



Influence of Scan Body Design on the Accuracy of Digital Implant Impressions: A Narrative Review

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Abstract

In prosthodontics, digital implant impressions are now a popular alternative as they can increase efficiency in the workflow, comfort for the patient and communication in the digital environment between the clinic and the lab. Their accuracy is influenced by various factors such as the scanner, the location of the implant(s), scanning strategy and the design of the scan model. Of these, scan body design has attracted a growing interest, as it directly influences the scanning and accurate reconstruction of prostheses' geometry, as well as the implant's position and orientation.

This narrative review examines how the geometry, height, diameter, material, retention system and surface modification of scan bodies affect the accuracy of digital implant impressions. There is some evidence that simplified geometries, stable seating and design aspects that have a clear optical landmark can facilitate trueness as well as precision. More complex shapes result in fewer capable designs than cylindrical or streamlined bodies and extensions that are far from rigid often have better performance, although there is no universal "best" design for all scanners and clinical situations. Most evidence available is laboratory studies and further standardised clinical research is required for the various design characteristics to be seen to produce clinically meaningful improvements.

Keyword : digital implant impression; intraoral scanner; scan body; scan body geometry; trueness; precision; implant prosthodontics.

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INTRODUCTION

The developments of computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have transformed the clinical practice and have introduced Intra Oral Scanners (IOSs) as alternative to conventional dental impressions, and have given a different look to the implant impression process in the current practice of modern prosthodontics [1]. Elastomeric materials and impression copings and analog transfers are not required to capture the position of an implant directly with an intraoral scanner, which may decrease chair time and increase patient acceptance. But the success of the workflow relies on the accuracy degree to which the 3-D implant site can be duplicated from the digital record [2,3].

While traditional impressions can be distorted, shrink and can be technique sensitive, IOS using scan bodies produce high resolution reproducible impressions with minimal discomfort [4,5]. This change has helped to increase the clinical use of IOSs [5].

With the advent of digital technology in implant dentistry, implant scan bodies (ISBs) were designed by many commercial companies and come in a variety of different designs and geometries. In general, ISBs consist of three different parts: the scan region (upper part), the body (middle part) and the base (most apical part, which will attach to the implant). The degree of tapering of the ISB or a material

mismatch between the base and implant may affect the displacement of the ISB in tightening into the base [6].

One or more scanning surfaces within the scan region can be included, which can be any shape to improve the accuracy of the digital impression (for instance the shape of the region can be asymmetrical to simplify identification to the CAD program). Commercial ISBs are mostly made of two types of material – polyetheretherketone (PEEK) or titanium – for the body material, although some aluminium alloys and different resins are used too. Machinability of these materials and tolerances of manufacturing process are both also important in relating to the ISB accuracy. Commercially available ISBs are between 3 and 17 mm in height [6].

The reflections created by saliva add to the difficulty of capturing a perfect representation of dull, smooth and opaque surfaces; shiny, rough and translucent surfaces tend to be more difficult to take a digital intraoral impression. Under cut surfaces deeper than 1/4” or steep, sharp, angled (or crowded) surfaces will also be more challenging to scan and thus will generate less quality point clouds. Gimenez et al. concluded that when there was no angle deviation gingivally placed implants demonstrated less scan deviation as compared to subgingivally placed implants ($p = 0.757$) [7]. It can thus be beneficial to prepare ISBs to suit the specific intraoral scenario such as a slenderly prepared ISB for a tight interproximal gap or shorter ISB for complete edentulism or other factors that affect mouth opening [6].

Scan bodies vary in shape, size, surface characteristics and materials which can impact scan quality as illustrated in Figure 1 [6]. Anti-rotational properties are also included in many designs and by forming a flat facet or bevelling surfaces, they mimic an internal connection; the best shape and size for these properties remains unresolved [8].

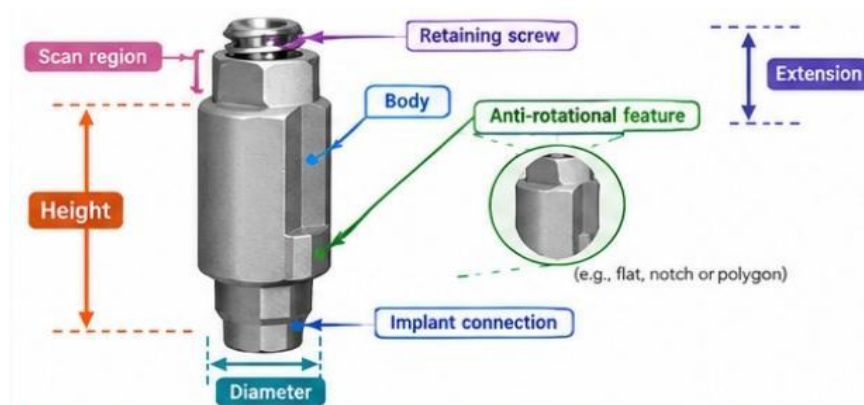


Figure 1. Labelled diagram of a scan body indicating the scan region, body, implant connection, retaining screw, anti-rotational feature, height, diameter and extension

