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VOLUME 35 | ISSUE 1 | 2023

JERD | Journal of Esthetic and Restorative Dentistry

Special Annual Issue

Advances in Esthetic Dentistry 2023

Scientific evidence for CLINICIANS, clinical relevance for RESEARCHERS

Official Publication of the:
Academy of Cosmetic and Adhesive Dentistry
American Academy of Esthetic Dentistry
British Academy of Aesthetic Dentistry
International Federation of Esthetic Dentistry
PROSEC
Serbian Society of Esthetic Dentistry
Society for Color and Appearance in Dentistry

WILEY

Received: 24 October 2022 | Revised: 13 December 2022 | Accepted: 14 December 2022

DOI: 10.1111/jerd.13004

REVIEW ARTICLE

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Digital workflow in implant prosthodontics: The critical aspects for reliable accuracy

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Abstract

Introduction: This paper is a comprehensive treaty about the variables that influence the transfer of the position of an implant to the laboratory when using a digital workflow.

Objective: The aim is to provide operators and manufacturers with a guide on how to improve certain aspects of the digital workflow specific to the fabrication of implant-supported restorations.

Overview: It addresses intraoral scanning issues and CAD software issues. In the former, the variables that play a part in the quality of the scan file are investigated: the implant scan body, the IOS and the operator. For the latter, instead, the focus is on those aspects that still today may create inaccuracies in the workflow and in the final product being fabricated: the identification of the specific implant placed in the patient and the generation of a virtual model with the representation of that implant platform correctly positioned in the three dimensions of space. Suggestions and recommendations are given to improve the control on the quality of the digital workflow's output.

Conclusion: In a digital workflow for the fabrication of an implant-supported restoration, the selection and use of the implant scan body, the use of an effective scan strategy and the appropriateness of the best fit function in the CAD software, that is, the procedure of superimposing the library of geometric shapes of the ISB linked to the implant with the shape acquired intraorally, are variables that can influence the positional precision of the FDP.

Clinical Significance: Fully understanding the importance of the information enclosed in the ISBs themselves can be crucial in the digital workflow. A proper ISB's selection, a correct scan of the ISB's shape and an accurate CAD superimposition of the ISB's library can lead the clinician to reduce the variables that affect the final result in daily practice.

KEYWORDS

best fit, cad-cam, digital workflow, implant scan body, intraoral scan

1 | INTRODUCTION

Intraoral scanners (IOS) are becoming more common among dental professionals (source: Key-Stone survey, Italy, https://www.key-stone.it/) and, as a consequence, their use for taking the impression of implants is increasing. Part of the reason is due to the marketing messages and claims being made by several companies that IOS's are devices which can capture accurate impressions more quickly and with increased ease compared to traditional impressions.

However, looking at the scans that dental laboratories and milling centers receive, it seems that many clinicians lack training and

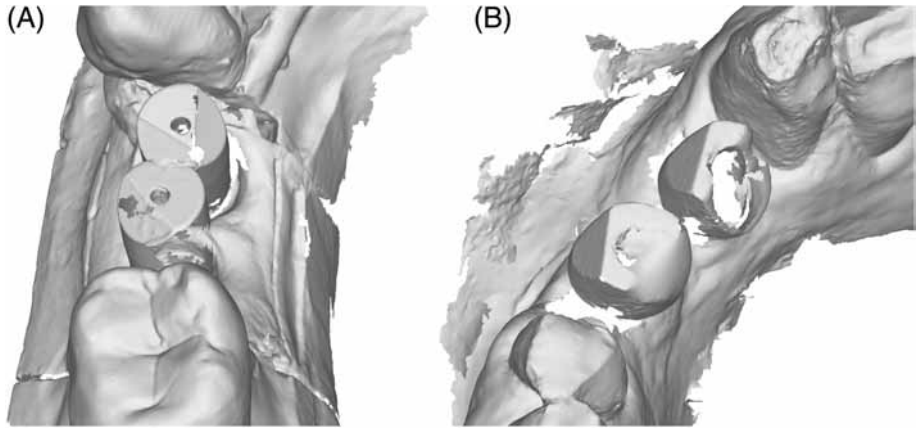


FIGURE 1 Sample scans commonly received by laboratories: (A) with doubling of the bevel of the ISB's scan area; (B) with a scan region that is insufficient to obtain a correct best-fit

knowledge about the variables that influence the accuracy of a digital impression for implant supported prostheses (Figure 1A,B). Indeed, there are many factors that the operator has to be aware of in order to perform an accurate implant impression which can then be used to fabricate a prosthesis that satisfies the requirements for placement in the oral cavity.

