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The Impact of Cone-Beam Computed Tomography (CBCT) on Dental Implant Placement in Oral and Maxillofacial Surgery in the United States

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ABSTRACT

Cone-beam computed tomography (CBCT) has emerged as a transformative imaging modality in oral and maxillofacial surgery (OMS), particularly in dental implant therapy in the United States. By providing accurate three-dimensional visualization of osseous anatomy and critical adjacent structures, CBCT has enhanced diagnostic precision, surgical planning, and outcome predictability. This article examines the impact of CBCT on implant site assessment, prosthetically driven implant placement, achievement of primary stability, facilitation of osseointegration, and long-term implant success rates. The application of CBCT in medically and periodontally compromised patients, including individuals with diabetes mellitus and chronic periodontal disease, is discussed in detail. Limitations of CBCT and its role in emerging digital and guided surgical innovations are also explored. As guardians of technological advancement in OMS, oral and maxillofacial surgeons must apply CBCT judiciously and ethically to optimize patient outcomes and maintain evidence-based standards of care.

Keywords
CBCT diagnosis, CBCT application, CBCT limitations, CBCT and Oral Surgery.

Introduction
North America, led by the United States holds the largest regional share of dental CBCT installations globally. Dental implant therapy is and has become a central component of contemporary oral and maxillofacial surgery, offering predictable functional and esthetic rehabilitation for partially and fully edentulous patients. Success in implant dentistry is dependent upon accurate diagnosis, careful surgical planning, atraumatic placement, and biologically favorable healing conditions. Historically, implant planning relied heavily on two-dimensional imaging modalities, such as panoramic and periapical radiographs, which are limited by distortion, magnification, and anatomical superimposition.

The introduction of cone-beam computed tomography has significantly altered this paradigm. CBCT provides high-resolution, three-dimensional visualization of maxillofacial structures with lower radiation exposure than conventional medical CT scans, making it particularly suitable for dentoalveolar applications. Its integration into implant dentistry has enabled prosthetically driven planning, improved surgical accuracy and enhanced risk assessment. This paper reviews the role of CBCT in implant therapy within OMS, emphasizing its influence on implant placement accuracy, primary stability, osseointegration, and long-term success.

Discussion
CBCT and Implant Site Assessment
CBCT has fundamentally improved preoperative implant site assessment by allowing precise three-dimensional evaluation of

alveolar bone height, width, and morphology [1,2]. Unlike two-dimensional imaging, CBCT eliminates anatomic overlap and distortion, enabling accurate visualization of critical structures such as the inferior alveolar nerve, mental foramen, maxillary sinus, nasal cavity, and adjacent tooth roots [3].

This level of detail is especially valuable in posterior mandibular and posterior maxillary regions, where limited bone volume and proximity to vital structures increase surgical risk. CBCT allows identification of anatomical variations, concavities, undercuts, and pathologic conditions that may compromise implant placement or necessitate site development procedures [4]. As a result, CBCT enhances diagnostic confidence and reduces intraoperative complications, contributing to improved surgical predictability [2].

Implant Placement and Prosthetically Driven Planning

One of the most significant contributions of CBCT to implant dentistry is the shift from surgically driven to prosthetically driven implant placement. CBCT allows implants to be planned three-dimensionally relative to the final prosthetic restoration, ensuring optimal positioning in the mesiodistal, buccolingual, and apicocoronal dimensions [5,6]. This approach is critical for achieving favorable emergence profiles, ideal screw-access locations, and biomechanically sound occlusal load distribution.

Integration of CBCT data with digital planning software enables virtual implant placement and fabrication of static or dynamic surgical guides. Numerous studies demonstrate that CBCT-guided-implant placement significantly reduces angular and linear deviation compared with freehand techniques, particularly in anatomically constrained and full-arch cases [6,7]. Improved placement accuracy reduces restorative complications such as non-axial loading, unfavorable crown-to-implant ratios, and prosthetic misfit [8].

CBCT-guided workflows also support minimally invasive surgical approaches, including flapless or limited-flap procedures when clinically appropriate. These approaches may reduce surgical time, postoperative morbidity, and disruption of peri-implant soft tissue architecture, thereby enhancing patient comfort and satisfaction [9].

Primary Stability and Osseointegration

Primary stability is a critical mechanical prerequisite for successful osseointegration and long-term implant survival. CBCT plays a central role in evaluating site-specific factors that influence primary stability, including cortical bone thickness, trabecular bone architecture, ridge morphology, and residual bone volume [10]. Although CBCT does not provide true quantitative bone density values equivalent to medical CT Hounsfield units, it allows reliable qualitative assessment of bone quality patterns relevant to implant stability [11].