The key factor is the scan body, which is vital to the process since it captures the 3D spatial location of the implant and communicates it to the virtual environment, enabling them to design and produce the definitive prosthesis [2]. Any inaccuracies at this stage may have consequences for the whole prosthetic process since it is the first step towards virtual registration. If the scanner and the file that represents that scan do not match up properly, positioning errors can occur resulting in mistakes in angulation, the position of platform, the fit of the prosthesis, occlusal harmony and longevity of the restoration [9]. An incorrect implant location transfer could lead to a sub-optimal implantation of the prosthesis, that will make the delivery difficult and a less satisfactory result for the patient, lead to complications afterwards. [10]

The scan bodies are optical elements that create an optical field between the implant and intraoral scanner, which allot known geometry that intraoral scanner can detect and correlate with implant library file, which enables intraoral scanner software to virtually locate the implant. However, if the

scan body is not captured accurately, there can be a positioning or angular error and this may impact on the fit of the prostheses [2,3]. The 3D positional data of an implant might be acquired with a photogrammetry system as first reported in the late 20th century but the height and arch position of coded healing abutments (ISB) has been demonstrated to impact the trueness of IOS scans and numerous ISB with varying geometry, material and mechanism of retention has since been marketed [11–13].

In recent years interest in scan body design has increased, owing to the huge variety of scan bodies available in terms of geometry, height, diameter, material and surface texture with anti-rotational features. The differences can impact the recognition of the scan body by the scanner, the consistency of the object reconstruction and the accuracy of the transfer of position of the implant into the digital model. However, despite the numerous investigations on this topic, there is still literature heterogeneity and no agreement can be reached on an optimal design [2,3].

LITERATURE SEARCH STRATEGY AND SELECTION CRITERIA

The present narrative review was based on literature search on the influence of the different scan body designs when utilizing digital imaging for implant impressions with intraoral scanners.

The literature search was conducted from their inception until September 2026 using the electronic database PubMed/MEDLINE, Scopus, Web of Science and Google Scholar. The following search terms in combination with any Boolean operator were used: 'scan body', 'scanbody', 'intraoral scanner', 'implant scan body', 'digital implant impression', 'trueness', 'precision', 'accuracy', 'geometry', 'height', 'diameter', 'material', 'and', 'or'. The reference lists of articles and reviews also were scanned.

Studies were selected according to the following criteria:

Inclusion criteria

Studies assessing the intraoral scanner impression trueness and/or precision with varying scan body characteristics such as geometry, size (height and diameter), material, retention system, surface or structural modifications.

- In vitro, animal and clinical studies and systematic & narrative reviews.
- Journal articles in English in peer-review journals.

Exclusion criteria

- Research pertaining to conventional (nondigital) implant impressions and/or tooth-supported scanning without implants.
- Case reports/expert opinions/editorials and conference abstracts with incomplete data.
- Publications where the accuracy (trueness/precision) were not reported.

The titles and abstracts were initially assessed by screening; if a full version of the article appeared to be potentially eligible, the full text was assessed for eligibility by two screeners who worked independently and any disagreements were discussed. Owing to the nature of this narrative review a formal risk-of-bias assessment and any quantitative synthesis was not undertaken. Instead, where appropriate, the type of evidence (in vitro, animal, clinical or secondary research) is specified and the implications of the evidence hierarchy will be.

ACCURACY CONCEPTS: TRUENESS AND PRECISION

Some studies have been previously reported that the accuracy of intraoral digital implant scans depends on ISB geometry [14]. Generally literatures evaluating digital impression of implants are based on the two notions which are very well related but also two very different concepts: trueness and precision. Trueness is defined as the closeness of the scanned result to the true (or reference) position of the implant and precision is defined as the repeatability of repeated scans performed under similar

conditions [2]. How the scan body design is integrated in the scanning algorithms and image stitching process can result in good precision and bad trueness or vice-versa.

Thus, many studies instead of a single global over-all accuracy, report linear, angular and/or three-dimensional deviations. That causes difficulties in making direct comparisons between studies; at the same time it illustrates the intricacy of the digital impression process. Both repeatability and accuracy to the reference should be taken into account when considering the performance of scan bodies with the aim to achieve clinical success [2,3].