Several in vitro studies have investigated the accuracy of digital impressions of implants comparing them to conventional impression techniques demonstrating that, potentially, their accuracy can be clinically acceptable.[1–3] On the other hand, several papers have pointed out that the outcome can be influenced by the operator (i.e., experience and scanning strategy),[4] by the equipment (i.e., scanning technology and algorithm),[5] and clinical conditions (i.e., ambient light, saliva, dental materials in the oral cavity, amount of attached gingiva).[6]

In the digital workflow for the fabrication of an implant-supported prostheses, three phases or steps are required: the first is that of the intraoral scan which generates a file (usually, an .stl format), the second is the acquisition of the IOS file by a CAD software which then creates a virtual model and designs the restoration, and the third is the production of the restoration and, if indicated, of a 3-D model, utilizing a variety of technologies which span from subtractive to additive.

This article analyzes the clinical and technical variables only of the first and second steps. The aim is to make all involved in the process of the fabrication of an implant-supported prostheses (both operators and manufacturers) aware of potential pitfalls that may compromise the outcome and may require the repetition of the entire procedure.

2 | INTRAORAL SCANNING ISSUES

The accuracy of an intraoral scan of one or more implants depends on three main factors: the implant scan body selected, the intraoral scanner and the operator.[7]

2.1 | The influence of the implant scan body

According to Mitzumoto,[8] the scan body is defined as a "complex implant-positioning-transfer device." In the literature and in the marketing material, many names are found for this device besides implant scan body: scan abutment, scan flag, scan post, and scan peg. In this paper, we will refer to it as implant scan body (ISB).

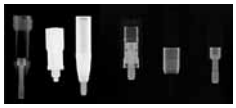
There is a profound difference between the ISB of a digital workflow and an impression coping used in the analog workflow. Both must engage the implant platform precisely, but, while the body of the latter can be modified if needed (such as reduced in height or narrowed in diameter in case of space constraints), the former cannot and should not be changed in any way. The only requirement of an analog impression coping is to be retained within the impression material that embraces it so that, when the implant or abutment analog is connected, it does not move or rotate. On the other hand, when matching the intraoral scan of an ISB with the library of shapes stored in the best fit function of the CAD softwares, the ISB's scan region should remain intact for a matter of superimposition. Some Authors[9,10] propose changes to the shape of the ISB to better adapt it to unfavorable clinical conditions that would prevent correct positioning in the fixture, such as situations in which the ISB makes contact with other ISBs or teeth present. Although this procedure allows the operator to still obtain a coupling with the implant library through best fit, later in the article it will be explained how this type of best fit may not be precise and may instead introduce positional errors of the virtual analog (see CAD issues below).[11]

Moreover, not all ISBs can be considered equal or comparable. They differ in many ways. They can be: metal, peek, plastic or a combination, 1-piece or 2-piece, single use or multiple use, screw-retained or snap on (friction grip), radiopaque or radiolucent, with a sand-blasted surface or a coated surface, tall or short, narrow or wide in diameter, simple or complex in geometry. Table 1 illustrates the main features of the ISBs available on the market indicating which should be avoided whenever possible.

2.2 | ISB materials and usage

ISBs are available in a variety of materials: metal (titanium, aluminum or stainless steel), PEEK (PolyEther-Ether-Ketone) or plastic. Even though they are more easily scanned than other materials,[12] the use of PEEK and plastic is discouraged since these materials tend to distort and wear due to the sterilization cycles, tightening of the screw,

TABLE 1 Main features of the ISBs available on the market and indications of critical aspects

Feature	Image	Which to avoid, if possible	Reason
ISB materials and usage			
Metal vs. PEEK or plastic		PEEK and plastic	May distort and wear and the consistency in their dimensions is lower than with full metal components.
1-piece vs. 2-piece		2-piece	May display variations in the assembly due to the variables when combining the parts or of the mechanical engagement.
Single use vs. multiple uses		Controversial	It depends on the material.
Screw-retained vs. friction fit (snap on)		Friction fit (snap on)	It may not be fully engaged (e.g., due to the interference of the periimplant tissues) without the awareness of the operator.
Radiopaque vs. radiolucent		Radiolucent materials	The correct seating cannot be checked with certainty.
ISB surfaces, dimensions and morphologies			
Coated vs. sandblasted surface		Controversial	There is no evidence to support the best surface treatment since it depends also on the IOS employed.
Height		Different than the neighboring structures, that is, short when next to teeth or tall next to edentulous spans	The component's height should be selected according to the clinical situation being scanned: it should be similar or close to the neighboring structures' height.
Diameter		Narrow with limited occlusal surface	If the occlusal surface is limited, it can be difficult to obtain a correct best fit in the CAD software.
Complex vs. simple scan region shape		Complex shapes (with undercuts or elaborated geometries)	It can be difficult to scan fully the component.

or biting on the component[13] (Figure 2). Furthermore, the tolerances in the consistency of their dimensions are much wider than for metal components.[14,15]

Thinking that in mechanics it is possible to produce consistent pieces according to the measurements of the technical project is utopic. Any piece produced will have a deviation from the actual measurements and its extent varies depending on the production method. Each manufacturer decides which is the range of acceptability (e.g., from + to − 30 μm) and whether the pieces just produced are checked and measured on a sample basis for each batch or piece by piece. This means that, at the end of the production process, from the same project, it is possible to have components on the market that may differ in size within the limits of this "acceptable" range. The ISB libraries in the CAD softwares, on the other hand, have a single dimension not subject to dimensional variations.

