

Case Report

Full Digital Model-Free Maxillary Prosthetic Rehabilitation by Means of One-Piece Implants: A Proof of Concept Clinical Report with Three-Years Follow Up

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Abstract: Implant rehabilitation is a daily practice in dentistry, and patients often have heightened expectations regarding both the functional and the aesthetic outcome. Implant–abutment connection (IAC) is involved in the long-term aesthetic quality of the rehabilitation. The use of one-piece implants for fixing dentures may prevent the mechanical and biological implication of the implant–abutment interface, resulting in a better quality of hard and soft tissue maintenance. In this case report, we present a novel one-piece implant in a maxillary rehabilitation with a full model-free digital approach.

Keywords: dental implants; digital dentistry; one-piece implants; implant–abutment connection



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1. Introduction

In the past few decades, osseointegrated dental implants have become a predictable and established method to support fixed restorations, and they are associated with long-term survival rates [1–6]. Recently, increasing attention is being paid to the aesthetic outcome and the stability of peri-implant tissues over time [7,8].

The factors conditioning the aesthetic quality of an implant-supported restoration include the 3D position of the implant [9], the quantity and quality of hard and soft tissues [10], and the design of the prosthetic emergence profile [11]. In this context, gingival architecture is crucial to maintain implant health and aesthetic [7]. In the literature, emerging evidence suggests that implants with an implant–abutment connection present a micro-gap between the fixture and the prosthetic components. Such space results in micromovements under mechanical load, which can jeopardize the stability of the surrounding peri-implant hard and soft tissues [12]. This dangerous behavior may be overcome using one-piece implants that present with no connection.

One-piece implants are well described in the literature [13]. They present certain advantages such as reduced surgical steps, the possibility to use smaller diameters while maintaining efficient mechanical strengths, less inflammation, pain and stress by reducing the prosthetic steps [14]. The absence of micromovements and good soft tissue healing are also well supported by the evidence [14].

Like any system, it also has some limitations, as implant insertion involves transmucosal healing, which can cause problems during the healing phases in the absence of primary stability [15].

Despite this knowledge, there are a lack of data about one-piece implant dedicated to guided surgery in order to restore full arches.

In view of the above, the present report aimed to clinically and radiographically evaluate the peri-implant tissues following full model-free digital rehabilitation by means of one-piece implants.

2. Materials and Methods

A 72-year-old male patient presented with the chief complaints of tooth mobility, gingival bleeding and unaesthetic appearance. The patient was seeking a fixed implant supported maxillary rehabilitation to replace the existing removable partial denture anchored to the remaining natural elements. The medical history was noncontributory. The preliminary clinical and radiological analyses showed a severely compromised residual dentition characterized by severe chronic periodontitis (stage IV grade B from American Academy of Periodontology) and bone loss (Figure 1), incongruous restorations and malpositioned teeth.

