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Case Report

Fully Digital Workflow for Immediate Loading Using a Minimally Invasive Surgical Approach: A Case Report

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Abstract: Objectives: CAD-CAM technology has enabled clinicians to provide accurate and predictable restorations. Chairside time has been reduced and patient's comfort has been improved. A fully digital workflow can be now predictably adopted in implant surgery and implant restorations. Methods: A male patient, 55 years old, was referred for the restoration of his edentulous mandible. Radiographs and clinical evaluation were assembled to plan implant placement. The flapless approach is preferred to provide for a mucosa-supported surgical guide and lessen the patient's post-operative complications. In flapless cases, the operator does not have any direct overview of the surrounding soft tissues and underlying bone. In this case, a new, minimally invasive H-shaped incision technique was performed. A fully digital protocol is presented with a two-piece stackable surgical guide to confirm accurate implant placement. Results: A high-performance polymer framework (PEEK) combined with zirconia crowns completes the digitally designed edentulous restoration. Conclusions: Adopting this technique offers the clinician benefits in both the surgical and the restorative part.

Keywords: digital dentistry; digital workflow; immediate loading; minimally invasive implant surgery; surgical guide

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1. Introduction

Guided surgery leads to more predictable and precise implant placement and, therefore, to optimal esthetic and functional results as far as the final prosthesis is concerned. Even experienced clinicians that previously preferred free hand implant placement have advocated that guided surgery results in a more precise placement of dental implants as far as positioning and angulation are concerned [1].

Treatment planning begins with a Computed Tomography (CT) or a Cone Beam Computer Tomography (CBCT) examination and the intraoral scanning of the patient's dentition or mucosa. This information is then merged via specific software, and a digital simulation of the implant placement follows [2,3]. There are several categories of guided surgery, such as static or dynamic, fully or partially guided, and open-flap or flapless. Flapless techniques are considered to be superior to open-flap surgery, mainly due to the reduction of chairside time and trauma since the periosteum remains attached throughout the process and the blood supply remains undisturbed [4,5]. In addition, not dealing with

soft tissue management is considered a significant benefit [6]. However, lack of unrestricted visual access, combined with lack of experience, often results in bone fenestrations and imprecise placement [5,7].

Guided surgery has been associated with several errors and inaccuracies, which are attributed to computer tomography image acquisition, template manufacturing, tolerance of the guiding sleeve, tissue support, mucosal thickness, and provider experience [8–24]. In full arch rehabilitation techniques, more factors are associated with clinical risk of inaccuracies in implant placement since guide orientation and stabilization is more difficult and mucosa-supported guides exhibit low in vivo accuracy [25].

The aim of this case report is to reveal the benefits for clinicians of following the digital workflow of a fully guided case, introducing a new minimally invasive surgical technique for the implant placement, immediate loading with a provisional prosthesis, and finally a high-performance polymer framework Polyether ether ketone (PEEK)-Zr crown definitive restoration.

2. Case Report

A male patient, 55 years old, was referred for the restoration of his edentulous mandible, presenting with an overdenture supported by one implant as an existing prosthesis. The patient's chief complaint was lack of retention and stability of the existing restoration which lead to poor functional and esthetic outcome (Figure 1). After a clinical and radiographical examination (orthopantomograph), a fixed restoration retained on six implants was chosen as a restorative option. Before any intraoral photograph, the patient was informed for the potential of all alternative treatment plans for his case. Informed consent for publication was obtained from the patient. The existing overdenture was trimmed in six different areas bilaterally, three on each side, with a carbide bur (H1S, Komet Dental); radiopaque sphere-shaped markers (Computed Tomography—SPOT 120, Beekley Medical, Bristol, RI, USA) were placed, and a digital impression was taken (TRIOS 3, 3Shape A/S, Copenhagen, Denmark).



Figure 1. Initial overdenture in the mandible. Frontal view (**left**) and occlusal view (**right**). Maxillary dentition was treated for periodontitis before implant placement.

A CBCT (Figure 2) was performed with the overdenture placed intraorally, and then only the overdenture was scanned using the IOS Scanner (TRIOS 3, 3Shape A/S).

