31,50,51).

Another limitation is that many authors conduct their studies under controlled conditions evaluating isolated variables. However, the accuracy of intraoral impressions is multifactorial and must consider other variables. Some of these clinical conditions that should be considered are scanning strategy, operator experience and patient-related conditions. Furthermore, the clinical application may be limited as several studies evaluated specific ISB system. This may restrict the applicability of this result to other ISB designs (40,41,43–45).

Despite the limitations mentioned, the finding within this review provide insight into the role of the scan body in the accuracy of intraoral impressions and highlights considerations that may be crucial for clinical practice and future research.

6. CONCLUSION

6.1 Main Objective

Within the limitations of this study, implant scanbody characteristics such as geometry, vertical height, connection and material composition influence the accuracy (trueness & precision) of intraoral digital impressions. This effect is multifactorial and depends on the interaction between these variables.

6.2 Secondary Objective

Furthermore, in the context of multi-unit and full-arch implant rehabilitations, the influence of ISBs become more critical, as cumulative errors and factors such as implant number, inter-implant distance and angulation may further compromise accuracy. As most available evidence is derived from in vitro studies, further in vivo research is required to confirm these findings under clinical conditions.

7. SUSTAINABILITY

Sustainability in healthcare requires the balance of environmental impact, patients' well-being and time and cost-efficiency. Application is evaluated using the United Nations Sustainable Development Goals (SDGs) (60). This study explores how the scanbody characteristic influence the accuracy of digital impressions and its indirect contribute to sustainable dentistry.

Digital impressions offer environmental advantages over conventional-techniques by reducing the dependance on single-use materials and decreasing carbon emissions (61). This supports the SDGs 12: Responsible Consumption and Production through improved resource efficiency (60). Inaccuracies increases laboratory processing and material consumption, undermining sustainability. Therefore, optimizing accuracy which is influence by ISB characteristics is essential.

Digital workflow also aligns with SGD 3: Good Health and Well-Being by enhancing patient experience. Intraoral scanning removes discomforts associated with conventional-techniques and

reduces clinical time (62). These benefits are contingent on accurate outcome, highlighting the need to improve ISB performance.

Economic sustainability must also be considered. Evidence suggests it can decrease laboratory time and increase efficiency. However, there are limitation due to greater costs of initial investment, maintenance and training. Economic advantages are possible by reducing inaccuracies. Scanbody accuracy can increase economic sustainability (63). Strategies to enhance ISB to improve accuracy to achieve environmentally conscientious, patient-focused and economically optimal outcomes.

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9. ANNEXES

9.1 Annex 1: Abbreviations

AM	Additively modified
AD	Angular deviation
CAD/CAM	Computer-aided design and computer aided manufacturing
EOS	Extraoral scanners
ISB	Implant scan body
IOS	Intraoral scanners
LD	Linear discrepancy
LDD	Linear distance deviation
NM	Nonmodified
PE	Polyether
PEEK	Polyether ether ketone
PVS	Polyvinyl siloxane
SM	Subtractively modified
3D	Three-dimensional
SDG	Sustainable Development Goals