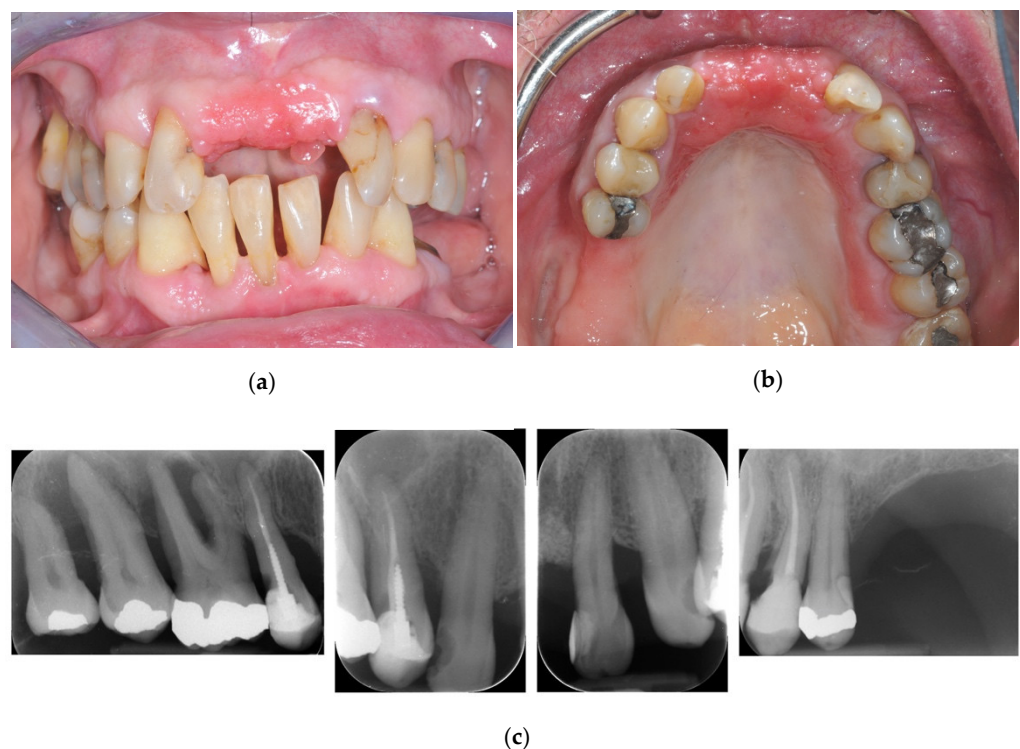


Figure 1. Baseline clinical situation: (a) the frontal view is represented, (b) the occlusal view of the maxillary arch and (c) the radiographic assessment of the case.

In the first sextant, teeth presented a grade 3 mobility and total attachment loss. An inflammatory response of the Schneiderian membrane was present, which was probably correlated with the compromised periodontal condition of the first molar. In the second sextant, the laterals were malpositioned and presented loss of attachment. In the third sextant, teeth 23 and 24 had root caries and attachment loss. In sextants 3 and 4, molars were missing, and 35 was a root fragment. In the fifth sextant, 41 and 42 showed a grade 3 mobility with probing above 10 mm. In the sixth sextant, the first molar was missing. The patient required fixed rehabilitation but refused bone reconstruction both because of the duration of treatment and the increased economic and biological costs. The patient presented a thick biotype, first dental class occlusion despite the missing element.

Different treatment options were presented to the patient, including benefits and disadvantages of each proposal. Finally, the decision for an implant-supported rehabilitation following a digital approach was made by mutual agreement. A signed informed consent was obtained prior to commencement of the therapy.

The first step consisted of a digital impression of both arches with an intraoral scanner (CS 3600, Carestream Dental[®], Carestream Health, Inc., Rochester, NY, USA) to register the virtual occlusal record and the occlusal vertical dimension (OVD). Intraoral and extraoral photographs with specific references were taken to visualize all the diagnostic data in a digital smile design software (Smile Lynx, 3D Lynx, Pero, Italy). A cone-beam computed tomography (CBCT, CS9600, Carestream Dental[®], Carestream Health, Inc., Rochester, NY, USA) scan was made to assess preoperatively the anatomy of the residual bone. At this stage, STL (Standard Triangulation Language) files retrieved from the digital scan were superimposed with the DICOM (Digital Imaging and Communication in Medicine) data acquired from the CBCT, exploiting the best-fit adaptation algorithm of the planning software (RealGuide; 3DIEMME, Figino Serenza, Italy) able to merge the DICOM volumes and the STL files of the teeth structures.

Once the diagnostic phase was completed, the ideal prosthetically guided position of the implants was virtually planned according to a digital waxing designed with dental CAD (Computer-Aided Design) software (exocad DentalCAD, exocad GmbH, Darmstadt, Germany). In this way, 4 immediate postextractive implants (FIXO, Oxy Implant Dental System, Colico, Italy) were planned in the maxilla (Figures 2 and 3).

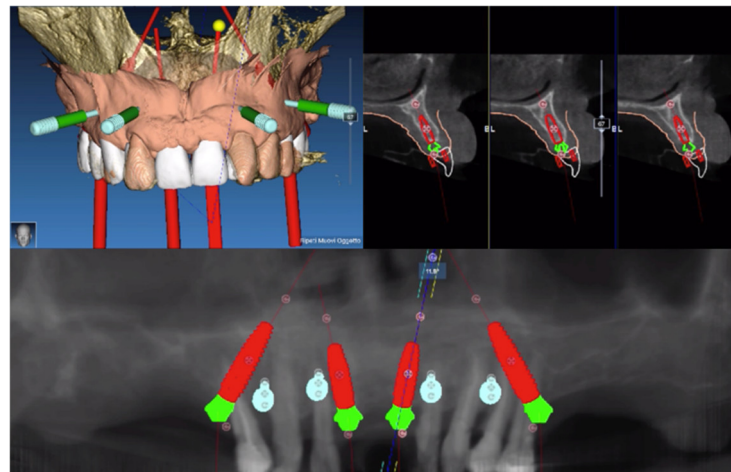


Figure 2. Maxillary arch digital project: on the left digital wax up integrated with the existing anatomy and anchor pins are represented, on the right CT slice of the project and below the implant position integrated with the patient radiological anatomy.