Digital Imaging and Communication in Medicine (DICOM) files and Standard Tessellation Language (STL) files were merged and superimposed using a dedicated software (Implant Studio, 3Shape, Copenhagen, Denmark). This dual scan technique allowed for the digital articulation of the maxillary prostheses with the edentulous mandible and the existing overdenture (used as the diagnostic digital wax-up). The digital planning and surgical placement of six implants (BLT, Straumann, Basel, Switzerland) to receive a screw-retained definitive prosthesis was performed (Figure 3A–C).

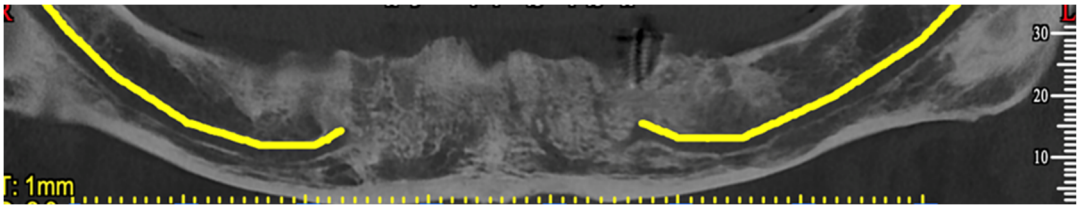


Figure 2. Panoramic view from CBCT. The inferior alvoral nerve is marked and the existing implant is positioned 5 mm above the mental foramen.

