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REVIEW ARTICLE

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Considerations for predictable outcomes in static computer-aided implant surgery in the esthetic zone

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Abstract

Objective: To provide technical and clinical recommendations for implementing a digital workflow in Static Computer-Aided Implant Surgery in the anterior maxilla.

Clinical Considerations: An optimal 3D implant position is crucial for achieving satisfying results in implant rehabilitation in the esthetic area. Due to its complexity, implant placement in the esthetic zone should be executed with precision and predictability. Static Computer-Aided Implant Surgery requires thorough planning and detailed attention to every step of the digital workflow protocol.

Conclusions: Implant positioning in the esthetic zone using Static Computer-Aided Implant Surgery is a technique-sensitive procedure that requires precise execution of each step. This approach ensures accurate prosthetically driven 3D implant placement and prevents potential errors that could lead to inaccurate positioning.

Clinical Significance: The proper implementation of Static Computer-Aided Implant Surgery may increase the level of agreement between the planned and definitive implant 3D positions in the esthetic zone, thus enhancing the esthetic outcomes of implant rehabilitation.

KEYWORDS
cone beam computed tomography, esthetic zone, optical scanning, static computer-aided implant surgery, surgical templates

1 | INTRODUCTION

Prosthetically driven implant placement in the esthetic area should be followed to achieve an optimal three-dimensional (3D) implant position regarding the planned restoration. This represents one of the main prerequisites for successful long-term functional and esthetic outcomes.[1] The rehabilitation of an edentulous site in the esthetic zone is considered an advanced and complex procedure. Therefore, this treatment should be executed with precision and with thorough attention to detail.[2]

Digital implant planning represents a milestone in modern oral implantology that brings together biological, prosthetic, surgical, and radiographic fields under a common virtual scenario. This allows for a pre-operative evaluation of the procedure prior to the surgical intervention. Subsequently, it is possible to translate the virtual plan to a clinical setting owing to the fabrication of a surgical template that guides the drill sequence and the implant insertion according to the virtual planning.[1,3]

The initial step of a restorative dental procedure in the esthetic zone, either digital or conventional, is the collection of information about the region to be treated, called data acquisition. When it comes to static computer-aided implant surgery (S-CAIS), the workflow entails collecting two types of files: Digital Imaging and Communications in Medicine (DICOM) files from the Cone Beam Computed Tomography (CBCT) and those obtained with an Optical Scanner (OS). These files are then imported into the implant planning software.[4]

Three-dimensional radiographic imaging is significant for an adequate site evaluation, while OS files contribute information regarding the soft tissue, occlusal surfaces, and relevant intraoral topographic information. Thus, intraoral or laboratory optical scanning of teeth and surrounding soft tissues provides enough information for an intraoral 3D rendering.[5] The summation of data sets results in a 3D reconstruction of the scanned structures. When it comes to surface scanning, there are different types of files obtained by optical scanners; however, the STL (Standard Tessellation Language), OBJ (Object), and PLY (Polygon File Format) represent the most common ones. When both datasets (DICOM and STL or OBJ or PLY) are imported into the virtual implant planning software, they can be merged by superimposition using the pre-established reference points such as teeth or fiducial radiopaque markers.[6]

Based on the patient's intraoral situation, there are three different scenarios with different specific planning pathways: partially edentulous patients with enough tooth reference points for a virtual tooth set-up, partially edentulous patients with inadequate occlusal references for a virtual tooth set-up along with fully edentulous patients, or partially edentulous patients with inadequate occlusal references for a virtual tooth set-up where the teeth have to be extracted for immediate implant placement.[7] After merging DICOM files with surface scan data, implant positioning can be virtually simulated based on the virtual prosthetic plan and its corresponding surgical template can be designed and exported in order to be manufactured via three-dimensional printing or milling.[4,5] S-CAIS has shown acceptable accuracy in various clinical situations.[8]

The file merging process and stable intra-operative fitting of a drill template are among the principal factors affecting the accuracy of the overall procedure.[9] Surgical templates can be tooth-supported, mucosa-supported, bone-supported, implant-supported, or designed based on a combination of the previous types[10,11] (Figure 1).

Implant-supported and tooth-supported templates have been described as more precise when it comes to the virtual-to-actual transfer of implant position than those supported by the bone or mucosa.[5,9,12]

Similarly, surgical templates provide three different drilling/placement possibilities such as pilot-guided osteotomy, guided osteotomy (with free-hand implant insertion), and fully guided drilling and implant installation, which has been suggested as the most accurate method.[13]

Every step of the digital workflow, especially in the esthetic zone, is sensitive to errors that, if combined, may lead to coronal, apical, and angular deviation of dental implants compared to the defined digital position.[4,13,14]

This article aims to provide an in-depth description of a digital workflow for S-CAIS in the anterior maxilla, to propose clinical recommendations in order to diminish potential cumulative procedural errors during treatment planning, and to optimize accuracy during guided implant placement.

2 | DIGITAL WORKFLOW

The most significant steps of the digital workflow for S-CAIS are as follows (Figure 2):

1. Data acquisition (CBCT and surface/optical scanning)
2. Data manipulation (virtual segmentation, file merging process)
3. Digital teeth set-up and virtual implant planning
4. Surgical templates design
5. Data preparation for manufacturing of surgical templates
6. Static-computer aided implant surgery

2.1 | Data acquisition

The first step in planning S-CAIS encompasses collecting data and relevant information on hard and soft tissues (Figure 3).

