Full arch immediate load rehabilitation with a reduced number of implants: comparative evaluation of tissue healing after flap less and open flap surgery. Follow up at 12 months

Abstract

Aim
This study aims to evaluate and compare the success of implant-prosthetic rehabilitations using a digital protocol versus the traditional "All on Four" technique.

Materials and Methods
Fifty patients at the Department of Dentistry of IRCCS San Raffaele Hospital were randomly divided into two groups: 25 underwent digital protocol rehabilitation and 25 underwent traditional rehabilitation. Key parameters such as Visual Plaque Index, Plaque Index, Probing Depth, and Bleeding On Probing were measured at multiple time intervals (T1, T2, T3, T4). Patient-reported outcomes on post-operative pain, swelling, bleeding, and overall satisfaction were assessed using questionnaires.

Results
Guided surgery offered superior outcomes in terms of precision and patient comfort. Patients in the digital protocol group reported significantly lower post-operative pain, swelling, and bleeding, particularly in the initial months post-surgery. IPV and PI were initially lower in the digital group, indicating better oral hygiene maintenance, but these differences diminished over time. Both groups exhibited similar long-term outcomes regarding peri-implant bone loss and PPD.

Conclusion
The findings highlight the advantages of digital planning and computer-assisted implant surgery, including enhanced surgical accuracy and improved patient experience. However, successful outcomes for both methods depend on careful patient selection, precise execution, and diligent post-operative care. Future research should aim to refine digital workflows further, assess their cost-effectiveness, and validate these findings in larger, long-term studies.

DOI

10.23805/JO.2024.674

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Keywords

Dental Implants, Immediate Dental Implant Loading, Dental Digital Imaging, CAD-CAM, Smile Design, Digital Dentistry

INTRODUCTION

Constant research into how to rehabilitate edentulous ridges with solutions that are not only functional but also aesthetically pleasing and stable has led dentistry to develop techniques that require implant support (1,2). Additionally, as life expectancy has increased, so have aesthetic standards. Removable prostheses are now rejected by many patients who increasingly require a fixed, aesthetically pleasing prosthesis (3,4). Aesthetics, which previously did not seem to be a fundamental requirement for the success of prosthetic rehabilitation, are now becoming essential (5).

Furthermore, the requirement for prosthetic stabilization has led, over the years, to the search for solutions involving the use of osseointegrated titanium implants to anchor the prosthesis. The concept of osseointegration, first introduced by Per-Ingvar Brånemark in the late 1960s, is fundamental to avoid implant failure. The first implant-prosthetic rehabilitation techniques for fully edentulous jaws involved stabilizing removable prostheses to implant fixtures, known as Overdentures (6,7).

In recent years, however, totally fixed implant-prosthetic rehabilitation techniques have been developed, which are no longer removable by the patient (8). Initially, these totally fixed rehabilitations involved using many implant fixtures to support the thesis that placing more implants would correspond to greater stability (9). Today, the therapeutic efficacy of rehabilitations based on using even a small number of implants, with high aesthetic and functional yield, such as the "All On Four" technique, is universally recognized (10,11). The results obtained with these protocols are also very promising in cases of advanced atrophy of the bone bases, leading to their increasing use (12,13). The standard protocol for implant placement with the "All on Four" technique involves the detachment of a full-thickness mucosal flap extended over the entire edentulous alveolar ridge and the creation of only four neo-alveoli for the insertion of the fixtures. The distal implants are angled to distalize the implant emergence and support the prosthetic arch up to the first molar, while avoiding the maxillary sinus in the upper arch and the mental nerve in the lower arch (14). Prerequisites of the protocol include a perfect knowledge of the anatomy and a correct diagnostic phase. The dentist must use adequate radiological examinations to plan a correct surgical intervention. These radiological examinations can be two-dimensional (intraoral X-ray and orthopantomography) or three-dimensional (CT and Cone Beam CT) (15,16). In a historical context where everything seems to be digitized, the world of dentistry is adapting to these demands. These demands call for the highest standards of excellence, precision, and speed. Dental digitization is making a significant contribution to this highly contemporary vision. Digital technology is now open to various branches of dentistry, with numerous advantages appreciated by the entire clinical team (17). Protocols have been developed for the realization of full-arch rehabilitations with a reduced number of immediately loaded implants using the flapless technique (minimally invasive surgery). By superimposing radiological images obtained via Cone Beam CT with those of the prosthetic project and the anatomy of the patient's tissues, acquired through intraoral and bench-top optical scanners, it is possible to access a complete virtual study of the patient. This allows for precise planning of implant positioning, guided surgery, and prosthetic design (18,19). Correct aesthetic pre-planning allows for communication between the entire team, including the dentist, dental technician, and dental hygienist, to propose a complete treatment to the patient. Virtual aesthetic planning systems also serve as a powerful communicative and motivational tool for patients, actively involving them in the rehabilitation process and facilitating acceptance of the treatment plan. All these aspects are fundamental to achieving correct compliance, which is significant for the treatment's success (20). The aim of this prospective clinical study was to compare tissue healing resulting from two different surgical techniques for full-arch rehabilitations with a reduced number of immediately loaded implants: the flapless technique and the open flap technique, with a 12-month follow-up. The null hypothesis was that there would be no significant difference in tissue healing between the flapless technique and the open flap technique for full-arch rehabilitations with a reduced number of immediately loaded implants at the 12-month follow-up.

