

Pitfalls in Guided Implant Surgery: A Case Series Highlighting Clinical Challenges, Complications and Preventive Strategies

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Abstract

Background: Guided implant surgery combines digital treatment planning, patient-specific surgical guide fabrication, and guided implant placement to improve the transfer of the virtually planned implant position to the clinical situation. Despite its advantages, guided surgery is not free from technical and clinical limitations, and errors may occur at different stages of the digital and surgical workflow.

Case Presentation: This case series presents three clinical situations demonstrating different challenges associated

with guided implant surgery. The observed pitfalls included pathological migration of a mobile tooth used for guide support, crestal bone resorption, and excessive guide height requiring modification for appropriate clinical adaptation. These cases illustrate how patient-related factors, anatomical limitations, guide design and fit, and clinician competency can influence the outcome of guided implant procedures. Appropriate amendments were undertaken according to the clinical problem, including guide modification and management of hard- and soft-tissue defects.

Conclusion: Guided implant surgery should not be considered an error-free technique. Thorough diagnosis, meticulous digital planning, verification of guide adaptation, appropriate case selection, and adequate clinician training are essential for minimizing complications and improving the predictability and safety of guided implant treatment.

Keywords: Guided Implant Surgery, Dental Implants, Surgical Guide, Digital Planning, Implant Complications, Clinical Pitfalls, Guided Implant Placement, Troubleshooting

Introduction

Dental implant therapy has evolved considerably with the incorporation of three-dimensional imaging, computer-aided treatment planning and computer-aided manufacturing technologies. Guided implant surgery enables the clinician to perform prosthetically driven virtual planning and subsequently transfer the planned implant position to the surgical field using a patient-specific surgical guide. The technique was developed to improve the predictability of implant placement with respect to three-dimensional position, angulation and depth, particularly in anatomically demanding and prosthetically critical situations.^{1,2}

The use of cone-beam computed tomography (CBCT), intraoral scanning and digital planning software has further facilitated the integration of anatomical and prosthetic information into a single virtual workflow. Surgical guides can subsequently be fabricated using computer-aided design and manufacturing techniques, including stereolithographic or three-dimensional printing technologies. This workflow allows the clinician to evaluate available bone, identify important anatomical structures and determine an implant position

based on the intended prosthetic outcome before surgery^{2,3}.

Computer-assisted implant surgery has demonstrated generally favourable accuracy compared with conventional freehand implant placement. Systematic reviews and meta-analyses have reported that although guided surgery provides clinically acceptable accuracy in most situations, deviations between the virtually planned and the surgically achieved implant positions remain unavoidable. Mean deviations of approximately 1–1.5 mm at the coronal and apical regions and angular deviations of approximately 3–4° have been reported across clinical studies^{4,5}. These deviations are clinically relevant because even relatively small discrepancies may become important when implants are placed close to vital anatomical structures, adjacent teeth or areas with limited bone volume.

Importantly, the accuracy of guided implant surgery depends not on the surgical guide alone but on the integrity of the entire digital workflow. Errors may be introduced during CBCT acquisition, impression making or intraoral scanning, image matching, virtual implant planning, guide designing, manufacturing, seating and fixation of the guide, osteotomy preparation and implant insertion^[6]. The accumulated effect of these individual discrepancies can result in a clinically significant difference between the planned and actual implant position. The choice of guide-supporting structures, number and location of supporting teeth, guide stability and fixation, implant site and surgical approach may also influence the final accuracy^{7,8}.

Although guided surgery is often perceived as a highly precise and relatively straightforward technique, clinical studies have demonstrated that it does not eliminate surgical risks or unexpected events. Reported problems

include inadequate guide seating, guide instability or fracture, restricted mouth opening and interocclusal space, difficulties with drill movement, inadequate primary implant stability, the need for additional grafting and deviation from the original treatment plan^{3,9}. In a review of stereolithographic surgical guides, substantial discrepancies between planned and achieved implant positions were reported, together with procedure-related surgical and prosthetic complications⁹. Similarly, a systematic review of computer-guided implant placement found that procedure-linked adverse events can occur despite the use of guided techniques, emphasizing that the clinical demands on the surgeon are not necessarily reduced¹⁰.

