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CONTENTS

Digital smile planning technique applied to prosthetic rehabilitation of dental esthetic area: a case report

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Nowadays, the objective of esthetic rehabilitation is not only to guarantee the results to the patients in terms of esthetic parameters but also the possibility to show the pre-visualization of possible results and therapy planning. Objective: The aim of this study is to apply the 3D-DPS digital planning technique, in the prosthetic treatment of a patient, to produces digitally the mockup for the digital previewing and esthetic crown and veneer for the final prosthetic treatment. Materials and Methods: A case report participant is a young patient, a female, 26 years old, with no oral, periodontal, or systemic diseases. After a sign of an informed consent and an explication of a plan of treatment, technical intraoral and extraoral pictures and intraoral digital impressions were taken. The digital images improved from the 2D Smile Lynx Software and the scanner stereolithographic (STL) file was matched into the CAD Lynx to obtain a virtual previsualization of teeth and smile design. Then, the mockup was milled using a CAM system. Minimally invasive preparation was carried out on the enamel surface with the mockup as position guides. Finally, the esthetic CAD-CAM veneer and crown were produced digitally using the CAD Wax as a guide. Results: The use of the digital project and the pre-operative mockup allowed a perfect initial evaluation and a better understanding of the patient's treatment plan. Conclusions: The 3D digital planning technique is a new, predictably and minimally invasive technique. It allows diagnosis and a better communication with the patient. It helps to reduce the working time and the possible errors usually associated with the classical prosthodontic manual step.

Over the past few years, the idea of what patients expect and what makes a smile beautiful has changed considerably (1-4). In prosthodontics the using of minimally invasive treatment to improve the aspect of the smile (5-7) allows the clinician to get better the entire perception of the patient (8) while preserving the health and function of teeth and soft tissue (9-10). The planning of a rehabilitative dental treatment is made by several steps and stage and requires following established protocol (11).

Prosthetic protocol is composed by making the impression and developing the model to developing the diagnostic wax-up and to constructing the laboratory mockup, the planning combined with creating a mockup (made by composite or PMMA or resin material) is a very central as it affects patients' understanding of the expected result (12-15). Whatever the patient is satisfied with the entire treatment depends on how similar the prosthesis is to the mockup (16, 17).

The reason to the long-term success in prosthetic and esthetic rehabilitation with porcelain laminate veneers (PLVs) is to find a predictable solution to dental esthetic problems using minimally invasive

key words: esthetic rehabilitation, rehabilitative dental treatment, digitalization of the dental process

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technique (18-21), and the respect of the tissue healing based on a correct initial evaluation of the healing state of the tissue of the patient, especially in the pandemic actual situation, is necessary to evaluate the inflammatory state of the oral cavity before a prosthetic or surgical treatment (22-24).

The final stages included the new shape of the teeth, the adaptation of the prosthesis, the size and the color of the new elements in relation to the soft tissue, lips, and the whole face are very important in the decision-making (25). The digitalization of the dental process can help the clinician to reduce a large number of mistakes that can occur at the various stages of the traditional prosthetic workflow (26, 27).

Each stage requires a transfer of two-dimensional and three-dimensional data between operators. As computer-aided design and computer-aided manufacturing (CAD/CAM) and new materials are leading to a paradigm shift in what many practitioners regard as standard care for patients, a priority is to drastically reduce operator error (28, 29). In the development of the clinical case, we have therefore chosen to use the 3D digital smile planning technique (3D-DSP) to realize, after the 2D digital planning, the mockup in polymethyl methacrylate (PMMA), and then the complete prosthetic crown of element 1.1 and veneer of element 2.1. (30). The making of the prosthetic manufacts was carried out using a CAD-CAM laboratory system.

MATERIALS AND METHODS

In 2018, a 26-year-old patient came to the Department of Dentistry of Vita-Salute San Raffaele Hospital, Milan, Italy, she had no oral, periodontal, or systemic diseases. The patient showed tooth trauma, discoloration, and recession on 1.1 element, the 1.1 natural element was previously treated by endo-canalar treatment. She asked for an esthetic improvement of her oral and aesthetic situation (FIG 1, 2).

Before the prosthetic rehabilitation treatment, it is recommended to mouth-rinse with hydrogen peroxide, iodine povidone and chlorhexidine to obtain a reduction of the existing bacterial load (31-32).

After radiological, phonetic, static and dynamic occlusal evaluation, two technical photographs of the

Fig. 1. *Initial case.*

Fig. 2. *Initial case.*

Fig. 3. *Initial case, protrusive movement.*

Fig. 4. *First technical picture: Patient's smiling face.*

Fig. 5. *Second technical picture: Snapshot with mouth opener.*

Fig. 6. *Smile Design Project.*

patient's face were taken: a first photograph with the patient's smiling face and a second intraoral snapshot with mouth opener (Fig. 3, 4, 5). These photographs are taken by making the patient wear a special calibrator, on which it is possible to identify the points of repression. The two photographs were inserted into the Digital 2D Drawing software (Smile Lynx, 3D-Lynx, 8853 Spa, Pero-MI) and thanks to the calibrator used, the software subsequently elaborates accurate measurements (Fig. 6).

Within the chosen software, a digital drawing of the patient's ideal smile was made, elaborated on the basis of the study of reference facial lines, using dental libraries contained within the software itself. Subsequently, we proceeded to take impressions with an intraoral scanner (3Di TS, MYRAY, CEFLA s.c., Imola -BO-Italy) to obtain digital impressions of the maxillary and mandibular arch in open bite and in occlusal contact (Fig. 7). A wax was then modeled to record the DVO after the incisors were positioned relative to normal overjet and overbite values. This wax represents the DVO to be replicated in future prosthetic rehabilitation. The dental arches were then scanned with the wax in the mouth after dividing it into two symmetrical parts to ensure the stability of the wax in the mouth. The digital data were sent to the laboratory in STL format.

All the digital images, obtained from the processing of the pictures into the software 2D-Digital Smile System (Smile Lynx, 8853 Spa, Pero-MI) and the STL file from the intraoral scans, were combined into the 3D-Digital Smile System (Cad Lynx Evolution, 3D-Lynx, 8853 Spa-Pero-MI) to display the patient's teeth and, from this, a virtual design of the potential dental prosthesis was created (Fig. 8).

When the patient is agreed to the virtual 3D view of her planned for prosthetic rehabilitation, a PMMA mockup (Bredent Srl, Italy) was milled using a CAM system (Zirkonzahn Srl, Italy), then the mockup was tested in the patient's oral cavity to make sure she would consent to the

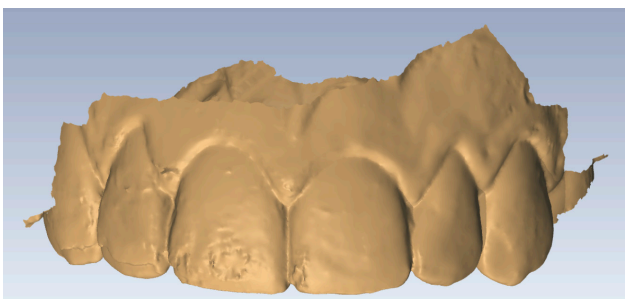


Fig. 7. *Digital impressions of the maxilla in the initial situation.*

Fig. 8. *A virtual design 3D of the potential dental prosthesis.*

esthetic therapy and be satisfied with the final result (Fig. 9). The newly milled mockup cemented using spot-etch technique (33, 34) (Fig. 10) was used to guide the position of the prosthetics and maintain the margins on the enamel surface of the teeth (35-37) (Fig. 11).

Fig. 9. *Testing the mockup.*

Fig. 10. *Spot etch technique used for the cementation of milled mockup.*

A Laser bleaching technique of the discromic theeth were performed, using a Diode Laser (Raffaello, Diode Laser, DMT srl, Lissone, MI). The following protocol was chosen: 2-Watt, continuous wave, handpiece with specific 600nm fiber, in addition of 38% hydrogen peroxide. (Fig. 12). The double cord techniques with the intraoral scanner (3Di TS, MYRAY, CEFLA, Imola, BO, Italia) used to make all the definitive impression of the prepared teeth (Fig. 13-15).

After the impression step, we use the Diode Laser LLLT protocol to improve the tissue healing and to reduce the inflammatory state of the tissue (300micron optical fibre-0,6 Watt) (38-40). Using the CAD design of the initial project, the PLVs and Crown (IPS e.max System, Ivoclar Vivadent Srl, Italy) were produced using CAD/CAM technique (Zirkonzahn Srl, Italy). The veneer and crown were cemented using Variolink veneers cement

Fig. 12. *Bleaching treatment by Diode Laser, 980nm.*

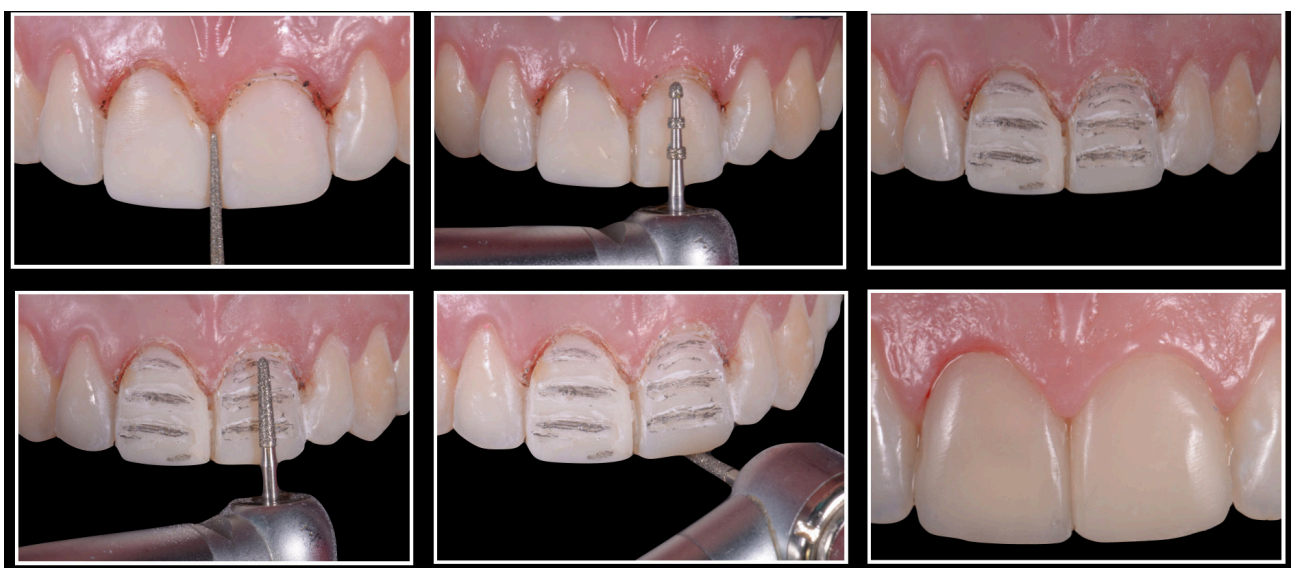


Fig. 11. *The sequence to prepare the teeth using a mock-up as a guide for the position of the prosthetics and maintain the margins on the enamel surface.*

(Ivoclar Vivadent Corp., Liechtenstein) and adhesive cementation (Fig. 16).

After definitive cementation is necessary an occlusal control, as the implant and prosthetic rehabilitations required (41). The patient had final intra- and extraoral digital images taken (Fig. 17, 18). Follow-up took place after 2 years (Fig. 19).