MATERIALS AND METHODS

From January 2022 to December 2023, patients were randomly selected for this study at the Department of Dentistry, San Raffaele Hospital, Milan, Italy. The primary aim was to evaluate and compare the outcomes of implant-prosthetic rehabilitations performed using digital protocols versus the traditional "All on Four" technique. The study adhered to rigorous selection criteria to ensure the inclusion of suitable candidates and the exclusion of individuals with contraindications to implant placement or those unable to comply with the study protocol. The research adhered to all ethical standards outlined by the institutional and national research committees, in line with the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards. All procedures involving human participants were conducted with the utmost respect for ethical guidelines to protect the rights and well-being of the patients. Informed consent was obtained from all individual participants included in the study, ensuring they were fully aware of the nature,

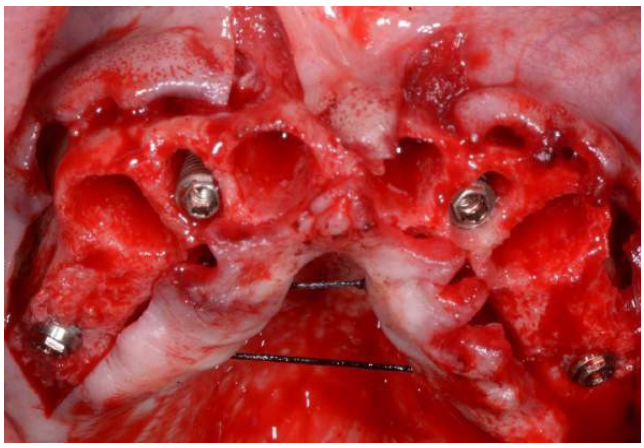


Figure 1. Insertion of implant fixtures with an open flap (traditional protocol).

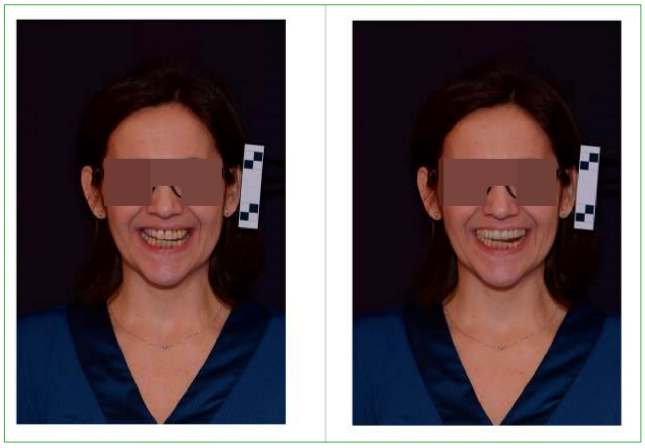


Figure 2. Two-dimensional digital design of the new smile.

procedures, risks, and potential benefits of the study. The study received ethical approval from the relevant ethics committee, under approval number CE/INT/10/2015.

Patients' selection

Inclusion and exclusion criteria were summarized in the following table (Tab. 1).

Inclusion Criteria

The inclusion criteria for this study were comprehensive to ensure the selection of appropriate candidates for implant-prosthetic rehabilitation. Eligible patients were required to be in good general health, irrespective of race and gender, with acceptable oral hygiene standards. Acceptable oral hygiene was defined by the evaluation of periodontal parameters, including a Plaque Index (PI) and Bleeding on Probing (BoP) score. The acceptable range for these parameters was a Plaque Index of ⩽25% and a Bleeding on Probing score of ⩽20%, indicating that patients had controlled plaque levels and minimal inflammation at the baseline. Patients needed to be physically and psychologically capable of undergoing implant-prosthetic rehabilitation, classified as ASA 1 or ASA 2 according to the American Society of Anesthesiologists' guidelines. Patients were included if they were edentulous in the maxilla, mandible, or both arches, or had dental impairments that necessitated the total restoration of one or both arches. Additionally, candidates with insufficient residual bone height in the posterior sectors, which precluded the placement of traditional axial implants, were considered ideal for the All-on-Four protocol. Conversely, patients with sufficient overall residual bone height for the placement of six axial implants with immediate loading were also included.

