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Original Article

Histologic and histomorphometric assessments of provisionally restored dental implants

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Abstract *Background/purpose:* Immediate provisionalization of dental implants has been considered a safe and predictable treatment modality; however, histologic evidence from human biopsies remains limited. The aim of this study was to evaluate bone-to-implant contact (BIC) and clinical outcomes of immediately provisionalized implants.
Materials and methods: This prospective clinical study included 5 patients receiving 7 immediately provisionalized implants in both the maxilla and mandible. All implants achieved primary stability and were restored with provisional restorations that were loaded with light centric contacts. Biopsies were obtained at 3 months and processed for histologic and histomorphometric analysis.
Results: All implants remained clinically stable throughout the observation period, resulting in a 100 % survival rate. Histologic examination confirmed direct bone-to-implant contact (BIC), with newly formed lamellar bone observed along the implant surface. Histomorphometric analysis revealed a mean BIC of 76.51 ± 7.91 %, which is comparable to values reported in conventionally loaded implants. No adverse biological or prosthetic events were observed.
Conclusion: Immediate provisional implants demonstrated substantial BIC and favorable

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clinical outcomes in this study. These findings provide histologic confirmation that immediate provisionalization is a safe and efficacious protocol when primary stability and careful occlusal management are achieved.

Introduction

Dental implant therapy is a predictable and widely accepted treatment for the replacement of single tooth to multiple teeth with long-term survival rates exceeding 90 % in many clinical studies.[1–3] Traditionally, patients were advised to wait for a healing period of at least six months before loading implants to avoid micromotion, which could have a negative effect on early osseointegration.[4] However, evolving surgical protocols and improvements in implant designs allow immediate implant provisionalization or loading when primary stability is achieved and occlusal forces are properly distributed.[5–7] Immediate provisionalization offers the benefit of preserving peri-implant soft tissue architecture and enhancing patient acceptance when teeth need to be removed, particularly for patients seeking a suitable replacement.[8,9]

Although many clinical and radiographic studies have supported the safety and efficacy of immediate provisionalization, histologic validation of its effect on osseointegration remains limited.[10–12] Thus, existing evidence leaves a critical gap in the literature regarding the bone-to-implant contact (BIC) of available dental implants obtained from humans.[13–16] Such data are essential to validate that immediate provisionalization not only provides favorable clinical outcomes but also does not impede the osseointegration comparable to conventional loading protocols. By definition, osseointegration is confirmed only through histology that demonstrates direct BIC, and the value of BIC is crucial in determining the long-term implant success and survival rates.[17,18]

Thus, the purpose of this prospective clinical study was to investigate the BIC in human biopsies of immediately provisionalized implants and to confirm that this protocol is safe and efficacious, and does not negatively affect osseointegration.

Materials and methods

Study design

The study protocol was reviewed and approved by the Institutional Review Board at Dentalevo Institute in Bucharest, Romania (DEI-2024-1008-R0). All participants provided signed written informed consent prior to enrollment. Patients were enrolled after meeting the following inclusion criteria: males and females between 20 and 70 years of age, presenting with multiple missing teeth and adequate bone volume for implant surgery without requiring soft and hard tissue augmentations. There must be opposing dentition so that occlusion can be established. The patients had to demonstrate good oral hygiene and be free from active periodontal disease. Exclusion criteria included uncontrolled systemic diseases, history of radiotherapy to the head and neck, smoking (>10 cigarettes/day), previous implant failure, and requiring immediate implant placement. Before surgery, participants underwent a comprehensive evaluation, which included clinical photography, periapical radiographs, and cone-beam computed tomography (CBCT).

