Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

INFLUENCE OF SCANBODY DESIGN ON THE TRUENESS OF IMPLANT INTRAORAL DIGITAL IMPRESSIONS. SYSTEMATISED REVIEW.

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RESUMEN

Introducción: Los escáneres intraorales se utilizan cada vez más en la implantología dental; sin embargo, la precisión de las impresiones digitales de arcadas completas sigue siendo cuestionable. El diseño del scanbody, incluyendo el material y la geometría, puede ser la variable decisiva, pero la evidencia actual es limitada y contradictoria. Esta revisión tiene como objetivo evaluar la influencia del diseño del scanbody en la precisión de la impresión; **Objetivos:** El objetivo principal de esta revisión fue evaluar la influencia del diseño del escáner en la precisión de las impresiones digitales intraorales de implantes en una arcada dental completamente edéntula. Los objetivos secundarios fueron determinar si destacaba un diseño específico de escáner o una precisión específica del escáner; **Materiales y métodos:** Se llevó a cabo una revisión bibliográfica sistemática utilizando MEDLINE Complete, Academic Search Ultimate y Dentistry & Oral Sciences Source. Se aplicó una estrategia de búsqueda amplia. Los criterios de inclusión abarcaban estudios in vitro e in vivo revisados por pares de los últimos 5 años sobre el diseño del escáner y la precisión en arcadas totalmente edéntulas, con; **Resultados:** La búsqueda en las tres bases de datos identificó 21 registros, todos los cuales se recuperaron y se sometieron a cribado. Tras aplicar los criterios de inclusión y exclusión, se incluyeron 5 estudios. La mayoría de las exclusiones se debieron a que se centraban en el tipo de escáner, en arcadas parcialmente edéntulas o en variables no relacionadas; **Conclusiones:** El diseño del scanbody influye significativamente en la precisión de las impresiones digitales intraorales en arcadas totalmente edéntulas. Los factores relacionados con el escáner también afectan a la precisión. Los diseños cilíndricos de titanio recubiertos de plasma mostraron la mayor precisión. Se rechazó la hipótesis nula, lo que pone de relieve la necesidad de realizar más investigaciones in vivo.

PALABRAS CLAVE

Dentistry, scanbody design, intraoral scan, trueness, full arch.

ABSTRACT

Introduction: Intraoral scanners are increasingly used in implant dentistry, however, the trueness of full-arch digital impressions remains questionable. Scanbody design, including material and geometry, may be the decisive variable but current evidence is limited and contradictory. This review aims to evaluate the influence of scanbody design on impression accuracy.; **Objectives:** The primary objective of this review was to evaluate the influence of the scanbody design on the trueness of the intraoral implant digital impressions on a fully edentulous dental arch. The secondary objectives were to determine wether a specific scanbody design or a specific scanner accuracy stood out; **Materials and methods**: A systematised literature review was conducted using MEDLINE Complete, Academic Search Ultimate, and Dentistry & Oral Sciences Source. A broad search strategy was applied. Inclusion criteria included peer-reviewed in vitro and in vivo studies from the last 5 years on scanbody design and trueness in fully edentulous arches, with; **Results:** The search across three databases identified 21 records, all of which were retrieved and screened. After applying inclusion and exclusion criteria, 5 studies were included. Most exclusions were due to focus on scanner type, partially edentulous arches, or unrelated variables; **Conclusions:** Scanbody design significantly influences the trueness of intraoral digital impressions in fully edentulous arches. Scanner-related factors also affect accuracy. Plasma-coated titanium cylindrical designs showed the highest trueness. The null hypothesis was rejected, highlighting the need for further in vivo research.

KEYWORDS

Dentistry, scanbody design, intraoral scan, trueness, full arch.

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1. INTRODUCTION

1.1. Justification

This systematised review of the influence of scanbody design on the trueness of intraoral scan is necessary as the information about this topic is scarce and contradictory or inconclusive. As a result, no clear conclusions can be drawn about which design offers the best scan quality and trueness. The limited number of studies calls for further research of this topic.

1.2. Acquisition of a digital impression

Intraoral scanners are becoming widespread in the field of dentistry, (1) and they are being used more commonly for implant and full arch scans (1–3). Although professionals would like to use the scanners reliably, the research about their precision and trueness leaves uncertain and contradicting results (4,5). There is no clear consensus, but for an implant scan to be considered precise, it must have an error of less than 150µm and an angular deviation of less than 0.4 degrees (4–6). Full-arch digital scans are have been considered too inaccurate but new research suggests that sufficient level of accuracy can be achieved but there are many factors at play (2,4,6,7).

The most common category of scanners in dentistry are non-contact optical scanners, whether they are intraoral or laboratory desktop types (8). Different scanner manufacturers have designed and developed their own different acquisition technology such as confocal microscopy, active triangulation, structured light scanning, photogrammetry and other (4,9). The quality of the scan depends on various factors starting with the scanner itself (10). The different acquisition technologies and even different scanner models made by the same manufacturer have different trueness and precision where confocal microscopy repeatedly appears as the most true and precise across multiple studies, namely the CEREC Primescan, Dentsply Sirona, Charlotte, USA and Trios T3/Trios T5, 3shape, Copenhagen, Denmark (4,11).