Fig. 13. *Double cord impression technique.*

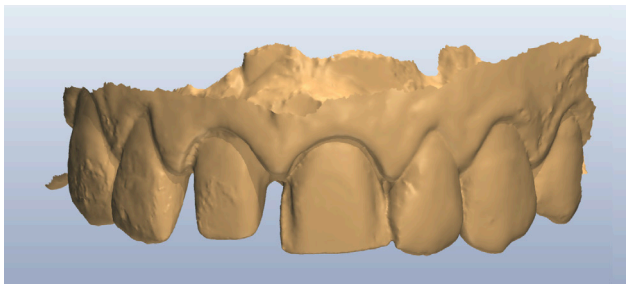
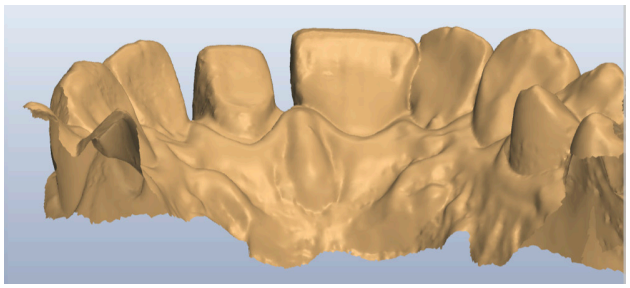


Fig. 14. *Definitive digital impression of the prepared teeth.*



ig. 15. *Definitive digital impression of the prepared teeth.*

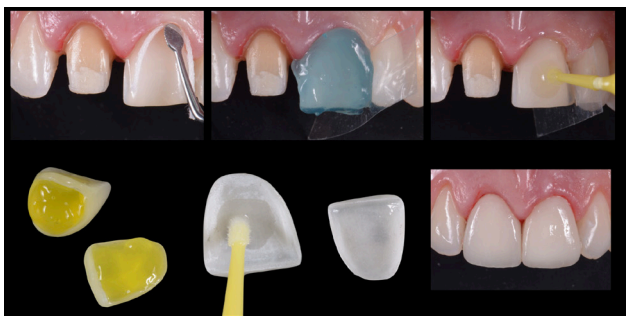


Fig. 16. *The sequence of adhesive cementation.*

RESULTS

We obtained results by using digital methods to encourage the patient's desired result in terms of aesthetic and functional rehabilitation. The use of the digital project and the pre-operative mockup allowed a complete initial evaluation and a better comprehension of the patient's treatment plan.

The 2 years follow-up revealed an absolute stability of the gums, the maintaining of natural design of soft tissue and the integrity of the manufacts. Full range of clinical distortion in terms of debonding, chipping, microleakage, discoloration, or secondary caries, and no root canal therapy were evaluated. The patient answering to a questionnaire to determine her

Fig. 17. *Final intraoral and extraoral photos of the patient.*

Fig. 18. *Final intraoral and extraoral photos of the patient.*

Fig. 19. *Follow-up after 2 years.*

satisfaction with the digital smile design planning and the test in the form of the mockup. The patient classified both the planning and the test as effective, very effective, or ineffective. Digital smile design previsualization, with visual analogical scale (VAS scale) was effective for 85% and patent identify the milling mockup very effective at the 100%.

DISCUSSION

The continuous development in dental processing ensures new opportunities in the field of fixed prosthodontics in a complete virtual environment without any physical model situations. To achieve the success in all prosthodontic aesthetic treatment is fundamental having an accurate communication with the patient delineate a stablished design planning (42). The creation of a mockup allows to the clinician to show the best and a real previsualization treatment to the patient and explain him the possible customization (18, 21).

Using the digitalized techniques, it is possible to re-design a patient's smile completely as Chen J.H. et al showed in 2015 (43). Conventional "analogical techniques" are based on a planning process that require radiological and clinical evaluation, intra and extraoral photographic analysis, static and dynamic occlusal evaluation, and traditional impressions (44).

Another evolution of "analogic prosthetic planning" is limited to bidimensional digital workflow and necessitate, after digital smile design protocol, the stone model, the manual processing of a laboratory diagnostic wax-up, and the printing of the classic mockup in the patient's oral cavity through the use of silicone keys.

In traditional planning techniques, the data transfer from virtual design to laboratory is difficult and probably full of possible failure because it uses a manual procedure to obtain the computer design of canine zenith lines for the laboratory stone model (30, 33, 44).

As Blatz M. said in 2019, one of the most noteworthy advancements is the implementation of digital technologies in the 3-dimensional planning and realization of truly natural, individual, and aesthetic smiles (45). Gastaldi et al. in 2018, explained that the perception of the improvement of the smile of the patient, is really important for the self-perception and for the well-being of the patient (30).

This research suggests a possible way to measure self-perception of the subject after an appearance-altering procedure such an implant-prosthetic rehabilitation, applying the virtual planning using "Smile-Lynx" smile design software in association with prosthetic rehabilitation (8). The digital process can reduce manual errors, as Cattoni et al. explained in 2019: the study showed a difference in accuracy between traditional moulded and milled mock-ups: the data analysis reports that the digital method allows for greater accuracy (17). The minimally invasive prosthetic procedures are nowadays one of the most common choice in prosthodontic rehabilitation, to preserve natural tissues and to improve the aspect of the smile, respecting the naturality of the teeth ang gums (6).

The most recent literature confirms that patients with systemic diseases (HIV, HCV, SJOGREN and others) can be placed in implant-prosthetic rehabilitation treatments with the same results in terms of survival and implant success. (46-50). The variety of CAD/CAM ceramic restorative systems is constantly evolving to meet the increased demands for highly aesthetic, biocompatible, and long-lasting restorations (51). The prosthetic manufacts produced with CAD-CAM process are precise and accurate as Gherlone et al said in 2014 (52).

Kim J.H. in 2013, explained that the Monolithic CAD/CAM lithium disilicate crowns are applicable to posterior implant-supported restorations (53). As Tetè et al. showed in 2020, the esthetic prosthetic manufacts, especially digitally produced, can also help the patient during the delicate phase on the long-term maintenance, guaranteeing a long-term durability of the products (54).

The 3D digital planning technique is a recent, predictable and minimally invasive technique. It allows diagnosis and a better comprehension of patient's desire thanks to clear communication between patient and clinician. It helps to reduce the working time and the possible error commonly associated with the classical prosthodontic manual step. The new procedure increases the predictability

of data matching to build CAD/CAM- milling mockups and improves accuracy and reproducibility of the final mockup with very little discomfort and very high esthetic results.

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Computer-assisted prosthetic planning and implant design with integrated digital bite registration: a treatment protocol.

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The aim of this clinical study is to present an integrated digital project through the description of a clinical case, made entirely in digitized form, taking advantage of the opportunity offered by instrumental diagnostic software. A case report participant is a 65-year-old female patient presents with loss of diffuse bone support, caused by periodontal disease. After a sign of an informed consent and an explication of a plan of treatment, technical intraoral and extraoral pictures and intraoral digital impressions were taken. The digital images improved from the 2D Smile Lynx Software and the scanner stereolithographic (STL) file was matched into the CAD Lynx to obtain a virtual previsualization of teeth and smile design, and to mill the provisional and the definitive crowns. The digital prosthetic design allows the evaluation of the dental parameters in relation to the parameters of the patient's face for the new prosthetic project and the radiological examination using CBCT guides the insertion of the fixtures for the rehabilitation phase. The surgical and prosthetic design are subsequently integrated. The evaluation of the bone bases is carried out with a radiological diagnostic software for CT (Real Guide 5.0-3Diemme, Cantù-Italy) which can virtually design the implant insertion. The functional examination of the patient is carried out through an occlusion-postural examination that uses digital electromyographic assessments. The integrated digital protocol proposal inserts in the rehabilitation path the digital recording of the free mandibular movement, as well as the scan of the patient's face, data that will be integrated into the CAD software for the design of temporary and definitive prosthetic artifacts, made using the CAM method. This study showed guided implant placement and the application of fixed implant-supported prosthetic restorations carried out with a fully digital workflow, dependent on the functional digital evaluation of the patient's occlusion. The proposed protocol described the correct use of digitalization of clinical, surgical, and prosthetic procedures, and the matching of the data into a computerized environment, to improve team communication and to take advantage of the combination of collected data to not lose information using classic manual steps.

The continuous evolution of techniques and new materials in dentistry has made it possible to effectively recreate dental shape and function through a digital protocol that results in a minimally invasive therapeutic approach. Clinicians have been trying for decades to harmonize tooth shapes with the face, based on parameters such as gender, personality, and age, often without achieving desired results (1).

Key words: prosthetic planning and implant, radiological diagnostic software, minimally invasive therapeutic approach

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The introduction by Paolucci et al. of the concept of dental "visagism" in 2012 helped clinicians in the realization of restorations as individualized and personalized as possible (2).
Psycho-teeth-facial harmony is the aim that has led to the development of these concepts in recent years (3). At the same time, several Digital Design software has been developed in Dentistry, which have recently developed three-dimensional CAD / CAM design and modelling functions (4).

The "Digital Smile Design" is currently an aesthetic-prosthetic planning tool that can strengthen the diagnostic vision and improve communication by increasing the predictability of the entire rehabilitation treatment. This tool allows an accurate analysis of the individual characteristics of the face and teeth and to transfer the information detected during the objective, photographic and diagnostic evaluation on the model to the 2D software project (5, 6).

By drawing lines relating to the reference skin cephalometry and displaying the modelling using software on intra and extra oral digital photographs with a determined sequence, we can expand the data available during the diagnostic phase, creating a single file available to the specialists of the dental team. (7). In the subsequent interdisciplinary phase of management of the treatment plan, it is therefore possible to evaluate the various therapeutic options, the risk factors due for example to asymmetries, disharmonies, and alterations of aesthetic principles. The aim of Digital Smile Design is consequently to design better, plan better and increase the understanding of the proposed care plans (8).

The digital approach has therefore improved communication in the dental team, between the various specialists and with the dental laboratory: the acquisition of multiple data sets: CBCT, intra and extra-oral scans, virtual aesthetic and implant planning, instrumental study digitized occlusion and masticatory function, can be effectively integrated to optimize a synergistic diagnostic process (9).
The use of implant design programs on CBCT images and the use of surgical templates associated with the digital modelling of the prosthetic component make it possible to perform a monophasic operation that guarantees aesthetics and function in a single surgical time (10-12). In addition, virtual aesthetic planning systems represent a powerful, communicative, and motivational tool for patients, having the potential to actively involve them in the rehabilitation process, also facilitating acceptance and compliance with the treatment plan (6).

Aim of the study

The aim of this study is to present an integrated digital project through the description of a clinical case, made entirely in digitized form, taking advantage of the opportunity offered by instrumental diagnostic software. A digital prosthetic design allows the evaluation of the dental parameters in relation to the parameters of the patient's face for the new prosthetic project and the radiological examination using CBCT, for the guided design of the insertion of the fixtures is necessary for the rehabilitation phase. The surgical and prosthetic design are subsequently integrated.
The functional examination of the patient is carried out through an occlusion-postural examination that uses digital electromyographic assessments.

The integrated digital protocol proposal inserts in the rehabilitation path the digital recording of the free mandibular movement, as well as the scan of the patient's face, data that will be integrated into the CAD software for the design of temporary and definitive prosthetic artifacts, made using the CAM method.

Case report (initial situation)

The 65-year-old female patient presented to the Department of Dentistry of Vita-Salute San Raffaele Hospital in April 2019 and underwent a remote and forthcoming pathological anamnestic evaluation, physical and radiographic examination, and occlusal-postural evaluation. The intraoral radiography of the third sextant and the orthopantomography performed both prior to the sectoral prosthetic load that the patient received in 2018 were evaluated (Fig. 1, 2). Volumetric radiographic evaluation by CBCT of the maxilla was followed for second level investigation and basis for the surgical-prosthetic digital design (Fig. 3).