Implant surgery and provisionalization

Five patients presenting with edentulous sites were prepared for the routine dental implant surgery, and all surgical procedures were performed under local anesthesia. A full-thickness flap was elevated to expose the surgical site, and implant sites were prepared according to the manufacturer's instructions (Fig. 1A). Dental implants (Hiossen EK, Ridgefield Park, NJ, USA) were placed using an insertion device and hand ratchet, all achieving clinically acceptable insertion torque to ensure primary stability. In addition to placing one or two study implants, multiple implants were placed to provide comprehensive oral rehabilitation (Fig. 1B–E). For study implants, a chairside provisional restoration (PMMP resin enamel plus, Micerium S.p.A., Genoa, Italy) was immediately cemented (Temp-Bond, Kerr Corporation, Bolzano, Italy) to each provisional abutment. Provisional restorations were adjusted to light centric contacts (markings on 25–30 μm articulating paper) while remaining shim stock-negative (8–12 μm foil did not hold), and free of excursive contacts (Fig. 2A). The flaps were adapted for tension-free wound closure with interrupted sutures (Vicryl, Ethicon, Raritan, NJ, USA). A periapical radiograph was taken immediately after the surgery, and the patients underwent the standard post-surgical infection and pain control with Amoxicillin 500 mg three times/day for 7 days and Ibuprofen 600 mg three times/day for 5 days (Fig. 2B). The patients returned for routine follow-up appointments until the day of the biopsy (three months post-surgery), and any adverse events were documented.

Dental implant biopsy

Strategically placed seven study implants were biopsied at 3 months post-implant surgery using piezo surgery instruments. Hard tissue augmentation using bone grafts and membranes was performed to repair biopsy sites. Recovered specimens were immediately immersed in 10 %

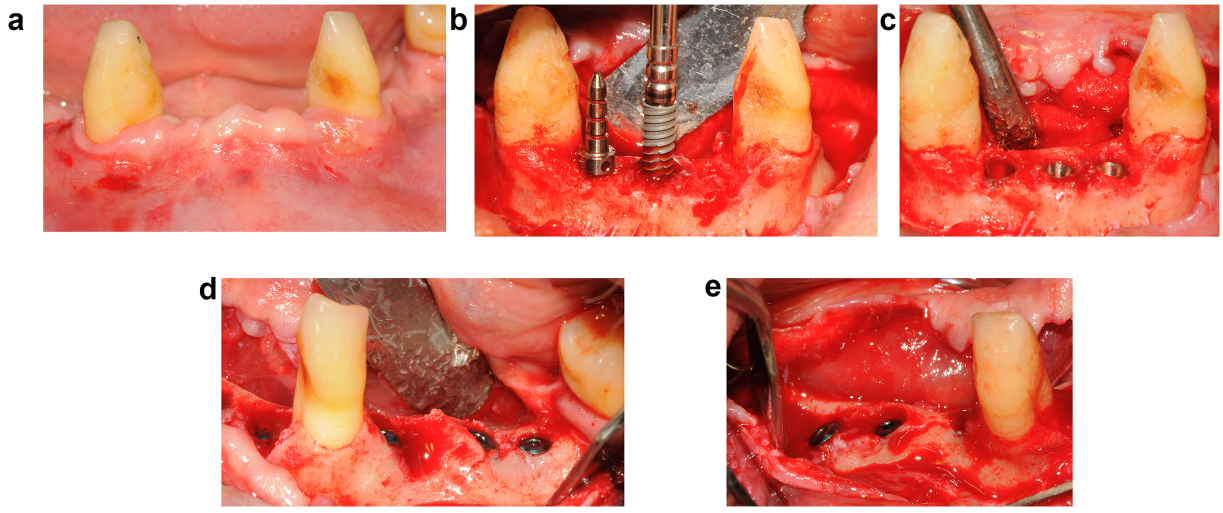

Figure 1 Clinical photographs of our patient. (A) A 61-year-old female presented for full mouth rehabilitation, and two dental implants were planned to be inserted to fabricate a four-unit FPD. (B) Three dental implants were placed, with the idea of harvesting the middle implant as the biopsy implant. (C) Three dental implants have been placed for the mandibular anterior region. (D and E) Additional non-study implants were placed for the posterior regions in order to establish ideal occlusion and rehabilitation.