Exclusion Criteria

Patients were excluded from the study based on several criteria aimed at ensuring safety and protocol adherence. Those with prospects of restoring one or more teeth were not considered. Absolute contraindications to dental implant placement, such as current bisphosphonate medication or radiotherapy of the head and neck performed within the past year, led to exclusion. Uncompensated systemic disorders, which could affect the outcome of the surgery or the healing process, were also grounds for exclusion. Additionally, patients unable to adhere to protocol checks and oral hygiene sessions, as well as those facing economic

Inclusion Criteria	Exclusion Criteria
Good general health, irrespective of race and gender	Prospects of restoring one or more teeth
Acceptable oral hygiene standards (PI ≤ 25%, BoP ≤ 20%)	Absolute contraindications to implant placement (e.g., bisphosphonate medication, radiotherapy in the past year)
Physically and psychologically capable of implant-prosthetic rehabilitation	Uncompensated systemic disorders
Classified as ASA 1 or ASA 2 (American Society of Anesthesiologists)	Inability to adhere to protocol checks and oral hygiene sessions
Edentulous in the maxilla, mandible, or both arches	Economic infeasibility of treatment
Dental impairments requiring total restoration of one or both arches	
Insufficient residual bone height in posterior sectors for traditional axial implants (All-on-Four protocol)	
Sufficient residual bone height for placement of six axial implants with immediate loading	

Table 1 Inclusion and exclusion criteria.

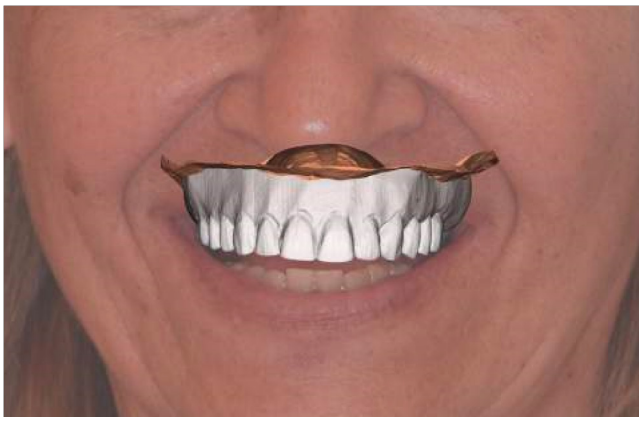


Figure 3. Three-dimensional digital design of the prosthesis.

infeasibility in providing treatment, were excluded from the study.

Clinical procedure

The implant-prosthetic protocol was conducted on a population of 50 patients, aged between 18 and 85 years, who underwent rehabilitation of the edentulous maxilla with a reduced number of implants at the Department of Dentistry of the Vita-Salute University of San Raffaele. Twenty-five patients were randomly selected to undergo the implant-prosthetic protocol using the digital method, while the remaining 25 patients underwent the traditional "All On Four" protocol. Randomization was performed using a block randomization method to ensure balanced group sizes. Blocks of four patients were created, and within each block, an equal number of patients were assigned to the two treatment groups: the digital method and the traditional "All-on-Four" protocol. The allocation sequence was generated by a computer algorithm using random block sizes, ensuring unpredictability. Assignments were placed into numbered, sealed, opaque envelopes, which were opened sequentially by an independent coordinator who was not involved in the clinical procedures. During the first visit, detailed medical and dental histories were compiled. The presence of an edentulous or terminally dentate maxilla was confirmed for each patient. An orthopantomography was prescribed to assess the overall dental and bone structure, and alginate impressions were taken to fabricate a diagnostic wax rim. Upon confirming the patient's eligibility for inclusion in the clinical protocol, informed consent specific to implant surgery was obtained. As secondary step, patients underwent a professional oral hygiene session to optimize pre-surgical clinical indices. They were instructed and motivated to maintain these clinical standards. Photographs of the edentulous maxilla were taken for baseline documentation. The wax rim was "functionalized" using traditional methods to record the patient's occlusion and maxillomandibular relationship. A Cone Beam CT scan was then prescribed. For patients following the digital protocol, this scan included a reference marker for radiographic evaluation (Scan Marker 3DIEMME, Como, Italy).

Traditional Protocol

For the traditional protocol, the third visit included several evaluative tests. A tooth test was conducted to assess the mechanical properties and potential issues with the patient's remaining teeth and included: clinical examination, focusing on aspects such as tooth mobility, the integrity of the enamel, and any signs of fractures or wear, percussion test, pulp vitality test and periapical radiographs to detect potential root fractures, bone loss, or other pathological conditions.
An aesthetic and phonetic evaluation test was performed to plan for the prosthetic outcomes. The patient's appreciation of the proposed aesthetic outcome was measured using a one-dimensional Visual Rating Scale (VRS). During the fourth visit, the surgical phase and immediate load prosthetics were performed. One hour before surgery, patients were administered 2g of amoxicillin combined with clavulanic acid, which