Another major factor influencing the quality of the scan is the operator experience and scanning pattern (1,9,10). Due to the different manufacturers using different stitching algorithms certain scanning patterns show better results in one scanner compared to others (1,8). An example of this is the use of the One Shot technique with the CEREC Primescan, Dentsply Sirona, Charlotte, USA (12). Operator experience also plays a role in terms of stitching, the more experienced

operators tend to have smoother and less chaotic movements compared with novices (1). This is especially important in fully edentulous scans as reference points are harder to obtain compared with partially edentulous arches (1,8). One study suggests that using horizontal scan bodies decreases operator error compared to the use of vertical scan bodies (13). Experienced operators perform the scans faster and more precisely than those with little experience (9).

Furthermore, studies have shown that ambient lighting intensity influences the quality of the scan, and each scanner has its ideal ambient lighting intensity value, usually presented in lux (10). Saliva also has an effect on the quality of the scan (5,6,14). Studies show that the presence of saliva has a negative impact on the scan quality due to the increase in reflectivity and noise (1,8). All the factors mentioned above and more affect the final scan quality and the quality of the data (2,5,8,10,11,15,16). The acquired data is then exported into a 3D file, usually Standard Tessellation Language (STL) (8), to be viewed or used further for CAD-CAM digital workflow (8,14).

1.2.1. Scanbody definition

Scan bodies, also known as scan pegs, scan abutments, scan flags or scan posts, are intraoral devices that are used to record the exact 3D position of the implant in the dental arch (1,6,8). They consist of 3 parts - the scan region, the body and the base - (8,15) and can be attached to the implant by a screw, by a magnet or by a friction grip system (1,6,10) where all the parts and systems of attachment influence the final quality and precision of the implant position is a digital impression (1,6,10). They are mostly made of polyetheretherketone (PEEK) or titanium although other resins, metals and alloys are used (1,6–8,13,14).

1.2.2. Types of scan bodies

As mentioned above, scan bodies generally consist of 3 parts, (8,15) but they can be further categorised according to several other characteristics (1,3,8,10). Scan bodies can be made as 1-piece, such as the Cares Mono RN, Institut Straumann AG, Basel, Switzerland or the MIS SP V3 (15), or 2-piece, such as the MUA, M6 Dental, Shenzhen, China (13).

Another factor differentiating types of scan bodies is the retention system (1,10). In the screw-retained system the scanbody is screwed into the implant itself and studies show that this system is the most accurate as the scan body cannot be displaced from the implant (1,10). The friction grip system , such as the Atlantis IO FLO-S, Dentsply Sirona Implants, Mölndal, Sweden, is attached to the implant without any screws by “snapping on” (1,10), however, the long-term

repeatability and accuracy of the scanbody is less certain, especially if the scanbody is made of a weaker material (1,6–8,10). Finally, the magnet-retained system, such as the ScanPeg, Neoss Inc, Westborough, USA (17) is a 2-piece system that uses a magnet to attach itself to a metallic base that is screwed into the implant (10).

Scan bodies can further differ in the material they are made of. The most common materials are PEEK, titanium and a hybrid construction although other materials and alloys are used (1,8,10,12,13). Each material has its strengths and weaknesses that make the different scan bodies appropriate for a particular situation (1,3,6–8,10,13). PEEK has the advantage of being non-reflective, but its dimensions can be altered with wear and sterilisation (1,5–8,10). Titanium scan bodies are more dimensionally stable and can be reliably reused for longer, however, due to being a metal, they are highly reflective and hence their surface must be treated by coating or sandblasting to become non-reflective and obtain a high quality scan (1,6–8,10,14,15).

Finally, the shape of the scan region influences the accuracy and trueness of the scan along with the material it is made of (3,8,13,15,16). Comparisons of the morphology of the scanbody seem to suggest that vertical cylindrical scan bodies without sharp angles are more precise (3,15), however, other studies suggest that horizontal scan bodies might be the most precise option (13). As mentioned in the previous paragraph, in terms of materials, PEEK is less reflective when compared to titanium and other metals as it is semi-crystalline, however, previous studies suggest that due to it being a polymer, it tends to become less accurate because of wear and repeated sterilisation cycles (1,6–8,10,12). Titanium has less structural issues due to it being a metal and being more resistant to wear, but its surface, if untreated, is reflective (1,6–8,10,14,15). The effect of all these variables on the trueness and accuracy of the intraoral scan is discussed and elaborated in the following sections of this systematised review.

2. OBJECTIVES

2.1 PICO question

In adults with fully edentulous arches (P), how do different scanbody designs (C) influence the trueness (O) of intraoral digital impressions (I)?

2.2 Primary objective

The primary objective of this systematised review was to evaluate the influence of the scanbody design on the trueness of the intraoral implant digital impressions on a fully edentulous dental arch.

2.3 Secondary objectives

To determine whether the intraoral scanner used to obtain the intraoral implant digital impression on a fully edentulous arch has any effect on the trueness of the scan.

To determine which of the scanbody designs has the highest trueness in a digital intraoral scan of a fully edentulous cast.

2.4 Null hypothesis

The null hypothesis is that the design of the scan body has no impact on the trueness of the intraoral scan on a fully edentulous arch.