2.1.1 | CBCT scanning

CBCT imaging is a well-established diagnostic tool indicated in various clinical disciplines such as implant dentistry.[15]

The size of the Field of View (FoV) describes the volume of the anatomical structures included in the examination. The FoV should

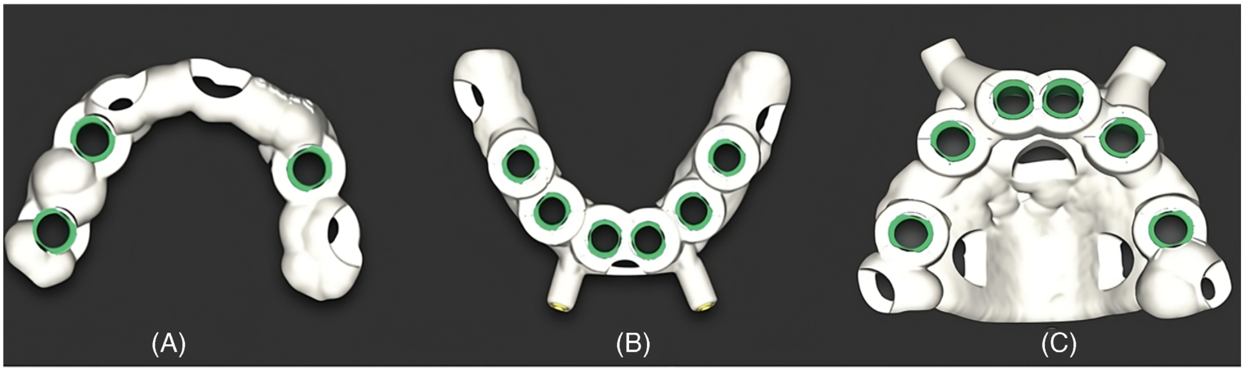

FIGURE 1 (A) Tooth-supported surgical template. (B) Bone-supported surgical template. (C) Mucosa-supported surgical template.

FIGURE 2 The steps of a digital workflow.

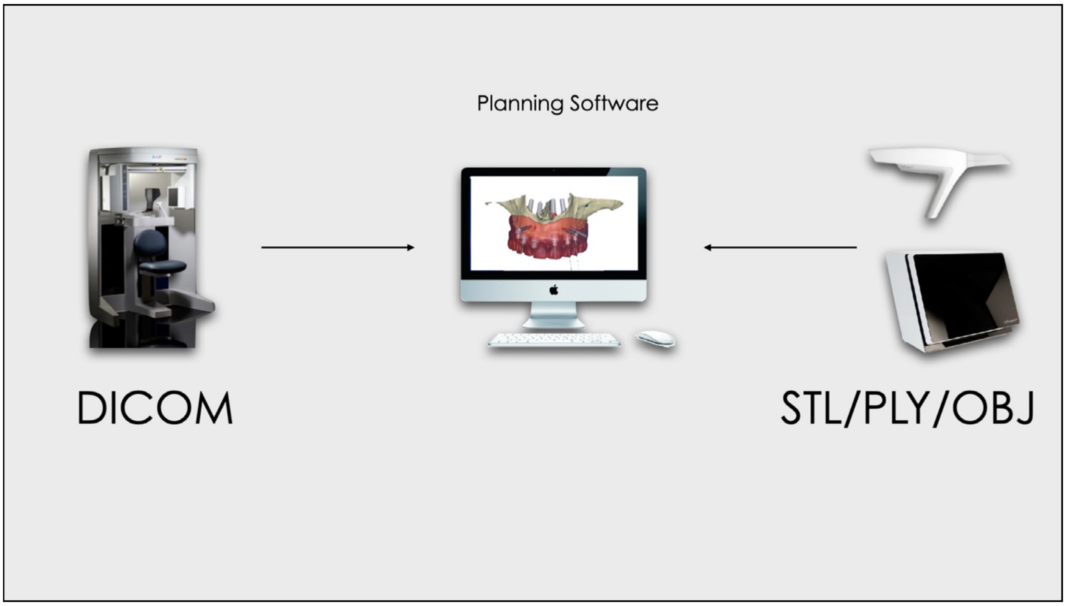

FIGURE 3 Data acquisition process.

slightly exceed the anatomical area that is in the center of interest. Using a larger FoV indicates a higher dose of radiation; therefore, restricting the FoV can lower radiation exposure.[16] For dataset merging, the medium-size FoV is recommended (jaw-size).[17] However, it has been demonstrated that a small FoV (quadrant size) can be acceptable if there is a sufficient number of teeth that are well-distributed around the implant site, but due to its reduced area for dataset merging, it can lead to inaccuracies.[16,17] Also, during digital planning, it is essential to consider bone density at the site of planned implant placement, as this is another important aspect of planning the surgical procedure that can help ensure successful primary stability. Norton and Gamble have proposed a classification based on the Hounsfield units (HU) from CT. Higher HU values indicate higher bone density.[18] However, it has been shown that HU are not accurately applicable to CBCT.[19]

Various advantages have been indicated in relation to CBCT in Implant Dentistry; however, there are limitations that need to be considered. These include limited soft tissue information, the presence of artifacts, and low reliability when it comes to detecting thin bone structures.[20]