FIGURE 2 Wear of a PEEK ISB due to multiple uses

FIGURE 3 2-piece ISBs with a different height of the base due to incorrect assembly. Assuming that the right is the correct one, the use of the component on the left would lead to a vertical incongruity of the position of the analog and, subsequently, a possible under occlusion of the FDP

FIGURE 4 Friction fit (left) and screw-retained (center for an internal connection implant and right for an implant with an external hex) scan bodies

When we apply an ISB to the implants of a patient for taking a digital impression, potentially we could use components or scan bodies which are at the extremes of the tolerance range. A greater or lesser tolerance from the point of view of circumferential measurement, if uniform, does not cause inaccuracies in matching the scanned ISB with the library. This is because the best fit algorithm will still have a unique positioning since it is based on a mathematical average. On the contrary, variations in height can create different vertical positions of the virtual analog head. The use of these components would lead to a vertical incongruity of the position of the analog and, subsequently, a possible over or under occlusion of the FDP (e.g., if the ISB is +30 μm in height, the restoration will likely be under occluded by 30 μm).

The same reasoning applies to the engagement geometry (base): too wide or too narrow tolerances can cause an incorrect positioning in the vertical axis and in the rotational position.[16]

There are a number of manufacturers that sell 2-piece ISBs, often a metal base onto which a second piece (which can be of the same material or different) is either glued or engaged by friction. These scan abutments may display variations due to the assembly process or to incomplete seating of the top part (Figure 3). Therefore, these components can potentially generate a wider range of error since their variability is due to the sum of the tolerances of the two components.

Most manufacturers recommend to use the scan abutments only once to avoid the introduction of variables due to wear and tear in case of multiple uses, but this is controversial. As regards the nondisposable metal ISBs, the literature suggests a limited use of maximum 10 times, provided that there are no obvious signs of premature wear.[17] The clinician should, therefore, always inspect visually the components (preferentially, under magnification) prior to use and discard those that are no longer pristine.

The market offers dentists the opportunity to choose between two types of ISBs based on the method of engagement in the implant connection: screw-retention or friction fit (snap-on) (Figure 4). Even though a friction grip component (usually made of PEEK or plastic) may be quicker and apparently easier to apply, having a component held in position by means of a screw has the advantage of providing greater stability and, above all, of avoiding altogether the risk of partial dislodgment during the scanning procedure. Furthermore, one has to consider that, when two unlike materials are coupled by friction, the softer one will eventually wear (e.g., metal vs. metal wears less than PEEK vs. metal). As already mentioned, ISBs are subject to wear with multiple uses and those in PEEK and plastic in particular. For the aforementioned reasons, we do not recommend the use of snap-on scan bodies. In the absence of alternatives, they should at least be considered disposable.

On the other hand, due to the problem of mechanical tolerances in the production phase, screw-retained components for internal conical connections, even the metal ones, can have different degrees of

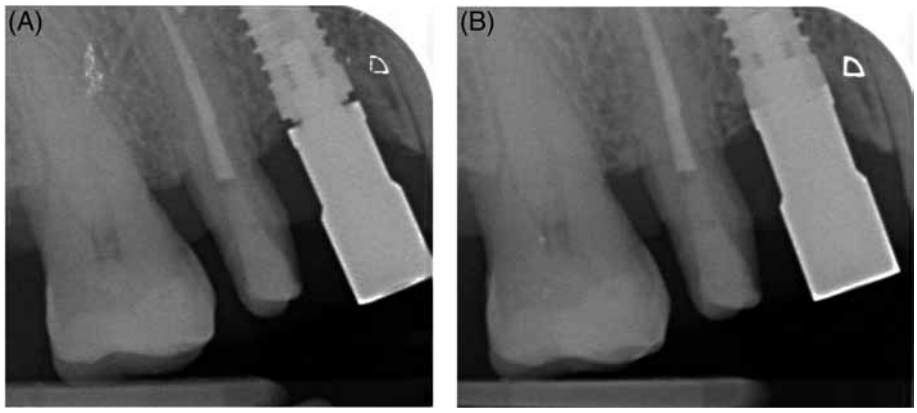


FIGURE 5 Radiographic examination should reveal improper vertical seating of the ISBs every time the interface is not visually inspectable. Only metal components allow the identification of the incorrect (A) or correct (B) adaptation to the implant platform. PEEK is a radiolucent material

adaptation. The clamping force of the prosthetic screw must be considered. While, on one hand, some authors recommend not to exceed 10 Ncm to avoid vertical displacement of the scan abutment, especially in conical connections,[18] there are manufacturers who recommend a torque of 30 Ncm.[19] Kim et al.[18] have shown that, if scan bodies in plastic material or PEEK are used, the vertical displacement at high torque values will be evident, because this screwing load creates a permanent deformation. Therefore, it is a good habit to torque ISBs at a defined value not superior to 10 Ncm through the use of calibrated screwdrivers.