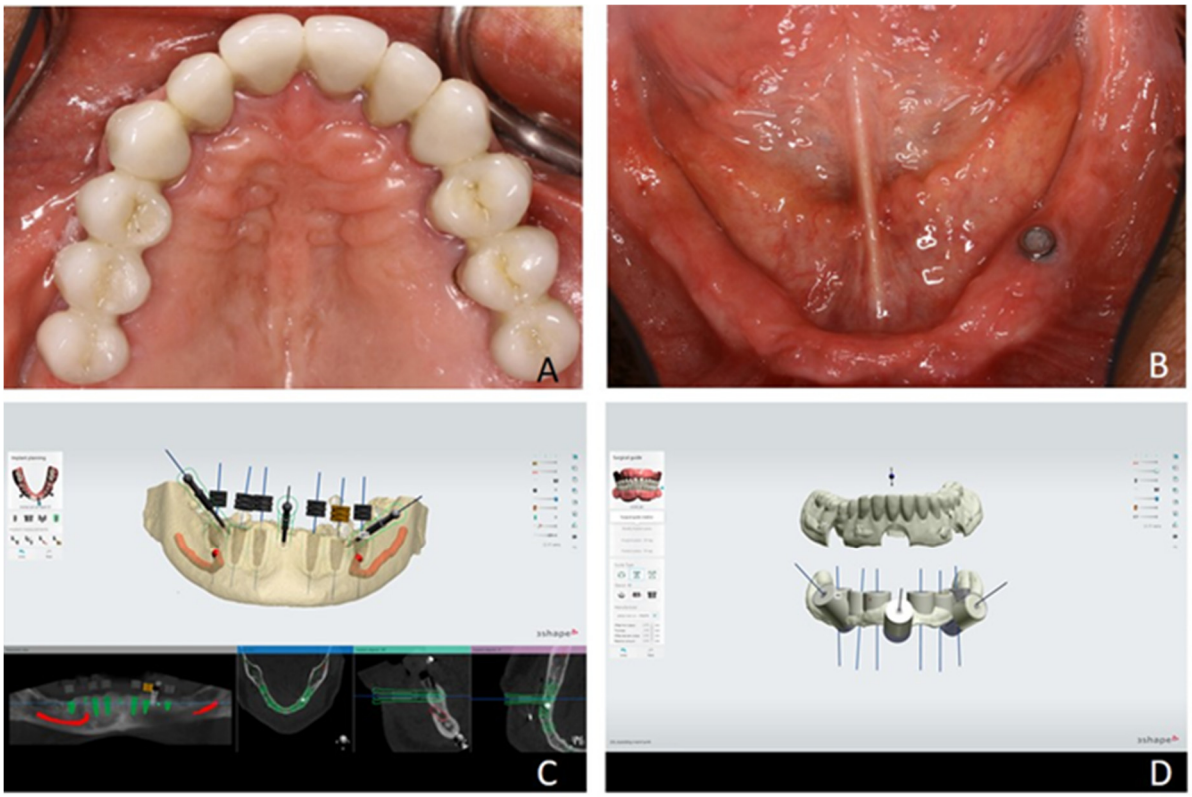


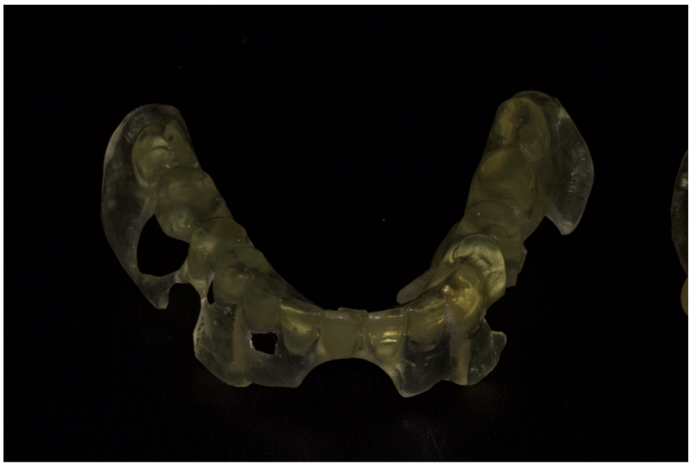
Figure 3. (**A**) Pre-existing maxillary restoration. (**B**) Pre-existing mandible. (**C**) Digital planning. Implants, fixation pins, and sleeves positioned preserving the anatomical structures. (**D**) Two-piece surgical guide design. Stackable parts allow for correct orientation of the surgical guide intraorally.

A mucosa-supported surgical guide design was determined to offer stability during surgery. The insertion holes for the surgical sleeves were designed to transfer the exact tooth position already determined by the acceptable existing overdenture. A two-piece surgical guide (Figure 4) was fabricated where the intaglio first part featured the implant insertion drilling holes with cemented metal sleeves. The overlay second part (Figure 3) accurately fit over the first piece, featuring the same occlusal surface with the existing overdenture to ensure accurate occlusion and positioning during the process (Figure 3D).

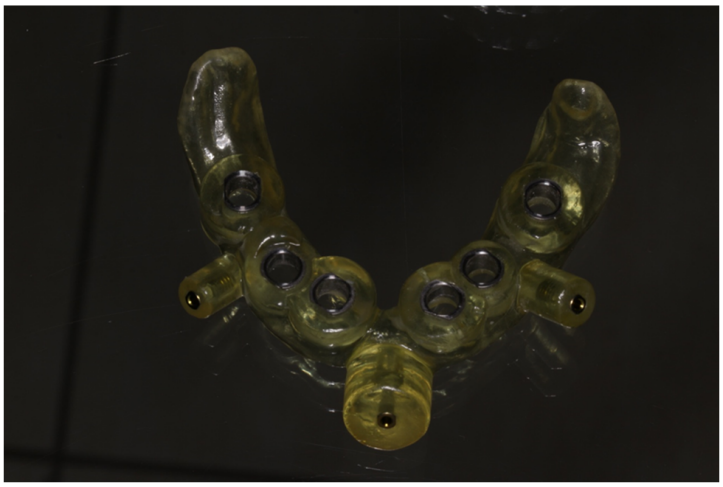
At the same time, a provisional restoration was milled (Telio CAD, Ivoclar Vivadent AG, Liechtenstein) following the previous occlusal scheme but altering teeth morphology and aesthetics. The milled provisional restoration featured insertion holes at the occlusal surfaces to allow for intraoral activation of the temporary abutments and to achieve passive fit (Figure 5D).



(**A**)



(**B**)



(**C**)

Figure 4. Two-piece surgical guide. (**A**) Both parts are positioned together to evaluate the accurate and passive fit. (**B**) The occlusal part is a duplication of the pre-existing reference denture. It will give stability to the surgical guide through the established occlusal scheme. (**C**) Surgical part of the guide. It will be attached to the bone through the fixation pin. Support is performed from the contact areas with the mandibular mucosa.