Artifacts are structures that are visualized on CBCT images but are not present in the scanned object.[9] Besides scattering, another most frequent artifact is produced by beam hardening. It occurs in the presence of high-density objects such as dental implants. The sensor records excessive energy because only higher-energetic x-rays penetrate the implant.[21] Previous research has identified several favoring factors for artifacts with implant material being one of them. A larger FoV, lower kilovoltage, and smaller voxels were associated with more artifacts.[22]

In order to decrease the risk of artifacts, clinicians should pay attention to technical details during the CBCT scanning procedure. Accordingly, patients are advised to take off their jewelry, glasses, hair clips, and hearing aids. Metal parts that are not fixed in the mouth should be removed and patients should try to avoid movements during scanning.[23] Placing cotton rolls into the vestibule or using plastic lip retractors will help move the lips and cheek from the region of interest in order to achieve clear visualization of hard and soft tissues.[24]

When collecting high-quality data obtained from the CBCT for the purpose of planning S-CAIS, the following recommendations should be followed: ensuring upper and lower teeth separation for adequate segmentation and subsequent data merging with the surface information coming from the OS, defining the extent of the FoV, and the use of radiographic templates when tooth references are insufficient for an adequate virtual teeth arrangement.[7,8,17]

2.1.2 | Surface/optical scanning

Digital impression techniques have many advantages compared to conventional impressions, such as the lack of distortion of impression materials, the possibility of providing 3D previsualization, patient comfort, and time optimization.[24,25,26]

The accuracy of intraoral digital scans is measured by trueness and precision. Trueness describes how far the measurements of the object deviated from its actual dimension, while precision refers to the reproducibility of the intraoral digital scans recorded under the same scanning conditions.[27,28] Various factors can influence scanning accuracy such as scanning technologies,[29] scanner calibration,[30] clinical experience and training,[31,32] scanning protocol,[33] surface characteristics,[34] the illuminance of the room light,[35] post-processing method,[36] and moisture on the tooth surface.[37] It has been suggested that blow-drying can reduce scanning errors, whereas cutting-off and rescanning should be minimized to decrease inaccuracy.[28,37]

There are three techniques for taking digital impressions: (1) a digital impression with an intraoral scanner (IOS), (2) direct scanning of the intaglio surface of the conventional impression with an intraoral or laboratory scanner and (3) scanning the plaster model with a laboratory optic scanner. Owing to trueness and precision, a digital impression with IOS is as accurate as a digital impression obtained by a laboratory scanner.[36]

One of the limitations of IOS devices is the inability to capture mobile soft tissue. The minimal presence of the attached mucosa will influence the ability of an intraoral scanner to capture and stitch together the surfaces, thus making it challenging to obtain an accurate scan. It is recommended for completely edentulous patients and extended edentulous sites to be assessed carefully.[8,38]

2.2 | Data manipulation

The next step is to import DICOM and STL or OBJ or PLY files into the digital implant planning software. In this article, CoDiagnostiX Software (Version 9.0, Dental Wings GmbH, Freiburg, Germany) was described. However, these files can also be processed using other software designed for S-CAIS. These file formats have their own advantages and limitations. While STL files are commonly used due to their size, PLY and OBJ are useful for analyzing keratinized tissue as they include information about the object's color and texture.[39] Data manipulation includes the identification of the panoramic curve, virtual dissection (segmentation), mapping of inferior alveolar nerves, and merging data from DICOM-based reconstruction and superficial scanning files (STL, PLY, and OBJ).[4]

The following section will describe the process of segmenting and merging data from DICOM and STL files.

2.2.1 | Virtual segmentation

The purpose of segmentation is to differentiate anatomical structures and fields of interest from one another, which enables the planning process for S-CAIS. Additionally, this process may reduce the distortion of the image affected by metal scattering and motion artifacts.[4] The segmentation steps include obtaining the appropriate density threshold and visualization of the bone and teeth. The gray-value threshold has an influence on the quality of 3D reconstruction images. When choosing lower threshold values, the volume of the reconstructed bone image can appear to be larger than its real size.[40,41] This can be especially misleading for beginners when choosing a higher threshold value since the volume of the bone could seem inadequate. Since most of the available planning software allows for different views (usually cross-sectional, tangential, axial, panoramic, and three-dimensional), it is recommended for clinicians to assess bone parameters on all of them and take the three-dimensional segmentation as a complement reference. Anatomical structures can be segmented by creating layers, which allows the separation and coloring of different structures. Scattering can be reduced manually during the segmentation process, which requires caution so that real anatomical structures are not removed.[6,13] Scattering reduction achieved by this means may help during the alignment process of CBCT and OS data.

The development of deep-learning-based artificial intelligence (AI) systems has shown high accuracy and low time consumption in terms of automatic tooth and bone segmentation from CBCT images.[42]

As with any AI-based technology, the system's learning process gets alimented by information that previous users have agreed to share. Basically, all the cases that clinicians have approved to share with the AI platform are improving its ability to make the automatic segmentation process faster and more accurate.