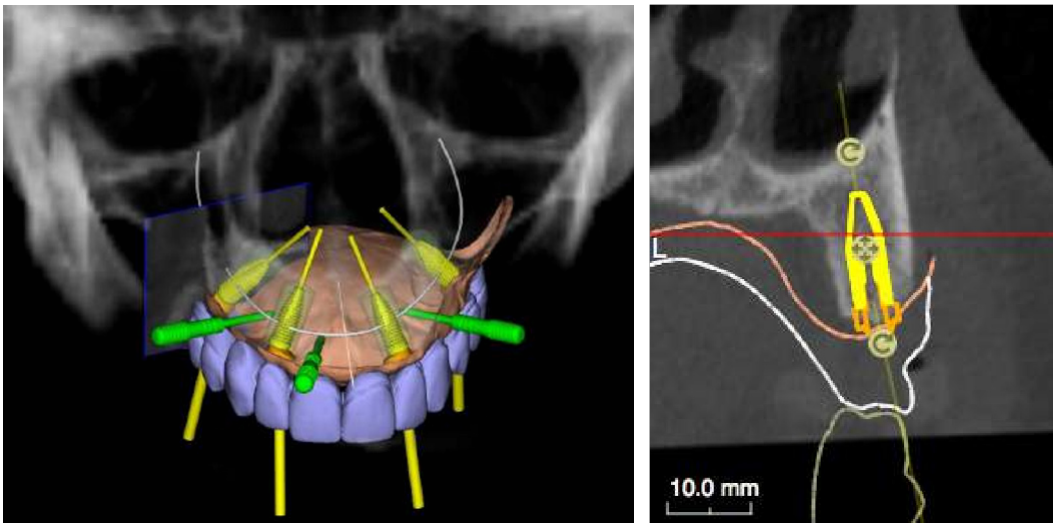


Figure 4. Virtual planning of the position of implant fixtures, guided by the prosthetic project.

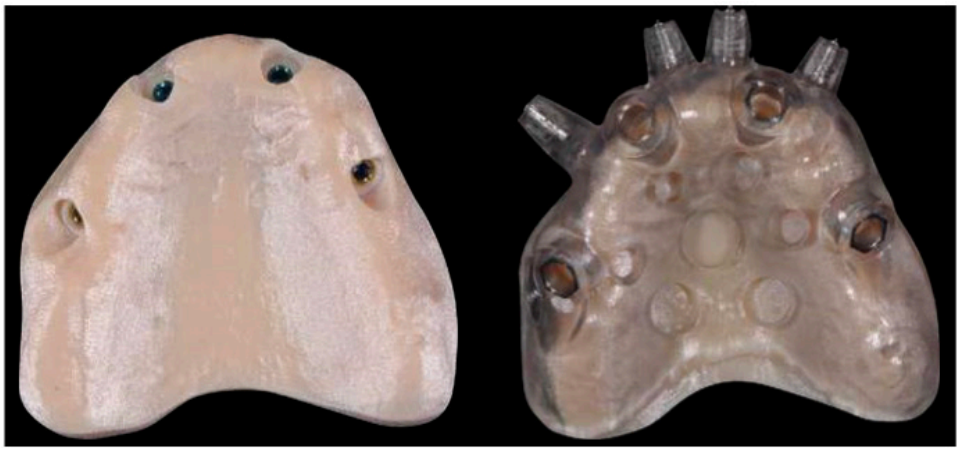


Figure 5. Working model with the analogues in place (left) and the model with the surgical template in place (right).

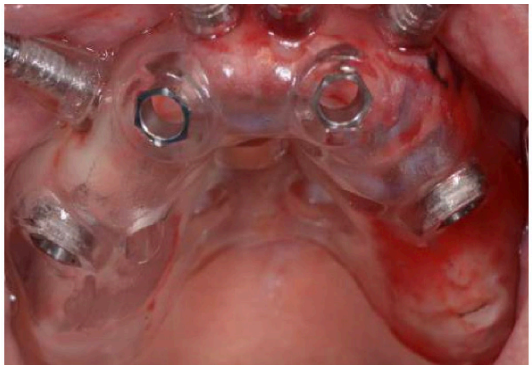
they continued post-surgery at 1g twice daily for one week. Following local anesthesia, a mid-crest incision was made along the entire ridge from the first molar on one side to the contralateral first molar, with bilateral drainage incisions. The mucoperiosteal flap was fully reflected, and any necessary bone remodeling (crestal marginotomy) was performed to achieve a uniformly leveled bone ridge. Two implant fixtures were placed in the posterior sectors, tilted at approximately 30-35 degrees relative to the occlusal plane, followed by two fixtures in the anterior sector (Fig. 1). In patients with well-represented trabecular bone, implant sites were under-prepared to ensure sufficient primary stability for immediate loading. Abutments were then screwed in at angles of 0°, 17°, or 30° to compensate for implant angulation, positioning the access holes for prosthetic clamping screws at either the occlusal or lingual surfaces of the prosthesis. The access flap was repositioned and sutured with 4-0 non-absorbable sutures. The provisional denture, previously fabricated, was adapted and relined directly in the patient's mouth and finished in the laboratory, enabling immediate loading.