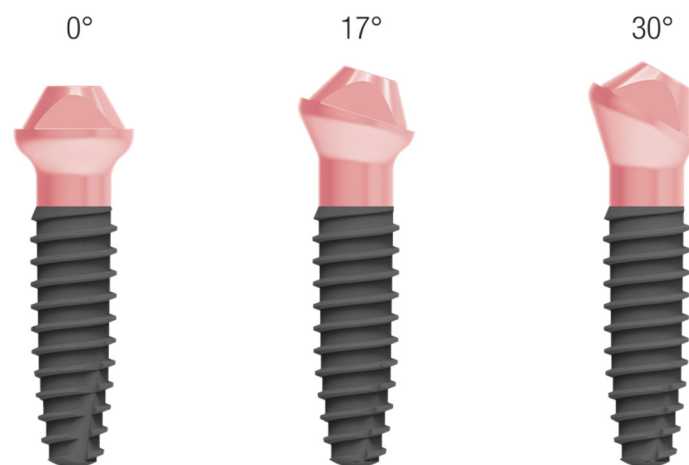


Figure 3. The FIXO system with integrated MUA in its 3 inclinations, 0°–17°–30°. It can be seen that the absence of the multiunit abutment reduces the thickness of the neck.

1. 15: 4×15 mm 30°
2. 11: 3.5×11.5 mm 17°
3. 21: 3.5×11.5 mm 17°
4. 25: 4×13 mm 30°

Concurrently, a provisional maxillary polymethyl methacrylate prosthesis reinforced with metal framework was designed and produced on the basis of the digital waxing with a model-free approach. The pre-existing occlusal vertical dimension was reproduced in the provisional restoration.

The virtual project was transferred into two surgical guides produced with a 3D printer (DWS020D; Digital Wax Systems, Thiene, Italy). The first tooth-supported stent was used to create the guides for the accurate insertion of the anchor pins. Teeth were then extracted, and the second stent was secured in the correct position with the aid of 4 bone pins inserted in the guiding holes prepared with the first stent. Thus, 4 one-piece implants were positioned with an insertion torque ≥ 35 Ncm (Figure 4). A bone profiler was not required since the multiunit abutment was integrated into the one-piece implant.

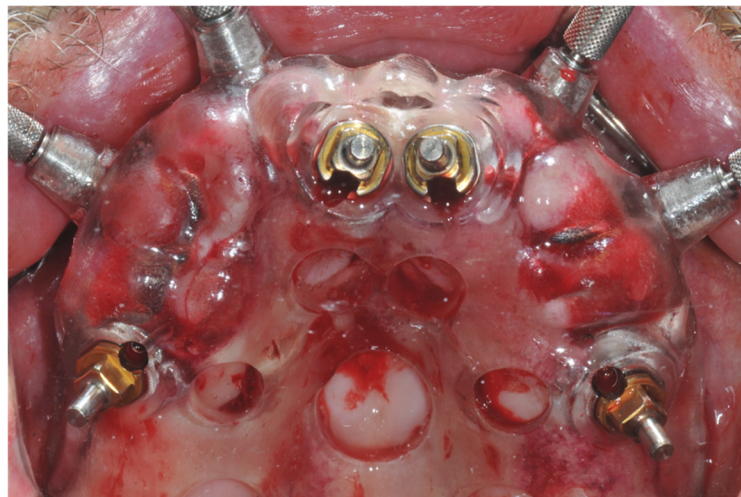


Figure 4. Implants inserted through the second surgical stent.

Alveolar socket preservation with deproteinized bovine bone mineral particles (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) was performed to minimize bone remodeling of postextractive sites [16]. In order to increase the buccal volume of the peri-implant soft tissues and prevent mucosal recessions, connective tissue grafted from the palate was sutured in the lateral incisor area with a bilaminar approach. The flap was coronally advanced, and the gingival margin was adapted to the right lateral incisor intermediate element [17].

