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Original Article

Case Report on a 3D-Printed CAD-CAM Implant Abutment for Angulated Implant Correction in the Esthetic Zone

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ABSTRACT

Achieving an aesthetically pleasing outcome is crucial for patients requiring anterior tooth replacement. Dental implants are the preferred treatment in contemporary dentistry; however, ideal placement is not always possible due to bone limitations or anatomical constraints. By utilizing advanced digital design and fabrication techniques, including 3D printing with DMLS technology, prosthetic solutions for angulated implants can be achieved with superior accuracy, precision, and minimal error. This case report focuses on the step-by-step process of anterior aesthetic rehabilitation in a young patient who had lost their anterior teeth. This case report presents a 38-year-old female patient with grade III mobile teeth who underwent rehabilitation using a CAD-CAM customized partial hybrid prosthesis, where aesthetics played a major role from the outset. To maintain a natural appearance, an immediate denture was planned that included the patient's natural teeth as denture teeth. The CAD-CAM abutment demonstrated exceptional precision, with internal fit digitally optimized via scan body and digital analog. The superstructure framework was fabricated based on a digital wax-up, then layered with indirect composite to improve aesthetics and allow for easy repair. A screw-retained prosthesis was chosen to facilitate straightforward retrieval and maintenance. This case highlights the role of digital implant dentistry in achieving optimal aesthetic rehabilitation.

Keywords: Digital dentistry, Custom abutment, Angulated implant, 3D printing, CAD CAM, Esthetic.

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Introduction

The appearance of anterior teeth is a crucial factor for patients, as it contributes significantly to orofacial structure, which is influenced by the stomatognathic system. Implant-based rehabilitation has become a widely adopted approach to enhance patient satisfaction and ensure long-term success. However, achieving an optimal implant position is not always feasible because of bone availability or anatomical constraints. When implants are placed at unfavorable angles, abutment customization is necessary to meet prosthetic requirements effectively.

The accuracy and design of the implant-abutment connection play a vital role in the functionality of implant-supported restorations, as well as in maintaining the health and stability of adjacent soft tissues. Based on extensive experience in implant dentistry, stock abutments have been considered a practical choice for restorations. However, technological advancements have led to the development of custom abutments, which can be individually tailored using various materials to meet patient-specific needs. With the aid of CAD/CAM (computer-aided design and computer-aided manufacturing) technology, these abutments can be fabricated efficiently [1-4].

One of the primary limitations of stock abutments has been their difficulty in achieving proper tissue adaptation and their insufficiency for angulated implants. Custom abutments, on the other hand, are designed specifically for individual patients, providing improved fit and allowing for better hygiene by preventing food debris accumulation beneath the abutment. Customization options include Ti-base castable abutments, milling, or other individualized solutions. However, the debate regarding the necessity of a precision fit continues.

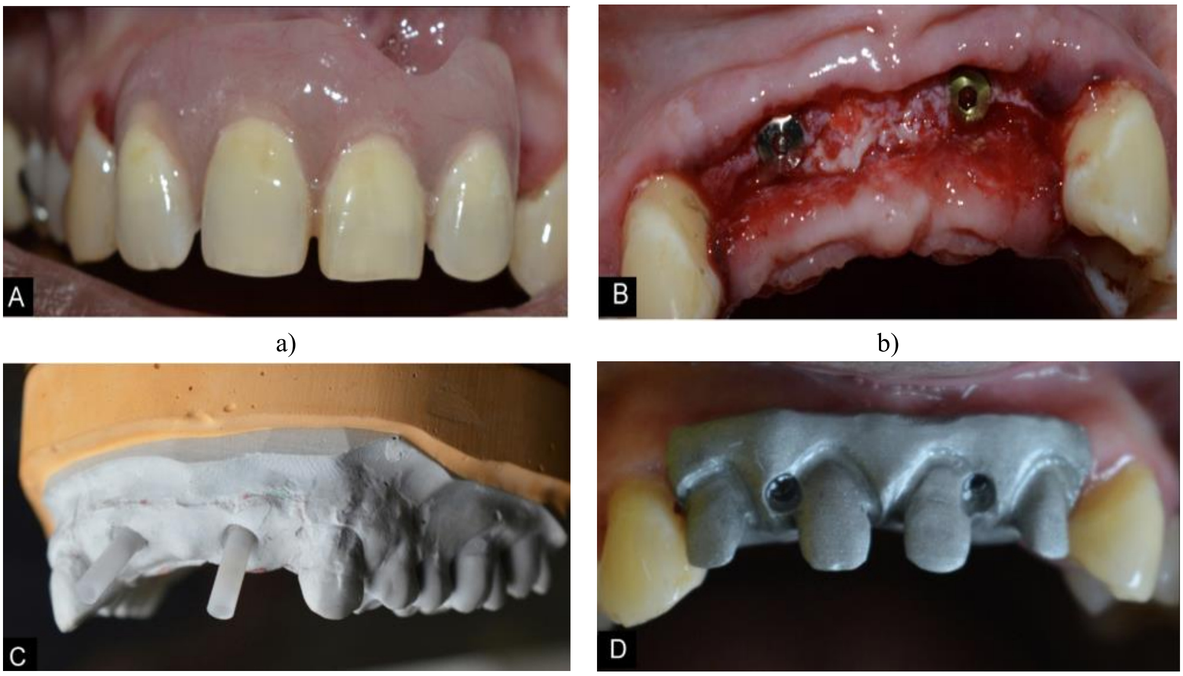
The primary drawback of custom abutments is that their connection to the implant is not inherently original. The subsequent hex connections may not achieve complete compatibility with the implant, as they require manufacturing with highly calibrated and precise equipment. In contrast, stock abutments present another challenge—over time, surrounding tissues conform to their shape, which can complicate the maintenance of ideal emergence contours. This makes it more difficult for clinicians to achieve a natural appearance and may also lead to reduced tissue support for adjacent teeth.