Digital Protocol Development

In the digital protocol, the procedure continued between the third and fourth visits. Laboratory scans of the edentulous model and wax rim, both with and without the Scan Marker, were produced. These digital 2D designs and scans were matched within the Lynx CAD design software (3D Lynx, Varese, Italy), enabling the three-dimensional design of the prosthesis. Using the implant design software RealGuide (3DIEMME, Como, Italy), the CAD design was matched with the DICOM data from the patient's CBCT scan. This facilitated the precise planning of the implant positions, guided by the prosthetic aesthetic project (Fig. 2 - 3). The implant design was then sent to the Lynx CAD software to adapt the implant housing to the provisional prosthesis design (21,22). This data was transmitted to a CAD/CAM milling machine for rapid prototyping, creating a physical model that faithfully reproduced the implant analog housings designed in the software. The laboratory then fabricated the surgical template and the provisional PMMA prosthesis (Fig. 4 - 5). During the fifth visit, the surgical template was placed and fixed in the patient's oral cavity after local anesthesia (Fig. 6). Implants were inserted through the surgical guide using a flapless technique and a prearranged sequence of dedicated guided surgery drills (Fig. 7). Immediate loading was applied by positioning the provisional prosthesis, created using the CAD-CAM method, which was adapted and relined directly in the patient's mouth (Fig. 8 - 9). Post-operative instructions for home oral hygiene were provided, tailored to the level of tissue healing.

Post-Surgical Assessment and Care

The Visual Plaque Index (IPV) was measured using



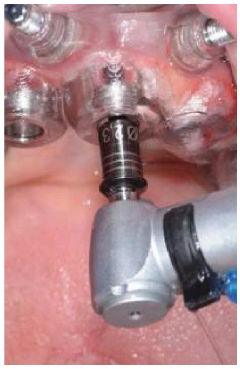


Figure 6. Surgical guide fixed in the patient's mouth (left) and flapless surgery (right).

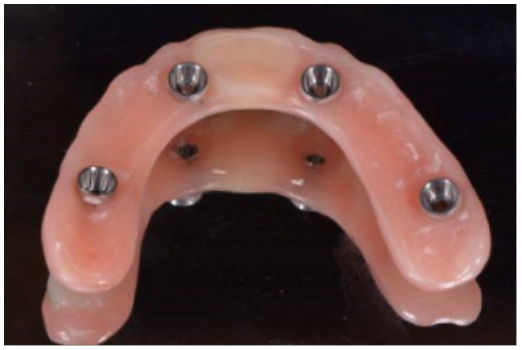
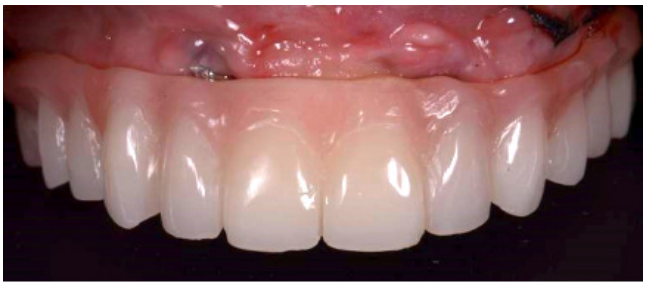
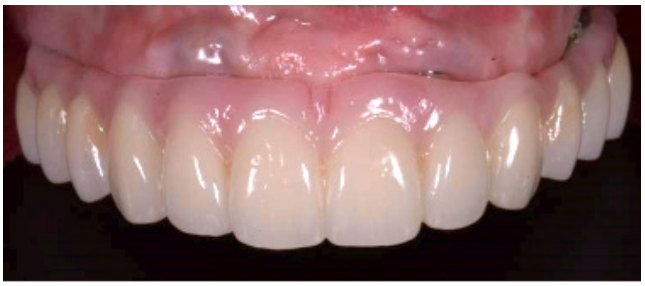


Figure 7. Provisional CAD-CAM prosthesis.





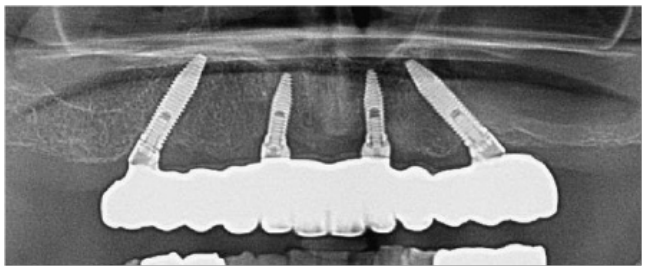


Figure 8. Provisional immediate loaded prosthesis.
Figure 9. Final aesthetic result of the definitive prosthesis, made of monolithic zirconia with vestibular ceramization, using the CAD-CAM method.
Figure 10. Final Orthopantomography.

fluorescein, which highlights bacterial plaque when exposed to blue light from an LED lamp. Plaque index on probing (PI), Bleeding on Probing, and probing depth (PPD) were also evaluated. Additionally, a questionnaire was administered to evaluate pain, swelling, bleeding, and appreciation after surgery.
Patients were given a questionnaire with four questions to assess their personal perception of pain, edema, and bleeding in the days following the operation, and their overall appreciation of the surgery. For all questions except bleeding, the Visual Analog Scale (VAS) was used. The VAS scale, developed by Scott Huskisson in 1976, consists of a 10 cm line with notches numbered from 0 to 10, where 0 indicates no pain and 10 indicates the worst pain imaginable. This scale is simple and intuitive, suitable for all types of patients.
Follow-up visits were scheduled as follows:

- T1: 8 days after surgery:
  - For patients who underwent the traditional protocol, sutures were removed. For both protocols, the following procedures were performed:
  - Prosthesis removal;
  - Photographic documentation of the prosthesis and mucous membranes;
  - Detection of IPV using a fluorescent plaque detector;
  - Completion of a questionnaire assessing pain, swelling, bleeding, and overall appreciation of the surgery.
- T2: 3 months after surgery
  - For both protocols, the following procedures were performed:
  - Prosthesis removal;
  - Photographic documentation of the prosthesis and mucous membranes;
  - Detection of IPV using a fluorescent plaque detector;
  - Measurement of the implant PPD at four sites (lingual/palatal, mesial, and distal);
  - Detection of BoP;
  - PI detection during probing.
- T3: 6 months after surgery
  - Prosthesis removal;
  - Photographic documentation of the prosthesis and mucous membranes;
  - Detection of the IPV using a fluorescent plaque detector;
  - Measurement of the PPD at four sites (lingual/palatal, mesial, and distal);
  - Detection of BoP;
  - PI detection during probing;
- T4: 12 months after surgery:
  - Prosthesis removal;
  - Photographic documentation of the prosthesis and mucous membranes;
  - Detection of the IPV using a fluorescent plaque detector;
  - Measurement of the PPD at four sites (lingual/palatal, mesial, and distal);
  - Detection of BoP;
  - IP detection during probing.

At the end of the surgical and prosthetic procedures, patients in both groups were assessed for pain during and after surgery using a VAS scale. Six months post-surgery, the final prostheses were delivered. For patients treated with the traditional method, the prostheses were made of metal-composite. For those treated with the digital method, the prostheses were made of metal-composite or monolithic zirconia with vestibular ceramization, utilizing CAD-CAM technology (Fig. 10). A professional oral hygiene session was conducted six months after surgery, during which the patient was motivated and instructed on correct home maintenance techniques, and a 4-month recall system was implemented to ensure ongoing care. Follow-up and data recording protocol steps have been

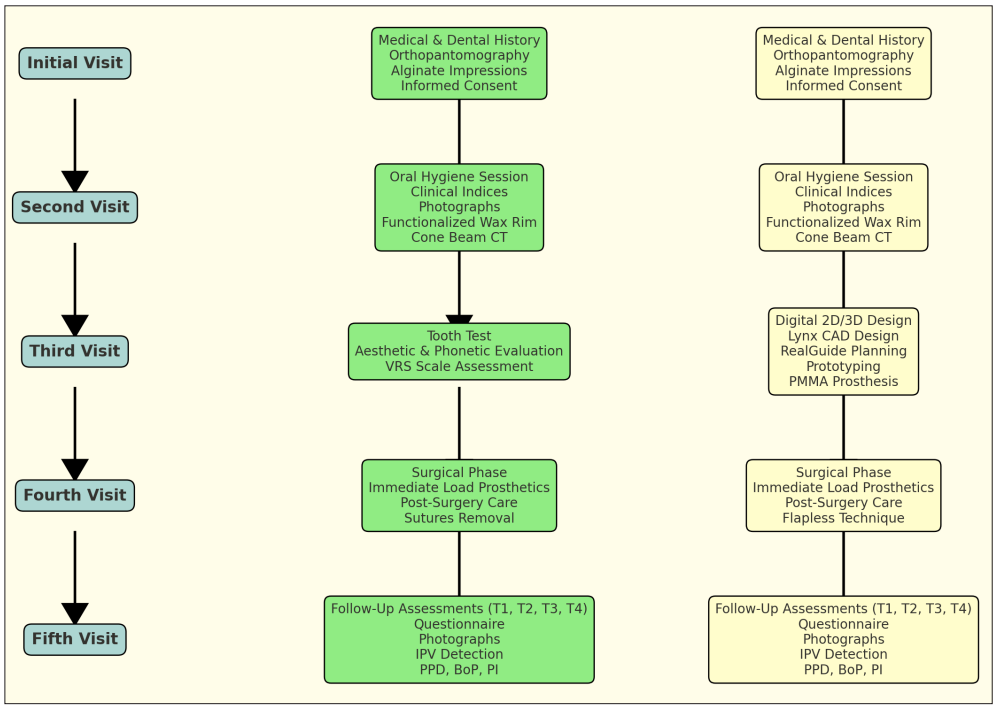


Figure 11.
Follow-up and data recording protocol steps.

summarised in the following Fig., in which the steps for the traditional protocol are highlighted in green, and the digital protocol in yellow (Fig. 11).