Using this innovative system, clinicians can easily visualize renderings of different anatomical structures such as the maxillary sinuses, alveolar bone, inferior alveolar nerve, teeth, roots, and so on. This feature can be particularly relevant for cases where immediate implants are planned to be placed in the anterior maxilla. The segmentation process allows the extraction of teeth virtually, permitting a detailed visualization of the remanent socket, bone walls, and bony architecture of the buccal wall.[43,44] It has been shown that using an AI system for the segmentation process makes it 500 times faster than the conventional one. These results demonstrate that the potential of AI can increase the efficiency of the workflow for digital implant dentistry.[42,45]

2.2.2 | File merging process

The superimposition of DICOM files and the STL, OBJ, or PLY is achieved by indicating common references present in both and pertaining to either anatomical structures or fiducial markers (Figure 4).[4]

In order to achieve precision during this process, the recommendation is to spread the merging points over four areas bilaterally.[17]

Once the matching is completed, the user should check the accuracy of the merging process in the validation window in the axial, tangential, and cross-sectional views. If the alignment is correct, the congruence of the contour from both hard and soft tissues should match in the three-dimensional reconstruction. Sometimes, incorrect merging can occur, however, the user can repeat the process and select other reference areas, improve contour matching with manual adjustment, and/or repeat the data acquisition process (Figure 5).[17]

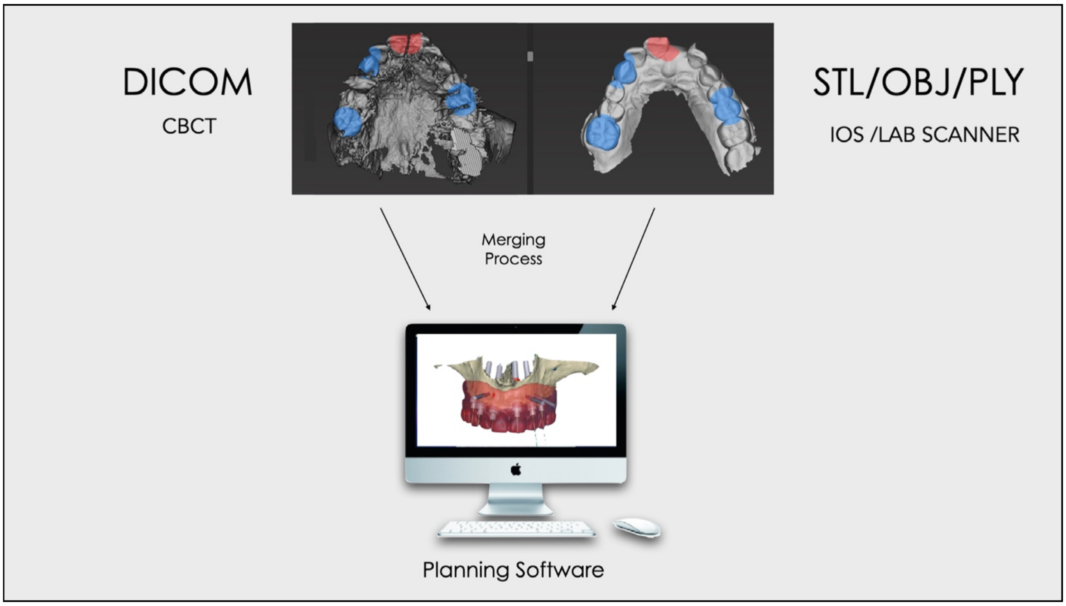

FIGURE 4 Merging datasets in the implant-planning software.