To overcome the limitations associated with traditional castable abutments, CAD-CAM abutments were introduced. These digitally designed and manufactured abutments allow for precise angulation correction, passive fit accuracy, and optimal adaptation to the surrounding soft tissue. By utilizing software to create and produce a DMLS digital CAD-CAM abutment, these enhancements can be achieved efficiently [5, 6]. Within the aesthetic zone, CAD-CAM abutments are preferred for implant restorations, as they enable the formation of a natural emergence profile between the crown and implant. Additionally, they offer customization for Crown Margin Depth and contribute to improved hygiene, aesthetics, and proper alignment with angulated implants.

3D printing, recognized as a disruptive technology, is expected to transform manufacturing processes. One such method, direct metal laser sintering (DMLS), allows for the precise customization of implant abutments, ensuring a perfect fit and passive integration. One of the significant risks in implant-supported restorations is mechanical complications, including screw loosening or porcelain fractures, often exacerbated by excessive crown height space [7-10]. In these challenging cases, a digitally designed, 3D-printed screw-retained framework paired with a custom abutment is considered the most effective solution [11]. This method offers advantages such as high precision, elimination of casting errors, and the production of lightweight, efficient prostheses. This case report focuses on the step-by-step process of anterior aesthetic rehabilitation in a young patient who had lost their anterior teeth.

Case report

A woman, 38 years old, visited a dental clinic in Bangalore with the main concern of loose upper front teeth. Upon examination, it was found that the mobility affected the right and left maxillary central and lateral incisors, which exhibited compromised horizontal bone width and insufficient vertical height. The periodontal condition of the remaining teeth was healthy. The patient had no known medical conditions and was in good overall health. The mobility was classified as grade III, and extraction was recommended, followed by an immediate denture due to the patient's primary concern about aesthetics. A temporary acrylic immediate partial denture was created using the patient's natural teeth to maintain the anterior aesthetic. Before taking the impression, all the anterior teeth were splinted with dental floss, and the dental cast was made. After fabricating a putty index, the teeth were trimmed, and the pulp was removed from the natural teeth to create the dentures (**Figure 1**). The immediate denture was placed with a soft lining material (GC), and the patient was advised to wait for six weeks for healing. A CBCT (cone-beam computed tomography) scan showed sufficient bone for implant placement, making the patient a suitable candidate for implant-supported prostheses.



a) b)

c) d)

Figure 1. a) immediate partial denture made from naturally extracted teeth; b) implant placement during the surgical phase; c) implant angulation during the prosthetic phase; and d) 3D printed metal framework with custom abutment-trial fitting in the patient.

2 implants (MIS 3.75 x 11.5 millimeters standard platform) were placed using a manually crafted acrylic surgical guide derived from a wax-up. Following the recommended protocol, implants were inserted with a torque of 40N, resulting in excellent primary stability. Following a healing period of six months, osseointegration was evaluated, and second-stage surgery was performed. Because of the compromised bone structure, the implant placement was not ideal. Consequently, a decision was made to fabricate a custom abutment with a screw-retained substructure and an indirect composite layer for enhanced aesthetics and ease of repair. Three weeks later, a polyvinyl siloxane impression material (3M) was used to capture an implant-level impression. The impression coping (MIS Closed tray) was attached to the implant laboratory analog (MIS), and a cast was made using a soft tissue gingival mask (GiMASK Coltene) and type IV die stone (Kalrock). The model was then scanned with a laboratory intraoral scanner (Medit scanner), with scan bodies placed on the implant analog to capture the implant position and transfer the data to the design software. The missing teeth and deficient soft tissue were planned using digital design software (Exocad), where a substructure framework with a labial access hole was created based on the digital wax-up (**Figure 2**). The abutment with an internal hex was designed alongside the framework after verifying the fit with a digital analog. The implant angulation was addressed within this digital design, ensuring a precision fit. The chrome cobalt (Cr-Co) framework was manufactured using DMLS (direct metal laser sintering) technology, which provided a precise, lightweight, and accurate result (**Figure 3**). To match the pink gingival component, a photograph, and customized shade tab were used, while tooth color matching was done with the VITA classic shade guide and a digital spectrophotometer.