The accuracy of guided surgery may also be affected by factors related to guide support and the local anatomy. Studies have shown that the number and location of teeth supporting a surgical guide can influence implant placement accuracy, with distal-extension situations and extraction sockets presenting additional challenges⁷. Guide fixation has also been identified as an important determinant of accuracy, particularly when guide movement can occur during osteotomy preparation or implant insertion⁸. Furthermore, limitations in the digital planning software, errors in image acquisition and registration, and inadequate understanding of the software and surgical system by the operator can compromise the intended treatment outcome⁶.

The clinical implications of these limitations are particularly important because the apparent precision of a digitally planned procedure may create a false sense of security. Guided surgery should therefore be regarded as an aid to, rather than a substitute for, sound clinical judgment, comprehensive diagnosis and appropriate surgical expertise. Careful assessment of the surgical

site, verification of the guide's fit and stability, appropriate selection of guide support, confirmation of the virtual plan and awareness of the limitations of the guided system are essential for safe clinical practice⁹.

The present case series highlights clinically encountered pitfalls during guided implant surgery and demonstrates how apparently predictable digital workflows can be affected by anatomical, technical, guide-related and operator-related factors. The cases also illustrate practical modifications and troubleshooting measures that may help clinicians recognize potential problems early and prevent avoidable complications. The purpose of presenting these cases is therefore not to question the usefulness of guided implant surgery, but to emphasize the importance of understanding its limitations and the need for meticulous planning and execution.

Aim and objectives:

Aim

To describe and critically highlight the clinical pitfalls encountered during guided implant surgery, their contributing factors, and practical strategies for prevention and management.

Objectives

1. To identify the common clinical and technical pitfalls encountered during guided implant surgery.
2. To describe the complications and challenges observed in selected cases undergoing guided implant placement, including problems related to guide fit, tooth-supported guide stability, ridge anatomy, crestal bone changes, and guide modification.
3. To analyse the potential sources of error associated with guided implant surgery, including software-related, hardware-related, anatomical, patient-related, surgical, clinician-related and human factors.

Materials and Methods

Study design and setting

A descriptive clinical case series was conducted to document and analyse the clinical pitfalls encountered during guided implant surgery and the measures undertaken to overcome them. The series comprised three consecutively managed clinical cases in which guided implant surgery was planned using digital diagnostic and treatment-planning protocols.

The cases were selected because they demonstrated clinically relevant challenges encountered during different stages of guided implant treatment, including patient assessment, digital planning, surgical-guide fabrication and adaptation, intraoral guide positioning, implant placement, and postoperative evaluation. The purpose of documenting these cases was not to compare treatment modalities, but to identify potential sources of error and describe their clinical consequences and corrective measures.

Patient selection

Patients requiring dental implant rehabilitation and considered suitable for guided implant surgery were evaluated clinically and radiographically. The cases included in the present series were those in which a specific technical or clinical difficulty was encountered during the guided implant workflow and for which adequate clinical documentation was available.

Patients underwent routine clinical assessment before implant treatment. Particular attention was given to the condition of the dentition, periodontal status, available edentulous ridge, soft-tissue condition, occlusal relationships, and the suitability of teeth or other anatomical structures for supporting the surgical guide.

The source material particularly emphasizes the importance of assessing the ridge before implant

placement, especially in the mandibular anterior region, and ensuring that teeth used to support the guide are periodontally adequate.

Preoperative clinical assessment

A comprehensive clinical examination was performed before digital treatment planning. The assessment included:

- Evaluation of the edentulous site and available ridge dimensions.
- Assessment of the buccolingual and mesiodistal dimensions of the ridge.
- Evaluation of the quality and quantity of keratinized and attached gingival tissue where relevant.
- Assessment of adjacent teeth and their periodontal status.
- Evaluation of occlusion and interarch space.
- Identification of mobile or periodontally compromised teeth that could interfere with guide stability.
- Assessment of the patient's ability to tolerate the surgical guide intraorally.
- Evaluation of oral hygiene and identification of factors that could adversely affect implant treatment.

