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Review Article

Computer-Assisted Immediate Implant Placement: From Static Surgical Guides to Dynamic Navigation: A Mini Review

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Abstract

Immediate implant placement has become an important treatment option in contemporary implant dentistry because it can reduce treatment time, preserve the peri-implant soft tissue contour, and improve patient acceptance. However, placing an implant into a fresh extraction socket is technically demanding. The irregular socket anatomy, thin facial plate, and tendency of the drill to deviate toward the path of least resistance may compromise the planned implant position. For this reason, computer-assisted implant surgery has gained increasing importance, particularly in esthetic and anatomically sensitive areas. Static computer-assisted implant surgery uses a preoperatively fabricated surgical guide to transfer the virtual implant plan to the patient, while dynamic navigation provides real-time visual guidance during drilling and implant insertion. Both systems aim to improve the accuracy of implant placement, but each has its own advantages and clinical limitations. Static guides are generally practical, time-efficient, and highly predictable when guide seating is stable. Dynamic navigation, on the other hand, allows intraoperative flexibility, better visual access, and real-time correction of the drilling trajectory. Available evidence suggests that both approaches can achieve clinically acceptable accuracy, although direct comparative evidence in immediate implant placement remains limited. The choice between them should therefore depend not only on radiographic accuracy, but also on case complexity, available support, mouth opening, cost, surgical time, operator experience, and the need for intraoperative modification.

Keywords: Immediate Implant Placement; Dynamic Navigation; Static Surgical Guide; Computer-Assisted Implant Surgery; Implant Accuracy; Digital Dentistry

Introduction

Dental implant therapy has changed considerably since the early concept of osseointegration was introduced. In the past, the main goal of implant treatment was simply to place the implant in available bone and achieve long-term biological stability [1]. With the development of restorative-driven treatment planning, this concept has shifted. Today, successful implant therapy is not judged only by implant survival, but also by function, esthetics, peri-implant tissue stability, prosthetic emergence profile, and patient satisfaction [2,3].

Immediate implant placement refers to placing the implant into the extraction socket at the same surgical visit as tooth removal.

This approach was classified as Type 1 implant placement by the ITI consensus group [4]. It has several clinical advantages, including fewer surgical appointments, shorter treatment duration, and preservation of the soft tissue envelope. However, immediate placement does not prevent the physiological remodeling of the extraction socket, especially the resorption of the buccal plate [5,6]. Therefore, implant position remains a critical factor in achieving a stable functional and esthetic outcome.

Immediate implant placement and accuracy challenges

Immediate implant placement is more sensitive than implant placement in a healed ridge. In a healed ridge, the clinician usually prepares the osteotomy on a relatively stable bone surface. In contrast, the fresh extraction socket has an irregular shape and a non-uniform bony wall. The buccal plate is often thin, while the palatal or lingual wall may be denser and more resistant. During drilling, the osteotomy drill may slide toward the path of least resistance, leading to implant malposition [6].

In the anterior maxilla, the buccolingual position of the implant is a major factor in the final esthetic outcome. When the implant is placed too far buccally, the facial bone and soft tissue may not remain stable, and this can lead to midfacial recession or an unaesthetic emergence profile. Chen and Buser reported that immediate implant placement can still give acceptable esthetic results, but recession of the midfacial mucosa may occur, especially in cases with thin facial bone or unfavorable soft tissue conditions [6]. Therefore, careful control of implant position is necessary, and the use of guided surgery may help the clinician place the implant closer to the planned position.

Digital planning in implant dentistry

Digital implant planning depends on combining radiographic and surface information. Cone-beam computed tomography provides three-dimensional information about bone volume, socket morphology, and nearby anatomical structures. The American Academy of Oral and Maxillofacial Radiology recommends cross-sectional imaging for implant-site assessment, with CBCT considered the imaging method of choice for most implant-planning situations [7].

In digital implant planning, the clinician usually works with both radiographic and surface data. The CBCT scan shows the available bone and nearby anatomical structures, while the intraoral or cast scan records the external surfaces of the teeth and soft tissues [7,8]. When the DICOM data are matched with the STL file, the implant can be planned in a position that respects the bone anatomy and also supports the future prosthetic restoration [8]. However, planning the implant virtually is only one part of the process. The main clinical challenge is to reproduce this planned position accurately during surgery [9].

Static computer-assisted implant surgery

In static guided implant surgery, the preoperative plan is applied clinically through a physical guide. This guide is designed from the digital planning data and fabricated through a CAD/CAM workflow [8-11]. When 3D printing is used, it represents one manufacturing method within that CAD/CAM workflow [12]. When the patient still has enough stable teeth, a tooth-supported guide is usually preferred, as the teeth help the guide seat firmly and repeatedly during drilling [13].

The main advantage of static guidance is that the drill path is mechanically controlled through guide sleeves. Once the guide is fully seated and verified, the drill follows the planned entry point, angulation, and depth. Systematic reviews have shown that static guided surgery generally improves implant placement accuracy compared with freehand placement [9,10].

However, static guides also have limitations. The accuracy of the final implant position depends on every step of the workflow, including CBCT acquisition, surface scanning, image merging, guide design, guide fabrication, and intraoral guide seating. Any error in these steps may be transferred directly to the surgical field. Static guides may also reduce visibility and irrigation during drilling and may not allow the surgeon to easily modify the plan once surgery has started [11].