The DMLS 3D printed framework was placed in the patient's mouth for assessment of its precise, passive fit. Indirect composite resin (SR Adoro, Ivoclar Vivadent AG, Liechtenstein) was layered over the framework to achieve an optimal pink-and-white aesthetic. The abutment screw was tightened to 30N torque, and gutta-percha and cotton were used to secure the screw and seal the access hole. The hole was then covered with direct composite, with careful attention to color matching. A small, natural stain was applied to the screw access hole area, making it nearly invisible but allowing for easy identification for future adjustments (**Figure 4**).

To prevent food accumulation, the inner surface of the prosthesis was modified with a ridge lap pattern. Occlusion was adjusted both in the articulator and the patient's mouth, with anterior guidance corrected before final polishing to maintain the existing canine-guided occlusion. The patient was instructed to use WaterPik for optimal oral hygiene maintenance.

Follow-up and maintenance appointments were scheduled.

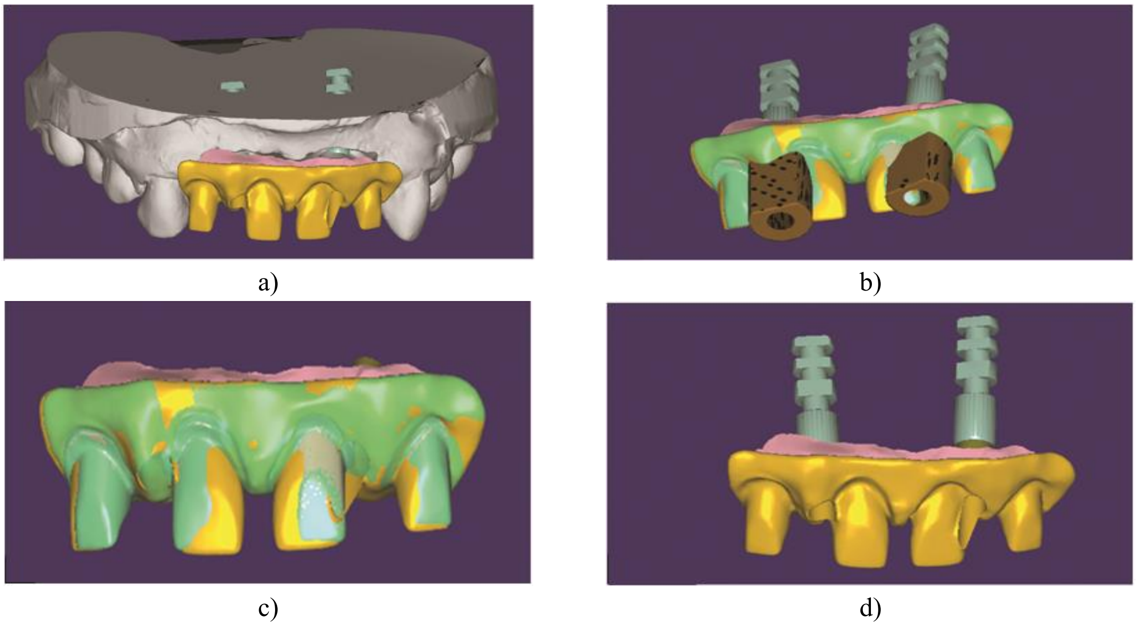


Figure 2. a) virtual cast with the digital framework design; b) framework with scan body and virtual analog for assessing position; c) evaluation of the digital framework; and d) virtual fitting of the framework.