Adequate oral hygiene was considered an important prerequisite for predictable treatment. Periodontally weak or mobile teeth were not considered reliable support structures for a surgical guide and were evaluated for appropriate management before surgery.

Radiographic and digital assessment

Three-dimensional radiographic assessment was performed using cone-beam computed tomography (CBCT) as part of the digital implant planning workflow. The radiographic data were evaluated to assess the available bone volume and the relationship of

the planned implant site to relevant anatomical structures.

The quality of the CBCT data and the dimensional and positional accuracy of the radiographic dataset were considered important components of the guided surgery workflow. Poor image quality or inaccuracies in CBCT acquisition may subsequently affect virtual implant positioning and the accuracy of surgical-guide fabrication.

Where applicable, intraoral impressions or intraoral scanning were used to obtain the patient's dental surface anatomy. Accurate acquisition of the intraoral surface data was considered essential for subsequent digital integration and fabrication of the surgical guide.

Digital treatment planning

The digital treatment-planning workflow consisted of integration of the patient's three-dimensional radiographic information with the dental surface data. The virtual implant position was planned according to the available bone, prosthetic requirements, anatomical limitations and intended implant position.

The virtual plan was used to determine the proposed:

- Implant position;
- Implant angulation;
- Implant depth;
- Implant dimensions where applicable; and
- Relationship of the implant to adjacent anatomical structures.

Guided implant surgery aims to reproduce the planned implant position intraoperatively in terms of **position, angulation and depth** through the use of a patient-specific surgical guide.

Particular attention was paid to the limitations and accuracy of the planning software because errors introduced during virtual planning may subsequently be

transferred to the surgical procedure. The source material identifies improper or inadequate virtual implant positioning as one of the important risks associated with guided implant surgery.

Surgical-guide fabrication and verification

Patient-specific surgical guides were fabricated according to the digitally planned implant position. Depending on the clinical requirement, guides may be produced using laboratory models, computer-aided design/computer-aided manufacturing procedures, milling, digital printing, or stereolithographic techniques.

Before surgery, the guide was examined for:

1. Adequate adaptation to the supporting structures;
2. Stability during intraoral positioning;
3. Absence of interference with adjacent teeth or soft tissues;
4. Appropriate access for the guided surgical instruments;
5. Adequate guide extension and height; and
6. Structural integrity of the guide.

The clinical cases demonstrated that guide design and adaptation could present important practical problems. In one case, the guide required trimming because excessive guide height interfered with appropriate positioning and adaptation.

Assessment of guide support and stability

The supporting anatomy of the surgical guide was assessed immediately before surgery. Particular attention was paid to the condition of teeth used for tooth-supported guides and to the stability of the guide during intraoral positioning.

Potential sources of instability included mobile or periodontally compromised teeth, inadequate ridge

anatomy, improper guide adaptation, and limitations imposed by patient-specific intraoral anatomy.

Where necessary, modification of the guide was performed to achieve appropriate seating and stability before proceeding with implant osteotomy.

Guided implant surgical procedure

After completion of the preoperative assessment and verification of the surgical guide, guided implant surgery was performed according to the digitally planned implant position.

The surgical guide was positioned intraorally and its seating and stability were verified before osteotomy preparation. The osteotomy was subsequently prepared using the appropriate guided surgical instrumentation according to the implant system and the digitally planned implant position.

The surgical guide was intended to transfer the planned implant position to the patient and guide the osteotomy with respect to the predetermined implant position, angulation and depth.

Where guide instability, inadequate adaptation, excessive guide dimensions, or other procedural limitations were identified, the problem was addressed before continuing the procedure whenever clinically feasible.

Identification and classification of pitfalls

For systematic analysis, the problems encountered in the three cases were classified according to their likely source. The classification included:

- **Software-related errors:** errors associated with digital planning, virtual implant positioning or limitations in planning software.
- **Hardware-related errors:** problems associated with digital hardware, surgical instrumentation or guide-related components.

