Solving Challenges in Static Computer-Assisted Guided Surgery for Posterior Open-End Situations

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This technical note serves as a practical guide for clinicians aiming to provide solutions to optimize the precision of static computer-assisted implant surgery (sCAIS) and the success of implant placement in free-end situations. Five methods are introduced for enhancing surgical guide stabilization and improving the accuracy of implant placements in situations lacking stabilizing adjacent teeth. These techniques include the use of keratinized soft tissues, implant-borne stabilizers, lateral fixation pins, transitional implants, and digital bone segmentation for guide support. Each method is evaluated for its potential to address the specific challenges faced in sCAIS, aiming to contribute to the field through practical solutions for clinicians. *Int J Oral Maxillofac Implants 2025;40:xxx-xxx. doi: 10.11607/jomi.11060*

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The integration of static computer-assisted implant surgery (sCAIS) has emerged as an important tool for ensuring the efficacy and accuracy of implant placement.[1] The correct positioning of implants in a 3D space, aligned with anatomical and prosthetic considerations, is crucial for avoiding potential biologic, technical, and mechanical issues.[2,3] The accuracy of implant placement is substantially enhanced with sCAIS.[4,5]

The accuracy of sCAIS is dependent on the support structures within the patient's oral cavity.[6] Notably, static templates supported by immobile teeth on both sides of the implantation site exhibit the highest degree of accuracy. At the same time, relying on soft tissue is less precise due to its inherent mobility.[7] In scenarios where implant sites lack the stabilizing support of adjacent teeth, the use of sCAIS becomes more challenging and intricate.[6,8,9] The loss of multiple teeth eliminates prosthetic references, making the situation more complex, particularly in distal open-end cases.[10]

This technical note serves as a practical guide for clinicians and aims to provide solutions to optimize the precision of sCAIS and the success of implant placement in free-end situations.

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CLINICAL TECHNIQUES

In addressing open-end scenarios during sCAIS, a range of solutions emerged in order to stabilize the surgical guide.

Keratinized Tissue Stop

The first proposed technique involves using the distal aspect of keratinized soft tissues as a physical stop for the surgical guide. In this way, the surgical guide is supported mesially on stable teeth and stabilized distally on the soft tissues (Fig 1). This method offers a simpler surgical template design and manufacturing process than other approaches. Considering existing literature linking soft tissue use to diminished stability due to mucosal mobility,[7] the amount of keratinized mucosa around and distal to the planned implant is of utmost importance. In the maxillary jaw, the tuberosity area can fulfill the role of stabilizer in the open-end distal aspect, whereas in the mandible the retromolar area can assume the stabilizing role. An additional strategy to enhance stability is using a flapless strategy for implant placement. This way a more extensive area of keratinized mucosa can be used to help stabilize the guide. However, a critical prerequisite for this method is the presence of a minimum of 2 mm of keratinized mucosa both buccally and orally to the implant shoulder in order to ensure implant health.[11] This is imperative as the mucosa covering the implant will be removed to facilitate the implant's placement.

Implant-Borne Stabilizers: Screw-Retained Implant Carriers or Screwed Template Pins

In clinical situation where multiple adjacent implants are planned to restore an open-end arch situation, the most mesial implant can be placed primarily and then

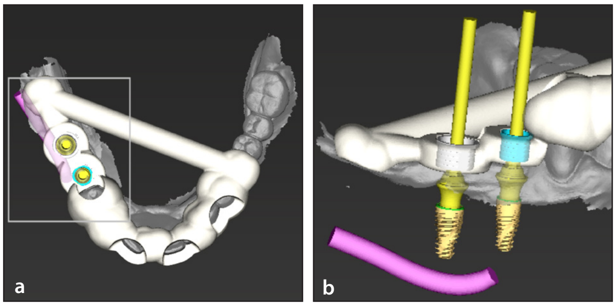

Fig 1 Keratinized tissue stop: A guide design using the distal aspect of the keratinized soft tissues as a physical stop for the surgical guide. *(a)* Image of the mandible with the guide in place. *(b)* Closer image of the *gray box* in *a* showing a lateral view of the setup. Note the usage of the horizontal stabilizing bar, which helps stabilize the guide without reducing the tongue space.