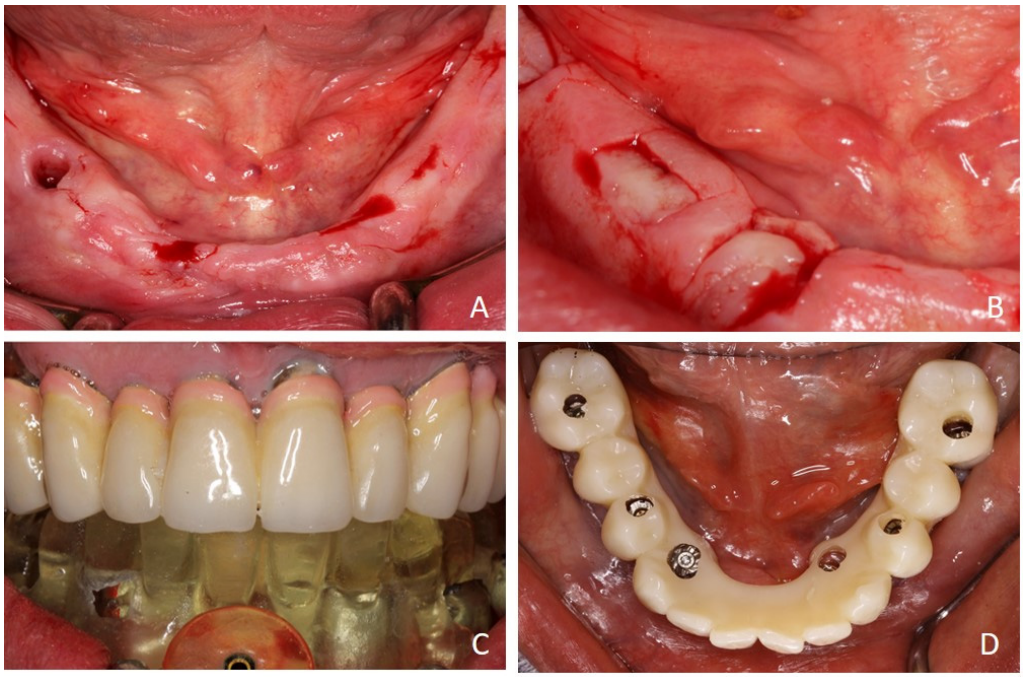


Figure 5. (**A**) Initial marking of drilling points with a probe following primary surgical guide placement. (**B**) H-shaped incisions allow direct visual access and precise surgical guide seating. (**C**) Correct surgical guide seating in maximum intercuspation. (**D**) Milled provisional restoration seated for intraoral activation to achieve passive fit.

3. Surgical Strategy

Additional stabilization for the surgical guide was provided with three fixation pins buccally, one at the midline and two at the premolar areas (Figure 4C). Instead of choosing to proceed to the implant placement in a flapless manner, a new, minimally invasive, H-shaped incision technique was performed. More specifically, the two parallel, vertical lines of the H correspond to the mesial and distal end of the perpendicular incision line, whose length slightly exceeded the implant diameter. This technique encompasses the benefits of visual access to the underlying bone and a balanced distribution of keratinized tissues buccally and lingually/palatially. This is particularly important in cases when thick mucosa could lead to perforation of the buccal or lingual plate if implants were placed following a flapless technique (Figure 5A–C). In this case, the H-shaped flap was proven to be even more beneficial, since there was very little keratinized mucosa, further decreased after the use of a tissue punch. Moreover, the minimal tissue reflection facilitated the cooling of the area without disrupting the blood supply due to periosteum elevation. Lastly, the H-shaped flap allowed for more favorable healing and reduced post-operative stress.

Gradual drilling through the guide sleeves was performed until the final diameter for each implant and the final placement were attained, maintaining accuracy throughout the whole surgical process (BLT, RC, Straumann, Switzerland).

Multi-unit abutments were placed (SRA, Straumann, Switzerland) at 35N torque and the milled provisional restoration was activated intraorally and delivered. Occlusal adjustment was performed to allow for even load distribution (Figures 5D and 6A). Canine guidance was selected as an occlusal scheme with special attention to avoid occlusal disturbances in the non-working side [26].