Whenever the correct seating of the ISB on the fixture cannot be inspected directly, as in the case of an implant positioned at bone level or subcrestal, a radiographic examination should be performed. If the ISB is made of a radiopaque material, this verification can intercept improper vertical seating which will have significant negative repercussions on the prostheses' positional and occlusal features. All components made entirely of PEEK or radiolucent materials cannot benefit from this verification (Figure 5A,B).

FIGURE 6 Ceramized-like modification of the titanium dioxide sandblasted surface produced in a wet chemical process (left and center) compared with a common coating (right)

2.3 | ISB surfaces, dimensions and morphologies

An important aspect that impacts on the ease of the scanning procedure is the type of surface of the ISB. The surface should not be reflective. For this reason, metal ISBs are preferentially either sandblasted or coated. Despite this, some IOS have difficulties in obtaining the scan. PEEK, on the other hand, has a nonreflective surface because it is a semi-crystalline material, therefore opaque. There is research going on in the development of coatings which combine the advantages of an easily scannable surface with the durability and reliability of metal components (e.g., Plasma Electrolytic Oxidation by Thommen Medical, Switzerland, that is a ceramized-like modification of the titanium dioxide sandblasted surface produced in a wet chemical process) (Figure 6). At the moment, the main problem with the application of these coatings is the difficulty to guarantee consistency in distribution and thickness (Figure 7). Moreover, the coated layer can degrade or go away during the cleaning and sterilization.

Another important feature is the diameter. In partially edentulous patients, the diameter should be such as not to interfere with the

FIGURE 7 Nonhomogeneous coating distribution. This may cause improper alignment when using the best fit function in the CAD software

neighboring teeth (Figure 8) or scan abutments (Figure 9) and, at the same time, should provide enough space to capture the proximal surfaces of the teeth or of the scan abutments.

Some scan bodies have the fixation screw inside the body of the component itself, without the possibility of removing it (Figure 10). It can be accessed through a small occlusal hole, sufficient only for the passage of a thin-shank screwdriver. This solution responds to two desires: firstly, not losing a horizontal portion of the occlusal surface of the component (needed for an

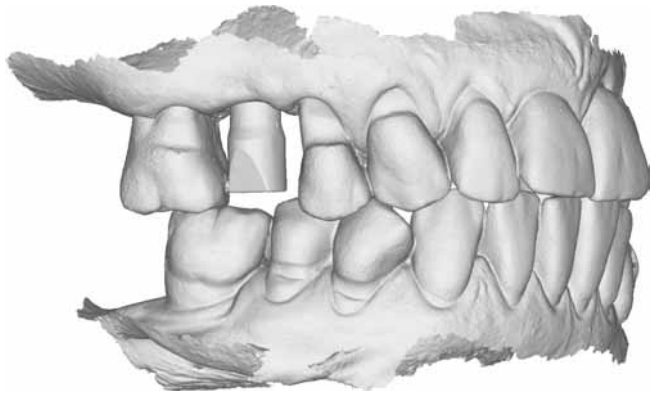


FIGURE 8 Even when there seems to be sufficient space, check that the ISB does not interfere with neighboring teeth. In this case, the ISB is contacting the mesial surface of the molar, thus not allowing the complete scan of that surface

FIGURE 9 The ISB diameter and height should be such as not to interfere with the neighboring teeth or scan bodies. In this patient, the convergence of the implants does not allow the respective ISBs to be placed at the same time since they interfere with each other at the top. Either shorter ISBs should be employed or a double impression must be recorded

accurate best fit) like it occurs whenever the hole is large and the dimensions of the ISB are kept within certain limits for not interfering with the neighboring teeth in narrow spaces. Secondly, it allows the user not to lose the screw during insertion in the mouth and the sterilization processes. On the other hand, it is not possible to visually check the integrity of the prosthetic screw and, if damaged, replace it. Furthermore, it is necessary to reflect on how this component is produced. It is obvious that the screw must undergo an assembly process. As a matter of fact, even if visually it appears as a 1-piece, it has to be considered a 2-piece component with the possible variations to which this type of ISB is subject.

As far as the height is concerned, it should be as close as possible to the height of the neighboring teeth or scan abutments to facilitate the advancement of the scanner during the scan limiting as much as possible vertical excursions of the tip[20,21] (Figures 11 and 12). In fully edentulous patients, the height should be as low as possible. In both situations, the matching surface needs to be fully exposed and not partially covered by the soft tissues[22] (Figure 13).