- **Guide-related errors:** inadequate guide adaptation, excessive dimensions, fracture or instability.
- **Anatomical factors:** limitations related to arch anatomy, ridge morphology, available bone and the position of critical anatomical structures.
- **Patient-related factors:** restricted intraoral access, limited mouth opening or other anatomical and behavioural limitations.
- **Surgical/procedural factors:** difficulties arising during guide positioning, osteotomy preparation or implant placement.
- **Clinician-related factors:** limitations in knowledge, competency, experience or familiarity with guided surgery.
- **Human errors:** errors occurring at any stage of data acquisition, digital planning, guide fabrication, guide positioning or surgical execution.

These categories correspond to the principal problem areas identified in the source material.

Documentation of complications and corrective measures

Each case was reviewed from the preoperative stage through implant placement and postoperative assessment. The following parameters were documented:

1. Planned guided implant procedure;
2. Specific pitfall or deviation encountered;
3. Stage of the workflow at which the problem was identified;
4. Probable contributing factor;
5. Clinical consequence of the problem;
6. Immediate corrective or modifying measure undertaken;
7. Postoperative outcome; and
8. Preventive strategy applicable to future cases.

The three cases demonstrated different forms of clinical difficulty.

These included pathological mobility/migration of a tooth used in relation to the guide, crestal bone resorption requiring subsequent management, and excessive guide height requiring trimming for proper fit.

Postoperative assessment

Patients were clinically reviewed following implant placement. Postoperative clinical and radiographic findings were documented where available. In cases demonstrating postoperative hard- or soft-tissue defects, appropriate clinical management was undertaken.

The presentation documents postoperative CBCT assessment in one case and the use of **platelet-rich fibrin (PRF) and connective tissue grafting (CTG)** for management of a crestal defect.

Troubleshooting and preventive protocol

Based on the problems encountered during the three cases, a practical troubleshooting approach was developed. The following measures were emphasized:

- Acquisition of an accurate impression or intraoral scan;
- Careful assessment of the alveolar ridge, particularly in anatomically challenging regions;
- Evaluation of the periodontal stability of teeth used to support the guide;
- Removal or management of periodontally compromised supporting teeth when clinically indicated;
- Maintenance of good oral hygiene;
- Verification of CBCT image quality;
- Verification of the accuracy of virtual implant positioning;
- Verification of complete guide seating before osteotomy;

- Assessment of guide stability before surgical drilling;
- Appropriate fixation of the guide where required; and
- Awareness of the limitations of the digital planning system and the clinician's level of experience.

The source material specifically recommends appropriate fixation, including fixation with mini-screws where indicated for mucosa- or bone-supported guides, to improve guide stability.

Outcome assessment

The principal outcome of this case series was the **identification and description of clinically relevant pitfalls associated with guided implant surgery**.

Secondary observations included:

- Type and source of the encountered pitfall;
- Stage at which the problem occurred;
- Effect on guide stability or implant placement;
- Need for guide modification or additional intervention;
- Postoperative tissue or implant-related consequences; and
- Corrective and preventive measures that could reduce recurrence of similar problems.

As this was a descriptive case series, **no formal statistical comparison or hypothesis testing was planned**. The cases were analysed individually and collectively to identify recurring technical and clinical themes.

Ethical considerations

The study should be conducted in accordance with the principles of the Declaration of Helsinki. Institutional Ethics Committee approval and/or exemption, as applicable to a retrospective or prospective case series, should be obtained before manuscript submission.

Written informed consent for treatment and publication of anonymized clinical photographs and radiographs should be obtained from each patient.

Results

Three clinical cases involving guided implant surgery were evaluated to identify procedural pitfalls, their likely contributing factors, clinical consequences, and corrective measures. The cases demonstrated that although guided implant surgery facilitates digitally

planned implant placement, successful clinical execution depends on accurate diagnosis, appropriate guide design and fit, adequate support and stabilization, careful assessment of the residual ridge, and clinician competency. The principal problems identified included pathological migration of a mobile tooth used for guide support, crestal bone resorption, and inadequate guide dimensions requiring intraoperative modification.