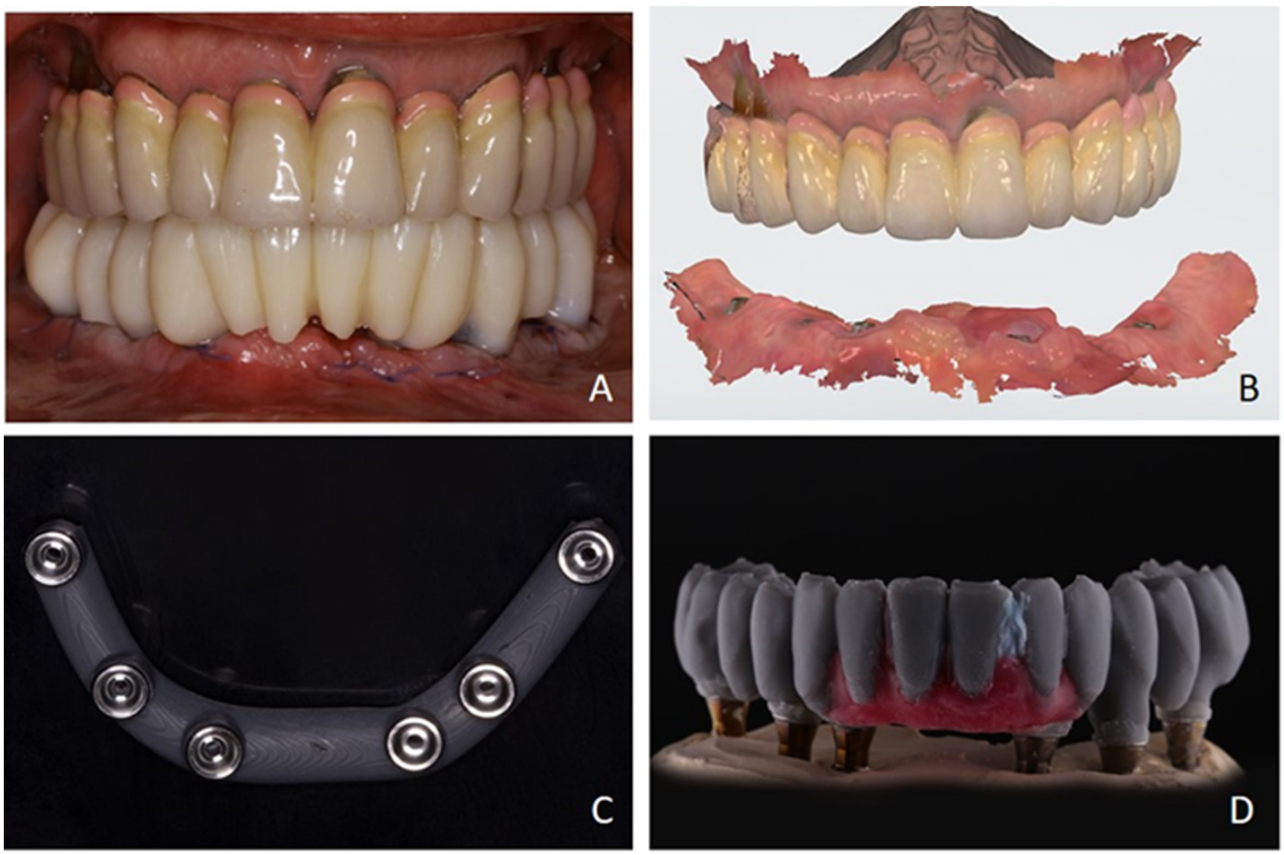


Figure 6. (**A**) Provisional milled restoration delivered. (**B**) Digital articulation in centric relation. Vertical dimension of occlusion was maintained by scanning the bite registration before removing the provisional restoration. (**C**) 3D printed verification jig to evaluate passive fit. (**D**) 3D printed mock prostheses to check esthetics and occlusal contacts.

After the osseointegration period, small adjustments were made to the occlusal scheme and esthetics, and a pre-preparation scan was taken with the mandibular provisional implant restoration placed intraorally.