ISO 5725 defines accuracy as having two basic attributes: trueness and precision. The latter (Precision) is the closeness of the agreement between independent test results obtained under stipulated conditions, the former (Trueness) is the closeness of the agreement between the average value obtained from a large series of test results and an accepted value. Thus, it is necessary to have trueness (low systematic error) and precision (low random error) in high accuracy [15]. These two features result in increased reliability and a decrease in uncertainty when taking digital impressions.

In the clinical aspect, when the trueness is high, the actual clinical state of the mouth is again reproduced in the digital impression ensuring the correct fit of prosthetic restorations. This accuracy, in turn, ensures consistent scanning results over time, a factor that is especially essential for reliable results in multi-step digital workflows. These properties all affect the life of the restoration, patient comfort, and the efficiency of the restoration process.

Factors Influencing Scanning Accuracy

Although various factors like the skill of the operator, patient movement, environmental factors etc. may influence all implant intraoral scanning, but these variables have the most significant effect on digital accuracy. Operator-dependent variables involved are intraoral scanner type used, size of the head of the scanner, system calibration, light in the room, scanning strategy, operator experience [16] as well as the extent, depth and angulation of the scan [18].

Patient related factors include intraoral anatomy such as tooth morphology, interdental spaces, arch width, palate shape, moisture control, existing restorations and edentulous areas [19]. For implant scanning, variables are like the implant depth, angulation, inter-implant distance and the geometry of the scan body like the length, head geometry, materials and retention system. The presence of any factors that may negatively impact scanning accuracy may result in cumulative distortion [20] and therefore, understanding the factors is essential for enhancing the predictability and reliability of digital implant workflows.

SCAN BODY DESIGN AND ITS INFLUENCE ON ACCURACY

Geometry and Shape

The most common and perhaps the most important scan body attribute studied is geometry. Generally, simplified geometries are more likely to yield more predictable scanning results because they offer more clean and stable surfaces to acquire images; cylindrical scan bodies can work very well due to their regular form which is more easily registered by the scanner [2].

For more complex shapes performance may be enhanced or decreased depending on design. A few scan bodies feature rigid extensions or flat facets that are designed to provide greater optical landmarks and for better scans body recognition, in some studies, such features lead to better trueness especially in comparison to cuboidal or spherical forms [2]. But with too much irregularity, the accuracy of the scan could suffer as the software may not be able to consistently recreate the complex shape. The available evidence at present therefore points towards a balanced strategy: an easily recognizable scan body while being sufficiently distinct in its geometry to be unambiguous without spoiling the quality of the surface reconstruction by needless and avoidable stitching mistakes. This might be one reason why some hybrid designs work equally as well as traditional scan bodies and don't seem to be superior [2,3].

An eleven studies systematic review on ISB geometry [21] concluded that the ISB geometric properties (such as macro-shape and dimensional parameters) – surface properties and accessory structures – played an important role in the linear and angular trueness under various scanning conditions. Macro-shape comparisons revealed that round (dome-shaped) bodies had smaller surface misfits than cuboidal bodies had similar linear positioning as the polygonal and bevel designs, with the exception that polygonal and beveled designs generated different angular misfits on the XZ axes. Displacement results were strongly different between the three and two dimensions, and between the various manufacturer-specific geometries, with the best results achieved by ELOS A/S and Team Ziereis as compared with NT-Trading. The cylindrical body shape with optimal height and diameter demonstrated a superior linear and angular trueness in the various body shapes, hybrid systems (healing-abutment) were comparable to conventional scan bodies in single-implant scans and one-piece designs outperformed two-piece constructions in terms of trueness. Surface modifications and accessories, such as subtractive modification, accessory parts and geometric attachments, had positive effects on either accuracy or trueness (if negative, it was because the modification was too extensive); modest depression-type modification had a positive effect on trueness in complete-arch scans.

Ten out of the eleven studies examined reported that ISB geometry had an impact on the accuracy of the scanings, while one study indicated that tested geometries yielded similar results in terms of accuracy, irrespective of ISB (scan-body ring) geometry [22]. Pan et al. compared the dome and cuboidal-shaped ISBs of a single manufacturer in vitro study and found that dome-shaped ISBs had lower deviation from the normal surface while the cuboidal-shaped ISBs had lower angular deviations [13]. Motel et al. demonstrated that the impact of ISB geometry to scan accuracy was scan pattern dependent [6,23] and Mishimoto et al. confirmed that ISB geometry had a similar impact on scanning time.