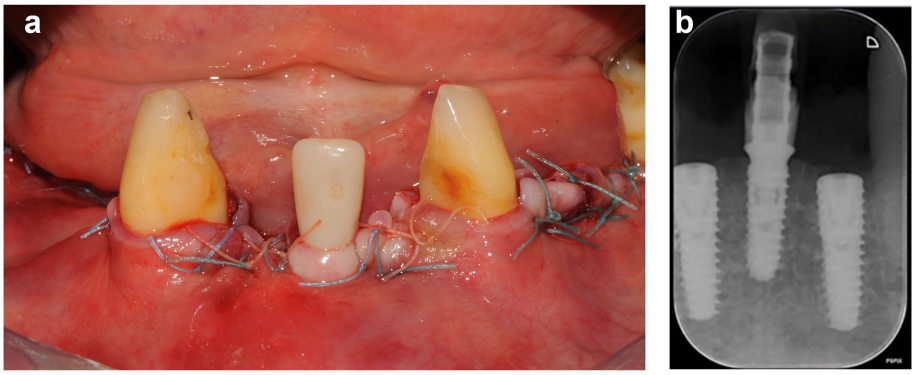

Figure 2 Clinical photograph and radiograph of our patient. (A) A provisional restoration has been placed on the study implant. (B) A periapical radiograph of the provisionalized dental implant.

buffered formalin for fixation and processed for histologic and histomorphometric analysis.

Histological and histomorphometric analyses

The block specimens were sectioned in a mesio-distal direction and parallel to the long axis of the implant, resulting in multiple sections for evaluation. The fixed samples were dehydrated in a graded series of ethanol (60 %, 80 %, 96 %, and absolute ethanol) using a dehydration system with agitation and vacuum. The blocks were infiltrated with Kulzer Technovit 7200 VLC-resin. Infiltrated specimens were placed into embedding molds, and polymerization was performed under white- and blue light. Polymerized blocks were sectioned in a mesio-distal direction and parallel to the long axis of each implant, except one implant that was cut in bucco-lingual section. The slices were reduced by microgrinding and polishing using an Exakt grinding unit to an even thickness of 60–70 μm. Sections were stained with Sanderson's RBS and counterstained with acid fuchsin and examined using both a Leica MZ16 stereomicroscope and a Leica 6000DRB light microscope. Histomorphometric measurements were performed by using software (ImageAcess, Imagic, Zurich, Switzerland) to calculate the percentage of direct contact between mineralized bone and the implant surface (BIC).

Results

Clinical outcome

A total of 5 patients (4 females and 1 male; mean age 59.4 years; range 49–74 years) received 7 immediately provisionalized single implants on both the mandible and maxilla (5 maxillary and 2 mandibular implants). All implants achieved primary stability at placement, with locations including 3 maxillary anterior, 2 posterior maxillary, 1 mandibular anterior, and 1 mandibular posterior sites. All

patients completed the follow-up period without major complications. No implant failures or prosthetic complications occurred during the observation period, resulting in a 100 % survival rate. Healthy soft tissue was noticed around the study implants. All patients received oral rehabilitation on non-study dental implants.

Histomorphometric analysis and bone-to-implant contact analysis (BIC)

Histologic examination confirmed direct BIC in all retrieved specimens (Fig. 3A–C). The soft tissue surrounding the provisional restorations appeared healthy, without direct soft tissue attachment to the provisional restoration. In Sanderson's RBS/acid fuchsin–stained ground sections, newly formed bone appeared as a more deeply fuchsin-stained band lining the implant surfaces, often delineated from paler, pre-existing trabeculae by scalloped reversal (cement) lines. This pattern was evident from the crestal to apical regions on all retrieved specimens and was accompanied by well-organized lamellae and abundant osteocyte lacunae adjacent to the implant surface; no fibrous tissue interposition was observed. The results reflect a high degree of osseointegration and stable integration of the implant within the surrounding bone. Out of 7 implants, three implants experienced bone remodeling to the first thread at the time of the biopsy; however, this finding did not interfere with the overall integration of the implants.

Histomorphometric analysis revealed a mean total BIC of 76.51 ± 8.66 % (SD), ranging from 63.35 % to 90.01 % at 3 months. By surface, mesial BIC averaged 81.07 ± 9.26 % and distal BIC 75.93 ± 10.04 %. One specimen was sectioned bucco lingually only and therefore lacked a total BIC%; its buccal BIC was 82.85 %. BIC values were consistent across implant sites and comparable to those reported in conventional healing protocols. Due to the small number of samples, no statistical analysis was performed to compare BIC on different regions of the mouth.