A maxillary scan followed, and then the bite registration was scanned as well. This workflow allowed for the accurate transfer of all detail morphology, occlusal contacts, and the vertical dimension of occlusion, which were verified during the interim provisional stage to the new digital articulation (Figure 6B). The emergence profile and implant position were also scanned together with the final digital scan of the mandible. A verification jig was printed to confirm implant position and passive fit of the final restoration. After the radiographic verification of an accurate implant–abutment connection, a mock restoration of the definite prosthesis was printed to evaluate occlusion and esthetics (Figure 6C,D) over multi-unit abutments (Figure 7). A high-performance polymer framework (PEEK)-Zr crown definitive restoration was fabricated and delivered (Figure 8A–C). Bonding protocol included extraoral-laboratory treatment of the PEEK framework with sulfuric acid 98% [27]. Then, a self-adhesive bonding system was used (Speedcem plus, Ivoclar, Schaan, Liechtenstein), except for the crowns on top of the implants, which were cemented with temporary cement (Temp bond Clear, Kerr, Scafati, Italy) to maintain retrievability and the ability to revisit multi-unit abutments.

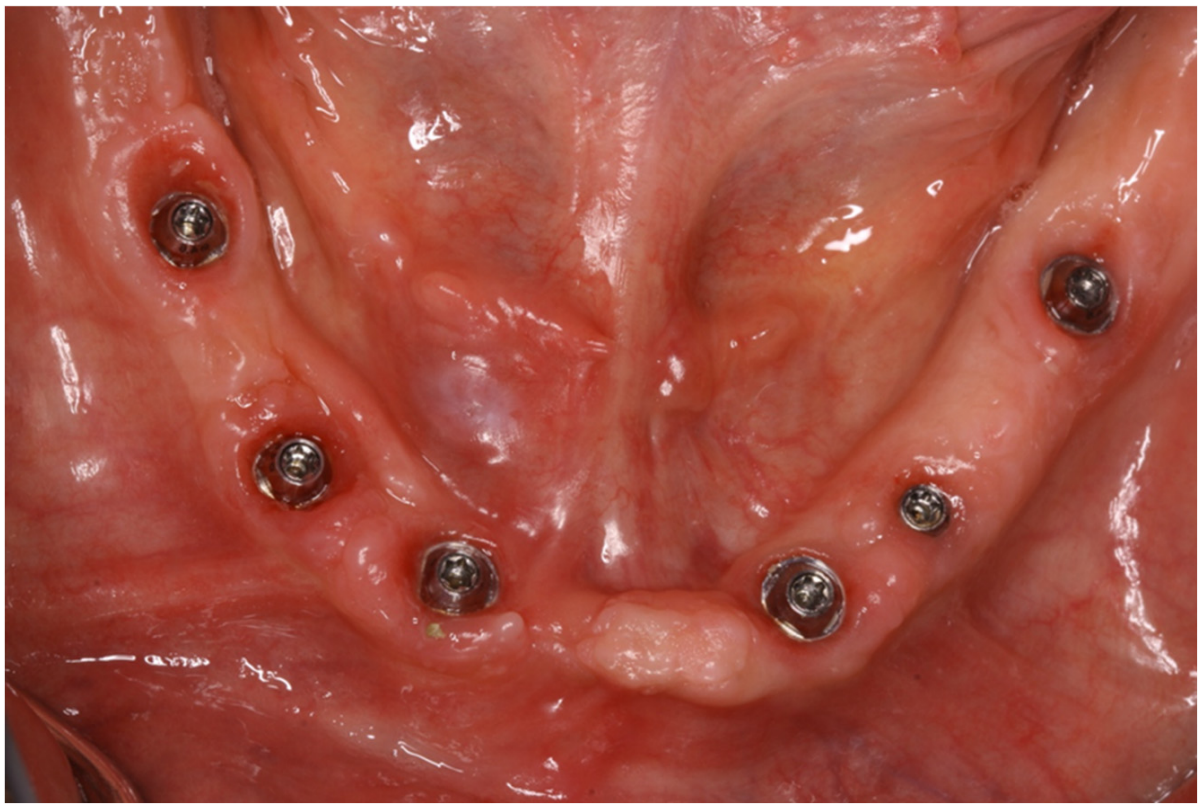


Figure 7. Keratinized tissue and multi-unit abutments placed.