The last meaningful feature to be discussed is shape. Simple shapes of the coupling geometry allow the operator to be faster and more precise in scanning the ISBs.[23] Ideally, a scan abutment should be read almost in its entirety in a single passage from the occlusal side. Only a simple ISB, linear in shape, free of undercuts and concavities, allows the operator, with simple movements, to capture and reach every portion of the geometric shape. This translates into shorter scanning time and a reduction in the possible errors that can occur when going over the same surfaces several times with the scanner.[23] Scan abutments that do not have bevels to determine the position and orientation of the implant fixture can complicate intraoral acquisition in the absence of other unique points of reference (such as stable teeth or attached gingiva), especially if they are very distant from each other (e.g., those for multi-unit abutments by Thommen Medical, Switzerland) (Figure 14A). The acquisition software may have difficulty to recognize the single scan body because it is completely identical to the others (Figure 14B,C). The presence of a bevel adds a distinctive element to each ISB which allows the scanner, during progression, to understand that it is not the same component since they will have different orientations.

2.4 | The influence of the IOS

The acquisition of the shape of a scan body may or may not be facilitated depending on the intraoral scanner used.[12,20,24] To start, the size of the acquisition window, called scan window, affects the amount of information detected in a single passage.[20,24] A large window will acquire more data faster, but, at the same time, the tip will be bigger and more cumbersome.[24] In situations where the scan bodies themselves, by position or shape, limit the access of the scanner, it is more difficult to perform linear and correct maneuvers to capture the shape of the component. Being able to choose smaller tips or using software features that vary the scan depth can give the clinician an advantage in such situations.[24]

Some of the early IOS contemplated the use of a powder in order to acquire the scan (e.g., True Definition, 3M, USA). The more recent models, instead, are marketed as "powder free." On the other hand, most of the IOS manufacturers recommend the application of a powder when the patient presents highly reflective surfaces (such as shiny metal FDPs) in order to opacify them. Titanium dioxide powders are available for this purpose. They are sprayed onto the surface and differ on the basis of whether or not they contain an adhesive.

The risk of powder application is that of creating a coating which may distort the shape of the object, as demonstrated in vitro by Dehurtevent et al.[25] This is particularly dangerous if the powder is applied to a scan abutment because it may modify its dimensions. Using a spray containing adhesive, if not correctly applied, will inevitably lead to the alteration of the shape of the ISB due to the thickness of the spray that is deposited on the surface. These

FIGURE 10 The access hole in the ISB on the left allows the screw to be removed. The ISB on the right, instead, has the fixation screw inside the body of the component itself, without the possibility of removing it. This offers a wider occlusal surface without increasing the component's overall diameter

FIGURE 11 A correct height and diameter of the ISB facilitates and speeds up the IOS acquisition

FIGURE 12 An excessive height of the ISB may interfere with the linear advancement of the intra-oral scanner, thus affecting the acquisition of a proper scan

sprays are easier to manipulate extra orally, for example in the lab, since the application can be made at the correct distance (e.g., 20 cm) to have a uniform diffusion and the object to be opacified can be rotated in any direction to be exposed to the spray. In the mouth, obviously we do not have the opportunity to do the same. Powders without adhesive are easier to apply and any excess dust can be easily removed by blowing air. However, the fact remains that it is a possible variable and source of distortion and there is no way to standardize the powdering procedure for each scan.[26]

2.5 | The influence of the operator

Many studies agree that the operator's experience affects the final quality of the scan.[4,27–29] Experience should not be interpreted as the number of scans performed, but as proper training and knowledge of the objectives to be achieved when taking impressions.[20]

The scanning strategy, that is how the scanner is positioned and moved across the arch, has been shown to affect profoundly the impression's accuracy and trueness.[30–32] It must be considered that the IOS is nothing more than a noncontact measuring instrument using optical technology. Any freehand measurement system is obviously subject to errors due to the operator's use and to the lack of measurable fixed references. A lab scanner, instead, has a plate whose size is known and onto which references are incorporated. It follows that a reading distortion can be more easily corrected by the processing algorithm of the final file.[33] In addition, the acquisition sequence is always the same since it is guided by a mechanized standard path. In contrast, the IOS operator represents the most relevant variable. Recent literature, therefore, has investigated the best scan path that, when applied faithfully, can minimize this variable.[30–32]

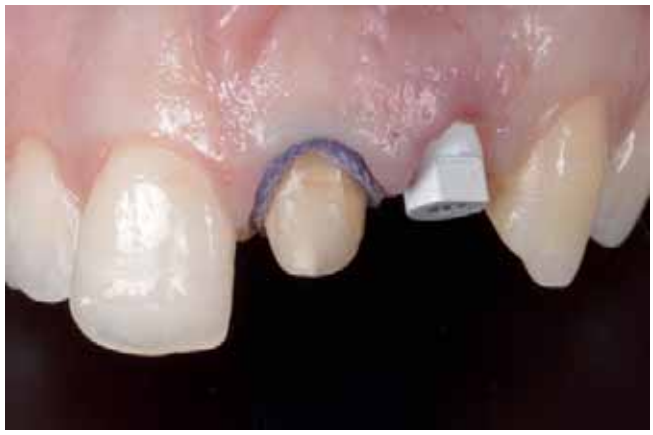


FIGURE 13 Whenever the soft tissue partially covers the ISB, it reduces the scan region for an effective best fit superimposition

FIGURE 15 An effective lip and cheek retraction allows the operator to perform a correct scan thanks to the unimpeded movement of the scanner inside the mouth

