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Personalized Implant Placement
A Case Report

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Introduction

Recent advancements in implantology, driven by digital technology and 3D printing, have established personalized implantology as the gold standard in restorative dentistry. This approach prioritizes creating implants tailored to each patient's unique anatomical and clinical needs, replacing the traditional one-size-fits-all model.(1)

The integration of 3D printing and CAD/CAM software enables precise fabrication of implants, surgical guides, and custom abutments, improving surgical accuracy, clinical outcomes, and patient satisfaction. Additionally, digital tools like intraoral scanners, CBCT imaging, and advanced planning software streamline workflows, enhance diagnostic precision, and promote real-time collaboration among dental professionals.(2)

These innovations have resulted in faster, safer, and more predictable implant procedures, ushering in a new era of patient-centered care. As these technologies evolve, the future promises even more advanced and personalized dental solutions.(3)

Clinical Presentation: A 45-year-old patient presented with a missing lower right first molar, seeking a durable and functional dental implant restoration. The patient reported challenges with chewing on the affected side. A thorough clinical examination revealed no significant medical history contraindicating implant placement. Cone Beam Computed Tomography (CBCT) was performed to assess bone morphology and anatomical landmarks.

Diagnostic Approach: The CBCT scan, acquired using the Planmeca ProMax® 3D Mid (Planmeca Oy, Asentajankatu 6, 00880 Helsinki, Finland), revealed adequate bone volume with a D3 density in the region of the missing molar. The bone morphology analysis highlighted a trabecular structure with a pore size ranging from 300 to 500 microns, characteristic of D3-type bone. The force of mastication in this region was quantified as moderate, with a magnitude of approximately 100–150 Newtons.(4-6) This analysis was conducted using BlueSky Plan® software (BlueSkyBio, LLC, 651 Daybreak Ln, Grayslake, IL 60030, USA), which allowed for precise visualization and measurement of anatomical and functional parameters. This comprehensive data set was critical for designing an implant tailored to the patient's bone structure, ensuring optimal osseointegration and long-term biomechanical stability.(7-9)

Treatment Plan: A fully personalized implant was planned using the patient's CBCT data. The implant design mimicked the patient's unique bone morphology, incorporating a trabecular structure to enhance osseointegration. Advanced reverse engineering software was utilized to replicate the intricate bone patterns, ensuring optimal fit and integration.

Implant Design and Fabrication:

1. **Design Process:**The implant fixture was digitally modeled using CBCT scans and developed in SolidWorks® software (Dassault Systèmes, 175 Wyman St, Waltham, MA, USA). The implant incorporated a trabecular architecture that closely mimics D3 bone morphology, featuring a pore size of approximately 500 µm to enhance osseointegration by facilitating bone ingrowth through the porous structure.(Figure 1) The implant surface was sandblasted to increase micro-roughness, improving bone-implant contact and promoting biological integration. Additionally, the thread thickness was specifically engineered to endure masticatory forces, with a design strength exceeding 1050 MPa to ensure structural durability.(10-15)

   This biomimetic design distributed functional stresses evenly along the implant-bone interface, significantly reducing the risk of crestal bone loss while ensuring stability under masticatory forces. The abutment was custom-designed to match the patient's occlusion and gingival contours, providing both aesthetic and functional harmony. The tailored abutment ensured a natural-looking restoration and optimized biomechanical performance.(16)

   Additionally, the implant design was engineered to be compatible with the **Straumann® Surgical Kit** (Institut Straumann AG, Basel, Switzerland), enabling precise osteotomy preparation and placement. This compatibility streamlined the surgical procedure, ensuring accuracy and reliability during implant placement while reducing surgical complexity.(17)

2. **Manufacturing:** The implant fixture and abutment were fabricated using Selective Laser Melting (SLM) technology on a Concept Laser Mlab® machine (GE Additive, Lichtenfels, Germany) in the Center of Precision Technology, Huddersfield University, United Kingdom. This high-precision additive manufacturing technique ensured detailed control over the implant's shape, trabecular architecture, and surface texture. (Figure 2) The SLM process involved layer-by-layer fusion of titanium powder under a high-energy laser, resulting in an implant with optimal mechanical properties, superior primary stability, and enhanced tissue integration. (18-20)

3. **Restoration:** The final restoration involved the fabrication of a zirconia crown using stereolithography with the Formlabs Form 3B+ 3D printer (Formlabs Inc., 35 Medford St #201, Somerville, MA 02143, USA). This method enabled the creation of a crown with superior precision, aesthetics, and durability. The zirconia crown was carefully shaded and polished to match the patient's natural dentition, achieving an optimal functional and aesthetic result.(20)

Surgical and Prosthetic Procedure: The surgical procedure was carried out under local anesthesia using Lidocaine 2% with epinephrine 1:100,000 for optimal pain control and hemostasis in the dental hospital of the Faculty of Dentistry, Beni-suef university. The lower right molar region was accessed using a mid-crestal incision with minimal flap reflection to preserve soft tissue integrity. The personalized implant, designed based on CBCT data and fabricated to match the patient's bone anatomy, was positioned in the prepared osteotomy site.