Printed scan bodies demonstrated study-dependent variations in trueness when directly compared to geometric shapes, as in the study employed by Moslemion et al. which, for this investigation, required only geometric (straight) scan bodies in order to allow a more focused comparison of geometric shapes and control for the orientation of the scan body [24]. This is agreeable with the previous evidence regarding the effect of printed geometry and surface topography of scan body on the accuracy of digital impression [2]. Features like sharp edges, complex contours, deep or angular surfaces can negatively impact the accuracy of scanning, as the quality of the point clouds generated for 3D images can be affected in certain areas [2] while extensional features have been shown to increase the scanning accuracy by providing areas and superiority of reference points for the stitching algorithms applied during the intraoral scanning procedures [25]. Compared to laser sintered and milled scan bodies, the resin printed scan bodies may have less precision given that the additive scan body structures are typically done by low resolution layered techniques with more surface irregularities which may increase their sensitivity to geometric distortion [26].

Cylindrical, higher and smaller scan bodies have been the most geometric configurations with the lowest three dimensional and angular deviations among the studied ones especially when adapted to intraoral (Instead of laboratory) platform sizes such as those studied by Tan et al. which focused only on cylindrical scan bodies with different heights and diameters [4]. The reason for the superiority of the cylindrical geometries is probably related to the fact that they have no sharp edge or facet, which cause specular glare and shadowing effects and the geometries have complete, smooth curve. Simplified designs with fewer facets and with little sharp angles have also been found to have a greater mesh to library congruence and impression accuracy as well. In a review of the literature identifying potential factors that impact on scan accuracy, geometry was among the five largest factors, although no clear consensus existed on an optimal design [3]; and according to a recent classification of intraoral scanning errors, implant scan body geometry was one of the primary sources of the operator scanning errors, as well as mesh holes, stitching errors, and scanning noise, and clearly improved accuracy was demonstrated by the simplified shorter, and cylindrical designs [27]. Three different scan body

configurations were tested in the in vitro study by Revilla-León et al., although the dynamic-abutment IOS group was not included in this study because it could not be evaluated with coordinate measuring machine (CMM) [28].

Add-on blocks and components attached to scan bodies have been demonstrated to lessen 3D and linear deviations without impacting on any angular accuracy, possibly through stability and better scan body recognition ensuring fidelity of orientation. To avoid any confounding factors due to implant angulation, data from the parallel-implant group was used in Farah et al. to isolate this effect of geometric attachments only [29]. Another systematic review of scan body application methods concluded that auxiliary geometric devices in an edentulous arch were beneficial to increase the accuracy of the scans, however, the use of scan bodies and splinting systems were not consistent [30]. Accordingly, Shetty et al. have conducted a systematic review reporting in most clinical situations, complete-arch digital impressions might be improved by splinting the scan bodies together using light cured resin, dental floss, pattern resin or custom-made splints, with varying effects of splinting based on different clinical scenarios, scanning protocols and IOS types [31].

Differences in the accuracy metrics were also found between the different manufacturer designs, which depended upon a number of parameters such as material used, surface texture, design standardization etc. and some proprietary bodies (e.g. ELOS A/S, Team Ziereis) systematically outperformed others (e.g. NT-Trading). The scanning method of Motel et al. (both single and double) were both used, though just single-step data were allowed here, for consistency with the majority of the literature included [23]. In contrast, more radical geometric modifications like the large slots placed in the proximal position or additive material improvements, negatively impacted both linear and angular accuracy, presumably due to decreased continuum of the scan, scanner artifacts or occlusion of important alignment planes. In the study by Moslemion et al., only data in the Doowon group was used here since the scan body shape is closest to the ones used clinically to ensure external validity [24].

Cumulatively, this evidence indicates scan bodies with extensions, optimized cylindrical dimensions or simple faceted designs (bar extended or flat-sided) should be preferred by clinicians to achieve a more true form to linear and angular dimensions in day-to-day practice [32]. Most of this evidence comes from laboratory studies and the use of this recommendation should be viewed taking these caveats from Section 8.1 into consideration. Accompanying this, manufacturers should make standardized rules that must be followed when validating per intra oral scans under certain criteria such as geometric characteristics, minimal geometric criteria and performance level of the scan body design, to create a consistency between implant systems [23].

Height and Diameter

Several studies have highlighted that this scan body height is a very important factor in the trueness of digital impressions, especially in challenging cases such as complete edentulism, where the trueness improved with decreased scan body length, potentially improving the accuracy of full-arch digital implant impressions, an area where digital impressions still pose clinical challenges [33]. A longer scan body might be able to be scanned more clearly above the soft tissue and near by structure; on the other hand, the elongation may accentuate the influence of the scanning angle, the patient's movement, and the distortion, especially in the posterior zone or in case the interarch space is limited [3].