3. MATERIAL AND METHODS

3.1 Research objective

The research objective was formulated using the PICO framework. Articles were obtained using three databases: MEDLINE Complete, Academic Search Ultimate and Dentistry & Oral Sciences Source. These databases were accessed through the Biblioteca Digital of the Universidad Europea de Madrid.

3.2 Research equation

The research equation was *"scanbody design AND trueness of intraoral scan"*. The research equation was left intentionally vague as any more specification, such as "AND full arch", eliminated resources that were answering the research question.

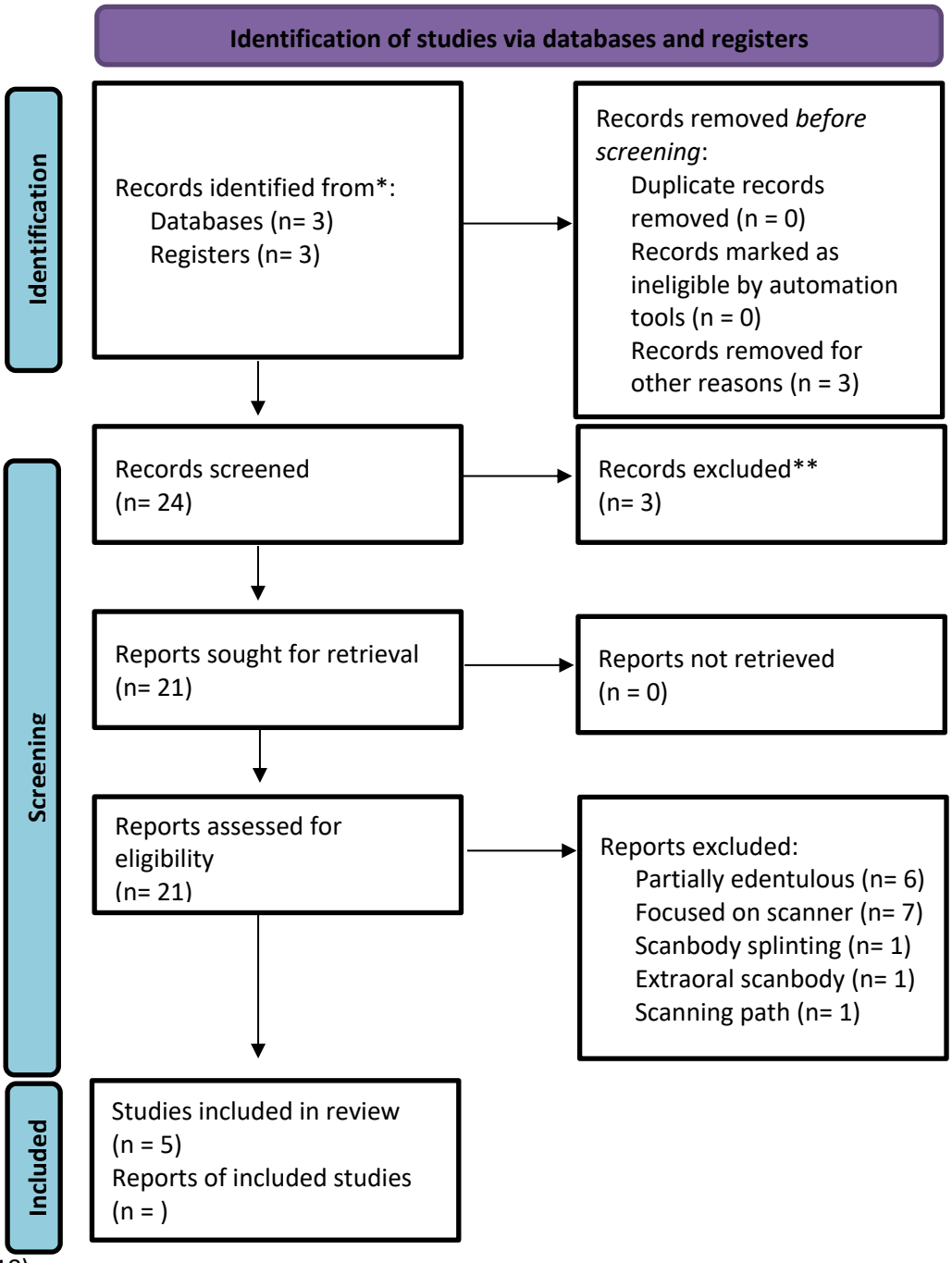
3.3 The inclusion criteria

In vivo and *in vitro* studies focusing on the effect of scanbody design on the accuracy of the scan in fully edentulous arches. Peer reviewed studies from the past 5 years that were available in full text form and written in English were included.