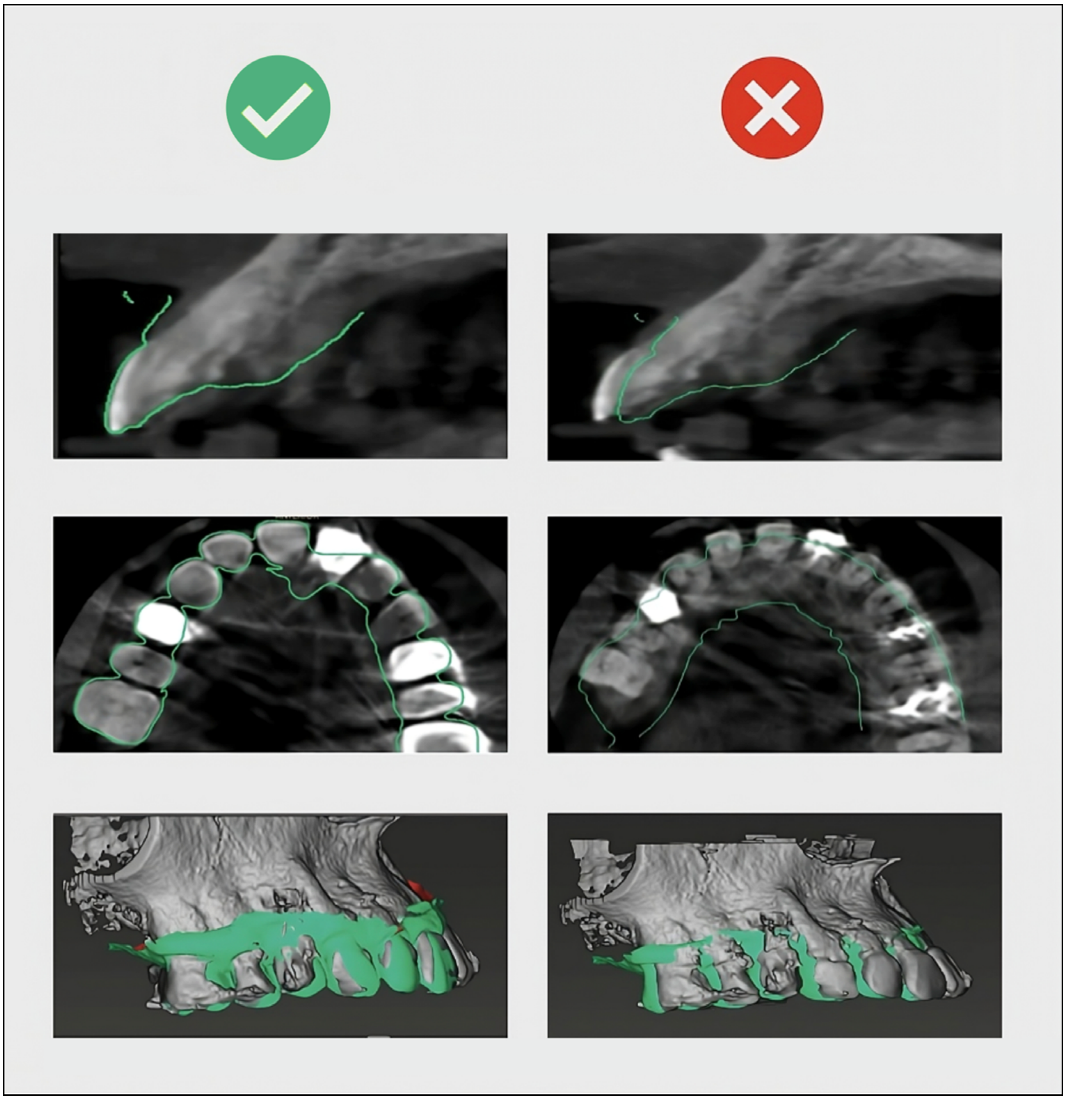

FIGURE 5 Left side: correct alignment of the merged files where the contour of both 3D datasets is matched. Right side: Incorrect alignment of the merged files which leads to an error during the planning phase.

Ensuring the accuracy of the matching process is one of the most critical steps for a successful transition from the virtual plan to the final implant position. If the files are not properly aligned, errors may occur during the planning phase. This situation can be explained by the virtual implant position transference to the real surgical site by the surgical template. Since the surgical template is designed over the STL/PLY/OBJ image, an inadequate matching will transfer the implant position defined by the surgical template without considering the bone structure. Hence, a misalignment of the STL/OBJ/PLY and DICOM files will not influence the surgical template fitting nor the sleeve position, but the final implant position will be different from the one observed in the bone.[17,46]

Incorrect alignment of the merged files usually occurs when the number of common reference areas is insufficient. A lack of reference areas can be observed when the CBCT is performed with upper and lower teeth in occlusion or if metal artifacts are present.[8]

2.3 | Digital teeth set-up and virtual implant planning

After the merging process is checked and approved, a virtual model is created containing superficial and tomographic information of the patient. Based on the remaining dentition, a virtual teeth arrangement can be performed simulating the future prosthetic structure, allowing for a virtual prosthetically driven implant positioning. If desired, a digital workflow allows us to import files of an analog wax-up, import a digital tooth set-up from third-party software, or follow a dual scan technique.[17] Before virtual teeth arrangement was developed, radiographic templates were routinely used with the purpose of importing future prosthetic information to the planning phase. The disadvantages of radiographic templates are related to additional laboratory costs and the possibility of inaccurate template fitting.[7,17,47] Once the prosthetic plan is determined, the implants can be selected from a digital library and planned according to the virtual tooth/teeth position (Figure 6).

The software offers a selection of implant types and sizes through its implant libraries. If multiple implants are planned, the software also provides a paralleling tool. During the planning process, an implant should be placed in the correct 3D prosthetically driven position but considering the available bone amount, anatomical limitations, and structures. Most systems provide the safety boundary option around and between implants.[4] Moreover, certain libraries offer the option to select virtual abutments, which enables the user to choose the abutment type, as well as its height and angulation, while considering the height of the soft tissue. With this feature, the user can plan every aspect of the procedure in advance.

2.4 | Surgical templates design

After the surgical plan has been established, the user may proceed with the digital design of surgical templates (Figure 7).