Flaps were sutured with 6/0 polyglycolic acid suture. Intermediate abutments were screwed to the prosthetic platform of the one-piece implants. Such temporary abutments were designed and cut with a specific vertical stop with the aim to visualize the right apico-coronal position of the provisional during the intraoral fixation. In this way, it was possible to verify the proper seating of the prosthesis without the aid of the posterior mandibular teeth. An autopolymerizing composite resin (DEI Lab Easytemp2; DEI Italia, Mercurio, Italy) was placed over the abutments to fix the temporary prosthesis (Figure 5). The passive fit of the provisional was obtained by an intraoral fixation to the temporary abutment. A flowable light-polymerizing nano-hybrid composite (Tetric EvoFlow; Ivoclar Vivadent, Schaan, Liechtenstein) was used to close the screw access holes.



Figure 5. PMMA-reinforced temporary prosthesis: (a) frontal view and (b) occlusal view.

After 4 months, an additional connective tissue graft was needed to improve soft tissue thickness and to better condition and shape the gingival margin in correspondence of the left lateral incisor intermediate element [18] (Figure 6).



Figure 6. Soft tissue graft performed after 4 months to increase thickness in the 2.2 pontic area.

After a healing period of 6 months (Figures 7 and 8), an intraoral scan (CS 3600, Carestream Dental[®], Carestream Health, Inc., Rochester, NY, USA) was acquired and mounted on a virtual articulator according to the digital cross-mounting technique [19,20]. Implant scanbodies (FIXO Scanbody, Oxy Implant Dental System, Colico, Italy) screwed to the prosthetic platform were used to register the 3D position of the implants. Aesthetic and functional parameters were transferred to the definitive restoration by scanning the temporary prosthesis accepted by the patient.



Figure 7. Soft tissue frontal view after 6 months of provisional conditioning.



Figure 8. Soft tissue occlusal view after 6 months of provisional conditioning.

A virtual occlusal registration was acquired through an optical scan of the buccal surfaces of the mandibular and maxillary arches in contact, so as to maintain the pre-existing vertical dimension.

The extended scans of the soft tissues registered in all optical acquisitions, including the vestibule, the keratinized mucosa, the palatal rugae and the incisal papilla, were used to superimpose the consecutive digital impressions. As a consequence, the maxillary and mandibular arches were positioned in the virtual articulator respecting the correct intermaxillary relation.

The accuracy of the digital position of the implants was verified clinically and radiographically with the aid of an aluminum prototype designed in the virtual environment. The fit was assessed on the prototype, clinically by visual inspection, finger pressure with Sheffield test and by using peri-apical radiographs. A zirconia monolithic (Xanos Evo Blank, Dentag Italia SRL, Terzano, Italy) full arch prosthesis assembled with a model-free digital workflow was finally cemented to the titanium framework (Figures 9 and 10).

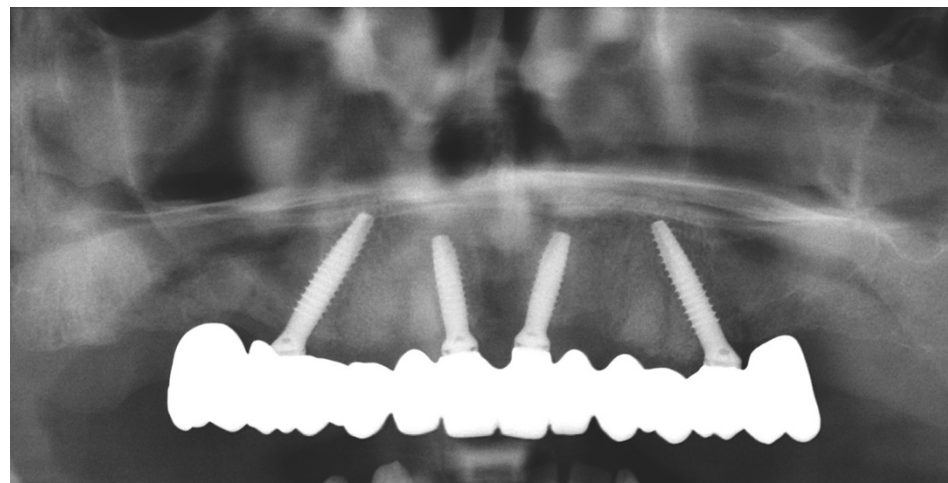


Figure 9. Panoramic radiograph showing good prosthetic fit and absence of bone remodeling after definitive restoration.



Figure 10. Cubic zirconia monolithic full arch assembled on a titanium framework with a model-free digital workflow was delivered (frontal view).