3.4 Exclusion criteria

Studies from more than 5 years ago or focusing on partially edentulous arches and studies that focused on the influence of the scanner or scanning technique instead of the design of the scanbody were excluded. As the research question was vaguer, articles about partially edentulous patients were excluded manually. Studies about extraoral scanners were also excluded

4. RESULTS



(18)

The results of this systematised review were collected from three databases: MEDLINE Complete, Academic Search Ultimate and Dentistry & Oral Sciences Source. No duplicate records were removed, no records were marked as ineligible by automation tools, however, 3 records were removed for being more than five years old. 21 records were screened, all of which were sought for retrieval, and all were retrieved. The resulting 21 records were assessed for eligibility with 6 being rejected for focusing on partially edentulous arches, 7 rejected for focusing on the scanner instead of the scan bodies, 1 rejected for focusing on scanbody splinting, 1 focusing on extraoral scan bodies and 1 focusing on scanning pathway. 5 studies were included in this systematised review. 4 of these exclusions were made after reading the title and the remaining 17 after reading the abstract. This table was finalised on the 10th of March 2026.

Table 1. General information about selected articles

	Year and author	**Study type**	**Scanbody material**	**Scanbody type**	**Control**	**Scanner used**	**Statistical analysis**	**Conclusions**	**Trueness (µm)**	**Angular deviation (degrees)**
1	2023, Meneghetti et al. (11)	In Vitro Study	PEEK, PEEK with metal connection, 3D printed grey resin	Cylinders with various morphologies, horizontal bar with a convex ball in the extremity	Master model of an edentulous maxilla in form of an STL file modified with 6 parallel holes for implant placement. D2000 desktop scanner was used to establish reference points in the STL files.	Primescan, Omnicam, Trios 3 and Trios 4, D2000 (extraoral scanner)	Kruskal-Wallis test + Bonferroni correction.	SB2 and SB7, vertical cylindrical PEEK scan bodies with an angular surface had the highest precision and resing scan bodies had the highest deviation. Primescan was the most	SB1 = 118.47 SB2 = 72.27 SB3 = 158.23 SB4 = 165.08 SB5 = 190.29 SB6 = 182.51 SB7 = 93.31	SB1 = 0.45 SB2 = 0.25 SB3 = 0.63 SB4 = 0.77 SB5 = 0.89 SB6 = 0.71 SB7 = 0.51

								accurate scanner.		
2	2025, Azevedo et al. (13)	Comparative In Vitro Study	PEEK and titanium	Vertical and horizonal cylinders, angulated horizontal polygons, T-shaped scan bodies and a 2-piece quadrangular scanbody.	An edentulous mandibular reference cast was manufactured with 6 implant analogues. The Elos Accurate scanbody was used as a control and was digitised by IScan4D extraoral scanner.	TRIOS 3, TRIOS 4, Primescan, iTero Element 5D and IScan4D (desktop scanner)	Root mean square	Horizontal scan bodies showed higher scan accuracy when compared with vertical ones while scanned by multiple scanners and two different operators.	***Table 2***	N/A
3	2024, Lawand et al. (19)	In Vitro Study	PEEK	Cylinders with a flat angled surface that	Completely edentulous translucent resin	Trios 3 and E3 (desktop scanner)	Root mean square error calculation.	Modifying the morphology of the	NM = 92 ±15	NM = 1.266 ±0.074

				either was not modified or was modified by addition or subtraction of material.	maxillary cast with 4 implant analogues was fabricated. CARES Mono PEEK scan bodies were fitted to the analogues with the index facing the vestibular surface and scanned using the 3Shape E3 extraoral scanner and converted to an STL file.			scanbody affects the trueness of the scan where subtractive modification increased accuracy and additive modification decreased accuracy.	AM = 266 ±30 SM = 100 ±4	AM = 1.273 ±0.120 SM = 0.993 ±0.062
4	2025, Gómez-	Comparative Clinical Study	PEEK and metal	Standard cylinder with an angled	Maxillary type IV plaster cast taken from a	Trios4 and E4 (desktop scanner)	1-way ANOVA, Shapiro-Wilk	Scannable healing abutments	STD = 94 ±6	N/A

	Polo et al.(6)			surface and cylinders, 5 and 7mm tall, with the superior part angled at 35 degrees.	patient with 7 healthy implants that were splinted and later this cast was digitised using the E4 desktop scanner and converted into and STL file.		test, Tukey pairwise comparisons test, Levene test	yielded higher accuracy when compared with a reference scanbody.	TS5 = 72 ±10 TS7 = 63 ±9	
5	2024, Azevedo et al. (20)		PEEK and titanium	Cylinder with an angled surface and a horizontal indentation for both scan bodies.	Mandibular gypsum model from an edentulous patient with 6 dental implants was digitised using IScan4D LS3i extraoral scanner.	Trios4, Virtuo Vivo, Medit i700, iTero 5D, Primescan and IScan4D LS3i (extraoral scanner)	Descriptive statistics, root mean square, two-way ANOVA, Tukey test, Kruskal-Wallis test + Bonferroni correction.	There are significant differences in the trueness and precision of PEEK and titanium scan bodies. There are also significant differences in	***Table 2.***	N/A

								results between scanners scanning PEEK and titanium scan bodies.		