The osteotomy was prepared using a sequential drilling protocol with the Straumann® Surgical Kit (Institut Straumann AG, Peter Merian-Weg 12, 4002 Basel, Switzerland) to ensure precise alignment and depth. Implant placement was guided with a customized surgical template generated using BlueSky Plan® software (BlueSkyBio, LLC, Grayslake, IL, USA), ensuring accurate angulation and optimal positioning relative to adjacent teeth and anatomical landmarks.

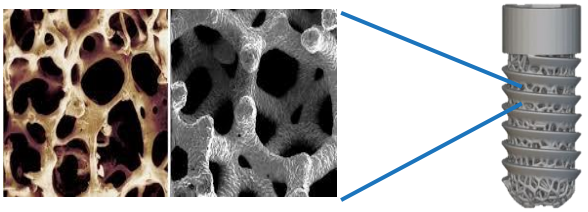

Fig. (1) Implant trabecular structure mimicking D3 bone density

Fig.(2): 3D printed Implant , abutment and zirconia crown

Following placement, the implant achieved excellent primary stability, confirmed using a torque wrench calibrated to 35 Ncm. A healing abutment was attached, and the surgical site was closed with Vicryl® 4-0 sutures (Ethicon, Johnson & Johnson, Somerville, NJ, USA) to promote healing.

After three months, A 3D-printed abutment was then screwed into place, followed by an optical impression taken using the Medit i700 scanner (Medit Corp., Seoul, South Korea) to ensure high accuracy and detail. Finally, a zirconia crown was fabricated and placed, providing functional and esthetic restoration for the patient.

Outcome and Follow-Up: Post-operative healing was uneventful, with no complications observed. At the six-month follow-up, the implant showed excellent osseointegration, with no signs of crestal bone loss. The patient reported improved masticatory efficiency and was highly satisfied with the functional and aesthetic outcome.

Discussion: This case underscores the transformative potential of integrating digital workflows and 3D printing into modern implantology. The personalized trabecular implant effectively addressed the patient's specific anatomical challenges, offering a tailored solution that optimized both functional and aesthetic outcomes. (1-7)The trabecular architecture, with its biomimetic design and pore size of approximately 500 µm, played a pivotal role in enhancing osseointegration by promoting bone ingrowth through the porous structure. This feature not only accelerated the healing process but also established a stronger and more stable bond between the implant and surrounding bone tissues.(3-6)

Moreover, the implant's design ensured even stress distribution along the bone-implant interface, significantly reducing the risk of crestal bone loss, which is a common long-term complication in conventional implantology. The surface treatment, achieved through sandblasting, further improved the bone-implant contact by creating a micro-rough surface conducive to tissue integration.

These design features collectively contributed to the implant's primary stability and long-term success.(5,9)

By leveraging high-resolution CBCT imaging data obtained with the Planmeca ProMax® 3D Mid system, detailed anatomical insights were gathered, allowing for precise implant modeling using SolidWorks® software. This digital design process ensured a perfect fit to the patient's existing bone morphology and dimensions, eliminating the need for invasive bone grafting procedures and minimizing surgical risks. Additive manufacturing via Selective Laser Melting (SLM) provided the precision necessary to fabricate the trabecular implant and custom abutment with intricate geometry and controlled surface characteristics.(11,12)

This case exemplifies a paradigm shift toward precision and patient-centric care in implantology. The seamless integration of advanced imaging, computational modeling, and 3D printing highlights the ability to address complex anatomical conditions with high accuracy and reduced surgical complexity. Additionally, the use of personalized implants has been shown to improve patient satisfaction by delivering superior functional and aesthetic results.(18,20) This approach not only enhances clinical outcomes but also represents a significant advancement in the efficiency and accessibility of dental care. Future applications of this technology hold promise for further expanding the scope and success of dental and maxillofacial rehabilitation.(15-20)

Conclusion: Personalized dental implants, designed and fabricated through a fully digital workflow, offer a promising solution for complex clinical cases. This technology improves patient outcomes, reduces surgical time, and enhances overall satisfaction, paving the way for a new standard in dental implantology.

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