Table 1: Clinical characteristics and principal pitfalls identified in the three guided implant surgery cases

Case	Principal clinical situation	Pitfall identified	Major contributing factor	Clinical implication
Case 1	Guided implant surgery using tooth-supported guidance	Pathological migration of a mobile tooth	Use of a periodontally compromised/mobile tooth as guide support	Potential alteration of guide position and deviation from the planned implant position
Case 2	Guided implant placement with assessment of the alveolar ridge	Crestal bone resorption	Local ridge/crestal bone deficiency associated with the implant site	Compromised peri-implant hard-tissue support requiring additional management
Case 3	Guided implant placement requiring adaptation of the surgical guide	Excessive guide height requiring trimming for proper fit	Inadequate guide dimensions/clinical adaptation and limitations related to clinician competency	Difficulty in achieving appropriate guide seating and stable surgical guidance

The three cases demonstrated different categories of pitfalls during guided implant surgery. Case 1 highlighted the importance of selecting stable and periodontally sound structures for guide support. Case 2 demonstrated that the availability and quality of alveolar

bone remain important determinants of the clinical outcome despite digital planning. Case 3 emphasized the importance of proper guide design, dimensions, clinical fit, and operator competency.

Table 2: Case-wise advantages of guided implant surgery and corresponding clinical pitfalls

Case	Expected advantage of guided surgery	Pitfall observed	Effect on the expected advantage
Case 1	Comprehensive diagnosis and treatment planning; reduced risk of injury to critical	Migration of a mobile tooth	Guide stability and positional accuracy may be compromised

	anatomical structures; reduced operating time	supporting the guide	
Case 2	Flapless placement; preservation/use of available alveolar bone; possibility of optimal implant dimensions and angulation	Crestal bone resorption	The anticipated benefit of optimal implant placement may be limited by local hard-tissue deficiency
Case 3	Comprehensive planning; reduced operating time; avoidance of flap elevation and suturing	Excessive guide height requiring trimming	Additional chairside modification was required before satisfactory guide adaptation

The cases illustrate an important distinction between the theoretical advantages of guided implant surgery and their actual clinical realization. The presentation identified several expected benefits, including comprehensive treatment planning, reduced risk to critical anatomical structures, reduced operating time, flapless surgery, and avoidance of flap elevation and suturing. However, these benefits can be undermined by errors in guide support, local anatomy, guide design, or clinical execution.

Table 3: Identified sources of error and their potential clinical impact

Category of potential error	Examples relevant to guided implant surgery	Potential clinical impact
Software-related errors	Inaccurate virtual planning or inappropriate implant positioning	Deviation from the intended implant position
Hardware-related errors	Problems involving imaging, scanning or guide-production systems	Reduced accuracy of transfer of the virtual plan to the patient
Anatomical factors	Complex arch anatomy, ridge morphology and limited alveolar dimensions	Difficulty in guide seating and achieving the planned implant position
Patient-related factors	Intraoral limitations and inadequate clinical conditions	Difficulty in obtaining accurate records and stable guide positioning
Surgical/procedural factors	Limitations during guide placement or osteotomy preparation	Intraoperative deviation from the planned procedure
Clinician-related factors	Inadequate knowledge, experience or familiarity with guided surgery systems	Incorrect handling, positioning or modification of the guide
Human errors	Errors during diagnosis, planning, guide handling or surgical execution	Cumulative reduction in treatment accuracy and predictability

The analysis of the cases, together with the problems identified in the presentation, indicates that errors in guided implant surgery are multifactorial rather than exclusively technology-related. Software and hardware limitations may interact with anatomical constraints, patient-related limitations, procedural difficulties and operator competency.