The patient presents loss of diffuse bone support, caused by periodontal disease. The patient also reported having performed an orthodontic treatment

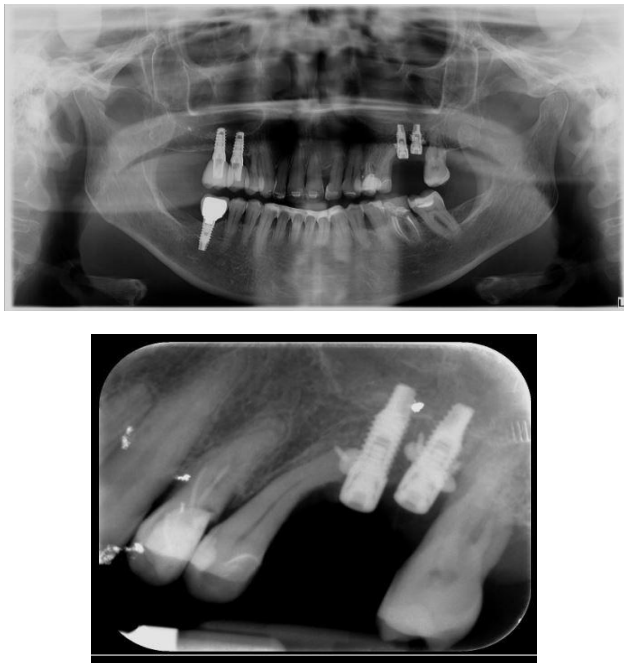


Fig 1-2. *Initial intraoral X-ray and OPT 2018 prior to prosthetic loading.*

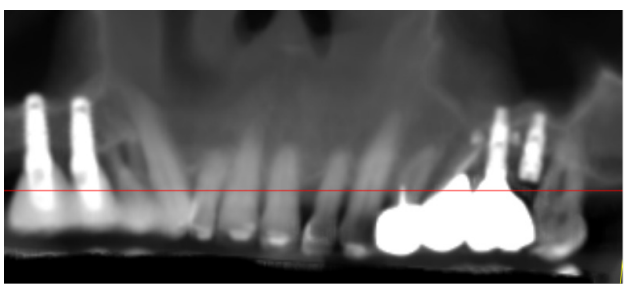


Fig 3. *Pseudo panoramic image obtained with CBCT of the maxilla. (myray X5, Cefla Ita) Peri-implant bone defects confirm the diagnostic suspicion of peri-implantitis and crestal graft failure.*

on the upper and lower arch in adulthood (2003), the residual elements have been joined with composite splinting and metal ligation, the elements of the front group appear vestibular. On physical examination, edentulous areas treated with implant-prosthetic rehabilitation are highlighted. The implant fixtures in positions 15-16 and 46 are well tolerated and presumably osteo-integrated, they do not show pathological probes or mobility. The analysis of the skeletal segment in the third sextant shows an implant failure: recurrent abscesses with pain, edema and chronic peri-implant suppuration led to a short-term failure of the integration of the grafted heterologous material and consequently of the fixtures.

The implant-prosthetic complex has two implants whose very close emergence does not make the prosthesis favorable. The existing rehabilitation excludes the use of the more distal implant as a prosthetic abutment (Fig. 3). From the first level investigations, a severe bone recession is also evident in the element 25 which appears mobile and painful on percussion and with a distal probe greater than 8 mm. An incongruous endodontic treatment associated with an incorrect reconstruction of the abutment, not aligned with the coronal third of the treated canal, is found on element 24.

The reconstructive project envisaged a minimally invasive reconstructive solution with rapid re-functionalization times associated with the removal of elements 24 and 25. The fixtures in zone 26/27 will be removed to ensure tissue healing. The clinical case is dealt with using implant techniques

Fig 4. *Initial clinical case, patients in IM.*

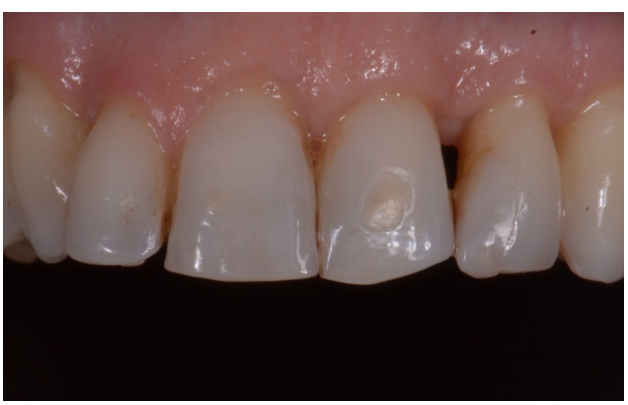


Fig 5. *Initial clinical case, superior vestibular view.*

Fig 6. *Initial clinical case, lower arch vestibular view lower arch.*

Fig 7. *Initial clinical case, superior occlusal view.*

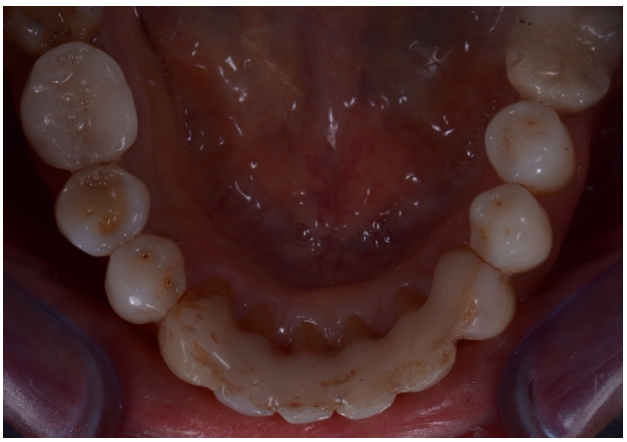


Fig 8. *Initial clinical case, inferior occlusal view.*

that exploit sufficiently large portions of basal bone to integrate stabilized implants with a high torque value and able to support immediate prosthetics (Fig. 4-8).

At the initial functional physical examination, the patient also presents left joint noise and associated pain in opening and closing movements. The gnathological evaluation showed joint creaking on the left and a limited opening with significant pain in the right temporomandibular joint.

For the reduced translation of the ipsilateral joint, an MRI (nuclear magnetic resonance) was required which showed disc degeneration with non-reversible anterior dislocation (Fig, 9-12). The execution of an articular CT scan was necessary to verify the

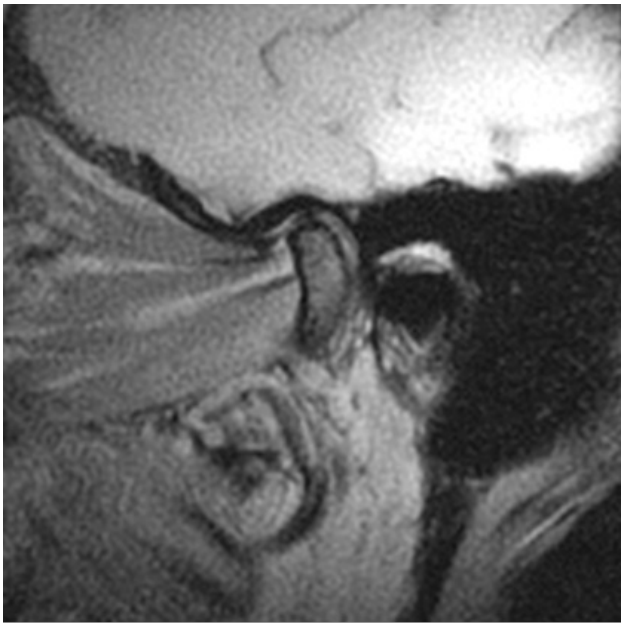


Fig 9. *RMN TMJ right closed mouth. Normal morphology of the disc condyle.*

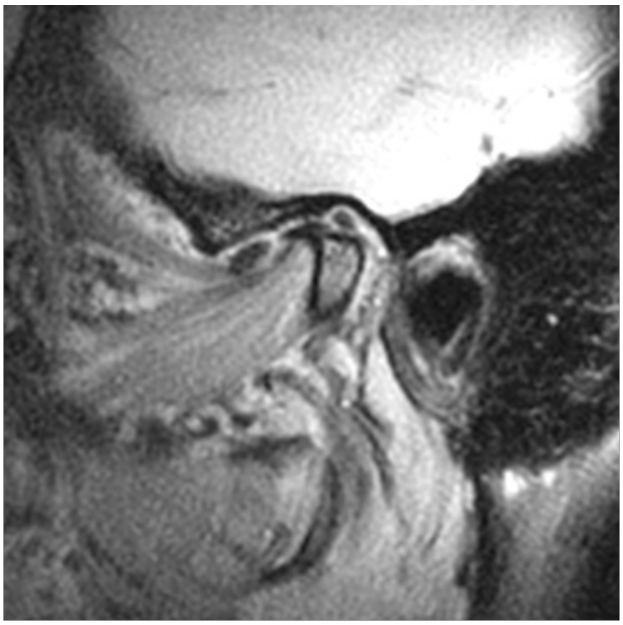


Fig 10. *MRI TMJ left closed mouth. Joint head degeneration with disc dislocation.*

degeneration of the joint heads of the TMJ on the left side (Fig. 13, 14).

The initial assessment of muscle activity during maximum voluntary clenching also highlighted a condition of asymmetry with an anterior center of gravity and a reduced inter-arch impact, again resulting from joint pain (Fig. 15).

Prosthetic-surgical digital project

The patient is initially subjected to a professional oral hygiene treatment, an implant-prosthetic treatment plan is planned which involves the removal of the implants in the area 26/27, extraction of 24 25 and 27. At the same time, the placement of two implants with emergence 24 and 26 in guided surgery is hypothesized, of which the distal "tilted" distally to exploit the tuberal bone underlying the maxillary sinus according to the technique of inclined implants.

The evaluation of the bone bases is carried out with a radiological diagnostic software for CT (Real Guide 5.0-3Diemme, Cantù-Italy) which can virtually design the implant insertion, qualitatively assess the degree of bone density of the receiving site and transfer position information for making a surgical guide. It is therefore necessary to