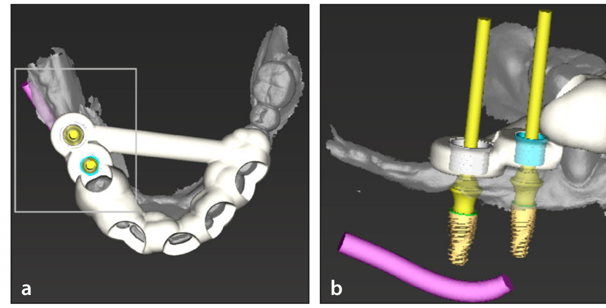

Fig 2 Implant-borne stabilizers: A guide design using the most mesial implant to assume the role of an anchor, contributing to the stabilization of subsequent implants situated more distally. *(a)* Image of the mandible with the guide in place. *(b)* Closer image of the *gray box* in *a* showing the lateral view of the setup.

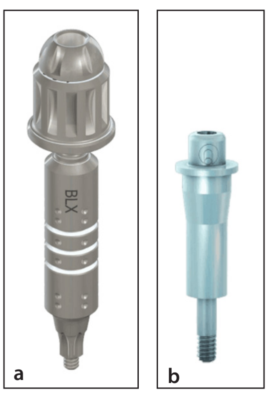

Fig 3 Implant-borne stabilizers: *(a)* An implant driver (BLX, Straumann)**[AU: Ok?]** with a built-in screw to stabilize the implant. *(b)* A dedicated implant-borne stabilizer using a vertical stop on the guide to further stabilize the guide.

assume the role of an anchor, contributing to the stabilization of subsequent implants situated more distally from the last remaining natural tooth (Figs 2 and 3). Various solutions exist for stabilizing surgical guides with implant-borne stabilizers; some systems use the implant-carrier as a stabilizer, which is screwed into the implant and—once the implant is placed—remains in place to prevent movement of the guide.[12] This method leverages the insertion torque achieved during implant placement. Alternatively, other systems allow stabilizers to be inserted into the implant after placement, which provides additional stability by using the guide as a vertical stop (see Fig 3).

Lateral Fixation Pins

This approach becomes more important in scenarios marked by a complete absence of keratinized mucosa or where keratinized mucosa is strictly localized around the implant site. In such cases, the introduction of a lateral fixation pin becomes a viable solution for achieving stabilization.[13] The workflow entails the fabrication of two surgical guides. An initial guide is used to drill the osteotomies for the lateral fixation pins. This guide does not have the sleeves for implant placement and can therefore use the entirety of available keratinized mucosa to facilitate the osteotomy for the lateral fixation pin (Fig 4). A subsequent second guide is also used to capture the same osteotomies for the lateral fixation pins to guide the implant placement (Fig 5). Even when the elevation of a mucoperiosteal flap is required, this approach provides a reliable form of distal stabilization.

Transitional Implants

This method involves the use of transitional screw implants, as described by Gallucci et al.[14] Note that this method mirrors the principle of the lateral fixation pins method. The initial placement of the transitional implant is through a flapless procedure that uses the complete keratinized mucosa (Fig 6). Following the successful placement of the transitional implant, a mucoperiosteal flap is elevated, and the transitional implant is picked up and incorporated in the surgical guide to provide stabilization. The placement of the transitional implant has an occlusal path of placement similar to a conventional dental implant, and the surgical osteotomy guide can be designed to be laterally open, which simplifies the procedure and creates space for potential bone graft procedures if necessary. The transitional implant can also be strategically used to provide patients with a provisional restoration, which can be a protective measure for the bone graft during the critical healing period.

Digital Bone Segmentation

This technique uses a distally positioned bony support as a vertical stop to stabilize the surgical guide. For this method, it is necessary to perform a digital segmentation of the patient's CBCT, which converts a DICOM data set (.dcm) into standard tessellation language data set (.stl). Using the distal aspect of the bone offers a robust stop to hold the surgical guide in place (Fig 7). This technique is especially valuable in scenarios where a traditional surgical guide with no additional tools may not offer sufficient stability or precision.