Table 2. Results table from 2025, Azevedo et al. (13)

Year and author	Shortcut explanation	Median trueness operator 1 ± IQR(µm)	Median trueness operator 2 (µm)
2025, Azevedo et al. (13)	i5D – iTero Element 5D	i5D + V-EA = 68 ±12	i5D + V-EA = 95 ±17
	PS – Primescan	i5D + H-NB = 22 ±4	i5D + H-NB = 22 ±5
	T3 – Trios 3	i5D + H-NS = 29 ±3	i5D + H-NS = 32 ±5
	T4 – Trios 4	i5D + H-M6 = 18 ±17	i5D + H-M6 = 30 ±18
	V-EA – Vertical Elos Accurate	i5D + H-SF = 35 ±5	i5D + H-SF = 31 ±9
	H-NB – Horizontal Multi-unit Polo	PS + V-EA = 25 ±8	PS + V-EA = 29 ±9
	H-NS – Horizontal Nexus Scan Gauges	PS + H-NB = 13 ±3	PS + H-NB = 17 ±5
	H-M6 – Horizontal M6 dental	PS + H-NS = 14 ±2	PS + H-NS = 10 ±2
	H-SF – Horizontal Smart Flags	PS + H-M6 = 26 ±3	PS + H-M6 = 21 ±5
		PS + H-SF = 12 ±7	PS + H-SF = 18 ±6
		T3 + V-EA = 20 ±6	T3 + V-EA = 22 ±6
		T3 + H-NB = 21 ±7	T3 + H-NB = 24 ±6
		T3 + H-NS = 24 ±3	T3 + H-NS = 21 ±7
		T3 + H-M6 = 20 ±5	T3 + H-M6 = 21 ±2
		T3 + H-SF = 32 ±10	T3 + H-SF = 22 ±3
		T4 + V-EA = 33 ±11	T4 + V-EA = 36 ±15
		T4 + H-NB = 36 ±15	T4 + H-NB = 42 ±11
		T4 + H-NS = 40 ±11	T4 + H-NS = 33 ±5
		T4 + H-M6 = 22 ±9	T4 + H-M6 = 24 ±11
		T4 + H-SF = 31 ±7	T4 + H-SF = 34 ±7

Table 3. Results table from 2024, Azevedo et al. (20)

Year and author	**Shortcut explanation**	**Median trueness with PEEK scanbody ±SD**	**Median trueness with titanium scanbody ±SD**
2024, Azevedo et al. (20)	T4 – Trios 4 VV – Virtuo Vivo Mi700 – Medit i700 i5D – iTero Element 5D PS – Primescan	T4 = 94 ±18 VV = 27 ±5 Mi700 = 38 ±7 i5D = 46 ±5 PS = 27 ±4	T4 = 30 ±4 VV = 43 ±15 Mi700 = 31 ±4 i5D = 30 ±3 PS = 27 ±9

5. DISCUSSION

The studies in this systematised review were all carried out in a distinct manner, with different scanners, different scan bodies and using different statistical analyses and as a result, values of trueness cannot always be directly compared. As seen in the results section above, scanbody design was found to have a profound impact on the trueness of the intraoral scan in a fully edentulous arch but as the study by Azevedo et al. has shown, the operator has a large influence on the trueness of the scan (13). To understand the results in this systematised review, it is necessary to understand why they are presented the way they are. Root mean square (RMS) error is a common statistical test used mostly in model predictions where the data follows a normal distribution (21). In this statistical test a predicted/expected outcome is compared with observed results (21), in case of the studies in this systematised review it is the comparison of a reference model STL file that was scanned with an extraoral scanner and the scan done with intraoral scanners (6,11,13,19). Some authors opted to present the trueness and precision in form of overall 3D deviations using the RMS rather than analysing horizontal and angular deviations separately (6,13), giving the absolute value of deviation from the reference points in the scan instead of breaking the value down into its individual components. This information is not available for the articles in this review as the raw data is not accessible and scanner-scanbody pairs cannot be assessed in detail.

5.1 Differences between scanners

Even though scanners are not the subject of this review, understanding how they work is crucial to correctly interpret the results of this systematised review. The scanning technology is one area that needs to be briefly addressed, however, studies using the exact same scanners yielded vastly different results, where these differences need to be explored.

The fundamental variability in accuracy is mainly because of the different optical principles and algorithms used by different intraoral scanners (4,22,23). Confocal microscopy systems, like the TRIOS series, achieve high trueness through optical sectioning and spatial light filtering, which effectively delete out-of-focus signals to produce high-contrast 3D data (22). This technology often uses telecentricity, allowing for a variable focal plane while maintaining a fixed spatial relation between the scanner head and the object, and helps to create a more homogenous deviation pattern (22). In contrast, scanners based on triangulation calculate distances using

trigonometry by taking the fixed angle and distance between the light emitter and sensors to calculate the position of the scanned surface; this method is significantly more sensitive to occlusion where accuracy is lost if the light beam or camera is blocked from the target area (8,22). Newer smart pixel sensor technology, found in the Primescan, enhances these results by capturing up to one million 3D points per second through high-frequency contrast analysis, often yielding superior trueness when compared to traditional triangulation or older confocal models (15,24). The CEREC Omnicam had a generally lower accuracy in both trueness and precision when compared to more modern scanners like the Primescan or TRIOS series (24–26). A study done on single zirconia crowns showed that Omnicam produced larger marginal and internal gaps than other scanners (24). This result, of course, cannot be directly compared to a completely edentulous scan, however, it is indicative of differences between the performance of the scanners. This can also be seen in the study done by Meneghetti et al. where the Omnicam yielded the worst results on 5 out of the 7 scan bodies studied (11).