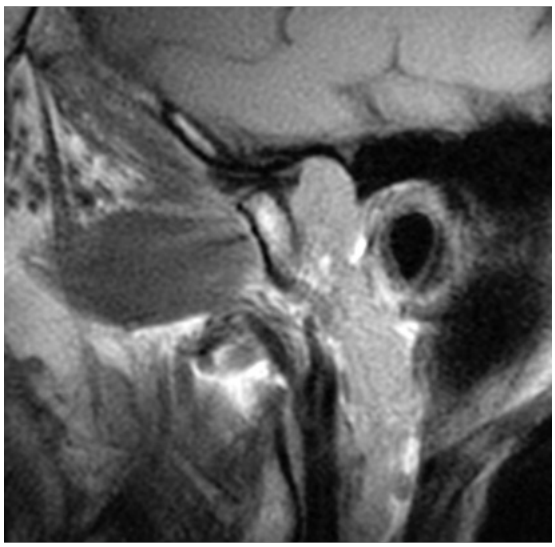


Fig 11. *MRI TMJ right open mouth. Correct interposition expires.*

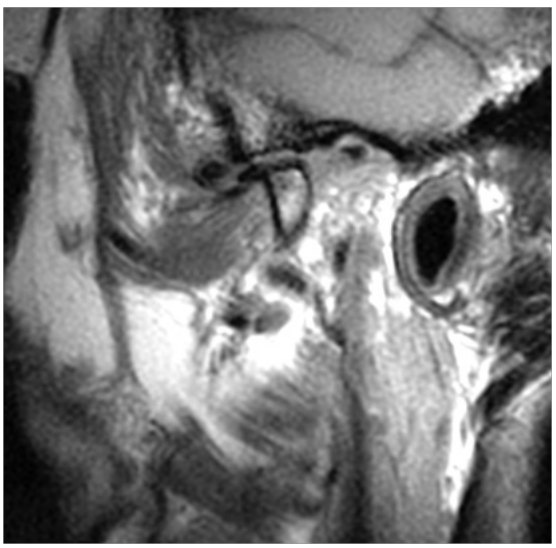


Fig 12. *MRI TMJ left open mouth. Absence of disc reduction*

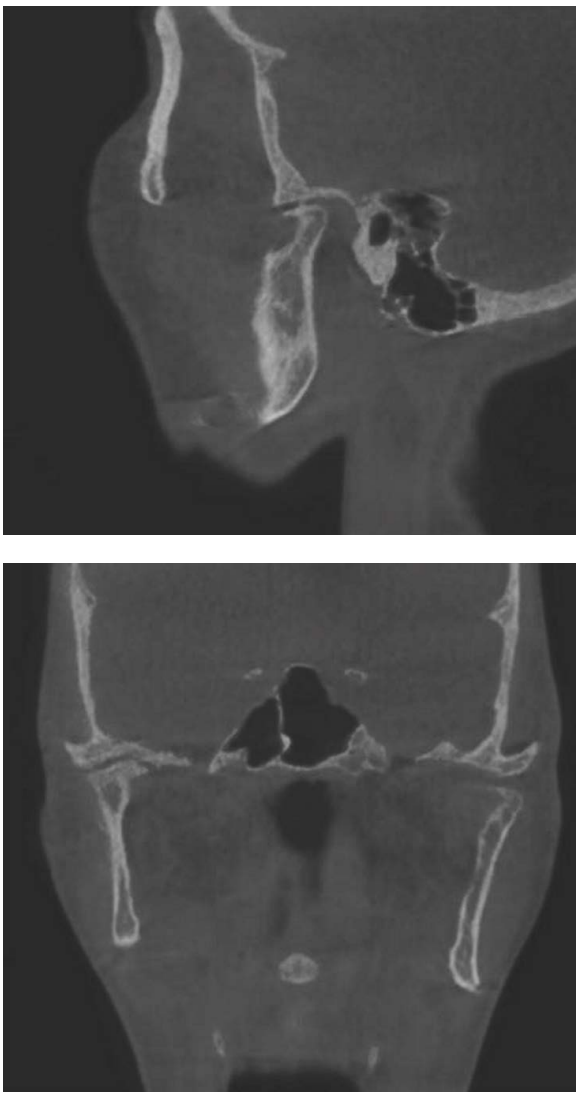
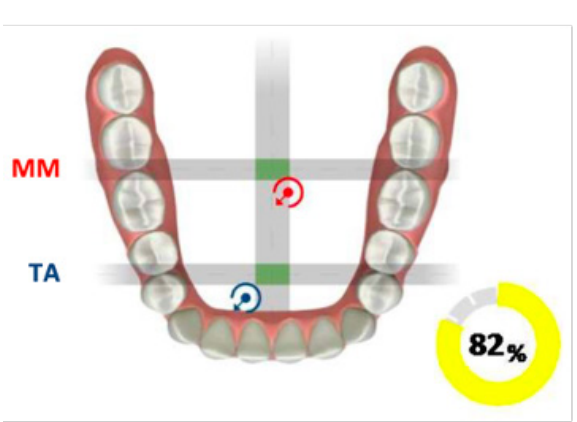
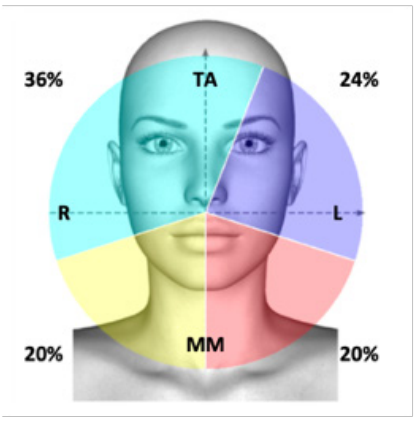


Fig 13-14. *TC TMJ right and left.*





INDICI	PRE		POST		NORMALITA'
POC TA	85.74%	Dx	87.27%	Dx	83≤(%)≤100
POC MM	65.14%	Dx	85.32%	Dx	83≤(%)≤100
BAR	74.59%	A	88.66%	P	90≤(%)≤100
TORS	88.76%	Sx	91.31%		90≤(%)≤100
IMP	57.89%		96.30%		85≤(%)≤115
ASIM	18.46%		4.30%		-10≤(%)≤10

Fig 15. *Initial EMG.*

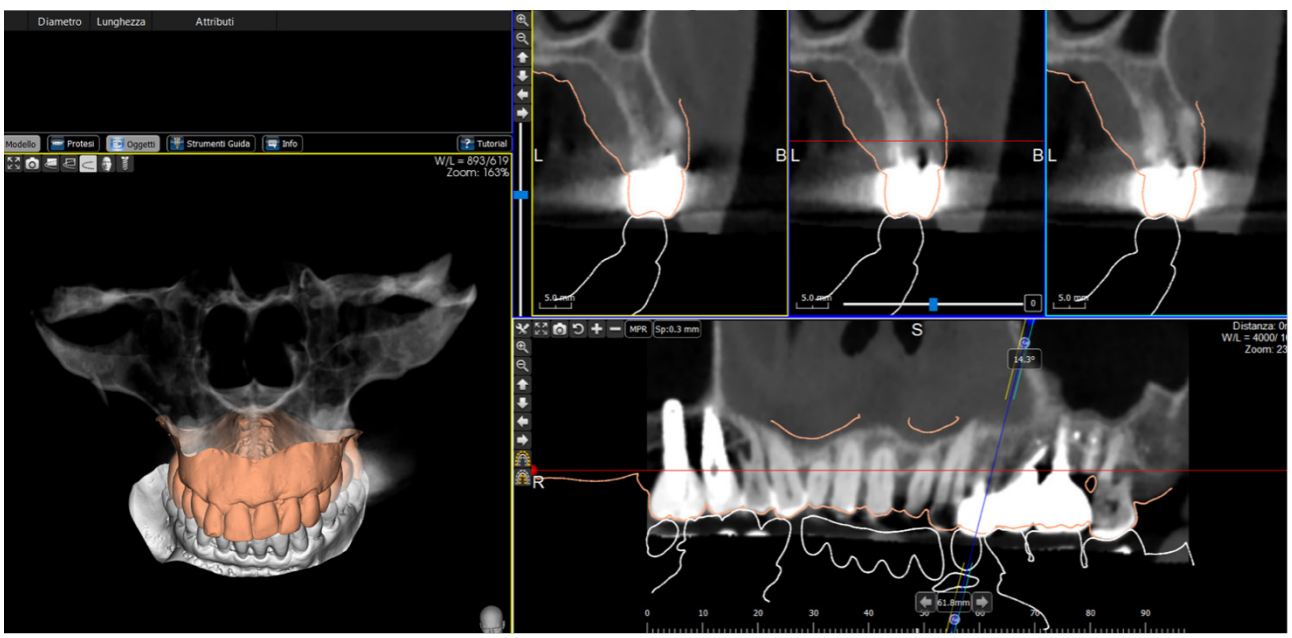


Fig 16. *Overlay of DICOM images from CBCT to the scan of the patient's articulated model.*

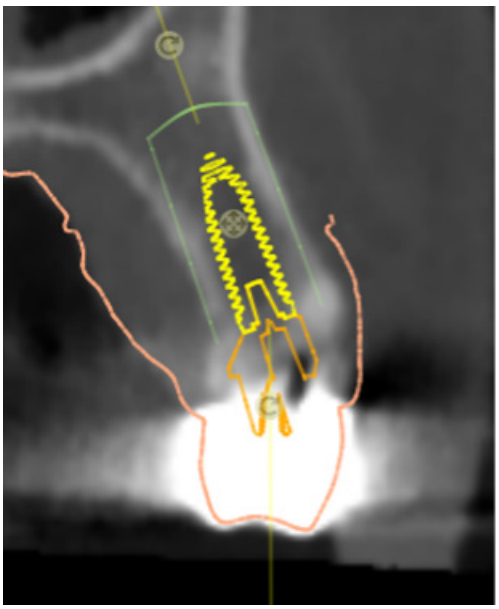


Fig 17. *Average bone density.*

superimpose the scan of the STL arch model on the DICOM images.

We can therefore associate a project for the construction of the template to the implant design and using the STL data of the dental anatomy to use it as a program for the prosthetic modeling of the provisional with immediate load. In Fig. 16 the working page of the design software is highlighted: through an automatic "matching" function we superimpose the DICOM images of the CBCT on the STL files obtained by scanning the articulated model of the patient (Fig. 16). The implant design phase is carried out on the cross images of the segment concerned. On the element 24 to be extracted, an inter-radicular bone defect can be appreciated, probably due to a fracture of the coronal root third or to periodontal compromise, associated

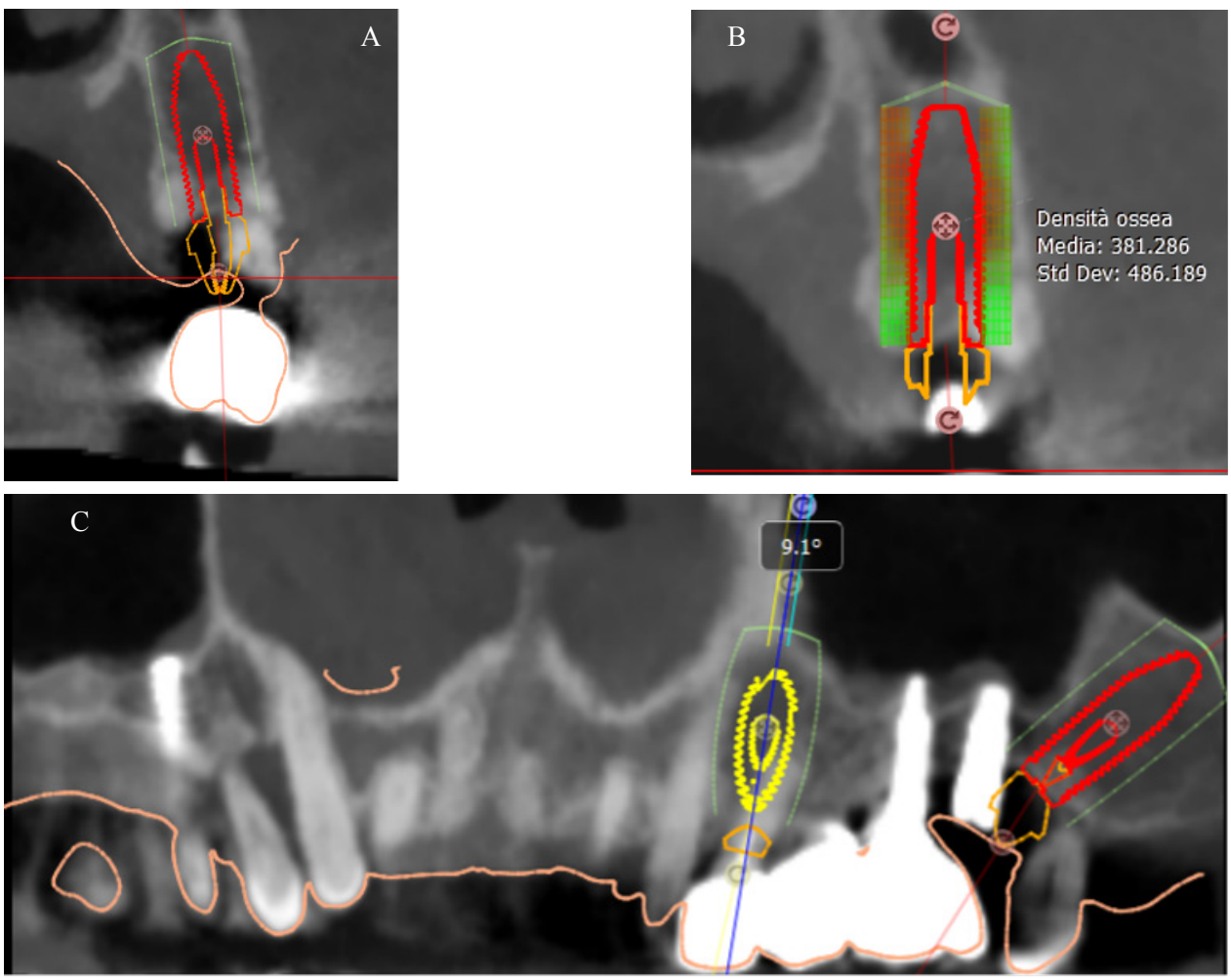


Fig 18. *a, b, c. Course of the major palatine artery near the implant site.*

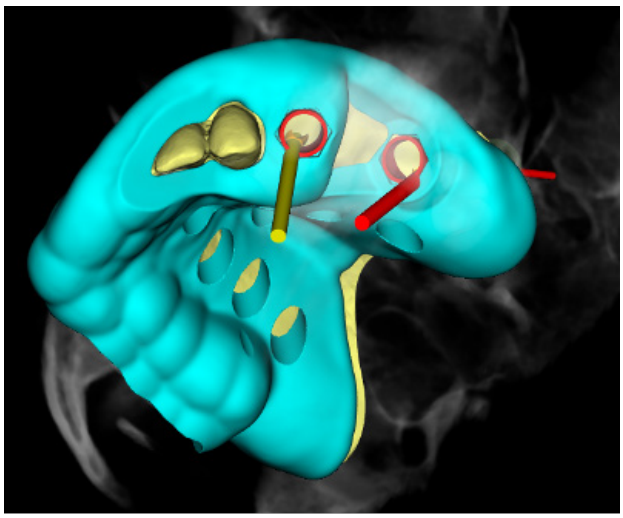


Fig 19. *Implant planning.*

with rhizolysis, the CBCT evaluation confirms the treatment plan that provides for its extraction.

