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ADVANCEMENTS IN DENTAL IMPLANT PLANNING THROUGH COMPUTED TOMOGRAPHY

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ABSTRACT
The planning of dental implants plays a crucial role in determining the success of dental treatments. Recent advancements in technologies, particularly computed tomography (CT), have significantly transformed this practice by allowing precise three-dimensional evaluations of oral anatomy and bone quality. This enhanced capability provides detailed insights that facilitate the optimal positioning of implants while minimizing surgical risks. Studies highlight the effectiveness of using customized surgical guides based on CT data, which not only improve the accuracy of dental interventions but also enhance patient experiences by promoting quicker recovery and ensuring implant stability. The shift towards digital techniques in surgical planning underscores the importance of tailoring approaches to the individual characteristics of each patient, thereby improving overall outcomes. Research supports the use of three-dimensional model-based surgical guides in conjunction with CT imaging, which leads to less invasive procedures and more predictable results. As a result, these technologies represent a significant advancement in dental implant procedures, elevating the quality of care and expanding clinical possibilities. The integration of imaging technologies and meticulous preoperative planning is essential in modern dentistry, and ongoing technological advancements promise to further enhance these methods. By continuing to incorporate these innovations into clinical routines, dental professionals can achieve superior results for their patients, marking a progressive shift in dental implantology.

Keywords: Dental implants. Computed tomography (CT). Surgical guides. Digital techniques. Preoperative planning.

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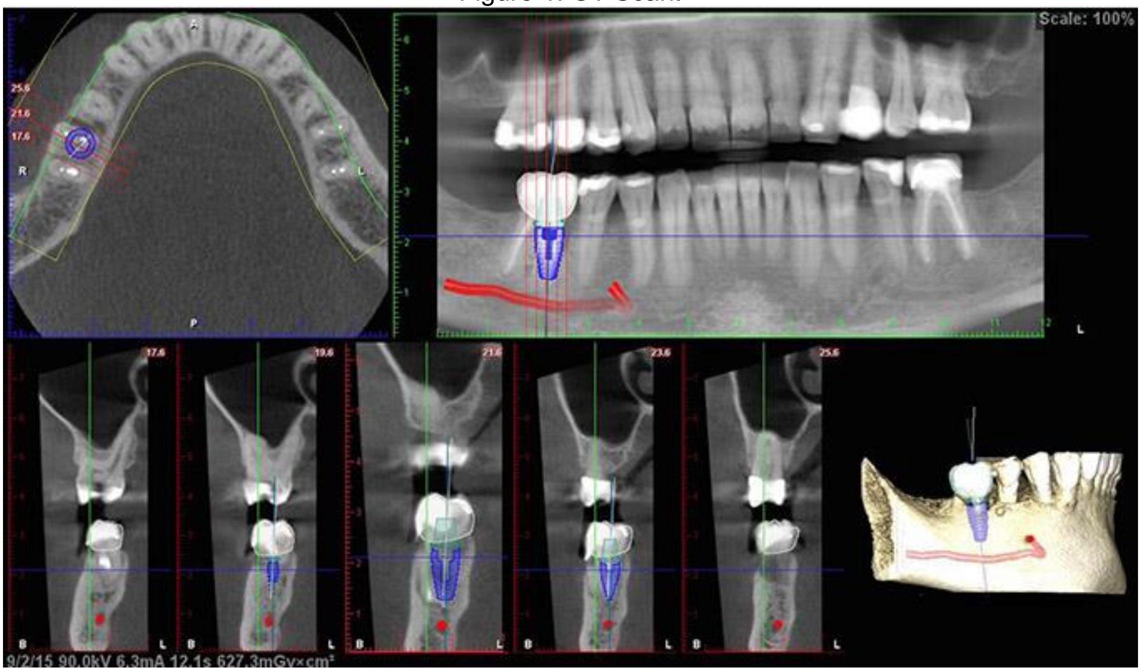
INTRODUCTION

Planning for dental implants is a critical phase that significantly affects treatment success. In recent years, computed tomography (CT) has become an invaluable tool in this process, enabling a precise three-dimensional assessment of oral anatomy and bone quality—key factors for optimal implant placement. CT produces detailed images that provide insight into bone structures, such as thickness, the presence of nerves, and maxillary sinuses, while also identifying potential anatomical anomalies. This advanced visualization overcomes the limitations of traditional radiographs, which offer only a two-dimensional view that can lead to misinterpretations. With CT, dental professionals gain more reliable information about bone topography, aiding in the planning of ideal implant insertion sites.