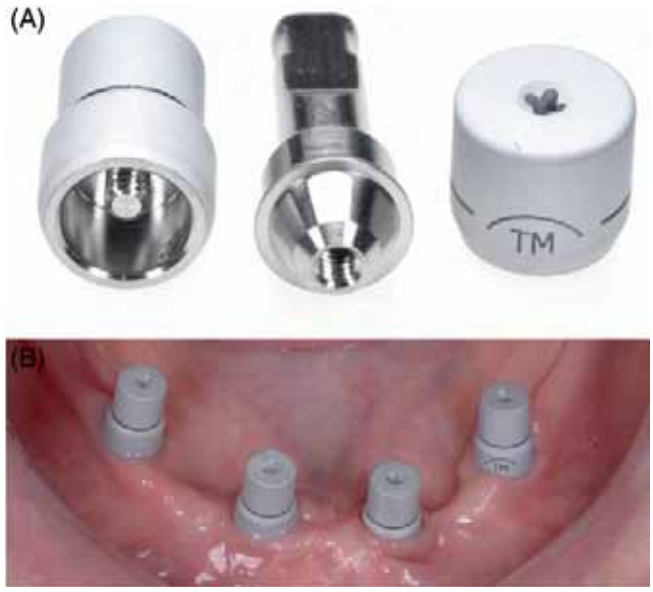


FIGURE 14 (A) ISBs for multi-unit abutments do not necessarily require an intaglio surface. (B) However, identical shapes of the ISBs without bevel make the acquisition difficult whenever the implants are far apart. (C) The operator's experience is crucial in order to obtain a proper scan, especially when the band of keratinized tissue is limited

In the absence of a scientifically validated scan strategy, we have relied on our experience that suggests to apply the following precautions which should be matter for future research projects:

- The IOS tip should be held close and parallel to the occlusal surface of the teeth or the gingiva in the edentulous spaces; although most of the IOS allow a contact scan, there are some devices that have a certain depth of field to respect. In this case, the advice is to try not to have oscillations outside the optimal working area.[20,33]
- It should not advance too quickly in order to facilitate stitching; a movement that is too rapid may create a poor and approximate acquisition of points.[20,24,33] On the other hand, dwelling too much on areas already correctly acquired can worsen the quality of the final mesh.[20] So, the advice is to scan the surfaces at their best, then move forward, avoiding to return several times in areas already fully scanned.
- The movements should be linear and not chaotic or random; a linear movement creates portions of surfaces on which new points are based for the progression. A random movement may not have these sure foundations to progress with the stitching of new surfaces.[20,24,33] Consequently, the acquired objects could incorporate distortions that are difficult to be appreciated once the mesh is created.
- The cheeks, lips and tongue should be kept away from the teeth through the use of appropriate devices and the field should be as dry as possible[34]; the visibility and accessibility of the operating field is a crucial factor. An effective lip and cheek retraction allows an ease of movement of the scanner inside the mouth, helping the operator to perform the correct scan (Figure 15). The assistant's role is to follow the dentist's movement by helping to keep the tongue away from the dental surfaces. He/she should, therefore, focus only on the patient. Instead, the dentist should only look at the progression of the acquisition on the monitor, avoiding as much as possible looking into the patient's mouth. A further important element is to dry the surfaces to be scanned in order to minimize the reflection that the scanning light will inevitably cause on saliva.
- In the case of a fully edentulous arch with little or no attached gingiva, the operator's experience and knowledge about the limits of the IOS are essential for the success of the scan. As a matter of fact, advancement on mobile and nonstable tissues without fixed references (such as teeth or a wide band of keratinized attached tissue) creates objective difficulties for the stitching process. There are, however, practical tricks in order to overcome them. Some authors have proposed special shapes of ISB with cantilevers (flag post)[35] or chains to be assembled and attached to the ISBs (e.g., Universal Scan Template, LaStruttura, Italy), or a customized over-scan body rings[36] or the use of liquid dam[37] to mimic replicate keratinized tissue when there is none. The concept behind all these solutions is to have fixed areas which can facilitate the stitching process.

3 | CAD ISSUES

Computer Aided Design (CAD) softwares have been undergoing continuous development over the past two decades to facilitate and automatise many functions. However, there are two aspects that still today may create inaccuracies in the workflow and in the final product being fabricated: the identification of the specific implant placed in the patient and the generation of a virtual model with the representation of that implant platform correctly positioned in the three dimensions of space.

3.1 | The pitfalls of implant platform recognition

At the moment, in the digital workflow, the information about the implants being captured by the IOS has to be entered in the prescription manually by the clinician or his/her staff. It is possible to use ISBs for different implant platform configurations and diameters with the identical scan area shape. Therefore, looking at the ISB in the digital impression, it is not possible to identify the implant type since the engaging portion is hidden (Figure 16A,B).