The fixed implant-supported prosthesis was screwed to the implants at 30 Ncm according to the manufacturer's instructions. Clinical and radiographic examinations were performed to assess the fit and precision of the final framework, and only minor occlusal adjustments were made (Figures 9 and 10).

The opposing arch was subsequently restored with fixed implant rehabilitations in sites 45–46, 34–36, and 41–42. Soft tissue management was required at all sites, and posterior bone reconstructions were performed using pin-fixed resorbable membranes.

3. Discussion

A crucial role in the long-term stability of peri-implant tissues is known to be played by the implant–abutment connection [12]. The functional gap between the two components allows matching the abutment and the fixture without frictions [12]. However, there is evidence in literature that under functional load, this gap results in a reduced quality of the seal, particularly in case of flat-to-flat connections [21]. Conversely, the conical connection seems to guarantee a significant reduction in the development of this micro-gap at the implant–abutment interface, resulting in a better quality of the seal [12]. It is worth mentioning that the presence of a micro-gap at the connection level may trigger the onset of mechanical and biological complications [22].

The mechanical issues are due to a possible loosening or fracture of the internal screw caused by micromovements. Several studies demonstrated that an internal conical connection is mechanically more stable than a flat-to-flat connection, and it is further able to provide a better seal [22]. Such mechanical drawbacks can be managed by a correct passivation of the prosthesis provided by the digital setup [23].

In the digital set up, it is essential to perform digital impressions with an accurate scanning device. In this matter, the intraoral scanner used in the present report achieved a remarkable trueness and precision in the impression of multiple implants [24]. Specifically, the CS3600 achieved a trueness of $35.7 \pm 4.3 \mu\text{m}$ in full arch rehabilitations [24]. To further increase accuracy, the completely digital cast-free approach performed in the present report led to a decrease in distortions related to cast printing and reduced the possible discrepancies in the positioning of dental implant analogs. This resulted in an accurate workflow supported by well-fitting and passive frameworks.

A good impression plays a crucial role also in the passivation of the framework. In particular, in the present report, the passivation was tested radiographically and clinically, and no misfit or friction on screwing was recorded. This can also be explained by the fact that it is easier to take an optical impression in the upper jaw compared to the mandible. Indeed, the presence of palatal rugae and the greater amount of keratinized gingiva facilitated the scanner detection. Several methods have been proposed in the literature to overcome this issue in the mandible. Among them, the use of a scanning stent with known geometric markers allowed reducing the implant distance and provided the necessary information for the matching [20]. In the present report, the use of additional devices was

not necessary during the scanning phase due to the reproducibility of clear anatomical landmarks provided by the attached mucosa and the palatal rugae.

The main biological complication is related to the potential risk for invasion of oral microorganisms into the fixture–abutment space, allowing bacteria to penetrate and colonize the inner part of the implant. This fact, *in vivo*, produces a bacterial reservoir that could interfere with the long-term health of the fixed rehabilitation [25–27]. In particular, the bacterial microleakage may lead to inflammation and consequently localized bone resorption [12]. The loss of a significant amounts of bone tissue may decrease the stability of the fixture, potentially threatening its function [12]. Moreover, the exposure of the implant surface to the oral environment as a consequence of bone loss can be considered a risk factor for the establishment of peri-implant disease [28]. Last but not least, a negative aesthetic outcome is frequently observed due to the soft tissue recession secondary to the crestal bone loss [29].

In order to overcome such drawbacks, in the present report, one-piece implants were used to avoid the implant–abutment connection and its related complications. The one-piece implant system is characterized by a transmucosal neck that brings the connection in the soft tissues, creating therefore a distance between the connection and the marginal bone [30]. The smooth surface of the neck prevents bacterial accumulation, improving the biological protection of the underneath implant surface and ensuring a long-term marginal bone stability [30].

The concave shape of the transmucosal collar ensured by the absence of the multi-unit abutment screw in the present one-piece implant provides an increased space for soft tissues maturation and the establishment of a biological width [30]. It has been shown that a better quality of the implant–abutment connection combined with a concave design provided a thicker soft tissue seal around the implants [21–31].

With this novel configuration, the thickening of the soft tissues provided by the concave neck together with an increased distance of the connection from the bone may act as protective factors that limit the apical bone repositioning, improving at the same time the functional and aesthetic outcomes.