Beyond the raw data acquisition, the 3D model acquisition is a major source of discrepancy between scanners, as these devices capture only small fragments of an object at a time which must be stitched together via complex algorithms (8,25). In complete-arch edentulous scans, the lack of reference anatomical landmarks complicates this registration process, leading to accumulated distortion and stitching errors that vary based on software of each manufacturer (8,22). The size of the scan window or field of view also affects accuracy; systems with larger windows require fewer images to cover the whole arch minimising the number of alignment events and the potential for error accumulation compared to devices with smaller windows (22). Furthermore, the optical interaction between scanner hardware and the scanned surface heavily influences the results, as dull and opaque materials are digitised more accurately than shiny or translucent ones that generate "noise" in the point cloud (4,8,14). Confocal scanners have shown better performance digitising plasma-coated titanium compared to PEEK, as these coatings manage light reflection more effectively than untreated surfaces (7,20). Environmental factors, such as the presence of saliva or specific ambient lighting conditions, also introduce variability because different sensors react uniquely to reflections and illuminance levels (8,10,14).

Finally, operator experience and the chosen scanning strategy are important variables that significantly affect the scan quality as more skilled professionals tend to produce faster, more complete scans with fewer redundant data points, while certain scan patterns, like the one-shot technique, may optimise frame-stitching for specific scanners and penalising others (8,9,23). Ultimately, the diversity in precision and trueness results suggests that there is no ideal scanner

suited for every clinical situation; rather, outcomes depend on the interactions between the scanner, software algorithms, and the clinical environment (8). Further research is needed to better understand the interactions between scanning technologies, scanners and scanned material.

5.2 Horizontal and vertical scan bodies

The first aspect to consider is the macro-morphology of the scanbody. Azevedo et al. focused on the comparison of horizontal scan bodies, referred to in the article as H-NB, H-NS, H-M6 and H-SF, with a vertical control referred to as V-EA (13). The results table can be viewed in *annex 1*. The V-EA scanbody had a significantly higher median error in the iTero Element 5D group for both operators at 68µm and 95µm respectively compared with the horizontal scan bodies whose median error was as low as 18µm in case of the H-M6 with operator 1 (13). In the other groups, scanned by Primescan, Trios3 or Trios4, this trend did not reappear. The Primescan group saw a higher median error for V-EA at 25µm and 29µm respectively for both operators (13). While the H-M6 had a comparable error of 26µm and 21µm, which is comparable with the vertical counterpart, the other scan bodies had a higher trueness with error as low as 10µm (13). Both the Trios3 and Trios4 had a comparable trueness regardless of the scanbody used (13). Trios3 had a median error range of 20µm to 24µm with an outlier (H-SF) at 32µm for operator 1 and the Trios4 with a range of 31µm to 40µm with H-M6 as outliers at 22µm and 24µm respectively for both operators (13). These results suggest that certain scanners could be better suited for certain scan bodies and are struggling more with others. The most notable being the iTero Element 5D with the V-EA scan bodies (13). It was also the most inconsistent across all the scanners and scan bodies, especially with V-EA scanned by operator 2 where the error range was from 56µm up to 117µm (13). This difference might be the result of the iTero using parallel confocal imaging and not structured light projection/Smart Pixel Sensors as is the case of the Primescan, Trios3 and Trios4 (22,27,28). Based on these results, each scanner appears to have its “preferred” scanbody. They could serve as a guide for dental offices, which already have one of the scanners mentioned in the study, for which scanbody is the best. For the iTero it would be the H-NB, for Primescan it would be the H-NS, for Trios3 it could be any of the scan bodies as they all performed similarly except the H-SF for operator 1 and for Trios4 it would be the H-M6 (13).

Similarly to Azevedo et al., Meneghetti et al. compared various commercially available vertical scan bodies with different morphologies to custom 3D printed grey resin designs, one of which,

SB6, was horizontal (11). Scans performed by Omnicam on scan bodies SB1-SB5 yielded the highest error but in case of SB6 the median error was 189.44µm, which was the second best (11). Scans by Trios3 and Trios4 were the least true with a median error of 267.55µm and 210.46µm respectively (11) and, finally, scans by Primescan were the most true with a median error value of 161.65µm (11). The overall error of SB6 was 182.51µm as can be seen in the results table above, which was the second highest error only exceeded by SB5 with an overall error of 190.29µm (11).

Since Azevedo et al. and Meneghetti et al. both used Primescan, Trios3 and Trios4 and their results are presented as median values, these studies can be compared easily. Since Meneghetti et al. had only one horizontal scanbody in their research (11), the data for the comparison is limited. Even so, the differences in the data are quite staggering. SB6 had a median error of 161.65µm with Primescan, 267.55µm with Trios3 and 210.46µm with Trios4 (11). Comparing with nitpicked worst results of horizontal scan bodies from Azevedo et al. study - Primescan had the largest error of 26µm by operator 1 in H-M6, Trios3 had the largest error of 32µm by operator 1 in H-SF and Trios4 had the largest error of 42µm by operator 2 with H-NB (13) – the difference in trueness considerably large. Both studies were done on casts with 6 implants in the position of the first molars, first premolars and lateral incisors (11,13) but some important differences can be noted that may have caused such a large discrepancy between results. Azevedo et al. used a model of the mandible made from plaster (13) while Meneghetti et al. used a 3D printed model of the maxilla made from grey resin with a 100µm thickness (11). The possible differences in scanning performance of the different scanners and differences in scanning the mandible and maxilla will be discussed in later sections.