Not having a physical impression with the impression copings trapped that allow the operator to verify the correct choice of components, as in the case of the traditional workflow, he/she must rely exclusively on the information provided by the clinician in the lab prescription. In the event that a mistake has been made in communicating implant type, brand and platform diameter, the dental technician has no way to intercept it. The incongruity can only be found when the work is completed and the clinician attempts to insert it in the implant.

Therefore, incorporating in the ISB a serigraph of a bar code or QR code that automatically identifies the correct library to the CAD software is desirable since it eliminates human error (Figure 17).

3.2 | The pitfalls of the best fit function

Once the shape of the ISB has been acquired with the IOS, in the CAD software, the dental technician must position the virtual analog for the creation of the virtual working model. To do this, a known library of geometric shapes (linked to the implant) must be coupled or superimposed with the shape acquired intraorally, a procedure called best fit[8] (Figure 18). The word itself denotes the best possible fit based on the selected surfaces. The bevel allows the ISB to have a unique orientation in space to initiate this overlapping process. Then, an algorithm based on a weighted average between the known measurements of the library and the ISB measurements obtained by the scanner determines the best fit. The amount of surface available for the best fit can be decided and adjusted by a

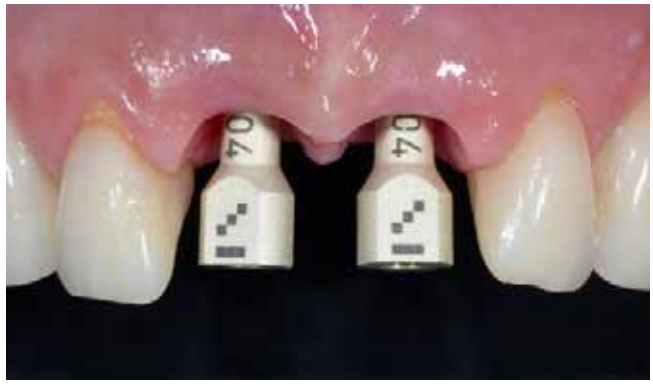


FIGURE 17 ISBs with a built-in QR code that automatically transfers the information and characteristics of the implant to the CAD software, thus eliminating a possible human error in selecting the correct prosthetic components

FIGURE 16 (A) ISBs with identical scan region shapes: it is not possible to identify the implant type from the top portion. (B) Only their engagement gives information about the different implant platforms, but this is not visible in the scan

special function in order to improve the overlap. Depending upon the area of best fit chosen, the position of the virtual analogue may change.

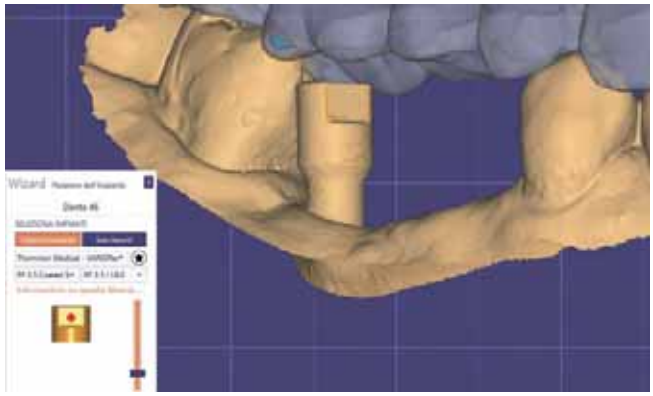


FIGURE 18 Rendering of the superimposition of the implant library and the scan body acquired by the IOS: in this view, the potential discrepancy between the two shapes cannot be appreciated

The best fit matching in the CAD softwares is an automatic process, but the operator can verify the correspondence of the two objects and how much they differ from each other by measuring the accuracy of the matching. As a matter of fact, blindly accepting the first best fit provided by the CAD software algorithm can result in an implant position that is not congruent with that of the patient. The authors, therefore, recommend the verification of the best fit during the CAD phase. This can be done in two ways:

- With a section view: the quality of the superimposition can be checked by making cuts that can highlight if and how much the library shape corresponds with the acquired ISB (Figure 19A).
- With a calibrated proportional color scale: enabling a function in the CAD software (i.e., by pressing the <CTRL> in EXOCAD, Align Technologies Inc., USA), the quality of the superimposition can be measured with a color scale (Figure 19B). The operator can improve that by cutting away the lower part of the geometry of the ISB library in the wizard window.