Screw loosening or fracture was recorded and observed in several studies, as reported by a recent review by Patzelt et al. [32]. Interestingly, in the present report, the use of one-piece fixtures avoided the use of multiunit abutments, allowing the use of 2.5mm-length 1.8mm-diameter screws.

Additionally, the present screws were designed to be screwed at a torque of 25 N, thus reducing the risk of loosening.

These implants show particular advantages when used in guided surgery with a post-extraction approach as they do not require multiunit abutment connection. This procedure in the posterior area for tilted implants can be challenging. Moreover, due to the absence of multiunit abutments, the bone profiler used to create the space for the prosthetic components was not contemplated. This resulted in a more conservative approach toward the hard tissue and in a less invasive and faster surgery, since the elevation of a full-thickness flap to position the multiunit abutments was not necessary.

The absence of an internal connection and of a connecting screw makes it possible to reduce the volume and thickness of the implant neck by ensuring a better emergence profile, again resulting in greater preservation of the peri-implant hard and soft tissues.

It is safe to assume that tapered connections perform better in terms of survival and marginal bone loss than the older flat technology [12–28]. However, also, conical connections present a gap, which could contaminate the peri-implant tissues with harmful liquids [12]. The use of one-piece implants may limit this condition and its biological implications. Indeed, in the present report, no clinical and radiological signs of peri-implant disease were observed in the short term. This is supported by stable peri-implant bone levels at the 3-year follow-up (Figure 11).

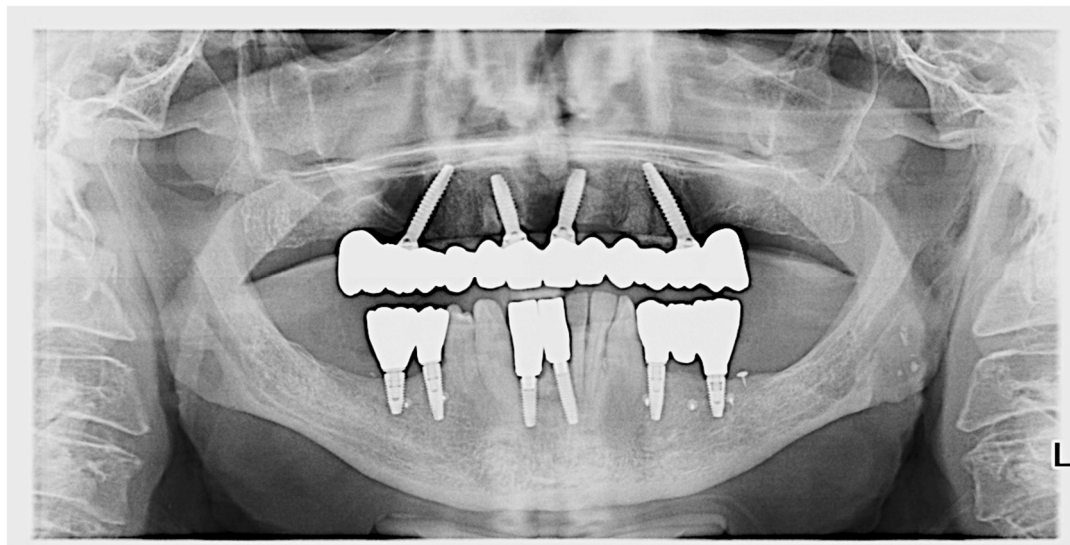


Figure 11. Three-year follow up of the final restoration.

This operating protocol has the limitation of being designed for guided surgery. In addition, the use of a monophasic implant makes it necessary to obtain sufficient primary stability, as transmucosal healing cannot be dispensed with. For these reasons, this systematic might be more indicated for experienced surgeons.

4. Conclusions

The present case report presented stable clinical and radiological results at the 3-year follow-up in terms of marginal bone and soft tissue stability. Within the limitations of a single case report, it can be stated that the systematic evaluated herein presented no prosthetic and surgical complications during the follow-up period. Further analyses are needed to evaluate the stability of both soft and hard tissues over time in a larger sample.

Author Contributions: Conceptualization, M.B and C.M.; formal analysis, M.B.; investigation, M.B.; data curation, S.T.; writing—original draft preparation, M.M.; writing—review and editing, P.P.P.; supervision, C.M.; project administration, M.B. 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 according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico and University of Milan (Protocol Code #24_2021).

Informed Consent Statement: Written informed consent has been obtained from the patient to publish this paper.

Data Availability Statement: Data supporting the results obtained can be requested to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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