The bone thickness in the vestibular-palatal direction and the absence of the anterior recess of the maxillary sinus allow the programming of a 3.8 X 13 mm implant, also planning the prosthetic connection for prosthesis screwed through an abutment inclined 20 degrees and calculated with a transgingival shoulder height 4. (Winsix TTi 3.8 / 13. Biosafin, Ancona. Italy). This planning is facilitated by the evidence in the program of the gingival profile obtained by superimposing the model on the DICOM data. Even the average bone density of a jaw that appears little mineralized is calculated automatically by the software that calculates the average bone density in Gray Scale on the surface of the programmed fixture (Fig. 17).

The same procedure occurs for the distal element (element 26) which will occupy the bone at the level of the maxillary tuber, well represented but with very low bone density. Its insertion, foreseeing the post-surgical load, must therefore provide for a minimum reaming of the neo-alveolus, with a sub-preparation that allows the implant to compact the cancellous bone trabeculae during its insertion and increase the insertion torque. A 4.5 mm diameter and 13 mm deep implant is planned (Winsix TTi 4.5/13. Biosafin, Ancona, Italy).

In Fig. 18 (a, b, c) it is highlighted how the computer assisted design for tuberal or tuberal implants with pterygoid anchoring offers an evident surgical advantage, the cross-sectional images clearly highlight the relationships with the adjacent anatomical structures such as the major palatine artery. An assisted intervention in areas of poor

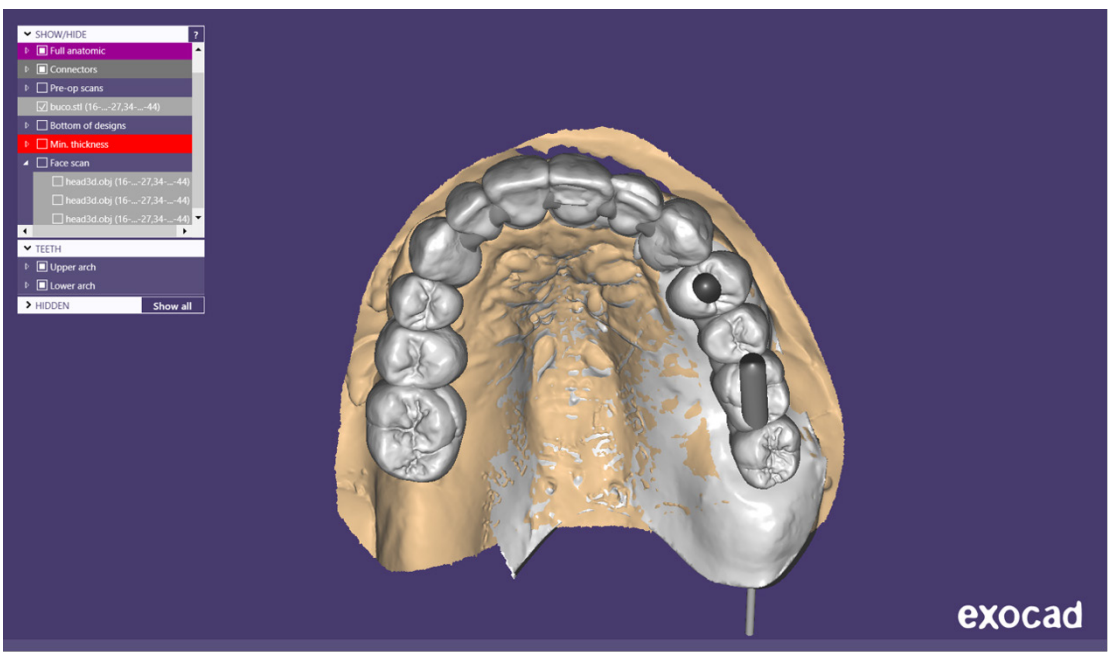


Fig 20. *Implant-prosthetic planning.*

Fig 21. *Extraoral photograph without mouth opener.*

Fig 22. *Extraoral photograph with mouth opener and landmark.*

visibility of the individual anatomy facilitates and optimizes the correct positioning of the implants. The implant planning is completed, and the project is sent to the prosthetist for the verification of the implant connections, the emergence of the abutments and the congruity with the CAD design of the post-operative provisional product.

The intermediate prosthetic connections are also chosen to be positioned during implant surgery: Extreme Abutment Straight for implant in seat 24, and Extreme Abutment angled 20 ° for implant in seat 26, to balance the angulation of the fixture. The template, made in the laboratory, allows a guided and therefore minimally invasive post-extraction flapless surgery (Fig. 18-20). The intervention in guided surgery, using the dental-supported surgical guide and the immediate prosthetic loading allow rehabilitation in a single step, making the treatment minimally invasive.

Surgical procedure

After preparation of the patient, a povidone and chlorhexidine rinses were performed and local anesthesia was administered (13, 14). A flapless surgery was performed, residual teeth and both fixture infected were extracted and the two designed implants were placed respecting the guided surgery protocol, using the surgical guide. The immediate temporary prosthesis was delivered immediately after the surgery without any occlusal contacts. (15). After surgery, a Low-level-laser Therapy Protocol with a 645 nm Diode Laser was performed to reduce tissue inflammation and to improve the tissue healing phase (Diode Laser, 645 nm, 0,6 Watt) (EGG Laser, DMT, Lissone, Italy) (16-18). After the post-surgical visit, occlusal balancing changes are made. Six months after the surgery, tissue healing and osseointegration of the implants were achieved, the control recording was made to verify functional adaptation, and the correct loading was made.

Prosthetic protocol

The implant project is supported by the design of the prosthesis elements to be used for immediate loading. Two technical photographs of the patient's face were taken: a first photograph with the patient's

smiling face and a second intraoral shot of the patient's face with a mouth opener. (Fig. 21, 22). These photographs are taken by making the patient wear a special calibrator, on which it is possible to identify landmarks.

The two photographs were inserted into the Digital Drawing software (Smile Lynx, 8853 SPA, Pero-MI) and thanks to the calibrator used, the software subsequently processes accurate measurements (Fig. 23). The digital design of the patient's ideal smile was carried out within the chosen software, based on the study of reference facial lines, using dental libraries contained within the software itself (Fig. 24). Subsequently, impressions were taken with an intraoral scanner (3Di TS, MYRAY, CEFLA sc, Imola-BO-Italy) to obtain fingerprints of the maxillary and mandibular arch in open bite and in occlusal contact (Fig. 25, 26).

A wax was then modeled to record the DVO (Occlusal Vertical Dimension) after the incisors were positioned with respect to normal overjet and overbite values. This wax represents the DVO to be replicated in future prosthetic rehabilitation. The dental arches were then scanned with the wax positioned in the patient's oral cavity, after having divided it into two symmetrical parts, to ensure the stability of the wax itself. The digital data was sent to the laboratory in STL format. The STL files obtained from the intraoral scan and the 2D digital planning project were sent to the CAD software for 3D modeling (Cad Lynx Evolution- 8853 spa-Pero-MI), and then used first for the CAD design of the prosthetic restoration and subsequently for the CAM realization of the provisional and definitive phase, using the milling technique (Fig. 27, 28).

A scan of the patient's face was also detected

Fig 23. *Digital Smile Project.*

Fig 24. *Digital Dental Library.*

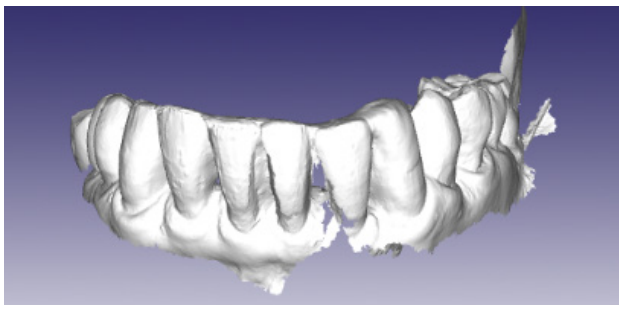


Fig 25. *Optical impression of the lower arch.*

Fig 26. *Upper arch optical impression.*

Fig 27. *2D project with outline represented from 13 to 23.*

using a facial scanner (Face Scan, Bellus 3D, San Diego-California) and inserted as an STL file in the CAD design software, a scan that overlaps the photographic project and the scan. intraoral already integrated within the CAD, as well as the dental project evaluated in the 2D digital design phase (Cad Lynx Evolution- 8853 spa-Pero-MI) (Fig. 29, 30). All the data entered in a single three-dimensional digital file were preparatory to the realization of the patient's final prosthetic project (Fig. 31).

The CAD programming allowed us to create temporarily milled temporaries from 24 to 26 initially for the immediate loading phase, and subsequently, after osseo-integration (6 months after the surgical phase), the temporaries were made and positioned for the upper arch and lower as per digital project, functionalized and a second EMG was performed which showed correct muscle activity in the provisional phase (Fig. 32). Digital diagnostics was also performed to detect free mandibular movement, using a software dedicated to the analysis of the chewing function (ITAKA Cyclops, Itaka Way Med, Kinejaw srl, Venice, Italy). This system is equipped with infrared cameras to detect the face and movements and to it is connected a PC and a software capable of detecting all the mandibular movements according to a commanded sequence (Fig. 33). It was the functional and aesthetic adaptation of the provisional phase, in the presence of good compliance by the patient and in the absence of any pain symptoms, that allowed the final prosthetic finalization, which duplicated the provisional phase, using the integrated digital project. A 3D scan of the

Fig 28. *2D project with 3D visualization of the chosen dental library.*

Fig 29. *Facial scan integrated into the 2D-3D digital project.*

temporary rehabilitation of the upper and lower arch was performed.

An impression of the natural and upper and lower implant posts was then taken with an intraoral scanner, definitive prostheses were made in milled zirconia with ceramization of the vestibular portion only and monolithic in the occlusal portion, keeping the natural posts separate from the implant posts. The occlusal modeling was carried out using CAD digital systematics (Exocad Dental CAD, Exocad GmbH, Darmstadt, Germany), exploiting the matching between the initial design, the STL files of the functionalized provisional scan, the computerized registration of the digital mandibular movements and the initial CAD drawing.

In the final phase, the definitive EMG was performed (Fig. 34) which confirmed a correct distribution of the occlusal contacts, and a final radiographic check with Orthopantomography (Fig. 35).