Discussion

A key requirement for implant success is the achievement of long-term direct bone-to-implant contact (BIC), also known as osseointegration, which provides stability and functional loading capacity.[4,17] The results of the present study demonstrate that immediately provisionalized dental implants achieved substantial BIC and maintained clinical stability throughout the observation period. These findings provide histologic confirmation that immediate provisionalization can be a safe and efficacious treatment option,

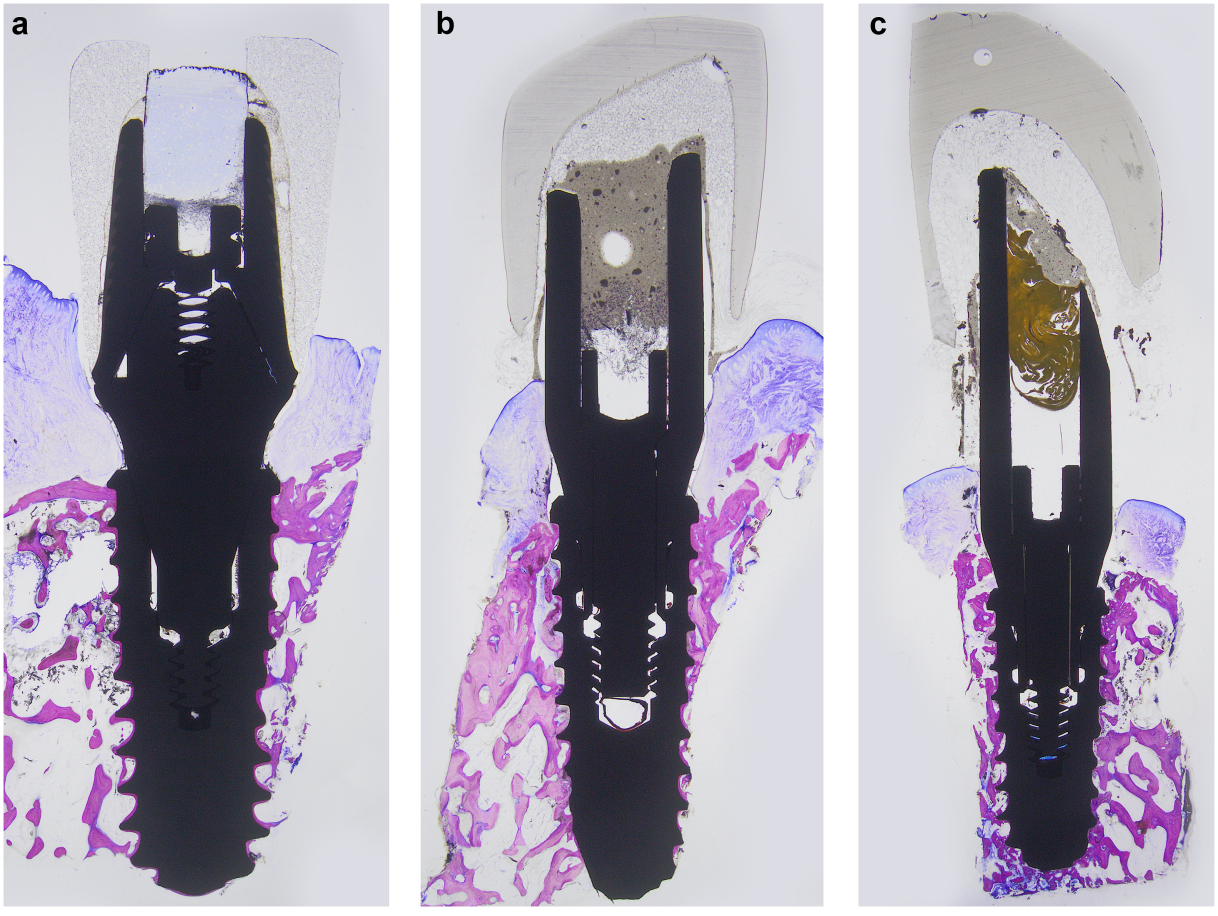

Figure 3 Representative Histologic Sections. (A, B, and C) Histologic sections of three biopsied provisionalized implants demonstrating maintenance of the crestal bone level and the direct BIC around implant threads. Histologic analysis revealed intimate contact between newly formed lamellar bone and the implant surface, with no intervening fibrous tissue.