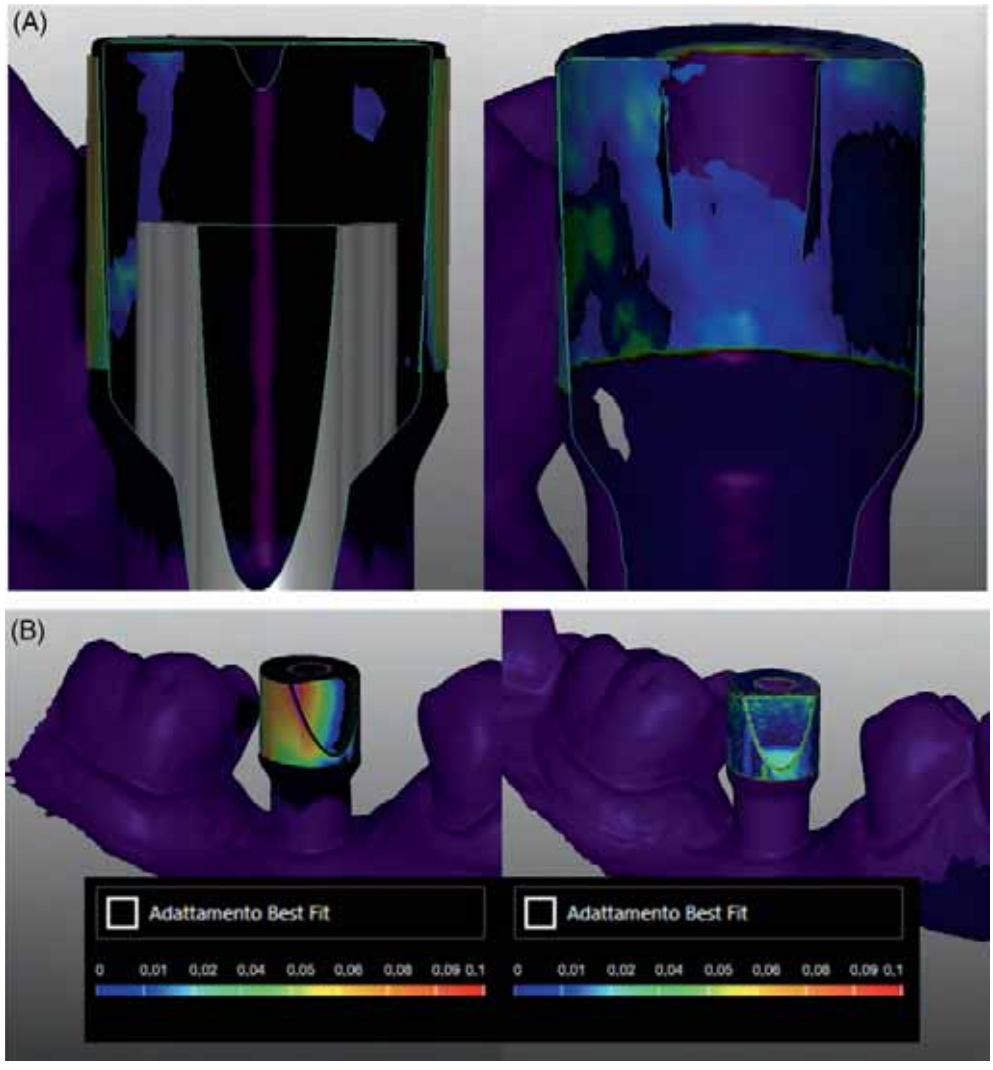


FIGURE 19 (A) Example of best fit verification using the section view in the CAD software. In the left side, the superimposition of the ISB's contours and the library contours shows a difference which demonstrates the fact that they do not coincide. In the right side, instead, the two contours coincide perfectly. (B) The same case in the view with a color scale measurement. In the left side, the gradient of colors is a demonstration of the lack of matching between IOS scan and library. The predominance of the blue color in the image on the right, instead, is a demonstration of a good superimposition

4 | CONCLUSIONS AND RECOMMENDATIONS

In a digital workflow for the fabrication of an implant-supported restoration, the selection and application of the implant scan body, the use of an effective scan strategy and the appropriateness of the best fit function are variables that can influence the positional precision of the FDP.

With so many manufacturers using different geometries and materials, probably to avoid patent infringement, it would be desirable to define a standard for ISBs. On the basis of what has been presented in this article, the following are the recommendations for the implant scan body of choice:

- 1-piece,
- screw-retained, with a clamping force not exceeding 10 Ncm,[18]
- metal (therefore, radiopaque),
- rough (sandblasted) or coated surface,
- same shape, but in different heights in relation to the clinical situation (dentate vs. edentulous),
- linear shape,[23] with minimum undercuts[23] and with as wide an occlusal surface as possible,
- with coding to identify automatically the implant platform underneath.

The operator's experience and knowledge of the limits of the IOS devices can contribute to improve the quality of the scans.[4,27–29] Appropriate scan strategies should be learnt while making sure that fixed references are always used to facilitate the stitching process.

As far as the best fit function is concerned, the operator should not blindly trust the best fit matching automatic function in CAD softwares.[8] He/she should instead verify the quality of the matching using the tools available (section view or the calibrated proportional color scale).

DISCLOSURE

Drs. Appiani and Noè do not have any financial interest in the companies whose materials are mentioned in this article. Dr. Gracis has no financial interest, but he is on the Scientific Advisory Board of Thommen Medical and 3Shape.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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How to cite this article: Gracis S, Appiani A, Noè G. Digital workflow in implant prosthodontics: The critical aspects for reliable accuracy. *J Esthet Restor Dent*. 2023;35(1):250-261. doi:10.1111/jerd.13004