DISCUSSION

From the clinical and instrumental results obtained we can affirm that the integrated digital design methods are of help both in the initial diagnostic and design phase, and in the surgical and prosthetic clinical phases, as well as functional verification and laboratory CAD design (4). The integration of data

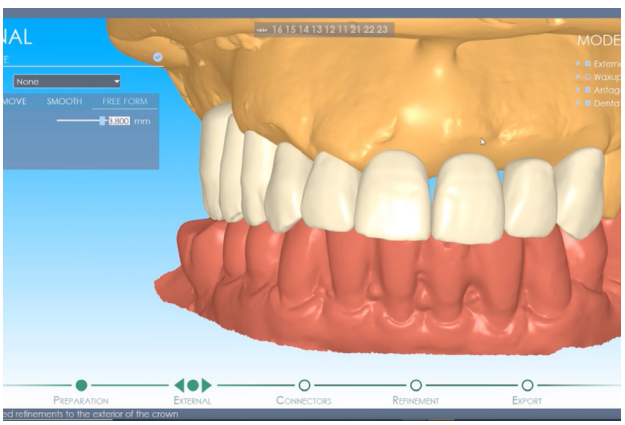


Fig 31. *Final prosthetic CAD design.*

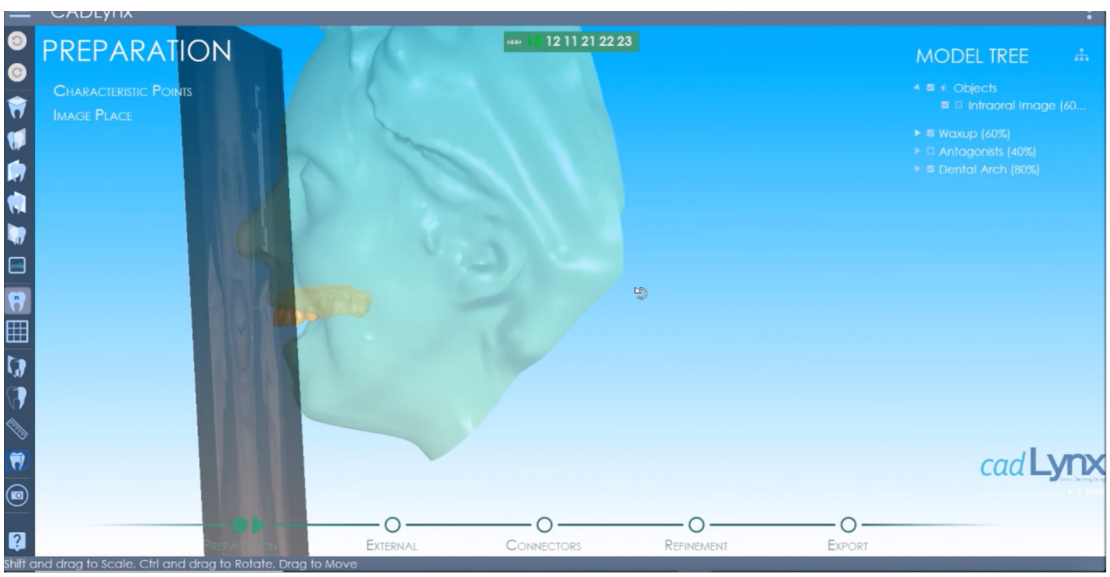
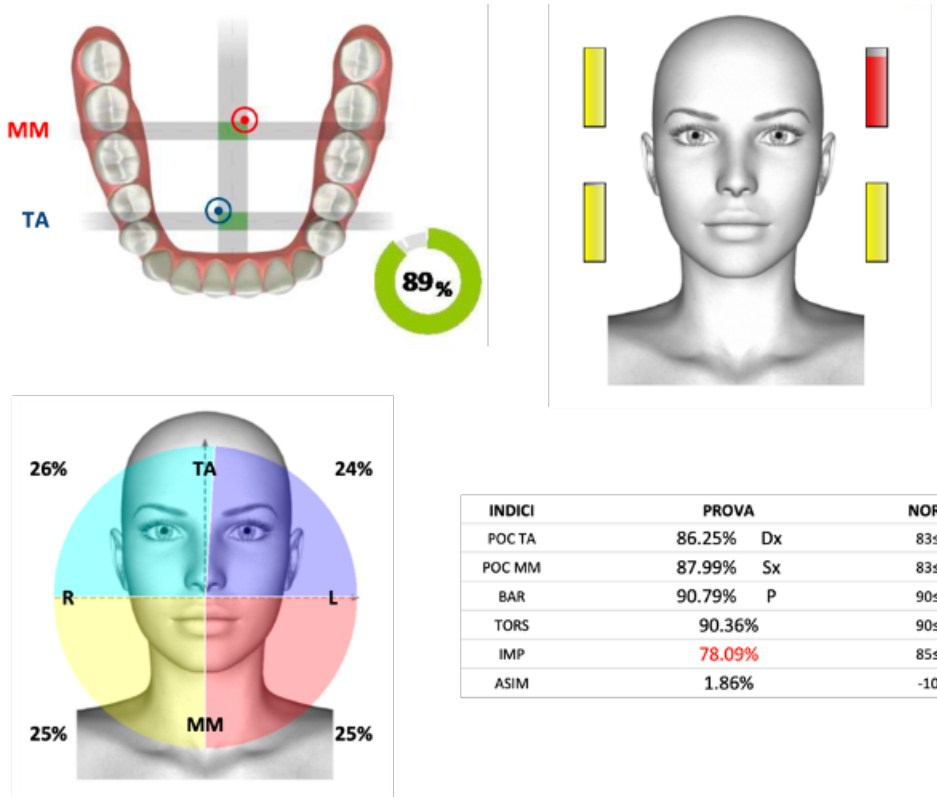


Fig 30. *Facial scan integrated into the 2D-3D prosthetic design.*



INDICI	PROVA		NORMALITA'
POC TA	86.25%	Dx	83≤(%)≤100
POC MM	87.99%	Sx	83≤(%)≤100
BAR	90.79%	P	90≤(%)≤100
TORS	90.36%		90≤(%)≤100
IMP	78.09%		85≤(%)≤115
ASIM	1.86%		-10≤(%)≤10

Fig 32. *EMG temporary phase.*

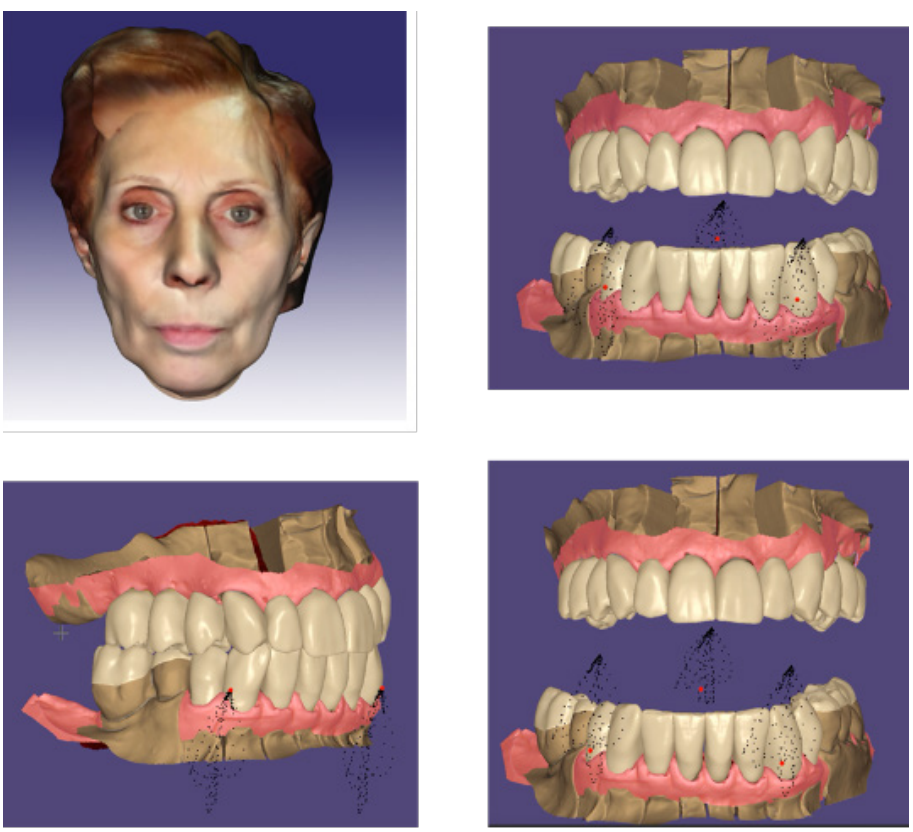
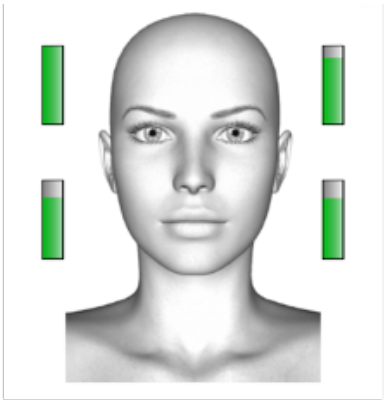
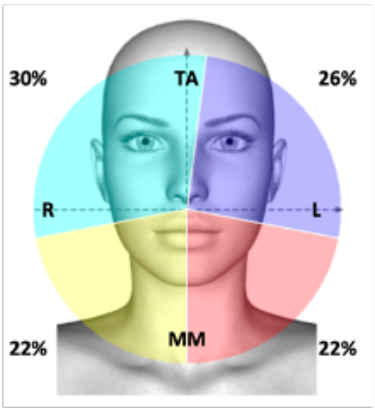


Fig 33. *Free mandibular movement. 3D digital recording.*





INDICI	PROVA	NORMALITA'
POC TA	85.07% Dx	83≤(%)≤100
POC MM	88.92% Dx	83≤(%)≤100
BAR	86.94% A	90≤(%)≤100
TORS	90.95%	90≤(%)≤100
IMP	62.59%	85≤(%)≤115
ASIM	4.46%	-10≤(%)≤10

Fig 34. *EMG post-finalization of the prosthetic.*

Fig 35. *Final orthopantomography.*

within a computerized world allows for the reduction of errors and better control of the therapeutic phases, as well as better interdisciplinarity (5).

Achieving an aesthetically pleasing result is one of the most crucial aims of a successful dental prosthetic rehabilitation since the position and number of missing teeth are important factors affecting the quality of life (6, 19). This often requires a multidisciplinary approach consisting of the teamed-up work of different professionals such as prosthodontists, oral surgeons, prosthodontist periodontists, and dental technicians (20).

Thanks to rapid technological advances and materials, it is now easier to achieve an excellent treatment outcome, the satisfied patient. It is also very convenient to visualize the outcome in advance with the aid of rendering software such as Smile Lynx (Smile Lynx, 3D Lynx, 8853 SRL, Varese, Italy). These kinds of software can process different images of patients, helping the clinician to draw guidelines for facial, dental, and gingival analysis, ultimately producing a digital pre-visualization of the result (6, 10, 21).

Surface electromyography was used to determine the impact on the activity of the masticatory muscles, using Teethan device, which consists of four wireless probes placed on the anterior temporal and masseter muscles to detect muscular activity during two clench tasks of 5 second each. This system allows to determine the presence/absence of prevalence, torsions and imbalances through the analyses of the collected data (22-26). Electromyography makes it possible to identify any imperfections in the occlusal load and correct them on the temporary restoration to obtain an adequate and above all tolerated final rehabilitation by the patient (27). Other Authors, on the other hand, have used electromyography to investigate patient satisfaction with implant rehabilitation, obtaining excellent results (28).

Proper occlusion and oral hygiene are critical to the long-term success of dental implants (29). The most recent literature confirms instead the same survival and implant success rate also in patients with systemic diseases (HIV, HCV, SJOGREN), it is also a minimally invasive technique and therefore more suitable in patients with chronic systemic diseases (30-33). Before the surgical and prosthetic treatment, especially in the pandemic actual situation, is however necessary the evaluation of the tissue healing, is necessary to evaluate the inflammatory state of the oral cavity (34-36).