Statistical Analysis

Dedicated software (IBM SPSS) was used for statistical analysis. The one-way analysis of variance (ANOVA) was applied to the variables IPV, PI, and PPD. The IPV was compared between the two groups at each time interval (T1, T2, T3, T4) and within each group across different time intervals. Similarly, the PI was compared between the two groups at each time interval (T2, T3, T4) and within each group across different time intervals. The PPD was also compared between the two groups at each time interval (T2, T3, T4) and within each group across different time intervals. The Crosstabulation test (Chi-Square) was utilized to compare the BoP variable as a function of time and the type of protocol used. Additionally, to analyze the variables Q1, Q2, Q3, and Q4 (the questions from the questionnaire submitted to both groups), the ANOVA test was used to determine the mean responses for both groups. The Crosstabulation test (Chi-Square) was employed to highlight the exact number of answers for each group.

RESULTS

Visual Plaque Index

The visual plaque index (IPV) was recorded at T1, T2, T3, and T4 by percentage. The one-way analysis of variance (ANOVA) test revealed statistically significant differences between the two groups at T1 ($F(1) = 69.2$, $p < 0.001$) and T2 ($F(1) = 38.7$, $p < 0.001$). No statistically significant differences were found at T3 ($F(1) = 0.06$, $p = 0.8$) and T4 ($F(1) = 1.12$, $p = 0.3$). Initially, at T1 and T2, there is a significant difference between patients operated with flapless and open flap protocols. Patients in the flapless group were able to maintain better levels of home oral hygiene immediately after surgery. Over time, the two groups tended to homogenize.

Plaque Index

The plaque index (PI) was recorded at T2, T3, and T4 as a percentage. The ANOVA test revealed a statistically significant difference between the two groups at T2 ($F(1) = 29.5$, $p < 0.001$). However, no statistically significant differences were found at T3 ($F(1) = 0.11$, $p = 0.7$) and T4 ($F(1) = 0.16$, $p = 0.7$). As hypothesized, the PI variable was lower at three months post-surgery (T2) in patients operated with the digital protocol. Over time, the values of plaque on probing became similar between the two groups.

At T2, the prosthesis had not been removed since T1, and patients with the traditional protocol could not perform home oral hygiene maneuvers correctly after suture removal at T1. Conversely, patients operated with the flapless protocol could immediately start with home oral hygiene, maintaining acceptable levels of hygiene.

Bleeding on Probing

BoP values were recorded at T2, T3, and T4 by peri-implant sulcus stimulation with a North Carolina probe. The Chi-square test revealed a statistically significant difference in the frequencies of the BoP

variable between the two groups at T2 ($\chi 2 = 42.3$, $p < 0.001$). No statistically significant differences were found at T3 ($\chi 2 = 0.64$, $p = 0.42$) and T4 ($\chi 2 = 0.02$, $p = 0.87$). Initially, there was a difference in bleeding on probing between the two groups, but this difference tended to homogenize over time. This trend suggests that the difficulty in managing home oral hygiene in patients operated with the traditional protocol contributed to the initial differences observed.

Probing Depth

PPD was recorded at T2, T3, and T4 using a 15 mm North Carolina millimeter periodontal probe. Physiological values were defined as ⩽ 4 mm, and pathological values as ⩾ 5 mm. The ANOVA test did not reveal statistically significant differences between the two groups at T2 ($F(1) = 2.51$, $p = 0.1$), T3 ($F(1) = 0.38$, $p = 0.54$), and T4 ($F(1) = 0.01$, $p = 0.93$). Both groups had no pathological surveys during the various follow-ups, indicating a positive outcome. The PPD variable remained constant over time with no statistically significant difference between the two groups.

Post-Operative Pain

The ANOVA test revealed a statistically significant difference between the two groups concerning post-operative pain (Q1), with patients in the flapless group reporting significantly lower pain levels ($F(1) = 53.6$, $p < 0.001$).

Post-Operative Swelling

The ANOVA test revealed a statistically significant difference between the two groups in terms of post-operative swelling, with patients in the flapless group reporting significantly lower swelling levels ($F(1) = 55.61$, $p < 0.001$).

Post-Operative Bleeding

The Chi-square test revealed a statistically significant difference in the frequencies of post-operative bleeding (Q3) between the two groups ($\chi 2 = 23.1$, $p < 0.001$), with the flapless group experiencing less bleeding.

Appreciation of the Intervention

The ANOVA test revealed a statistically significant difference in the appreciation of the intervention (Q4) between the two groups, with patients in the flapless group reporting higher satisfaction levels ($F(1) = 75.4$, $p < 0.001$).

DISCUSSION

Since the advent of modern implantology, surgical and prosthetic protocols have improved over time, leading to predictable treatment outcomes with well-documented long-term implant and prosthetic survival rates (23, 24). Dental rehabilitation on implants and natural elements is an expanding desire in our growing and aging society. In addition to patient comfort and aesthetic recovery, regeneration of physiological function with dental implants and prostheses supported by natural and implant abutments could be directly linked to improved general health and a higher quality of life (25).