Table 4. Corrective measures and amendments undertaken in the reported cases

Case	Problem encountered	Corrective/amendment measure	Purpose
Case 1	Pathological migration of a mobile tooth	Amendment of the guide/supporting arrangement	To restore appropriate guide positioning and stability
Case 2	Crestal bone resorption	Assessment using pre- and post-implantation CBCT; PRF and connective tissue grafting were used to manage the defect	To assess the hard-tissue changes and address the associated tissue defect
Case 3	Excessive guide height causing difficulty in proper fitting	Trimming/modification of the surgical guide	To achieve appropriate clinical adaptation and seating of the guide

Discussion

Guided implant surgery has transformed implant treatment by allowing prosthetically driven three-dimensional planning and transfer of the planned implant position to the surgical field. The technique integrates clinical examination, three-dimensional radiographic imaging, digital planning and fabrication of a patient-specific surgical guide. Although guided surgery is frequently associated with improved precision and predictability, it should not be considered an error-free technique. The present case series highlights several practical pitfalls that may occur despite digital planning and emphasizes that the final clinical outcome depends on the accuracy of every step in the digital workflow as well as on appropriate clinical judgement.

The most important finding emerging from the present cases is that **digital planning does not necessarily translate into accurate clinical execution**. The transfer from the virtual environment to the patient's mouth is influenced by multiple factors, including image quality, accuracy of registration, guide design, guide support and stability, implant drilling protocol, available surgical access and operator experience. Van Assche et al. reported mean deviations of approximately 0.99 mm at the implant entry point, 1.24 mm at the apex and 3.81° in

angular deviation in their analysis of computer-guided implant placement, demonstrating that clinically relevant discrepancies can persist even with guided surgery¹¹. Similar deviations have subsequently been demonstrated in clinical studies, reinforcing the need to maintain an appropriate safety margin around critical anatomical structures⁴.

Guide stability and support

One of the major issues demonstrated in the present cases is inadequate or compromised guide adaptation and stability. A surgical guide can only reproduce the virtual plan if it remains in a stable and predetermined position throughout osteotomy preparation and implant insertion. Any movement of the guide may result in cumulative deviation from the planned implant position. Clinical evidence supports the importance of guide support. Ozan et al., in a clinical study evaluating 110 implants placed using stereolithographic surgical guides, demonstrated that the accuracy of implant placement was influenced by the type of guide support, with tooth-supported guides providing greater accuracy than other support types¹². Similarly, Behneke et al., in 52 partially edentulous patients receiving 132 implants, found that the number and distribution of remaining teeth influenced transfer accuracy¹³. These observations are

particularly relevant to cases in which a guide is supported by a limited number of teeth or by periodontally compromised teeth.

In the present case series, the problem of using an unsuitable or mobile supporting tooth illustrates an important practical principle: the clinical reliability of a guide is only as good as the stability of its supporting structures. A tooth that is mobile, periodontally compromised or otherwise unsuitable for supporting the guide may permit micromovement during drilling. Therefore, careful assessment of the dentition and periodontal condition should precede guide fabrication. Where necessary, compromised teeth should be treated or removed before the guide is designed. This is consistent with the troubleshooting recommendations presented in the current case series, which emphasize proper impression or intraoral scanning, ridge assessment and removal of periodontally weaker teeth when they are intended to support the guide.

Accuracy is influenced by guide design and surgical technique

Another important consideration is that different components of the guided surgical system can contribute to cumulative error. The guide itself, the sleeve, the drill, the implant carrier and the relationship between these components may introduce small discrepancies. Van Assche and Quirynen demonstrated experimentally that tolerance within the surgical guide can contribute to positional inaccuracies and emphasized the importance of maintaining the drill in an appropriate position within the guide sleeve¹⁴.

The height and geometry of the guide are also clinically important. In one of the cases presented in this series, excessive guide height interfered with clinical access and required modification by trimming. Although

modification may be necessary in selected situations, excessive alteration of a prefabricated guide should be approached cautiously because inappropriate modification can compromise its stability or the intended relationship between the guide and the drilling system. Thus, guide design should consider not only the virtual implant position but also the patient's mouth opening, soft-tissue anatomy, access for instrumentation, sleeve height and the dimensions of the surgical instruments.

The importance of complete rather than partial guidance

The present observations also reinforce the distinction between fully guided and partially guided implant placement. When only the initial osteotomy is guided and subsequent drilling or implant insertion is performed freehand, errors introduced during the later stages may not be corrected by the initial guide.