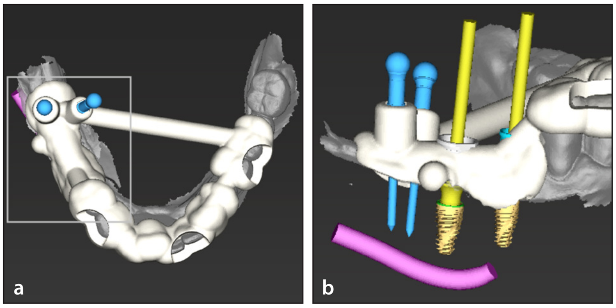

Fig 4 Lateral fixation pins: An initial guide using the entirety of the available keratinized mucosa to facilitate the osteotomy for the lateral fixation pin. *(a)* Image of the mandible with the guide in place. *(b)* Closer image of the *gray box* in *a* showing the lateral view of the setup.

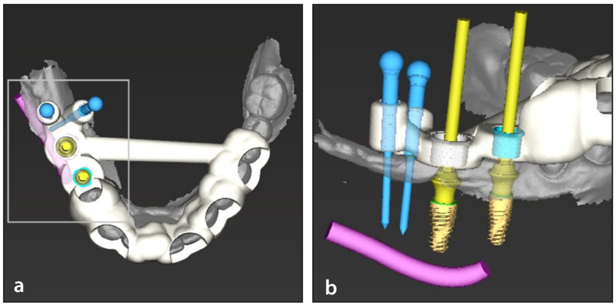

Fig 5 Lateral fixation pins: A subsequent second osteotomy guide capturing the lateral fixation pins helping to guide the implant placement.**[AU: Ok?]** *(a)* Image of the mandible with the guide in place. *(b)* Closer image of the *gray box* in *a* showing the lateral view of the setup.

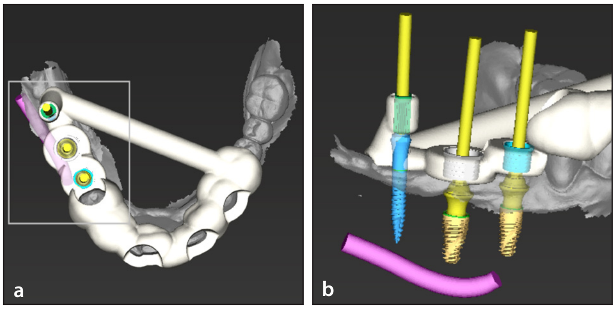

Fig 6 Transitional implants: A guide design using a transitional screw implant to stabilize the guide. *(a)* An implant driver with a built-in screw to stabilize the implant. *(b)* A dedicated implant-borne stabilizer using a vertical stop on the guide to further stabilize it.

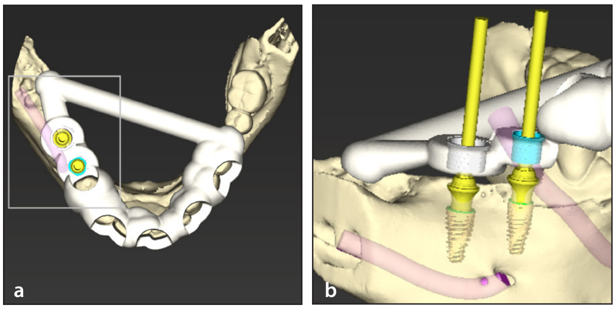

Fig 7 Digital bone segmentation: A guide design using a distally positioned bony support as a vertical stop for the surgical guide. *(a)* Image of the mandible with the guide in place. *(b)* Closer image of the *gray box* in *a* showing the lateral view of the setup.

DISCUSSION

Various approaches can be used to improve the stabilization of surgical guides in sCAIS in distal open-end scenarios. All proposed solutions have potential benefits and drawbacks, but all can be used in the right indication. The choice of a specific technical approach is therefore dependent on the individual clinical situation and the preferences of the clinician as all of them offer clinically acceptable accuracy.

Guides that are partially supported by the mucosa offer a straightforward and minimally invasive approach, making them a viable option, particularly in cases where additional stabilization devices are undesirable or impractical. However, deviations are more likely with these guides due to the mobile nature of soft tissues, which may shift under pressure.[7] The presence of keratinized tissues with high amounts of lamina propria could contribute to a more stable and less deformable environment.[15,16] Keratinized mucosa and its content in lamina propria not only stabilizes the guide to an acceptable extent but also ensures precise data capture, which is needed to manufacture a surgical guide.[17] Hence, as a general rule, tissues that can be accurately impressed—whether digitally or through traditional methods—can safely be used in the planning stages for designing a surgical guide.