Shorter scan bodies might be easier to use in hard-to-reach areas and minimise forces causing errors, but can be difficult to detect if the tissue or neighbouring teeth block the path on which the scanner works. Hence, there is no height that appears to be universally ideal and the optimal height may vary depending on the implant location, access, the technology of the scanners and the soft tissue environment [2,3]. Larger or taller scan bodies often go beyond the Intraoral scan field of view, and may need multiple scans, or multiple stitching points in three dimensional scanning that can result in stitching artifacts that decrease trueness. On the other hand, decreasing the height could successful increase the accessibility while decreasing the build-up of error, but extra reference surfaces designed to help with alignment can also result in angular variations [34]. In cases where there is limited

interarch space, limited mouth opening or the need to remove the scan body after occlusal registration, shorter scan bodies tend to be a benefit, and there is a strong demand for smaller scan bodies that can remain in place during the clinical workflow and do not negatively impact accuracy [35].

Choi et al. noted that an exposure of the scan body of less than 3 mm was linked to a higher angular deviation, especially for posterior implants [36] while Gómez-Polo et al. found reduced scan body height, especially when used in conjunction with inclined implants, were able to negatively impact a full-arch alignment [37]. Larger diameters have also been reported to be associated with increased anti-rotational resistance and larger vertical exposure of the scan body, especially for implants placed subgingivally, has been reported to be associated with increased landmark acquisition and a decreased angular deviation [36]. Regardless, shorter scan bodies are constrained by their own clinical drawbacks: limited interarch space and/or interference by soft tissues may lead to problems with capture and seating accuracy, or implants may be set deep within the oral cavity, resulting in suboptimal results with these scan bodies in clinical practice. There may be more difficulty accessing the implant and viewing it from this reduced body height in patients who may have their implants placed deep or interarch space may be limited, and there may be more difficulty with a geometrically complex implant where implants are divergent, interproximal spaces are limited, or any changes in saliva or patient movement changes may put artifacts that are not being seen with the in vitro scan. This suggests that shorter length would be beneficial in vitro, but has to be carefully weighed against these anatomical and procedural limitations in clinical applications.

One study found that introducing a third flat surface designed to facilitate angular registration actually increased the deviation in some of the models, implying that the more complicated the geometry or the length, the more deflection, in some models, occurs and, vice versa, the less the height the greater the accessibility of the scanner and the less the potential distortion would be [34]. It has also been suggested that a height or location of coded healing abutments may have an effect on angular deviation [12,38]: Batak et al. reported that a coded healing abutment with a height of 8 mm had a greater level of angular deviation than an 8 mm coded healing abutment, but the vertical height of an abutment had no effect on linear deviations and, anterior implants were associated with lower levels of linear deviations than posterior implants [12]. Its result showed that a negative correlation existed between the standard healing abutment and the angular differences; A longer standard healing abutment was associated with lower angular differences [38].

Diameter cannot be stressed enough, but it has received less research than height and it can affect the capture quality based on the amount of surface that the scanner can detect -- a larger diameter may help to capture the object, while a smaller diameter may help the object to fit in tighter spaces. Diameter is not necessarily the only dimension to consider and is dependent on other geometric dimensions [3]. In one in vitro study, the effect of different diameters (narrow or regular platform) as well as different materials (PEEK or titanium) on the accuracy of complete-arch implant scans was investigated by examining the partially edentulous reference cast (Kennedy Class III, modification 1) with two narrow- and two regular-diameter implant analogs. Narrow diameter PEEK ISBs were the most accurate followed by regular diameter PEEK, narrow diameter Titanium and regular diameter Titanium ISBs [39].

Material

Both the alignment of the scan data and the acquisition of scan data is affected by the scanned body material, surface treatment and geometry, and the mechanism of retention [40]. For clinical use, the early scan bodies were made from 100% polymer which over time with repeated use, tended to be changed by repeated deformation at the screw interface, reducing stability and the accuracy of the scan. A hybrid scan body of polymer and titanium was then tried to make the body more torque resistant, but in doing so 2 dissimilar parts were joined which subsequently allowed inaccuracies at the point that they meet. More recently, however, fully monolithic scan bodies have been designed with the goal of minimizing the variation of multi-component designs [35].

Both titanium and PEEK based scan bodies are commonly used and each have their own advantages: a titanium scan body offers high strength and dimensional stability, on the other hand, a PEEK based scan body may exhibit advantageous optical properties and it could be easier to scan under some circumstances [13]. The one-piece titanium ISBs may need to have an anti-reflective spray applied to it before digitization with an IOS is possible because of the high dimensional stability of titanium, compared with PEEK, it reflects less light. Single-use, two-piece, or one-piece titanium ISBs might be preferred where there is a concern for vertical displacement during implantation and distortion with repeated use and sterilization in one-piece PEEK ISBs, however [13].