A clinical study by Vercruyssen et al. demonstrated that different guided surgery protocols can produce different levels of accuracy and emphasized that deviations should be anticipated even with computer-assisted surgery¹⁷. Similarly, clinical data from Behneke et al. showed that guided implant placement through the template produced a more accurate transfer of the virtual plan than freehand insertion or freehand final drilling¹³.

Therefore, where clinical circumstances permit, a fully guided protocol may offer greater control over the planned implant position. However, this should not be interpreted as eliminating the need for clinical judgement. The surgeon must still verify that the guide is completely seated, stable and compatible with the patient's anatomy before commencing osteotomy preparation.

Anatomical limitations remain important

Guided surgery may improve the precision of implant positioning but does not eliminate anatomical limitations. The present case series includes a situation involving crestal bone resorption requiring subsequent management with regenerative procedures. This highlights an important distinction between accuracy of implant placement and biological success of implant therapy.

A digitally planned implant can be positioned accurately relative to the virtual anatomy, yet the biological environment may still be inadequate for optimal peri-implant tissue stability. Thin buccal plates, reduced ridge width, inadequate soft-tissue volume and pre-existing bone defects may remain clinically relevant despite accurate implant positioning. Consequently, CBCT assessment should not merely be used to determine the implant trajectory but should also be used to evaluate available bone volume, anatomical limitations and the need for augmentation before implant placement.

This is particularly important in aesthetically sensitive regions and in areas with narrow ridges. A guided approach should therefore be regarded as a planning and transfer technology rather than a substitute for biological assessment.

CBCT and digital planning errors

The accuracy of guided surgery begins with the accuracy of the diagnostic dataset. Poor-quality CBCT imaging, inadequate field selection, artefacts and errors during image registration may subsequently be incorporated into the digital treatment plan. The present presentation specifically identifies poor image quality and dimensional/positional inaccuracies in CBCT, together with inappropriate virtual implant positioning, as important risks.

Behneke et al. demonstrated that several patient- and procedure-related factors can influence the accuracy of transfer from CBCT-based planning to the surgical site^[13]. Consequently, careful acquisition of CBCT images and accurate integration of the patient's intraoral or model-based information are fundamental to the reliability of the final guide.

The clinician should also recognise that a digitally generated implant position may be technically correct within the software but clinically inappropriate if the underlying anatomical information is inaccurate or incomplete. Virtual planning should therefore always be subjected to a final clinical review before guide fabrication.

Flapless surgery: advantage but also a potential limitation

Guided surgery is frequently used to facilitate flapless implant placement. Avoidance of flap elevation may reduce surgical morbidity and can improve postoperative comfort in appropriately selected cases. However, flapless surgery also limits direct visualization of the alveolar ridge. This creates a potential discrepancy between the digitally reconstructed anatomy and the actual intraoperative anatomy.

The clinical literature indicates that flapless guided surgery can achieve satisfactory transfer accuracy when appropriate planning and guide stability are maintained^[9,13]. However, the absence of direct visualization means that the clinician must have high confidence in the preoperative anatomical assessment. In cases with uncertain ridge morphology, inadequate bone width, severe undercuts or unexpected anatomical findings, raising a flap may provide valuable information and permit appropriate modification of the treatment plan.

Thus, the objective should not be to perform every guided implant procedure flaplessly, but rather to select the surgical approach according to the patient's anatomy and clinical requirements.

Operator competency and the learning curve

An important message from the present cases is the role of clinician competency. The presentation specifically identifies the level of competency and knowledge of the clinician as a potential source of error. Guided implant surgery requires familiarity with digital planning software, CBCT interpretation, guide verification, surgical instrumentation and the limitations of the specific guided system.

Digital technology may reduce some operator-dependent errors, but it does not eliminate them. In fact, unfamiliarity with the software or guided instrumentation may introduce new types of errors. The clinician must understand how the virtual plan is translated into the physical guide and how deviations may occur at each stage.

Training should therefore include not only software use but also interpretation of CBCT images, recognition of inadequate guide seating, verification of guide stability, understanding of sleeve and drill tolerances, and appropriate management when the guide does not fit as expected.