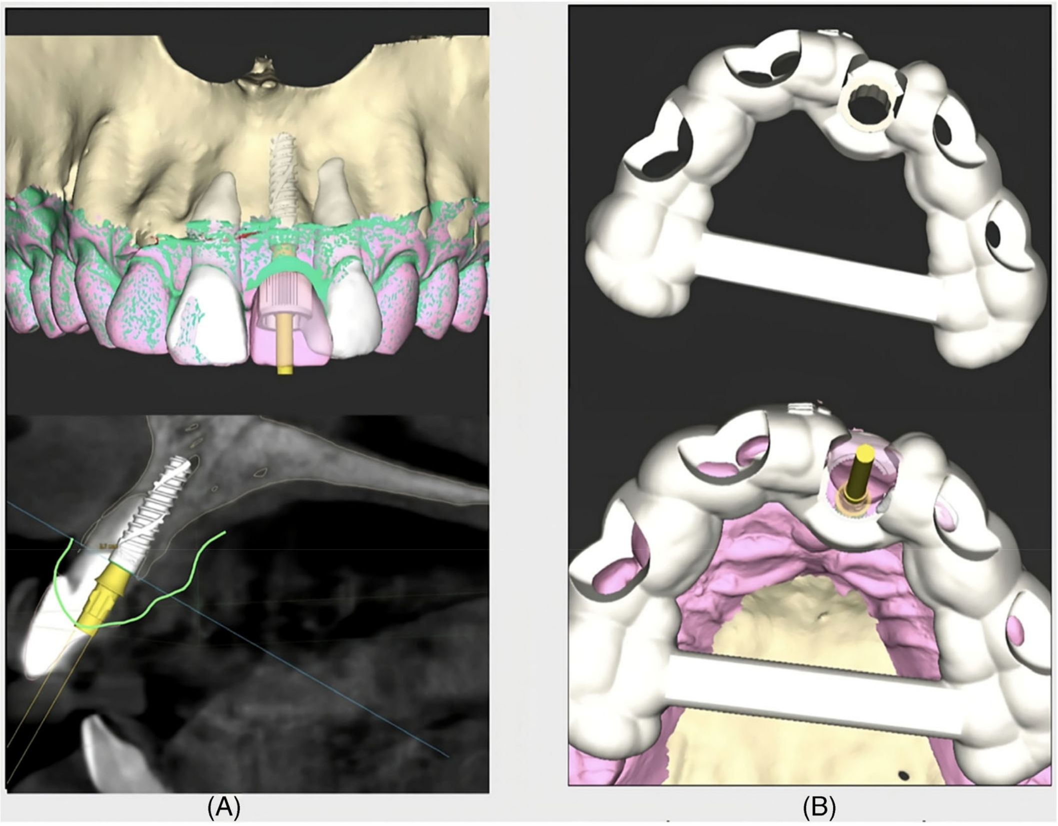

FIGURE 6 (A) Restorative and surgical planning. (B) Template design and export.

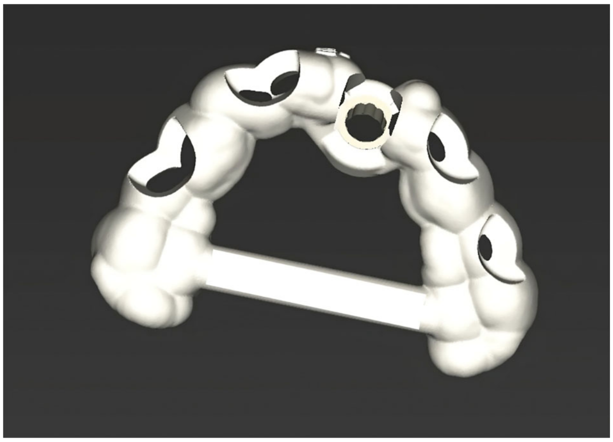

FIGURE 7 A digital design of a surgical template in the planning software.

adequate seating and to reduce the possibility for the template to be tilted and not seated adequately. However, too many inspection windows can weaken the surgical template and lead to its fracture.

When opting for immediate implant placement, it is recommended to virtually extract the tooth to provide a proper space for the surgical sleeve and to ensure the guide's correct design. In this sense, the template that will be designed over the modified STL/OBJ/PLY file will fit adequately in the patient's mouth after tooth extraction.

2.5 | Data preparation for manufacturing of surgical templates

Once the design is completed, the next step entails exporting the file containing the virtual prototype of the surgical template (Figure 8).

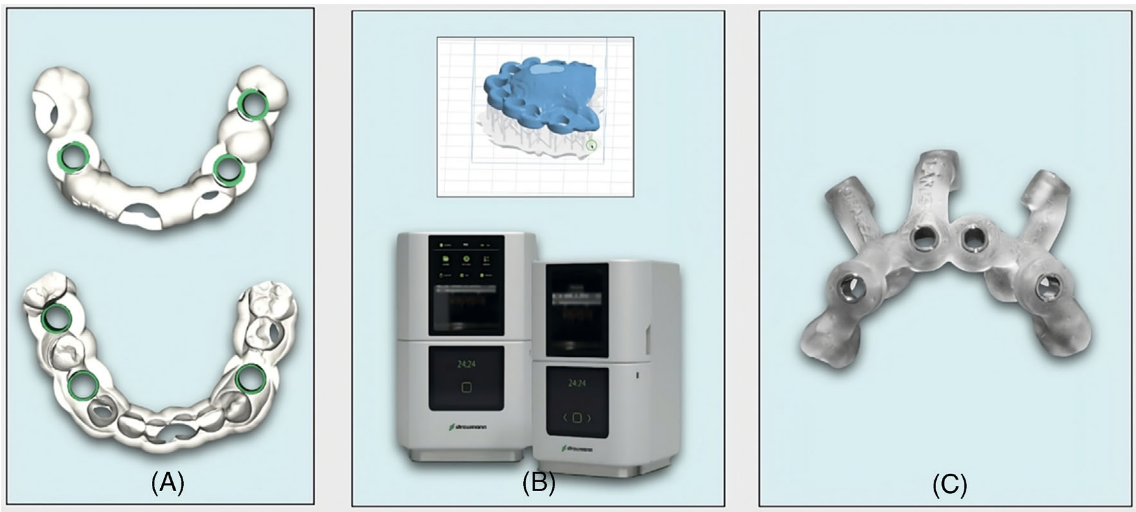

FIGURE 8 (A) Template design and export. (B) Template manufacturing. (C) Finished surgical template.