supporting not only favorable clinical outcomes but also true osseointegration at the microscopic level. Our findings are consistent with previous clinical studies reporting high survival and success rates for immediately loaded or temporized implants under controlled conditions.[19,20] In particular, Degidi and Piattelli demonstrated that both functional and non-functional immediate loading protocols can lead to predictable osseointegration when adequate primary stability is achieved.[6] Similarly, Glauser et al. reported favorable outcomes for immediately loaded implants in soft bone, suggesting that implant surface technology and careful occlusal management are critical determinants of success.[21]

Histologic evidence of osseointegration under immediate provisionalization protocols has been limited, particularly in human samples. The present study builds on these findings by providing direct histologic evidence in a clinical context of immediate provisionalization, thereby bridging the gap between experimental data and clinical outcomes. The review of histological and histomorphometrical data from retrieved dental implants over a 30-year period, under various loading conditions, revealed that loaded implants had a 10 %—12 % higher BIC compared to not-loaded, submerged implants.[18] Most of the present histological studies on human specimens, retrieved for various reasons, have found compact, lamellar bone with numerous Haversian systems and osteons near the implant surface, characterized by a very high BIC (60 %—90 %), while a few implants had a lower BIC of 30—40 %.[18] Traini et al. also found that a lower mineral density was present in the bone around unloaded implants, but still unknown are the BIC values necessary for the clinical stability of an implant, and different values have been reported from 25 % to 50 %.[22] Loading of the implant altered the microstructure of the peri-implant bone, and immediate loading did not pose problems for the formation of new bone at the implant interface level, likely providing a positive effect on the peri-implant tissues.[22] Osseointegration represents a highly dynamic physiological process, and the peri-implant bone tissue has undergone structural and organizational changes over the years.[22] These increased levels of organization are reflected in multiple remodeled areas of the bone, representing the numerous remodeling cycles that have occurred over the years of functional loading.[22]

The implant system (Hiossen EK implant) used in this study features sandblasted and acid-etched surfaces with a nano-hydroxyapatite (NH) coating, which facilitates early blood clot adhesion, promotes faster bone formation, and improves BIC.[23—26] In addition, the thread geometry and thread body increased the insertion torque and path correction, resulting in the stable seating of the implant. The EK system utilizes a single restorative platform across all implant diameters, allowing clinicians to work with a single connection geometry, from narrow to wide fixtures, thereby simplifying component selection, inventory, and chairside steps. The interface features a 15° morse-tapered internal hex that facilitates platform switching and is designed to produce a tight conical fit, a design long associated with smaller micro-gaps and reduced micromovement at the implant—abutment junction. Degidi and Guida reported the BIC of immediately loaded dental implants to be 52—60 % while this current study reported 76.5 %.[10,11]

Several limitations of this study should be considered. The number of biopsies was limited, and retrieval of implants or peri-implant bone tissue is inherently challenging in human subjects, restricting the sample size. Additionally, the observation period was relatively short, and longer-term studies are required to confirm the stability of osseointegration over extended functional loading. Finally, this study did not directly compare immediate provisionalization with conventional loading protocols, which could provide valuable comparative data. Nonetheless, the current histologic results provide further support for the adoption of immediate provisionalization protocols, particularly in esthetically demanding cases where conventional delayed loading may compromise tissue outcomes.

Within these limitations, the present findings suggest that immediate provisionalization of dental implants does not compromise osseointegration and can achieve BIC comparable to conventional protocols. Future research should aim to expand the histologic evidence base, include larger patient cohorts, and investigate the long-term biological and functional outcomes of immediate provisionalization.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that may have influenced the work reported in this study.

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