Figure 8. (**A**) Peek framework with abutment-shaped occlusal morphology and composite pink esthetics. (**B**) Zirconia crowns bonded with resin cement on pontics and provisional cement over implant abutments to ensure retrievability. (**C**) Definitive prosthesis delivered.

4. Discussion

In this study successful fixed restoration of a mandibular edentulism was obtained, transforming a poor-fitting implant-supported overdenture to an aesthetic six-implant screw-retained full-arch fixed partial. Immediate loading and fully digital protocol facilitated both the clinician's and the patient's expectations.

Guided surgery protocols advocate for improved accuracy, yet great heterogeneity among different studies can be noted. When analyzing the "accuracy" parameter, multiple factors are taken into consideration: the virtual implant position compared to the actual position as far as the coronal, apical, angular, and vertical deviation are concerned [2,9]. According to a meta-analysis by Bover-Ramos et al. [10], there is significantly greater accuracy in the in vitro studies, concerning apical deviation, in comparison with in vivo trials. Moreover, in vitro studies also present the greatest accuracy when it comes to angular deviation compared to clinical and cadaver ones. As far as the coronal deviation

(entry-point) is concerned, there was no statistically significant difference between the three groups, although it was close to a significant level between clinical and in vitro studies [9]. However, one of the most crucial yet insufficiently analyzed parameters remains the vertical deviation and no safe conclusions could be determined, except for the lack of any statistically significant difference in vertical deviation between fully and half-guided surgery groups. Deviations in the vertical dimension of the implant could be proven disastrous for significant anatomical structures, such as the sinus floor or the alveolar nerve. The authors' advice is for the clinician is always to consider the greatest value of deviation, derived from the meta-analyses, during the treatment planning [9]. Overall, what is also interesting, according to Jung et al., is that the presence of bleeding and saliva in clinical trials has a negative impact on implant accuracy [10].

Another important factor that affects accuracy is the type of tissue support of the guide. When a flap is reflected, bone support is insufficient, which makes repositioning of the guide difficult. The most accurate type of guide support is tooth support, yet it is not applicable in all cases [25]. Mucosal support presents a statistically significant higher accuracy compared to bone, but it also means that the procedure will be executed in a flapless manner [11]. This comes with certain prerequisites, which are a minimum of 4.5–5 mm of keratinized tissue and a minimum bone width of 4–4.5 mm [13]. However, a higher mucosal thickness is associated with more frequent deviation occurrence [14].

Flapless implant placement also includes the risk of thermal damage to the bone because of the decreased saline irrigation reaching the underlying tissues through the guide [15]. In addition to that, flapless procedures are 1.75 times more likely to cause failures and, according to Charchovic et al., the main reason for this is the removal of the surgical guide in the last step of surgery, which is the implant placement [16]. This is also confirmed by the meta-analysis of Zhou et al., indicating a much higher accuracy of fully guided surgery in angular, entry-point, and apex deviation [17]. In this case, report, the H-shaped incision technique is proposed, since it facilitates visual access to the bone at the area of placement while concomitantly being very minimally invasive to the soft tissue and also allowing mucosal support, as well as appropriate distribution of keratinized tissues circumferentially to the implant neck.

When choosing to proceed to static guide implant placement, it is advised for clinicians to consider the surgical sleeve height, key height, and drill length. El Kholy et al. found that the smaller the guided key height, the more accurate the implant position. Concurrence between the planned and actual position is also affected by the "free-drilling-distance", defined as the length between the bottom of the sleeve to the most apical part of the osteotomy, which is the tip of the drill. Should this distance be increased, apex, entry-point, and angular deviations occur. All these variables have a statistically significant effect on accuracy when measured jointly [18].

Experience also plays a key role and a careful selection of patients is necessary for the execution of this technique. Marei et al. [19] concluded that less-experienced surgeons could benefit from the partially guided system, as it combines freehand surgery and guided protocols. The characterization of a surgeon as "novice" is very diverse among different researchers, as some set a minimum number of implants as a measure of experience, whereas others define it as the "lack of clinical experience".