Standard (not coded) ISBs were evaluated using one-piece PEEK, two-piece PEEK and one-piece titanium, but those studies exacted comparisons between materials are complicated by geometry differences between the tested devices (i.e. ISBs with one-piece PEEK with two-piece PEEK, and one-piece PEEK with one-piece titanium); very few studies compared one-piece PEEK with 2-piece PEEK, or one-piece PEEK with one-piece titanium, and they with matched geometry. Moslemion et al. reported that 1-piece PEEK ISBs produced the lowest accuracy for most of the parameters which they investigated, and 2-piece PEEK ISBs for angular deviation; since additional geometry of the tested ISBs is also different in addition to the material, the results should be interpreted with care [24].

In practice, however, there is no evidence that indicates the superiority of either material in all situations. In a 2023 systematic review, the number of studies directly comparing the effectiveness of material was few and any available data were inadequate for a clear recommendation [3]. This means that material selection comes second to the integuments of the design and a precise seating as well as a scanner interaction.

Retention System

None of the studies reviewed focused specifically on the effect of ISB retention system on intraoral scanning accuracy; few exceptions also published studies on only screw-retained ISBs. However, the retention of the scan bodies is of high interest: If the scan body does not get full seated or the rotational stability is not enough to just get hold, the very best geometric design will not give an accurate impression. In the screw-retained systems, a stable positioning is achieved in general, but pointing errors may be caused by the lack of complete seating, or by the lack of complete engagement of the screw connection [3]. So, it becomes essential to retain to ensure reliability of the digital transfer process.

Surface Modifications and Auxiliary Features

Since surface modifications are meant to enhance show up by the scanner, its impact is not necessarily useful. Certain designs have additional facets, bars, or other surface markings to aid in optical differentiation and ease of scan body registration, which in a recent systematic review of scan body geometry, were often found to be related to higher trueness [2]. There is a threshold of modifications, however, that might affect the accuracy; or, in other words, experimental studies have demonstrated that the greater the modification of when modified (e.g., scan bodies), linear and angular deviations may rise [41]. Design modifications therefore should be clinically functional, meaning that they should make detection simple, but not difficult for the scan body to be reconstructed by the software.

The fabrications of the ISBs made from milled titanium, with extensional structures, have demonstrated a correlation between higher accuracy compared to ISBs without such structures [25,32] and additive manufacturing has also been used for the fabrication of auxiliary equipment to improve the scan accuracy and efficiency [22,42]. In two studies, one-piece PEEK ISBs with 2 screws were compared to a screw-retaining ISB with a PEEK 1-piece magnet-retaining component and the same CMM was used for reference measurements on all the groups; it was not possible to measure the magnet-retaining one-piece PEEK ISBs in one of the studies because of movement during the CMM analysis. In both studies, though, ISB design had an impact on the angular implant-analog position, from 4 to 18.9 μm [28].

In an in vitro study, Lawand et al. studied the effect of subtractively and additively modified ISBs on scanning accuracy where the surface discrepancy was greatest for additively modified ISBs, angular discrepancy was least for subtractively modified ISBs, and inter-implant distance discrepancy was most frequent for unmodified ISBs [26]. The ISB modifications with and without extensional structures were further tested in 2 other studies: On an animal study using beagle animals (for assessment of two-implant fixed partial denture) and an in vitro complete-arch model. Based on the animal study, it appears that the trueness (accuracy) was better with extensional structures than without, although one should be careful in extrapolating to their clinical implications in humans [32]. Increased precision was found for the extensional design of the mandibular complete-arch scans in the tested in vitro study; however, the trueness of the conventional impressions was higher than that of both tested ISB and higher precision than the extensional design [25].

Trimming pieces additively manufactured onto ISBs have also been tested; one was a module attachment to the chains in the IBs to restrain them each other, another was a ring with eight concentric braces. A set of rings over ISBs only resulted in higher scan efficiency while modular chain pieces over ISBs resulted in much more higher scan accuracy [22].

SCANNER INTERACTION

Unlike the case with flatbeds, a scanner's body design is inextricably linked to the technology employed, so you can't separate the medium from the materials. Studies have shown either inconsistencies with given designs and/or different outcomes depending on the intraoral scanner used; this might be related to the different optical systems, reconstruction algorithms, and stitching methods used by different intraoral scanners and how a certain scan body interacts with those features [2,3]. In full-arch or multi-implant scans, the interplay between scanner and scan body is even more critical as it can lead to large deviations in the overall scan if there is error in each implant. The impression generated by complete-arch implant has statistically significantly difference between scanner systems, scan body design of the complete-arch implant and between various combinations of both, with some combinations showing smaller three-dimensional deviation than others [42] and some studies suggest that splinting a complete-arch implant scan bodies might yield more trueness and precision in the scanning of complete-arch implants [43].