Overloading occlusion can compromise peri-implant health and cause inflammation that can lead to future peri-implant bone loss. Maintaining both the horizontal and vertical dimensions of peri-implant bone is essential to preserve the correct architecture and health of the soft tissues (37). The electromyography examination can be a valid aid in implant-prosthetic rehabilitation to establish the right occlusal load; in fact, some Authors underline how the immediate loading of the implant can influence a high production of the crevicular fluid (38).

Advanced maxillary atrophy is one of the most common clinical scenarios where implant placement could become difficult and volumetric evaluation using suitable diagnostic software could facilitate the implant planning as Manacorda et al. described in 2020, suggesting the potential application of the retro-canine maxillary area as a designated location for virtual tilted implants. (39, 40). A new treatment modality for fixed partial rehabilitation of posterior maxilla with immediate function using 1 anterior axial implant and 1 posterior tilted implant with intra sinus mesial insertion is now described from literature as Agliardi et al. showed in 2014. The results obtained suggest that this approach could allow rehabilitation of the posterior maxilla with immediate function in case of reduced bone volume, representing an alternative technique to bone grafting, short implants, and zygomatic or pterygoid implants (41).

Aparicio et al in 2001 indicated that the use of tilted implants is an effective and safe alternative to maxillary sinus floor augmentation procedures (42). The use of tilted implants to support fixed partial and full-arch prostheses for the rehabilitation of edentulous jaws can be considered a predictable technique, with an excellent prognosis in the short and medium term. (43). Furthermore, immediate loading is nowadays a new concept of implant rehabilitation, to meet the patient›s growing expectations in terms of comfort, aesthetics, and shorter treatment period

as Tettamanti et al described in 2017 (44).

Immediate loading of dental implants has gained widespread popularity due to its advantages in reducing treatment duration and improving patient aesthetics and acceptance, and compared to early loading, immediate loading could achieve comparable implant survival rates and marginal bone level changes, as Chen J described in 2019 (45). Jan D'haese in 2000 demonstrated how the invention of computerized axial tomography (now known as computerized tomography) and the developments of interactive software to allow virtual planning, with the aim of guiding the surgery precisely toward a specific target, has greatly improved general, as well as oral, surgery.

Virtual dental implant planning enables a prosthetically driven approach, which results in the best prosthesis possible, improved esthetics, optimized occlusion, and loading. This new digital, surgical, and prosthetic approach has also changed and the surgical paradigm of using large flaps to obtain a correct view of the surgical area because flapless implant surgery, with or without immediate loading, has become more predictable (46). As Vinci R and Manacorda M. et al demonstrated in 2020, computer-aided surgery is a predictable procedure for implant placement, the study data described that the detected horizontal and angular deviations indicated that flap surgery should be used to prevent implant positioning errors due to poor sensitivity and accuracy in cases of severe jaw atrophy (47). Furthermore, the digital prosthetic procedure is used to minimize the possibility of error and, at the same time, shorten working times. The clinician can rely on effective smile planning tools and CAD/CAM systems, which, as demonstrated by McLaren et Al. (47), have proven their reliability in the realization of adhesive restorations in aesthetic areas. A dedicated digital smile planning software, both two-dimensional-Smile Lynx and three-dimensional-Cad Lynx-3D associated with the use of digital models and CAD / CAM systems for the milling of both the mock-up, the provisional, and the definitive restoration, can obtain excellent results in a simple, standardized and less operator-dependent way (49-53). It should be added that the peculiarity of this study was the simplification of the combination of the dental design carried out on the photographs, according to the facial planes, with the intraoral scans, taking advantage of the integrated three-dimensional dental libraries that allow the automatic alignment, unlike other Authors, like Cattoni et al. described about esthetic dental treatments in 2016 (5).

Finally, this study showed guided implant placement and the application of fixed implant-supported prosthetic restorations carried out with a fully digital workflow, dependent on the functional digital evaluation of the patient's occlusion. The proposed protocol described the correct use of digitalization of clinical, surgical, and prosthetic procedures, and the matching of the data into a computerized environment, to improve team communication and to take advantage of the combination of collected data to not lose information using classic manual steps.

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Traditional prosthetic workflow for implant rehabilitations with a reduced number of fixtures: proposal of a protocol.

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The aim of this study was to describe a standardized protocol for the creation of a definitive prosthetic rehabilitation supported by a reduced number of implants, achievable with a limited number of an optimized appointments. The proposed protocol provides only for 4 appointments to finalize the set work. During the first appointment, definitive impressions are taken in order to obtain the master models and plaster bars. The second appointment is the most important: the aesthetic and functional evaluations of the provisional prostheses are carried out and the plaster bars tested. During the third appointment the teeth test is performed, with the corresponding phonetic and functional test. In the fourth appointment the definitive prostheses are delivered and screwed. The fundamental aspect of prosthetic finalization is the simplification and standardization of protocols to obtain better control of all different steps and to reduce the number of appointments with the patient. The realization of a correct definitive prosthesis is the key to long-term success in implant rehabilitation and can improve the patient's quality of life in various aspects. By optimising the time and standardising the procedures, it is possible to make definitive prostheses for rehabilitations with a reduced number of implants of excellent quality in only 4 appointments.

Obtaining an effective implant supported prosthetic device in edentulous patients is the main goal of an oral rehabilitation (1, 2). This type of rehabilitation is becoming more and more used considering the increase of life expectancy and the growth in the number of edentulous patients with specific and aesthetic needs, especially in cases where more traditional removable prosthetic solutions are not well tolerated (3).

In order to satisfy the need to stabilize the prosthetic devices, solutions have been developed that use multiple osteo-integrated titanium implants as support systems, the therapeutic efficacy of rehabilitations based on the use of a small number of implants, with a high aesthetic and functional yield is now universally recognized (4-8). Among the most used implantology protocols for the treatment dental arches with moderate / severe bone atrophy, the "All on Four" technique continues to achieve great success within the scientific community (9-12). This method involves the placement of 4 implants: two axial ones positioned in the anterior sector and two inclined at about 30 - 35 ° with respect to the occlusal plane in the posterior sectors. This inclination allows

Key words: All on 4, prosthetic rehabilitation, tilted implant, implant prosthetic rehabilitation

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Fig. 1. *Initial dental arches.*

to distalize the implant emergency and to provide support to a prosthetic arch up to the first molar, and to avoid any damage the noble structures such as the maxillary sinus (upper arch) and the inferior alveolar vascular-nerve bundle (lower arch). This also avoids the bone regeneration procedure in the presence of severe atrophies (13).

Implant positioning is not the only challenge for the clinician, but also the creation of a suitable prosthesis from both a functional and aesthetic point of view (14, 15).

The aim of this study is the description of a traditional protocol proposal for the realization of a definitive prosthetic rehabilitation supported by a reduced number of implants, achievable with a reduced number of appointments for the reduction of working times, and with standardized procedures, to reduce possible complications

MATERIAL AND METHODS

In 2018 a 78-year-old female patient came to the Department of Dentistry of Vita-Salute San Raffaele Hospital, Milan, Italy, presenting both dental arches affected by advanced periodontal disease and therefore highly compromised residual elements. A careful objective and radiological evaluation were performed. The dental elements were considered hopeless, and a fixed rehabilitation with a reduced number of implants was proposed to the patient (Fig. 1, 2).

Surgical phase

Before the surgery, the impressions of the two dental arches were taken and the provisional prostheses were made and delivered the day of the surgery. After preparation of the patient, a povidone and chlorhexidine (16,17) rinses were performed and local anesthesia was administered. A full-thickness flap was raised residual teeth were extracted and 4 implants were placed according to the all-on-4 protocol (Fig. 3).

The immediate temporary prosthesis was delivered 3 hours after the surgery and occlusal contacts were

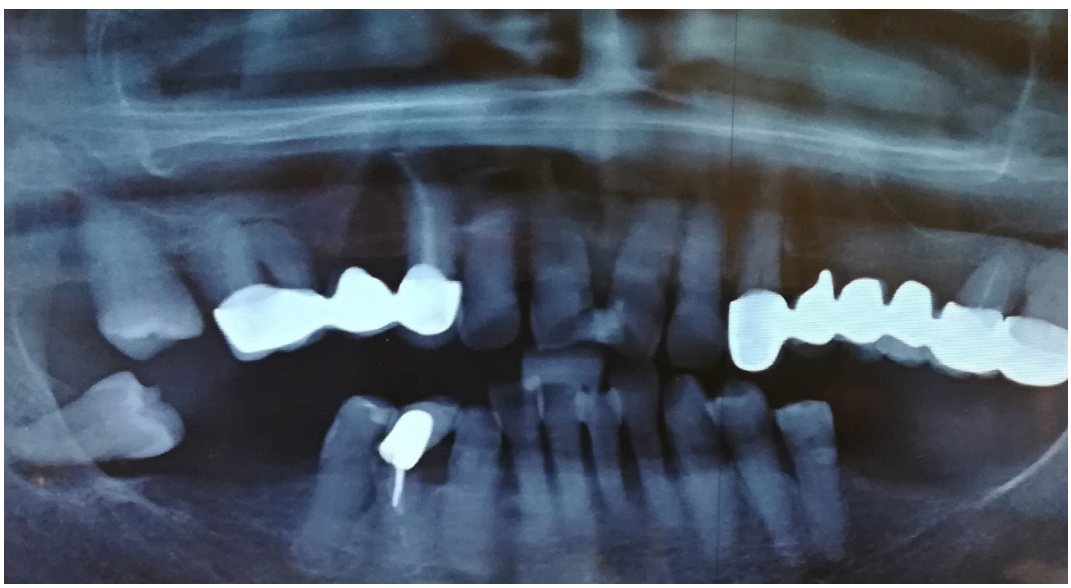


Fig. 2. *Initial orthopantomography.*

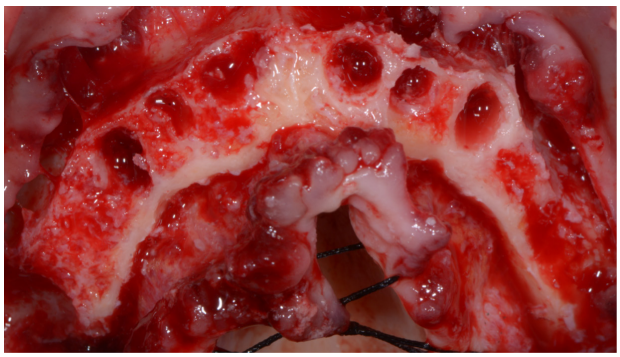


Fig. 3. *Full-thickness flap.*

maintained in maximum intercuspation between the anterior teeth as described in the original protocol (18, 19) (Fig. 4 a, b). After surgery, a Low-level-laser Therapy Protocol with a 645 nm Diode Laser was performed to reduce tissue inflammation and to improve the tissue healing phase (Diode Laser, 645 nm, 0,6 Watt) (EGG Laser, DMT, Lissone, Italy) (20-22). After the post-surgical visit, occlusal balancing was made and after 3 months, a control recording was made to verify functional adaptation.

Prosthetic proposed protocol

The fundamental aspect of prosthetic finalization is the simplification and standardization of protocols to obtain better control of all different steps and to reduce the number of appointments with the patient. A screw-retained prosthesis is usually preferred, it can be easily removed, if necessary, during hygiene maintenance sessions or in case of complications (23).

In recent years that has been the introduction of new materials and processing techniques that have increased the options available for definitive rehabilitation. The quality of the materials is a central aspect not only for achieving natural aesthetics, but also for the longevity of the prosthesis and implants (24). The most commonly used materials of definitive prosthetic rehabilitation supported by a reduced number of implants are metals (cobalt chrome or titanium), zirconia, carbon, with the aesthetic part modelled in acrylic resins, composite, lithium disilicate or ceramic (25, 26). The prosthetic part must contain a metal core, in order to increase the rigidity and fracture resistance. The material normally used for the fabrication of the aesthetic part of the final prosthesis is acrylic resin, an inexpensive but still biocompatible material with good mechanical and aesthetic properties (27). Conventional resin teeth are composed by polymethyl methacrylate (PMMA).