Overall, as far as the horizontal coronal deviation is concerned, a safety distance of 1.2–1.3 mm is recommended and of 1.7 mm for horizontal apical deviation, whereas for apical deviation, a 4.7 degree angle is recommended to be calculated. As far as the vertical deviation is concerned, some researchers suggest a safety distance of 1 mm. However, Sicilia et al. only suggested 0.5 mm [3,20]. Fully guided systems with screws are more reliable when proceeding in a flapless approach [11].

Protocols for immediate loading concerning implant surgery and restorations are well documented. New digital techniques continue to emerge to make clinician practice less time-consuming and more efficient. The combination of the existing surgical and prosthodontic principles with novel digital tools and techniques can potentially lead to more accurate and predictable treatment outcomes [5].

A significant issue is the material selection for the final restoration, since many alternatives could be documented. However, screw-retained restorations allow retrievability and PEEK frameworks seem to be reliable [28–31]. Mandibular flexure is an issue for the design of mandibular full-arch rehabilitations [32], while the reliability of full-arch monolithic mandibular restorations is questionable [33,34]. In this case, adhesion of zirconia crowns to PEEK framework followed recent adhesive protocols [27,35], and temporary cementation of crowns on top of implants maintained excellent aesthetics and retrievability for access to implant screws.

In conclusion, with this technique, the clinician can benefit in both the surgical and the restorative parts. When the flaps are made, mucosa does not interfere in the surgical guide placement since there is adequate space between the flap and the intaglio of the surgical guide. Consequently, the digital implant placement and the digital position of the surgical guide design are transferred intraorally in an accurate and passive way. Prosthetically, since the pre-existing full denture is set in centric relation and its teeth set-up is made on that position, duplicating the denture and placing it on top of the surgical part of the guide not only gives stability but also accuracy of the transferring data (design–3D printing–intraoral placement).

In addition, converting the previous denture to the new provisional restoration for the immediate loading helps the patient to maintain the same VDO, though occlusal contacts and minor adjustments are needed. The limitations of this technique are related to the anatomical, surgical, and design aspects. Mucosa thickness is crucial when opening the flaps. If the thickness jeopardizes the passive fit and stability of the surgical guide, the fixation will be displaced, and in the end, the implant placement will have a greater deviation than that described in the literature by Fonseca et al. [23]. Moreover, potential errors in guide manufacturing or intraoperative deviations compromise the possible benefits compared to partial-guided or non-guided approaches [36].

The alternative of non-guided implant placement in this case was not supported since it is well documented that guided placement increases accuracy [37], which is essential for immediate loading. A malposition of even one implant in this case could jeopardize the passive fit of both the provisional and the final restoration and could increase complications over time. The design of the provisional restoration is also affected since the implant placement may change and that may lead to esthetic problems with the position of the access holes and changing the teeth anatomy. This section could include specific recommendations for clinical practice based on the findings. Further limitations are the lack of long term follow-up of this case and the small sample size since it is a unique case report.

Future research directions could include evaluation of accuracy of guided techniques with digital scans over time. The field of fully digital implant restorations could be expanded through improvement of the accuracy of digital scanners and surgical guides, both of which could lead to optimization in every single clinical step until the final restoration.

5. Conclusions

By adopting this technique, the clinician can benefit in both the surgical and the restorative parts. The fully digital surgical approach eliminates potential errors, and the retrievability of prosthodontic restoration ensures long-term stability and clinical success, even if prosthetic complication occurs.

Author Contributions: G.K.: the prosthodontist who planned and treated the clinical case; E.P. and T.T.: associate prosthodontists who assisted in treating the patient; D.M.: attending student dentist; I.T.: dental technician fabricating surgical guides and restorations; E.-G.T.: review, editing, and submission; P.Z.: senior and corresponding author, manuscript review, editing, and submission. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the guidelines of the Declaration of Helsinki; ethical review and approval were waived for this study due to the nature of the manuscript being a case report. According to ethical standards, case reports that do not include identifiable information about the patient and focus solely on clinical observations do not require approval from an ethics committee. However, informed consent for publication was obtained from the patient.

Informed Consent Statement: Informed consent was obtained from the subject involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest and confirm that they do not have any financial interest in the companies whose materials are included in this article.

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