Moreover, CT facilitates the simulation of the surgical procedure itself. Dentists can utilize specialized software to plan the angulation, depth, and positioning of implants, tailoring the design to each patient's unique characteristics. This individualized approach minimizes risks and complications during surgery by considering all relevant factors beforehand.

Figure 1: CT Scan.



Source: Mint Hill Dentistry (2024).

An additional benefit of CT planning is the potential for guided surgeries. Custom surgical guides can be created based on tomographic images, ensuring precise implant placement. This not only enhances surgical effectiveness but also reduces operating time and accelerates patient recovery.

The research by Meneghetti et al. (2023) illustrates the effectiveness of a bone-supported surgical guide in enabling simultaneous implant placement and bone reduction, leveraging cone-beam computed tomography (CBCT) data. The study highlights that two-implant-supported mandibular overdentures are a reliable solution for restoring masticatory function, with digital planning significantly enhancing surgical precision. While innovations like CBCT and intraoral scanning (IOS) have streamlined the digital planning process, they have also introduced complexities that may confuse clinicians. Meneghetti et al. show that their innovative surgical guide, designed to fit securely on the bone, allows for customizable bone reduction through strategically placed windows, enabling clinicians to determine the necessary amount of bone removal and optimal implant placement. This approach not only leads to less invasive surgeries but also facilitates the parallel placement of implants. Their digital workflow simplifies fabrication processes and results in predictable surgical outcomes, emphasizing the benefits of integrating advanced imaging techniques with innovative surgical guides in dental implant procedures.

The clinical study by Ozan et al. (2009) underscores the significance of presurgical planning for achieving aesthetically pleasing and functionally effective dental implants. This research evaluated angular and linear deviations at the neck and apex of implants placed using stereolithographic (SLA) surgical guides based on CT scans. A total of 110 implants were analyzed with SLA guides derived from 3D CT images. The study found a mean angular deviation of 4.1 degrees ± 2.3 degrees and a mean linear deviation of 1.11 ± 0.7 mm at the neck and 1.41 ± 0.9 mm at the apex compared to planned positions. Notably, angular deviations varied by surgical guide type, with tooth-supported guides exhibiting greater accuracy (2.91 degrees ± 1.3 degrees) than bone-supported (4.63 degrees ± 2.6 degrees) and mucosa-supported guides (4.51 degrees ± 2.1 degrees). These findings suggest that SLA surgical guides based on CT data are reliable tools for implant placement, with tooth-supported guides yielding the highest precision.

The research conducted by Steenberghe et al. (2005) explores an innovative approach to implant dentistry that harnesses three-dimensional implant planning software alongside CT scan data. This study focuses on the development of customized surgical templates and prefabricated dental prostheses that enable the precise transfer of implant treatment plans to the surgical site, ensuring immediate stabilization of installed implants. Involving 27 patients with edentulous maxillae, all treated under the "Teeth-in-an-Hour"

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concept, the study showcased flapless surgery using CT-derived templates with immediate prosthetic restoration. Impressively, all patients received their final prosthesis right after implant placement, completing the entire procedure in approximately one hour. Follow-up of 24 patients over one year indicated stability for all implants and prostheses. These findings imply that this prefabrication strategy, founded on three-dimensional planning, is a reliable treatment option not only for immediate loading in fully edentulous patients but also for staged surgeries and cases of partial edentulism.