Without keratinized mucosa or limited availability, different approaches using implant-borne stabilizers, fixation pins, or transitional implants can offer viable solutions.

Alternatively, lateral fixation pins have been shown to increase the stability of free-end situations in open-end scenarios.[18,13] These stabilization techniques compensate for the lack of ideal tissue conditions but also adapt to the specific anatomical nuances of each patient. The lateral fixation pins presented in this study are notably smaller and less sturdy compared to other options. Therefore, it is usually preferred to use multiple lateral fixation pins whenever feasible to ensure adequate stability. In contrast, transitional implants are recognized as more robust, allowing a single transitional implant to suffice for stabilizing the guide. These screw-form transitional implants specifically offer a dual advantage.[14] They serve as a reliable method for stabilizing the surgical guide, and additionally, the design of screw form transitional implants (placed occlusally rather than laterally) facilitates flap management and improves access to the surgical site. They can also be used as an option for immediate provisionalization, which not only benefits the patient but also can facilitate the bone graft integration during the healing period.

For the approach using digital bone segmentation, the accuracy of a guide partially stabilized by bone depends heavily on the segmentation of DICOM files from CBCT scans of the patient. This process, involving the segmentation of the bone structure, inherently lacks the precision achievable through intraoral scans.[19] Despite this, recent technologic advancements—particularly the introduction of AI-based automatic segmentation in planning software—have made this task more manageable and potentially more accurate.[20]

Regardless of the type of guide used, or even in cases where no guide is employed, thorough pre-planning of surgical procedures has been shown to significantly reduce the likelihood of complications.[21] The combination of a precise CBCT scan and an intraoral scan, integrated into the surgical planning software, provides clinicians with a comprehensive overview of the case.[22]

In considering these methods collectively, practitioners must weigh the advantages and constraints inherent in each approach. Selecting the most appropriate method hinges on the specific clinical context, patient anatomy, treatment objectives, as well as the clinicians expertise. In the authors' opinion, the keratinized mucosa stop is best suited for less experienced clinicians. It is not technique-sensitive, does not require the placement of additional fixtures or larger flaps, and provides a straightforward approach. The inclusion of implant-borne fixtures allows for a simple approach with one additional fixture that does not penetrate the patient's tissues but instead uses the implant acting like an abutment to stabilize the guide. These approaches reduce the overall invasiveness of the procedure and may help in improving patient related outcomes. On the other hand, the lateral fixation pin and transitional implant methods are better suited for more seasoned clinicians with a solid understanding of the surgical and technical aspects of guided surgery. The bone stop method is often favored by clinicians with extensive surgical experience who are comfortable with larger flaps, as it enhances visibility and access. However, patient related outcomes may be worse due to the larger extent of the surgery.

Furthermore, ongoing advancements in sCAIS technology and techniques may continue to refine and expand the array of options available to clinicians facing these open-ended situations.

This technical note provides innovative, practical solutions for surgical guide stabilization in sCAIS, focusing on distal open-end scenarios. It offers a comprehensive range of strategies, ensuring applicability in clinical practice. This study advances sCAIS technology by addressing specific challenges, benefiting clinicians through detailed guidance, and contributing significantly to the field's general growth. It is imperative to acknowledge that while these methods present valuable contributions to addressing challenges in sCAIS, they are not exhaustive, and further research is warranted. Comparative studies, long-term outcomes assessments, and broader clinical applications could provide additional insights into the efficacy and limitations of each method. As sCAIS continues to evolve, an adaptive and evidence-based approach to guide fabrication in open-ended situations will contribute to the refinement and optimization of implant placement procedures.

CONCLUSIONS

This technical note proposes five straightforward methods to address challenges in sCAIS in open-end situations. The first method uses soft tissues to stabilize the guide in the distal aspect, with the tooth supporting the guide in the mesial aspect, offering a minimally invasive approach. The second involves implant-borne guide stabilizers and uses the initial implant's proximity to the most distal tooth. Other solutions include lateral fixation pins or screw form transitional implants, as well as CBCT segmentation, which enables the clinician to use the bone as a distal stop for the static guide. This study's insights contribute to the accuracy improvement of sCAIS.

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