CBCT assists clinicians in selecting appropriate implant diameter, length, thread design, and surface characteristics to maximize mechanical engagement at placement. This is particularly important in low-density bone regions such as the posterior maxilla, grafted sites, and immediate implant placements, where achieving adequate insertion torque is more challenging.

In immediate implant protocols, CBCT enables precise evaluation of socket morphology and available apical or palatal bone for fixation, minimizing micromotion that can impair osseointegration [12]. In delayed placement scenarios, CBCT facilitates assessment of graft maturation and volumetric stability, guiding appropriate timing for implant insertion and loading [3]. Postoperative CBCT imaging can assist in monitoring peri-implant bone remodeling and identifying early marginal bone loss or peri-implant defects not readily visible on two-dimensional radiographs [13,14].

Implant Success and Survival Rates

Contemporary dental implant therapy demonstrates long-term survival rates exceeding 90-95% when evidence-based protocols are followed. While CBCT does not directly induce osseointegration, its role in improving diagnostic accuracy, surgical precision, and biologic risk assessment contributes meaningfully to these outcomes.

CBCT reduces biologic complications such as nerve injury and sinus perforation, as well as mechanical complications related to improper implant angulation or inadequate prosthetic space [15]. By identifying unfavorable site characteristics preoperatively, CBCT allows modification of treatment plans to improve predictability and longevity.

Medically and Periodontally Compromised Patients

Patients with diabetes mellitus present increased risk for delayed wound healing and impaired bone metabolism, potentially affecting osseointegration. However, systematic reviews indicate that implant survival rates in well-controlled diabetic patients approach those of non-diabetic individuals when careful planning and atraumatic surgical techniques are employed [16-18]. CBCT facilitates individualized risk assessment and optimization of primary stability in this population.

Similarly, patients with a history of chronic periodontal disease are at increased risk for peri-implantitis and marginal bone loss. CBCT allows detailed evaluation of residual alveolar bone and defect morphology, aiding in implant planning and long-term monitoring [19,20]. Evidence suggests that implants placed in treated periodontitis patients can achieve favorable survival rates when periodontal disease is controlled and strict maintenance protocols are followed.

CBCT and Innovation in Implant Surgery

CBCT forms the foundation of modern digital implant workflows, including CAD/CAM surgical guides, custom abutments, and digitally fabricated prostheses. Emerging artificial intelligence applications aim to automate implant site analysis, enhance diagnostic accuracy, and predict implant failure risk. Oral and maxillofacial surgeons must critically evaluate these technologies and ensure their ethical, evidence-based integration into clinical practice.

Limitations of CBCT

Despite its advantages, CBCT has limitations. It provides limited soft-tissue contrast compared with medical CT or MRI and is susceptible to image artifacts from metallic restorations and existing implants. Radiation exposure, although lower than conventional CT, remains higher than standard dental radiography and necessitates adherence to the ALARA principle which stands for (As Low As Reasonably Achievable) meaning radiation exposure for patients and staff should always be minimized while still striving to achieve quality diagnostic images. For CBCT, this involves using the smallest possible Field of View (FOV), where covering only the area of interest, selecting appropriate scan settings, adjusting doses for patients (especially children/ high-risk), and implementing equipment techniques to balance diagnostic needs with radiation safety. CBCT should therefore complement, not replace sound clinical judgment.

Conclusion

Cone-beam computed tomography has fundamentally transformed implant therapy in the United States and the field of oral and maxillofacial surgery by enhancing diagnostic accuracy, surgical precision, and biologic predictability. Its influence on implant placement accuracy, achievement of primary stability, and facilitation of osseointegration has contributed significantly to the high success and survival rates reported in contemporary implant dentistry.

The benefits of CBCT are particularly evident in medically and periodontally compromised patients, including those with diabetes mellitus and chronic periodontal disease. In these populations, CBCT-based planning supports individualized risk assessment, atraumatic surgical execution, and early detection of complications, enabling favorable outcomes despite increased biologic risk.

As implant therapy continues to evolve, oral and maxillofacial surgeons must serve as responsible stewards of CBCT technology. Through judicious use, adherence to radiation safety principles, and continued education in digital innovation, CBCT can be leveraged to advance patient-centered, evidence-based implant care. The United States remains a leader in CBCT research publications globally, and a pioneer in installations of CBCT devices globally; as the effects on the success of implant therapy increases, further considerations for improvement, quality assurance, and assessment would need to be done to ensure continued positive success rates after utilization of CBCT scanning for implant placement therapies.

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