Many factors can influence the design and later the accuracy of surgical template fitting. The number of planned implants, type of support (tooth, mucosa, bone, or a combination), and type of retention (screws, pins, and mini implants).[4] A recent study has noted that mucosa- and tooth-supported templates are more precise when it comes to the transfer of implant position than those supported by the bone.[9] The position, fixation, and type of surgical template can also affect the accuracy of S-CAIS.[48] Moreover, the height and size of the sleeves, as well as the drill length, have an impact on the accuracy of guided implant placement. It has been shown that decreasing the sleeve height and drill length may contribute to reducing the angular deviation during drilling and implant placement.[14,49] The incorporation of inspection windows into the template design represents a significant step towards ensuring that a surgical template fits accurately. Inspection windows allow us to verify and check the fitting of the template, which takes place prior to the drilling procedure.[17] The recommendation is to position them bilaterally to the implant site in order to ensure

This file, which is usually obtained in an STL format, will then be imported to Computer-Assisted Manufacturing software (CAM) for 3D printing or milling.[50] In this phase, it is important to make sure that the planning software is calibrated to the printing/milling machine. Some types of planning software can output a sleeve calibration matrix which enables the operator to set the printing/milling offset for the fabrication process.

Computer-designed surgical templates can be milled out of a block or 3D-printed using biocompatible resins. The Committee of the American Section of the International Association for Testing Materials has named seven Additive Manufacturing (AM technologies) that are being used: stereolithography (SLA), material jetting (MJ), material extrusion (ME), or fused deposition modeling (FDM), binder jetting (BJT), powder bed fusion (PBF), sheet lamination (SL), and direct energy deposition (DED).[51] Most of the materials used for AM with dental purposes include binder/powder material combination and polymers (resins and thermoplastics).[52] Numerous factors such as the

FIGURE 9 Immediate postprocessing printed surgical template.

FIGURE 10 Intraoperative fitting of a surgical template.

laser speed, intensity angle, building directions, number of layers, shrinkage between the layers, amount of supporting material, and post-processing procedures can impair the accuracy of printed objects.[53–59] However, it has been demonstrated that the use of various 3D printing technologies does not have an influence on the 3D angle deviation and final implant position.[60]

After the printing is completed, surgical templates have to be treated following each specific material indication to achieve their definitive mechanical properties. When the SLA method is used, the UV polymerization of the resin is not fully finished. To remove the uncured resin a special post-processing protocol should be accomplished. This protocol usually includes cleaning in alcohol with an ultrasonic bath. After the cleaning, the object should be placed into a special light-curing chamber to ensure the maximum mechanical strength of the surgical template.[59] Some authors have suggested that surgical templates should be submerged in 70% ethanol for a minimum of 15 min or undergo sterilization using ethylene oxide gas to avoid deformation.[61]

Storage of surgical templates prior to surgery has also been studied and the use of wet-dry storage for no more than 30 days has demonstrated the best results in terms of reducing inaccuracies[62] (Figure 9).

2.6 | Static Computer- Aided Implant Surgery

Given the level of complexity of maxillary anterior implant restorations and the extensions of virtual planning options, it is highly recommended to place implants in the esthetic region by adhering to a fully guided protocol.[63] The advantages of guided implant placement have already been described, but clinicians should be aware that this procedure is not deprived of complications.[64]

The first step during guided implant surgery is an appropriate settlement of the surgical template (Figure 10).

To ensure proper retention and avoid template movement, additional fixation methods such as pins, or micro-screws can be utilized. At this point, anesthesia infiltration should be carefully performed by selecting an adequate localization in order to avoid soft tissue swelling in the template-supporting areas. Should this happen, it is recommended to wait for the tissues to restore their normal pre-procedural condition.[9]

As previously described, tooth-supported templates have shown the best implant accuracy. However, when the patient is fully edentulous, different supporting methods should be used and the retention systems will be different. In these situations, mucosa-supported and/or bone-supported templates are utilized. Whether the procedure is performed by elevating a mucoperiosteal flap or under a flapless approach, the lack of teeth for retention makes the use of accessory anchor pins necessary to immobilize the surgical template.[65]

As mentioned above, there are some variables to consider that are directly related to the accuracy of the surgery: decreasing the drilling distance to the surgical site (defined as the linear measurement from the bottom of the sleeve to the tip of the surgical drill) can increase the precision of implant placement[9,14]; using short drills, to avoid overusing or wearing drills and avoid bone overheating by using adequate irrigation during the whole drilling process, that is, using drills with internal irrigation if it is possible,[9] short sleeve height and longer drill key have shown better outcomes regarding accuracy in guided surgery.[14]

An unwanted lateral osteotomy during drilling can happen and this relates to the gap between the drill and the surgical sleeve defined as an "intrinsic error." This system tolerance can affect the accuracy and is proportional to the diameter difference between the drill, the drill tube of the handler, the external diameter of the tube handler, and the internal diameter of the sleeve and the drill length. However, reducing the diameter between these components can lead to mechanical friction and metal debris going into the surgical site.[9,66,67]

Performing S-CAIS in freshly extracted sockets can represent a challenge, mostly because designing of a surgical template in an area that will be modified after the extraction (Figures 11–13).