In a recent systematic review, Duttenhoefer et al. described the implant survival rate of examined patients with autoimmune diseases such as polymyalgia rheumatica, pemphigus vulgaris, scleroderma, Sjogren's syndrome, and systemic lupus erythematosus. The survival rate was 100% during follow-up periods ranging from 4 to 13 years (26). Several authors evaluated implant survival in subjects with multiple autoimmune diseases and concluded that these conditions do not influence the overall survival rate of dental implants (Sjogren's syndrome, dermatological myositis, rheumatoid dermatitis) (27-33). The osseointegration process of immediate load implant-prosthetic rehabilitations is considered challenging for both clinicians and patients. However, several authors have reported high success rates in immediate loading implant rehabilitations (34, 35). In 2004, Pjetursson et al. performed a systematic review to evaluate the survival rate of implant-supported and dental fixed single and partial dentures in the esthetic zone. At five years, the survival rate was 95.4%, and at ten years, it was 92.8%. Subsequently, in 2012, in another systematic review of 32 studies, the same authors reported survival rates of 95.6% and 93.1% at 5- and 10-years follow-up, respectively (36). Immediate loading of implants, which allows the delivery of a fixed prosthesis within 48 hours after implant placement, is greatly appreciated by patients. This procedure reduces treatment time and provides immediate comfort, as patients do not require a removable provisional prosthesis during the healing phase (37, 38).

Digital planning of an implant-prosthetic rehabilitation starts with the use of Smile Design software, which allows a two-dimensional design of the patient's future smile. This enables proper planning of the rehabilitation in aesthetic terms, improves interaction between specialists, enhances communication with the patient, and ultimately leads to a higher quality of treatment, as described by Coachman et al. in 2017 (39). Drawing reference lines and shapes over intra- and extraoral digital photographs in a determined sequence expands diagnostic visualization and helps the dental team assess the limitations and risk factors of a case, including asymmetries, disharmonies, and alterations in aesthetic principles, thus allowing for more accurate treatment implementation (30). Patients' appreciation of digital aesthetic planning has also been reported. Omar et al. in 2017 described using a VAS-like scale to assess patient satisfaction with the fabrication of crowns and veneers for anterior teeth (40).

Today, specific software enables the transition from two-dimensional pre-visualization of the smile to a three-dimensional study, facilitating CAD-CAM processing for prosthetic fabrication. Literature from Kapos et al. in 2014 reports that survival rates of crowns, abutments, and superstructures fabricated by CAD-CAM methods are similar to those made by traditional methods (41). Digital prosthetic fabrication can be paired with digital planning of the surgical procedure by matching prosthetic design data with CBCT data, as described by several authors (42, 43). Schneider et al. in 2009, along with others, have shown the effectiveness and accuracy of computer-assisted implant surgery. The superimposition of intra- and extra-oral photographs, models, endoral scans, and CBCT is recognized as a reliable procedure by the 5th Consensus Conference of the European Association of Osseointegration in 2015 (44, 45).

Meloni et al. in 2010, in a retrospective analysis of 15 patients, described the possibility of planning implant surgery in a guided and flapless manner with immediate loading. This has been confirmed by other authors such as Komiyama et al. in 2012 (46, 47). The main advantages of computer-assisted implant surgery, as described by Hultin et al. in 2012, include a significant reduction in post-operative pain and discomfort for the patient and the ability to use a provisional prosthesis for immediate functionalization of the implants (48). Additionally, the monitoring of the patient and their inclusion in a professional hygiene maintenance program may positively influence the results obtained (49,50). The levels of peri-implant bone loss observed in the present study were similar to those reported by other authors in the literature, for both the group of patients treated with conventional surgery and the group treated with guided surgery (51). Guided surgery, leveraging digital planning and computer-assisted techniques, offers notable advantages in precision, reduced post-operative discomfort, and improved patient satisfaction. Specifically, patients undergoing the guided, flapless protocol reported lower levels of post-operative pain, swelling, and bleeding, and showed better initial plaque control compared to those undergoing traditional open-flap procedures. Over time, the differences between the two groups tended to diminish, indicating that both approaches can achieve similar long-term outcomes with proper management and patient compliance.

The findings of this study align with existing literature, confirming that the integration of digital technologies in implant-prosthetic rehabilitation not only enhances surgical accuracy but also positively impacts patient experience and peri-implant health. However, it is crucial to consider the individual clinical scenario when choosing the appropriate surgical protocol, as the success of both methods depends on careful patient selection, precise execution, and diligent post-operative care.

Future research should focus on further refining digital workflows, exploring their cost-effectiveness, and expanding their application to a broader range of clinical cases. Additionally, long-term studies with larger sample sizes are needed to validate these findings and to continuously improve the predictability and efficiency of implant-prosthetic rehabilitation techniques.

CONCLUSION

Within the limitations of this study, the obtained results demonstrate that both traditional and guided implant-prosthetic rehabilitation techniques yield high success rates and satisfactory outcomes for patients requiring full-arch rehabilitations.

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