Dynamic navigation in implant surgery

Dynamic navigation was developed as another way of transferring the virtual implant plan when some limitations of static guides are a concern. Unlike static guides, it does not control the drill through a physical sleeve. Instead, the system tracks the patient and the surgical handpiece during the procedure, allowing the surgeon to follow the drill position, angulation, and depth on a monitor in real time [14-16]. Since no guide covers the surgical field, the operator can usually maintain better visibility and irrigation during drilling. Another advantage is that the planned trajectory can be adjusted during surgery if the clinical situation requires it [16,17]. These features may be useful in immediate implant placement, where the shape of the extraction socket and the risk of drill deflection require close control of the osteotomy direction [6,17].

Block., *et al*. reported that dynamic navigation improved implant placement accuracy compared with freehand placement [14]. Stefanelli., *et al*. also found that dynamic navigation can be an accurate method for transferring a CBCT-based implant plan to the clinical situation, while noting that operator experience may influence the accuracy of the workflow [15].

Static guides versus dynamic navigation

Static and dynamic guided surgery both aim to reduce the positional errors that may occur with freehand implant placement, although each system controls the procedure in a different way [9-11,14-16]. In static guided surgery, the drill is directed through a sleeve incorporated in the surgical guide, so the planned path is transferred mechanically to the osteotomy site [9-11]. In dynamic navigation, the drill is not locked into a fixed pathway; instead, the surgeon follows the drill position, angulation, and depth on a screen while working in real time [14-16]. Because of this difference, each approach behaves differently during surgery.

In simple cases, especially when there are enough stable teeth to support the guide and the mouth opening is adequate, a static guide can be a practical and efficient option [11,13]. Dynamic navigation may be more helpful when direct visibility, irrigation, or intraoperative adjustment of the drilling direction is important, since the surgeon is not limited by a physical guide [15-17]. For this reason, neither method should be described as better in all situations. A more balanced view is that the preferred technique depends on the case itself, including the available support, surgical access, clinical complexity, operator experience, chairside time, patient comfort, and cost [11,13,16].

Assessment of implant positioning accuracy

The accuracy of implant placement is usually checked by comparing the planned implant position with the actual position after surgery. In most computer-assisted implant studies, this is done by taking a postoperative CBCT scan and superimposing it on the preoperative virtual plan. After matching the datasets, the planned and placed implants can be compared in three dimensions, allowing the amount and direction of deviation to be measured [9-11,16,18].

Several measurements are commonly used for this assessment. Platform deviation describes the difference between the planned and actual implant position at the coronal part of the implant. This is clinically important because it may affect the emergence profile, prosthetic contour, and the final restorative position. Apical deviation measures the discrepancy at the implant tip, which is especially relevant when the implant is close to anatomical structures, adjacent roots, or thin cortical plates. Angular deviation reflects the difference between the long axis of the planned implant and the long axis of the placed implant, and it may influence the screw-access channel, restorative axis, and the need for prosthetic compensation [9-11].

Some studies also report lateral and depth deviations, as these help clarify the direction of the placement error. Lateral deviation refers to horizontal movement of the implant from the planned position, either buccolingually or mesiodistally. Depth deviation, on the other hand, indicates whether the implant was inserted deeper or more coronally than intended. These values are important because global deviation only gives the overall distance between the planned and actual implant positions. It does not always show whether the error occurred sideways, vertically, or in both directions. Therefore, reporting global, angular, lateral, and depth deviations together provides a more detailed assessment of how accurately the surgical plan was transferred to the patient [9,16,18].

This radiographic comparison is especially important in immediate implant placement. In a fresh extraction socket, the anatomy of the socket can influence the direction of drilling, and even a small change in the implant position may affect the facial bone, soft tissue stability, emergence profile, and final prosthetic result [6,17]. For this reason, accuracy assessment should not only report whether the implant was close to the planned position. It should also describe the amount of deviation, its direction, and the level at which it occurred, whether at the platform, apex, depth, or angulation [9,11,16,18]. This gives a clearer idea of whether the surgical plan was transferred accurately and whether the deviation may have clinical importance.

Clinical considerations and future directions

Although guided implant surgery has improved the transfer of the planned implant position, both static and dynamic systems still have possible sources of error [11,16,18]. In static guided surgery, the final accuracy may be influenced by guide stability, the accuracy of guide fabrication, limited surgical access, and incomplete seating of the guide during drilling [11,13]. Dynamic navigation also has its own limitations, mainly related to registration accuracy, calibration of the handpiece and reference markers, optical tracking, and the operator's learning curve during screen-guided surgery [16,18,19].

For future research, larger randomized clinical trials are still needed, especially studies comparing static and dynamic systems in immediate implant placement rather than healed ridges alone. Further evaluation should also include long-term clinical outcomes, such as marginal bone changes, soft tissue recession, esthetic results, implant survival, prosthetic complications, postoperative discomfort, patient satisfaction, learning curve, and cost-effectiveness [11,16,18].

Conclusion

Immediate implant placement is a valuable treatment option, but it requires careful three-dimensional control because the extraction socket presents unique anatomical and mechanical challenges. Computer-assisted implant surgery helps transfer the prosthetically driven digital plan to the clinical field more accurately than freehand placement.

Static surgical guides and dynamic navigation represent two different methods of guided implant placement. Static guides provide mechanical control through a physical guide and may offer a simple and time-efficient workflow when guide seating is reliable. Dynamic navigation provides real-time visual feedback and allows intraoperative flexibility, but it requires more equipment, calibration, and operator training.

Current evidence suggests that both systems can achieve clinically acceptable accuracy. Therefore, the choice between static guidance and dynamic navigation should be based on the clinical situation rather than accuracy alone.

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