Human errors and the need for verification

The occurrence of human error is particularly important because guided implant surgery involves a chain of interdependent steps. Errors may occur during impression taking or intraoral scanning, CBCT acquisition, image matching, virtual planning, guide design, manufacturing, guide seating and surgical execution. A small error at an early stage may be carried forward into subsequent stages.

The cases presented in this series illustrate the value of identifying problems before implant placement rather than after the osteotomy has been completed. Verification of the guide intraorally, confirmation of complete seating and assessment of stability should therefore be considered essential safety steps. If the guide does not seat completely or is unstable, the procedure should be reassessed rather than proceeding simply because the digital plan has already been completed.

Guided surgery should not replace surgical judgement

The central clinical implication of this case series is that guided implant surgery should be considered an adjunct to, rather than a replacement for, sound surgical judgement. Computer-assisted surgery can improve the transfer of a treatment plan, but clinically significant deviations remain possible. Tahmaseb et al. reported pooled mean deviations of approximately 1.2 mm at the entry point, 1.4 mm at the apex and 3.5° in angulation across clinical studies of static computer-assisted implant surgery⁴. These values demonstrate why adequate safety margins remain essential, particularly when implants are planned close to nerves, the maxillary sinus, adjacent roots or other critical structures.

The clinician must therefore be prepared to abandon or modify the guided protocol if intraoperative findings contradict the digital plan. A guide should never be allowed to create a false sense of security.

Practical implications of the present case series

The cases presented in this manuscript provide several practical lessons. First, accurate digital planning is necessary but insufficient for accurate implant placement. Second, guide stability and appropriate support should be verified before drilling. Third, the

supporting teeth and surrounding ridge should be carefully assessed before guide fabrication. Fourth, guide dimensions should allow adequate surgical access without compromising stability. Fifth, the clinician should understand the limitations of the specific software, guide system and instrumentation. Finally, adequate safety margins should always be maintained around critical anatomical structures.

The present case series therefore supports a “verify before you drill” approach to guided implant surgery. A systematic preoperative and intraoperative checklist incorporating CBCT quality, digital planning, guide adaptation, support, stability, access, drill–sleeve compatibility and anatomical safety margins could potentially reduce preventable errors.

Strengths and limitations

The main strength of this report is its practical clinical focus on problems encountered during guided implant surgery and the corresponding corrective strategies. Rather than presenting guided surgery solely in terms of its advantages, the cases draw attention to situations in which digital planning may fail to achieve the intended clinical outcome. However, as a case series, the findings cannot be used to estimate the incidence of individual complications or establish comparative effectiveness. The cases are illustrative and hypothesis-generating rather than representative of all guided implant procedures. Further prospective clinical studies with standardized definitions of guide-related complications and quantitative assessment of planned versus actual implant positions would be valuable.

Conclusion of the discussion

Overall, the present case series demonstrates that guided implant surgery offers substantial advantages in treatment planning and implant positioning but remains

susceptible to technical, anatomical, procedural and human errors. The most important determinants of success are accurate diagnostic data, appropriate digital planning, adequate guide support and stability, proper guide design, competent surgical execution and continuous clinical verification. Guided surgery should therefore be viewed as a precision-enhancing technology rather than an error-proof technique. Recognition of its limitations and early identification of potential pitfalls are essential for achieving predictable and safe implant treatment.

Conclusion

Guided implant surgery offers significant advantages in treatment planning and implant placement by facilitating the transfer of virtually planned implant positions to the clinical setting; however, it should not be considered an error-free or completely predictable procedure. The cases presented demonstrate that complications may arise from inadequate preoperative assessment, limitations in CBCT and digital planning, improper guide design or fit, anatomical variations, instability of the supporting structures, and clinician-related or human errors. Careful patient selection, accurate impressions or intraoral scanning, thorough assessment of ridge anatomy, appropriate virtual planning, verification of guide adaptation and stability, and adequate clinician training are essential to minimise these pitfalls. Early recognition of technical and clinical problems, together with appropriate troubleshooting and corrective measures, can improve the safety, accuracy and predictability of guided implant surgery. Thus, successful guided implant treatment depends not only on digital technology but also on sound clinical judgement, meticulous planning and appropriate surgical expertise.

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