Bornstein et al. (2014) aimed to systematically review and summarize existing evidence regarding the use of maxillofacial cone beam computed tomography (CBCT) in pre- and postoperative dental implant therapy. The research concentrated on three main areas: clinical usage guidelines, indications and contraindications for CBCT, and assessment of radiation dose risks. A thorough literature review employing a PICO-based search strategy yielded 12 relevant publications offering guidelines for CBCT use in evaluating potential dental implant sites. The study also discussed the indications and contraindications for CBCT in implant dentistry, revealing a mix of cohort and case-controlled studies. Additionally, a radiation dose risk assessment was conducted, incorporating 22 articles on the topic. Findings indicate that CBCT is indicated for various applications, such as preoperative anatomical analysis, site development with grafts, and postoperative evaluations of complications related to neurovascular structures. The study emphasizes considerable variability in radiation doses across different CBCT devices, with potential dose reductions attainable through exposure factor adjustments and optimizing the field of view to focus on the area of interest.

In the work by D'haese et al. (2017), the authors discuss the transformative effect of computerized axial tomography, now known as computed tomography, along with advancements in interactive software for virtual planning in both general and oral surgery. This innovation facilitates precise guidance for surgical procedures, particularly in dental implant planning, where a prosthetically driven approach enhances prosthesis design, improves aesthetics, and optimizes occlusion and loading. The paper underscores the transition from extensive flap surgeries to flapless implant techniques, resulting in more predictable and efficient surgeries. It outlines two primary protocols for guided implant surgery: static and dynamic. The static protocol, or computer-guided surgery, employs tissue-supported surgical templates based on computerized tomographic data, while the dynamic protocol utilizes motion-tracking technology for real-time navigation during surgery. As technology has progressed, varying levels of evidence demonstrating accuracy have emerged, along with multiple protocols distinguished by their guide production techniques and support methods. The authors emphasize the role of cone-beam computed tomography data in optimizing implant positioning by considering critical anatomical structures and future prosthetic needs. The overview aims to clarify guided surgery concepts, their advantages, disadvantages, and limitations while evaluating outcomes based on implant survival, precision, and complications, illustrated through clinical cases that showcase the workflow and guidelines for the safe implementation of these techniques.

In the study by Marchand et al. (2021), the authors examine the accuracy of preoperative implant planning based on computed tomography (CT) for robotic-assisted total knee arthroplasty (TKA) across various knee alignments, including varus and valgus deformities, neutral alignment, and cases involving retained hardware. This research encompassed 393 patients who underwent robotic TKA performed by a single surgeon, who reviewed the CT-based models and documented the expected component sizes. The final implants used were then compared to the surgeon's preoperative plan. The results indicated that in all patient groups, the CT-based implant plan was within one size of the implant utilized in 100% of cases for both tibial and femoral components. The surgeon achieved an exact match in 81% of cases for the femoral component and 80% for the tibial component. The mean age of patients whose original plan matched exactly was younger than that of patients who had upsized implants and older than that of those with downsized implants. Additionally, other patient demographics and preoperative knee alignment showed no correlation with predictive accuracy. These results underscore the reliability and precision of CT-based implant planning for TKA, irrespective of native knee alignment and other patient-specific factors, suggesting that predictive capability may improve over time—a crucial aspect as the field shifts toward outpatient surgeries with reduced capacity for prosthesis inventory.

The planning of dental implants is an essential process that determines the success of treatment, and the introduction of advanced technologies, such as computed tomography (CT), has revolutionized this practice. The ability to perform a precise three-dimensional evaluation of oral anatomy and bone quality provides detailed information, allowing for the optimal positioning of implants and reducing risks during surgery. Recent studies demonstrate that the use of customized surgical guides based on tomographic data not only increases the accuracy of interventions but also enhances the patient experience, facilitating recovery and implant stability.

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Furthermore, the integration of digital techniques in the planning and execution of surgical procedures emphasizes the importance of a personalized approach, adapting to the unique characteristics of each patient. Evidence from various studies reaffirms the effectiveness of CT and tools such as three-dimensional model-based surgical guides, which contribute to less invasive surgeries with more predictable outcomes.

In this way, the evolution of imaging technologies and surgical planning not only enhances the quality of dental treatment but also opens new possibilities for clinical practice, reaffirming the importance of meticulous preoperative planning in modern dentistry. As technology continues to advance, it is expected that these methods will become increasingly integrated into clinical routines, providing even better results for patients.

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