For clinicians, this should not be interpreted as without question taking at face value any manufacturers' recommendations, but rather the importance of checking whether a particular scan body/scan combination has been validated independently, preferably for high-stakes or full-arch implant cases, as part of the overall accuracy.

CLINICAL SIGNIFICANCE

The clinician has selected a scan body with the ultimate aim of fabricating a prosthesis that fits passively with good accuracy. A digital error can result in the need for subsequent changes to the final restoration or an implant prosthesis that doesn't seat correctly, and can impose biomechanical stresses to the implant–prosthesis complex, which may be more impactful in multi-unit or full-arch cases than in individual singles where errors can be cumulative across the mouth [2,3].

The best approach is to find a scan body that is validated for the system of implant and scanner being used for routine clinical practice. Stable geometries with retention and unambiguous reference surfaces seem to be preferred and unessential changes and adjustments may lead to a decrease in trueness [2,41]. But, it does not mean that there is no importance of good clinical technique anymore, as an excellent scan body can also be compensated by poor seating and/or bad scanning execution.

HOW CURRENT EVIDENCE IS LIMITED

There are some significant limitations in the current evidence base. The majority of the studies are in vitro and only a few are clinical studies. Conditions in the laboratory can provide standardized measurement, but the patient movement, soft tissue dynamics, limited access and operator variabilities

that occur intraorally are not be replicable in the laboratory [2,3]. Studies vary in the arrangements of the implants, the type of scanning path, how measurements are taken and how the outcomes are defined; as a result, this makes it difficult to compare the different studies and also limits the conclusions that can be made. A systematic review from 2023 resulted in a "nonspecific" conclusion regarding the current state of the evidence on the effect of different scan body designs on the outcomes compared to different types of scanners [3].

It is of major importance also to differentiate between statistical and clinical significance; that is, a statistically significant difference and a clinically difference may or may not be a clinically significant deviation and the only way to determine that is to evaluate the magnitude of the difference and the clinical context. More studies are required to identify and determine what is clinically different in terms of accuracy [2,3].

Hierarchy and Type of Evidence

Due to differences in the study designs, the results of studies presented here should not be weighted equally (Table 1). Literature present the majority of readings conducted in vitro where the variables can be tightly controlled and a reference measurement (d Harlow CMM, for instance) can be compared against, yet models do not have saliva, blood, soft tissue movement, restricted access and patient movement, and an in vitro absolute deviation value cannot be assumed in the oral cavity. A biological setting is presented here [32] in an animal study, but anatomic, mouth opening, and tissue behavior will vary from the human condition, and thus the results are only supportive. Although the clinical studies exhibited the highest ecological validity, these studies themselves are still relatively few and did not reference to the subject scan body design but rather to operator experience (as cited in this review [16]). Systematic reviews utilize summary of the primary studies, but have their own limitations, which include in vitro data predominance and methodological heterogeneity.

Table 1. Types of evidence cited in this review and their main limitations.

Evidence type	Examples cited	Main strength	Main limitation
<i>In vitro</i> (laboratory models)	[9,13,14,23,25,39,40,42]	Controlled variables; reference measurement (e.g., CMM); reproducible	No saliva, blood, soft tissue, patient movement, or limited access
Animal (<i>in vivo</i>)	[32]	Includes a biological environment	Anatomy and tissue behavior differ from humans
Clinical	[16]	Real intraoral conditions	Few studies; the example cited addresses operator experience, not scan body design
Systematic reviews	[2,3,21,30,31,44,45]	Synthesize multiple studies	Heterogeneous outcomes; mostly <i>in vitro</i> primary studies
Narrative reviews and classifications	[10,27]	Broad overview and conceptual framework	No systematic selection or quantitative synthesis

FUTURE DIRECTIONS

In the future, standardized testing procedures and clinically relevant outcomes should be targeted. More direct comparisons of scan body geometries under the same conditions could be helpful in identifying what features of one scan body may consistently enhance accuracy and additional clinical trials would help to determine if these patterns seen in vitro hold true in real clinical practice [2,3]. Finally, studies should explore the interdependence of design of scan bodies and the type of scanners used, shape of the arches, parallelism of implant angulation, and operator skills in order to go from a descriptive comparison to a guide toward the clear design of the scan bodies in practice. In the end, it's not about

who's when the most complicated or the newest scan body, it's who's the one that is going to work the best in the real clinical world [2,3].