5.3 Scannable healing abutments

Another alternative for horizontal or vertical scan bodies is using healing abutments themselves as scan bodies. Scannable healing abutments have the benefit of preserving the soft peri-implant tissue by avoiding repeated connections and disconnections that could irritate or damage the healing tissue (29). These healing abutments also have a longer useful lifespan compared to PEEK scan bodies since they are made of metal and do not suffer the same shrinkage or deformation as PEEK scan bodies do due to repeated heating and cooling cycles during sterilisation (1,10,20). Gómez-Polo et al. published an investigation where they compared a standard 10mm vertical intraoral scanbody (Scanbody 2800), labelled STD, with two scannable healing abutments TissueShaper 5mm, labelled TS5, and TissueShaper 7mm, labelled TS7 (6). A maxillary master cast made from Type IV plaster was obtained by pouring a conventional open-

tray impression from a patient with 7 implants (6). As can be seen in the results table in the previous section, the STD scanbody had the largest overall mean deviation of 94µm (6). The TS5 and TS7 scannable healing abutments had a notably better performance with overall mean deviation of 72µm and 63µm respectively (6). Even though the STD was the least true, it was the most precise, its precision being ±6µm, compared with the ±10µm of TS5 and ±9µm of TS7 (6). Interestingly, the taller the scan body the higher the precision and vice versa. Further investigation is necessary to establish whether there is a link between scanbody height with identical design and trueness and precision. The study further discovered that scans of scannable healing abutments were done in significantly shorter time, only 71.7s for TS5 and 77.3 for TS7, compared with the STDs time of 129.9s (6). These results indicate that using scannable healing abutments result in scans with higher trueness while taking 40-45% less time and thus being more comfortable for the patient, especially when there is no need to disconnect and reconnect healing abutments and scan bodies (6).

Another study done by Morón-Conejo et al. also focused on the trueness and precision of scannable healing abutments, however, this study was done on a partially edentulous cast, so the results are not directly comparable with the study of Gómez-Polo et al. but they put the trueness and precision values into context (6,29). Morón-Conejo et al. compared three different scannable healing abutments labelled BE, IP and EE (29). The mean trueness of IP was 49.9µm, which was significantly lower than BE at 235.6µm and EE at 188.6µm with their precision being 95.4µm, 461.0µm and 227.68µm respectively (29). For further context, Morón-Conejo et al. used Primescan while Gómez-Polo et al. used Trios4 (6,29). Considering all these factors, IP was the truest (in a partially edentulous arch) but its precision was low when compared to STD, TS5 and TS7 (6,29). Regardless, STD, TS5 and TS7 in combination with Trios4 fit into the error margin of 150m and 0.4 degrees deviation considered to be precise enough to be used in fully edentulous intraoral scan (4–6,29) while IP in combination with Primescan in a partially edentulous arch is right on the limit with all its values making it a viable option if the scan is done in ideal conditions but just not good enough if the scanning is not perfect (4–6,29). BE and EE currently seem to be unusable for completely edentulous scans given that their trueness and precision values are far too large in a partially edentulous arch and hence, unacceptable for a fully edentulous arch (29).

5.4 Morphological modifications of the scanbody

The specific geometry of a scanned surface significantly affects how the scanner interprets the data (19). The effects of subtractive and additive modification were investigated by Lawand et

al. where they used the CARES Mono Scanbody scanned by Trios3 (19). The non-modified reference scans (NM) yielded a root mean square error of 92µm while the subtraction group (SM) had an error of 100µm and the addition group (AM) 266µm (19). While the NM and SM groups were comparable, the AM group stands out as imprecise, however, taking into account angular deviation paints a clearer picture (19). The NM group had an overall angular deviation of 1.266 degrees, similar to the AM group with 1.273 degrees while the SM group stood out at 0.993 degrees (19). While maintaining a comparable 3D error with the reference NM group, the SM group shows to be more true when taking angular deviation into account as well (19). On the contrary, the AM group shows to be the most imprecise in all measured categories (19). Considering all the above, the NM and SM groups can be considered true enough for a full arch scan in horizontal deviations, however, angular deviations are significantly higher than the 0.4 degrees cut-off, making the combination of these scan bodies with Trios3 unsuitable for a fully digital workflow (4–6).

The geometric modifications affect how the scanner sees the scanbody by changing the amount of available surfaces (8,19). Subtractive modifications provide geometric details that help referencing, which has been shown to increase trueness and decrease angular deviations (7,19). Additive modifications, on the other hand, had a negative effect on the trueness of the scan and increased angular deviations (19). This may be because of the creation of acute angles and overlaps that cause noise in the data (3,19). This kind of additive modification may also cause disturbances in the stitching process as the software may excessively focus on individual scan bodies and the operator may need to excessively angle the scanner head to capture all the overhangs and obscured areas (19).