Moreover, prosthetically driven implant planning in areas where teeth are going to be extracted and where there is a lack of references for a virtual setup make it challenging to adequately plan the implants since a radiographic template cannot be tried in the patient's mouth. In these complex situations, the use of a modifiable radiographic template technique has been recommended.[68]

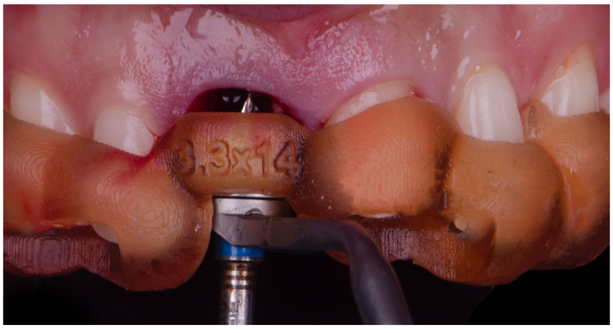

FIGURE 11 Computer-assisted osteotomy for immediate implant placement after tooth extraction.

FIGURE 12 Computer-aided implant placement after tooth extraction.

FIGURE 13 Implant in place after removal of the surgical template (Implant mount was positioned back to show the platform position).

FIGURE 14 One-year follow-up after definitive restoration delivery. Periapical x-ray shows bone tissue maintenance.

FIGURE 15 Before and after implant treatment in the esthetic zone.

One of the most common intraoperative complications is the fracture of the surgical template. As a preventive measure, clinicians should ensure a correct fit before the surgery to check whether the surgical template passively fitted and is thick enough (especially around the sleeves). Drill fractures or disintegration have also been described; to reduce this potential complication, it is recommended to insert the drill completely through the sleeve prior to its activation.[69]

Until today, the only contraindication described for the use of S-CAIS is the space limitation to place the surgical template and the use of S-CAIS instruments, most of all in patients with reduced oral aperture or when long instruments are used in posterior areas. Therefore, it is recommended to check available surgical space before starting the procedure.

In the current literature, the high accuracy of Static Computer-Aided Implant Surgery has been described.[9,12,14,70,71] The amount of relevant clinical information available in a digital environment contributes to the engagement of all the participants of the treatment and results in higher predictability and therefore prevention of later surgical and prosthetic complications (Figures 14 and 15).[9] Clinical

TABLE 1 Static computer-aided implant surgery clinical recommendations.

Data acquisition	CBCT	Remove jewelry, glasses, hair clips, and metal parts in the mouth which are not fixed. Put cotton rolls into the vestibule to move the lips and cheeks. The patient should minimize movements during scanning. Teeth out of occlusion.
	Intraoral scanning	Digital impression with an IOS Scan the conventional impression with laboratory scanner. Scan the plaster model with a Lab Scanner.
Data manipulation	Segmentation	Define the appropriate density threshold. Visualization of the bone and teeth. Manually erasing scatters (real anatomical structures should not be removed).
	Merging STL and DICOM files	Same anatomical structures (teeth or fiducial markers). Over four reference areas bilaterally. Check validation of the merging process.
Virtual planning		Various implant types and sizes. Multiple implants-paralleling tools. Implant in the correct 3D position. Virtual abutments. Design of the surgical template. Inspection windows on tooth-supported templates. Proper number, distribution, location, and inclination of anchor pins.
Exporting		Export STL file to printing/milling machine. Check the calibration of planning software and printing/milling unit.
Fabricating surgical templates		Additive manufacturing technologies. Post-processing protocol (cleaning, curing, etc.).
Static computer-aided implant surgery		Check the fitting of the template. Decrease drilling distance. Use shorter drills. Internal irrigation drills. Short sleeve height with longer drill keys.

Abbreviations: DICOM, Digital Imaging and Communications in Medicine; IOS, intraoral scanner; STL, Standard Tessellation Language.

indication and the use of a surgical template, lay the foundation for a flapless approach through which soft-tissue trauma and crestal bone resorption are minimized.[1] From a patient's standpoint, a digital treatment presentation simplifies the understanding of the procedure. The reduced operative time and absence of flap elevation and sutures (in the case of a flapless technique) mean less discomfort.[9,71] A significant decrease in postsurgical pain and swelling has been observed when the flapless S-CAIS had been used, with similar 1-year implant success and crestal bone loss compared to a freehand protocol.[9]

The disadvantages of guided implant surgery have also been described. The planning procedure is time-consuming, especially for inexperienced clinicians. During this process, numerous mistakes can occur which can then accumulate and lead to an unsuccessful surgical procedure. Therefore, it is highly recommended to follow the preceding steps accurately and obtain adequate training and surgical experience in this technique to ensure a predictable outcome (Table 1).[9]

3 | CONCLUSION

S-CAIS in the esthetic zone is a technique-sensitive procedure that contributes to an accurate prosthetically driven 3D implant position. Nonetheless, each step during this process should be thoroughly performed and carefully accomplished to avoid potential errors resulting in subsequent deviation of implant positioning or other surgical/prosthetic complications.

This review article has certain limitations related to the information available in the scientific literature. Available articles are heterogenous in their design and have been published over the years with different concepts changing in time and new software and applications emerging. Therefore, all of these concepts and recommendations should be updated in the following years.

CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

Research data not shared.

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