SYNTHESIS OF FINDINGS ON STRUCTURAL AUGMENTATION

In the review of literature, scan bodies with the addition of structural features performed desirable with respect to linear and angular trueness while taking digital implant impressions. There have been several studies that have concluded that there are advantages associated with extensional features, like wings or lateral projections, thought to increase the detectability of the scanbody and to increase the clarity of fixed points of reference; the data in the study by Farah et al. was selectively retrieved from the parallel-implant group to remove the geometric effect from that of the angular effect [29]. This trend is found in literature and can validate the merits of structural augmentation for a scan body design [30].

Gehrke et al. performed a systematic review on factors affecting an intraoral scan and concluded that factors that affect the precision of the implant impression using the IOS include scan body positioning, the structural design of the scan body, the materials of the scan body and abutment, the color of the scan body, the manufacturing process of the scan body, the type of IOS, the scanning technique, implant intertooth distance, the scan span and the number of implants, especially for single and short-span cases [44]. Some further systematic reviews have identified implant angulation, inter-implant distance, scan body characteristics and operator experience as additional factors influencing impression accuracy [45] and Sanda et al. have pointed out separation between implants and scan range, as well as scan body geometry (such as extensional structures) and operator experience, as influencing digital impression quality, since greater separation and scan range may affect impression trueness, which can be improved by enhanced scan body geometry, where extensional structures provide better engagement and spatial referencing for the scanner to improve trueness [15].

This study adds to the existing literature by specifically demonstrating that modifications which enhance geometry of the scan bodies do provide a real accuracy advantage, especially when there are inherent difficulties with scan range or implant configuration.

CONCLUSION

A digital scan's body design does have a measurable impact on the accuracy of digital implant impressions. While geometry, height, diameter, material, retention and surface modifications are all contributors to trueness and precision, geometry and seating stability seem to be the most significant contributors [2,3]. In general, simple designs using obvious optical landmarks function well, and rigid extension features can enhance scanning in some instances [2].

At present there is no one specific “best” scan body design. These options depend on the implant system and scanner platform used, clinical access, and the prosthetic needs [2,3]. In the absence of clinically more substantial evidence, the use of a particular body type should be decided on a case-by-case basis and by taking careful seating into account and relying on proper scanning technique [2,3].

Declarations

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تأثير تصميم جسم المسح (Scan Body) على دقة طبقات الزرعات السنية الرقمية: مراجعة سردية

ملخص

في مجال التعويضات السنية، أصبحت طبقات الزرعات الرقمية بديلاً شائعاً؛ إذ تساهم في تعزيز كفاءة سير العمل، وتوفير راحة أكبر للمريض، وتحسين التواصل في البيئة الرقمية بين العيادة والمختبر. وتتأثر دقة هذه الطبقات بعوامل عدة، مثل جهاز المسح الضوئي، وموقع الزرعة (أو الزرعات)، واستراتيجية المسح، وتصميم "جسم المسح" (scan body). وقد حظي تصميم جسم المسح باهتمام متزايد؛ نظراً لتأثيره المباشر على عملية المسح وإعادة بناء هندسة التعويضات بدقة، فضلاً عن تحديد موقع الزرعة واتجاهها.

تتناول هذه المراجعة السردية كيف تؤثر الخصائص الهندسية، والارتفاع، والقطر، والمادة المصنعة، ونظام التثبيت، وتعديلات السطح لأجسام المسح على دقة طبقات الزرعات الرقمية. وتشير الأدلة المتاحة إلى أن الأشكال الهندسية المبسطة، والثبات عند التثبيت، ووجود علامات مرجعية بصرية واضحة، تساهم في تحسين كل من "الصحة" (trueness) و"الدقة" (precision). كما تبين أن الأشكال الأكثر تعقيداً قد تكون أقل كفاءة مقارنة بالأجسام ذات الشكل الأسطواني أو الانسيابي، وأن الأجزاء الممتدة التي تتسم بصلابة كافية غالباً ما تقدم أداءً أفضل؛ ومع ذلك، لا يوجد تصميم "مثالي" موحد يصلح لجميع أجهزة المسح والحالات السريرية. ونظراً لأن معظم الأدلة المتوفرة تستند إلى دراسات مخبرية، فإن هناك حاجة إلى إجراء المزيد من البحوث السريرية المنهجية لتقييم خصائص التصميم المختلفة، والتأكد من قدرتها على تحقيق تحسينات ذات قيمة فعلية في الممارسة السريرية.

الكلمات المفتاحية: طبقة الزرعات الرقمية؛ الماسح الضوئي داخل الفم؛ جسم المسح (scan body)؛ هندسة جسم المسح؛ الصحة (trueness)؛ الدقة (precision)؛ تعويضات الزرعات السنية.