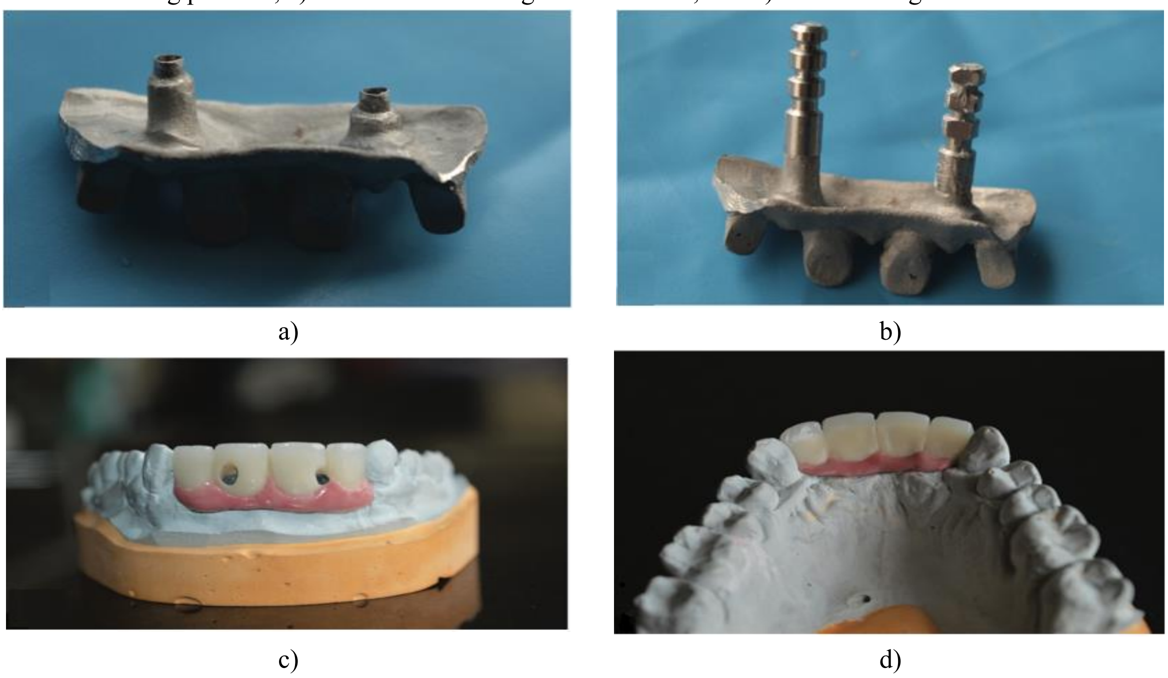


Figure 3. a) the inner surface of the 3D printed DMLS framework attached to the abutment; b) fit check using implant analog; c) layering of indirect composite with labial access hole (labial view); and d) layering of indirect composite with labial access hole (palatal view).

a)

b) c)

Figure 4. a) the inner surface of the 3D printed DMLS framework connected to the abutment; b) fit assessment with implant analog; c) indirect composite applied over the labial access hole (labial view); d) indirect composite applied over the labial access hole (palatal view).

Results and Discussion

Stock abutments provide limited support to the peri-implant soft tissues, both proximally and labially, due to their generally cylindrical or divergent shape, which contrasts with the emergence profile of natural teeth. Implant abutments can also be fabricated using computer-aided design/computer-aided manufacturing technology. This process enhances the abutment's geometry, aligning the outline with the adjacent natural roots and gingival margin to reduce the risk of cement remnants in the sulcus. The abutment's finish is carefully controlled to avoid sharp edges, and the design can correct suboptimal implant angulation. In custom-designed abutments, the abutment material, rather than the ceramic crown, plays a crucial role in supporting and interacting with the soft tissues, especially in hybrid prostheses [12, 13]. For individual implant-supported fixed prostheses, the abutment's configuration provides an optimal emergence profile, preventing bacterial entrapment. These features offer biological advantages [4]. Moreover, being digitally designed for a precise fit, the process is less time-consuming and doesn't require additional finishing procedures. The precision fit, passivity, and customized design contribute to biomechanical advantages, promoting a high survival rate.

Excessive weight and thermal expansion during the porcelain layering process can compromise precision fit due to multiple firing cycles [14, 15]. An alternative option is the hybrid prosthesis, which carries a higher risk of acrylic debonding and fracture [16, 17]. Therefore, the optimal choice is a composite material layered onto a 3D-printed metal substructure that better addresses these limitations. As a result, the Malo bridge framework design was selected, given the non-ideal implant placement caused by vertical bone loss. Additionally, this type of prosthesis eliminates screw access openings on the occlusal surface of the crowns and allows for the repair of the fractured composite without needing to remove the entire structure. The sealing of the gingival component also mimics the aesthetics of the natural gingival sulcus. Direct metal laser sintering is a 3D printing technique capable of directly producing metal components from a 3D computer model [18]. The implant abutment and hex connection were fabricated using this technology, eliminating casting errors and ensuring a precise passive fit for the non-engaging abutment.

Conclusion

Three-dimensional printing is considered a groundbreaking development with the potential to transform the manufacturing sector. The emergence of digital dentistry has significantly facilitated advancements in this field. Through digitalization, the internal hex can be designed using software, and production can be carried out with direct metal laser sintering (DMLS) technology. This shift in approach to aesthetic rehabilitation and smile makeovers, facilitated by digital tools, marks the beginning of a new era in implant dentistry.

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