5.5 Differences in scans on mandible and maxilla and differences in the material of the cast

Research indicates that there are differences in accuracy between the scans done on the maxilla and the mandible, with mandibular scans being more true and precise than maxillary scans (6,10,23). One of the reasons for this difference is the smooth appearance of the palate with no points of reference, which creates challenges for software algorithms during the data registration and stitching process (23). While some clinical studies have reported no significant difference in accuracy between the arches, the results are often contradictory and may be influenced by whether the palate was included in the scanning procedure (10,26). Furthermore, the impact of the arch is often affected by operator experience where inexperienced users tend to produce more deviation in maxillary scans than in mandibular ones (23).

The material composition of the scanned casts and scan bodies also significantly affects results because different scanners interact uniquely with surface characteristics such as reflectance, translucency, and opacity (8,22). The environmental factors like the presence of saliva or humidity can significantly reduce scan trueness by creating reflective layers on these materials (1,14,22). Dull and opaque surfaces are considerably easier to digitize than shiny or translucent ones, which often create noise in the point cloud that decreases accuracy (8,14). For example, plasma-coated medical titanium scan bodies have demonstrated higher trueness and precision than PEEK with specific scanners, as the coating prevents light reflections that cause data distortion (8,14,20). The final detail to consider is the material of the cast where the fabrication method of the cast itself influences outcomes; conventional stone models have shown higher linear accuracy and lower angular deviations than 3D printed resin models, which are tend to have more surface irregularities and geometric distortion from the printing process (30).

5.6 Influence of scanbody material

Various studies compared scan bodies made of different materials and significant differences were observed in the performance of each material. The 2024 study by Azevedo et al. focused on the difference between the performance of PEEK and plasma coated titanium (20). The fully edentulous mandibular cast was prepared with six implant analogs and scanned with five different scanners by different manufacturers and using different scanning technologies (20). The results of this study have shown that all of the scanners used in combination with both types of scan bodies could be a viable option for a fully edentulous arch but there were some differences in their performance (20). While PEEK scan bodies scans all fit withing the 150µm limit, the range of their mean error was between 27µm and 93µm with the Trios 4 (T4) having the 93µm mean error (20). The titanium scan bodies' mean error range from 27µm to 44µm (20), a much more tight and precise result across all the scanners. The titanium scan bodies also performed equally or better with all of the scanners except for the Virtuo Vivo (VV), indicating that it might be better suited for PEEK scan bodies (20).

As mentioned before, titanium scan bodies are more resistant to wear and dimensional distortion from repeated sterilisation (1,7,8,10,20). While titanium may have been a problematic material to use in the past due to being reflective, modern modifications, such as plasma coating, have solved this issue and, as shown by the 2024 Azevedo et al. study, titanium scan bodies appear to be more accurate in a fully edentulous arch (7,20).

5.7 Overall analysis of ideal scanbody

Based on the results of this systematised review, the design of the ideal scan body seems to depend on the scanner used but there are general features that predict an accurate scan. Vertical cylindrical scan bodies with rounded boundaries and a simple angled bevel seem to have the lowest errors as they allow for uniform light reflection and the bevel allows the implant index to be correctly located (1,3,7,8,15). Horizontal scan bodies have also shown high trueness and precision as they provide a simpler single-pass scanning path that decreases stitching events and artifacts (13). In terms of material, while PEEK is widely used, plasma-coated titanium seems to be the better choice due to its long-term dimensional stability and acceptable surface finish with little light reflection (7,13,20).

While outside of the scope of this review, it is important to mention that the arch scanned has an impact on the scan accuracy and mandibular scans appear to yield more accurate results (10,13,23).

6. CONCLUSIONS

The following conclusions were drawn:

1. The design of the scanbody has a major effect on the trueness of a scan in a fully edentulous arch. The morphology and the material have a major impact on the trueness of the scan.
2. The scanner used to obtain the intraoral scan has an impact on the trueness of the intraoral scan. The scanning technology, operator experience and ambient conditions all influence the scanner performance.
3. A simple vertical cylindrical scan body with an angled bevel made of plasma-coated titanium seems to be the most true.

The null hypothesis, that the scanbody design has no impact on the trueness of an intraoral scan in a fully edentulous arch, was rejected.

Further in vivo research is necessary to have a complex understanding of how scanbody design affects the trueness of fully edentulous intraoral scans.

7. SUSTAINABILITY

While titanium is commonly used in dental implantology, it is associated with a very energy intensive extraction from the ground and later processing causing a high environmental load on the environment (31). Even though the extraction and processing are a burden on the environment, it is highly recyclable and has a long functional life-span, which offsets this burden (31). PEEK, on the other hand, is a more environmentally friendly alternative (31). Its production requires less energy and the analyses of life cycles of both materials indicate a reduction in greenhouse gas emissions of PEEK when compared with titanium (32). The durability of both materials helps decrease replacement frequency, reducing long-term costs and material consumption, with titanium being a more durable material able to be used for longer (31). PEEK does, however, fall behind titanium in terms of recycling and has a potential for further reducing its footprint and improving its recyclability (31,32).

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9. ANNEXES