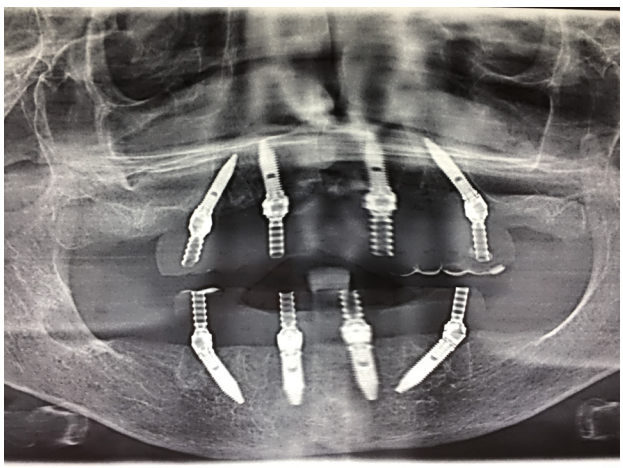


Fig. 5. *Post-surgery and immediate loading Orthopantomography.*

Fig. 4. *a): Provisional prosthesis screwed in the patient's mouth; b): Patient's smile with provisional prosthesis.*

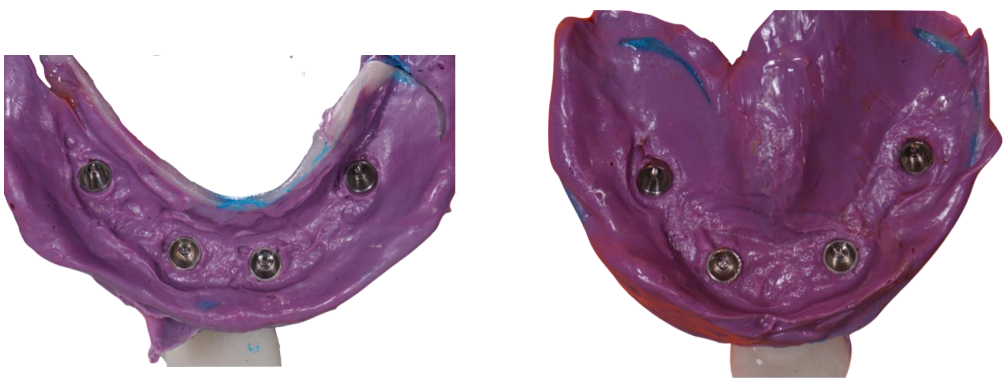
Nowadays, particularly strong and aesthetically pleasing types of resins are used; an example is Double Cross-Linked (DCL) allow for more wear-resistant dentures. The resins used for these types of teeth contain ultra-high molecular weight polyethylene molecules that increase their fracture resistance (28).

Proposal of protocol

Six months after surgery, tissue healing and osseointegration of the implants were achieved and the final prosthetic made. During these six months, the temporary prosthesis is monitored periodically. Before proceeding with the creation of the final prosthesis, the patient is asked to take an orthopantomogram follow-up X-ray (OPT) (Fig. 5).

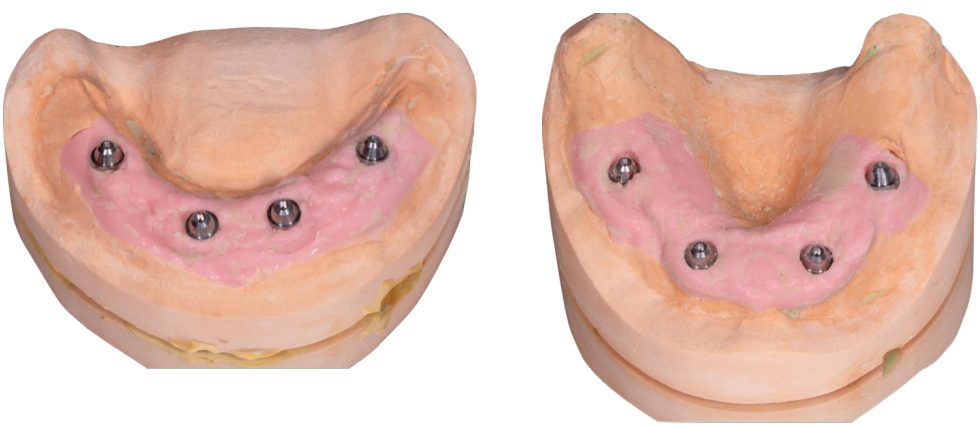
The first X-ray is necessary to verify the condition of health of the implant fixtures and to check the perfect matching of the prosthetic components: both the Extreme Abutment placed on the implant fixtures and the provisional prosthesis. It is very important to create the provisional prosthesis properly, following a correct vertical dimension, respecting the aesthetic and functional reference lines of the face, such as the bi-pupillary plane and the Spee and Wilson curves (the provisional prosthesis will guide the clinician in the creation of the definitive prosthesis) (29, 30).

The protocol includes the use of provisional prosthesis as a guide, which are created according to the aesthetic lines of the face and respecting the occlusal-functional planes, only 4 appointments are provide for the finalization



a). b).

Fig. 6. *Definitive impressions.*



a). b).

Fig. 7. *Master models.*

Fig. 8. *Provisional prosthesis in the articulator.*

of the treatment. The final impressions of the edentulous arches and the position of the implant fixtures are taken during the first appointment (Fig. 6).

The important factor in this phase is the use of an individual tray and the use of the specific transfer so that a master model can be obtained (Fig. 7a, b).

The second appointment is the most important: aesthetic and functional evaluations of the provisional prostheses are carried out so that the necessary modifications can be made to the final prosthesis. It is important to consult the patient about their aesthetic perception, such as the shape and color of their teeth.

An occlusion wax-up is taken, considering first of all the vertical dimension: if it is decided to maintain the same vertical dimension as in the provisional phase, a wax-up in maximum intercuspation is recorded. If it is necessary to make a minimum correction of the occlusion or the vertical dimension in the provisional phase, a wax-up with the clinically evaluated occlusion elevation should be recorded, manually guiding the patient's jaw into the centric relation. An assessment of the bipupillary, Spee and Wilson planes and the midline are then carried out, recording, where possible, the various adaptations to be applied to the wax-up. Intraoral photographs are taken to highlight the modifications, and to facilitate the laboratory's process.

After that, the provisional prostheses are removed from the oral cavity and placed on the master model. The laboratory clamps two master models with wax on position and transfers them to the articulator. In this way the position of the maxillae and the provisional denture in the articulator is found. Before returning the two provisional prostheses to the clinician, it is useful to record two silicone keys of the position and shape of the teeth of the prostheses (Fig. 8, 9).

In the articulator phase while waiting for the plaster to harden, the plaster baris tested, which is a type 4 plaster bar that incorporates transferts inside, which screw and close perfectly on the master model (Fig. 10). When the plaster bar is screwed into the mouth on the implant fixtures without damage, it confirms the accurate representation of

Fig. 10. *a, b): Plaster bars on master models.*

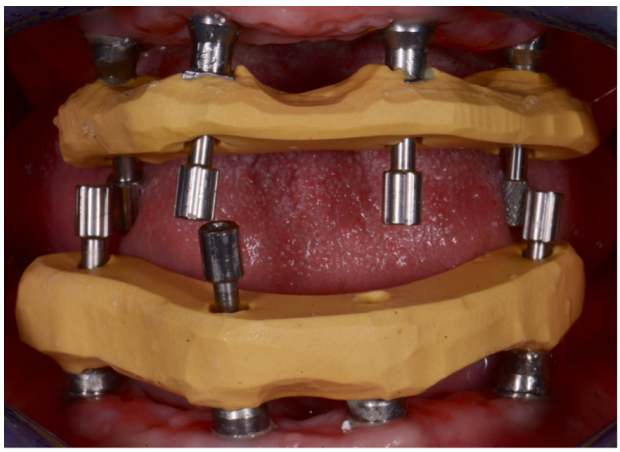


Fig. 11. *Plaster bars screwed into the patient's mouth.*

Fig. 12. *Wax-up teeth test in the patient's mouth.*

Fig. 13. *Definitive prosthesis in the patient's mouth.*

the analogues inside the master model (Fig 11). However, endoral X-rays are performed to verify the connection of the prosthetic components, to check the perfect fitting of the bar to the implants. If the bar is damaged (the plaster is very soft) at an implant fixture, it means that one or more analogues do not exactly represent the position of the implants. In this case, the bar is cut and is blocked with Pattern Resin inside the oral cavity in order to precisely reproduce the position of the fixtures. The laboratory will then remove the affected analog and re-locate the analogs in the master model in the correct position. Then the plaster bars are removed from the patient's mouth, the provisional prosthesis are returned, and the patient is dismissed.

The laboratory performs a wax-up of the teeth on the metal framework, in the articulator, following the instructions previously provided. During the third appointment, the teeth test is carried out, with the corresponding aesthetic, phonetic and functional test, and minor modifications are made if necessary (Fig 12). After the teeth test, the laboratory finalizes the final prostheses, replacing the wax with pink resin material.

At the fourth appointment, the final prostheses are delivered and screwed in, respecting the correct torque of the mechanical implant components (25-30 N, using a special dynamometric key). (Fig. 13). Correct occlusal balancing is carried out at the same session if necessary.

A final OPT is performed at the end of the appointment and the patient is included in a follow-up plan that includes professional hygiene sessions every 3-4 months, in order to monitor the good health of the implant-prosthetic rehabilitation and to highlight any problems at an initial phase (Fig. 14, 15).

DISCUSSION

The aim of this study was to describe a standardized method for the construction of definitive prostheses in "All on Four" rehabilitations or other rehabilitations with a similar small number of implants. The key

Fig. 14. *The patient's smile with definitive prosthesis.*

word in this kind of rehabilitation is the procedure of standardization that allow to avoid errors as far as possible

The "All on Four" protocol is already validated by numerous studies in the literature (9-12). In a longitudinal study (10 to 18 years of follow up), Maló et all reported a cumulative prosthetic survival rate of 98.8%, with a marginal bone level of 2.32 mm and a low incidence of biological and mechanical complications (31). The most recent literature confirms the same survival and implant success rate also in patients with systemic diseases (HIV, HCV, SJOGREN) (32-35). Cattoni et al. in 2020 also evaluated a possible neuro-cognitive measure of how self-perception can change as a significant consequence of aesthetic prosthetic rehabilitation (36).

The present study proposed an optimized and standardized protocol that can allow the clinician to perform a definitive prosthesis for rehabilitations with a reduced number of implants in 4 appointments. A two-year of follow-up, with quarterly professional hygiene appointment was evaluated. During the follow-up sessions all the clinical indicators are recorded, and no implant or prosthetic problems were detected. The patient was also asked to answer a questionnaire. The results showed a high rate of satisfaction with the aesthetics, function and speed of fabrication of the final prosthesis.

This surgical approach requires considerable knowledge of surgical anatomy and an accurate diagnostic phase to reduce the risk of post-surgery complications. After a thorough clinical examination, before proceeding with surgery, it is still necessary to request radiological examinations to deepen the study of the surgical and topographic anatomy, which can be two-dimensional (intraoral x-ray and orthopantomography), or three-dimensional (CT and CT Cone Beam).

The All-on-4 protocol is nowadays described in the literature (18) as a viable treatment option also in the long-term. This protocol allows to rehabilitate edentulous arches with four implants and an immediate fixed prosthesis (37, 38). Before the surgical and prosthetic treatment, especially in the pandemic actual situation, is however necessary the evaluation of the tissue healing, is necessary to evaluate the inflammatory state of the oral cavity (39-41). Furthermore, the realization of a correct definitive prosthesis is the key to long-term success in implant rehabilitation and can improve the patient's quality of life in various aspects (26).

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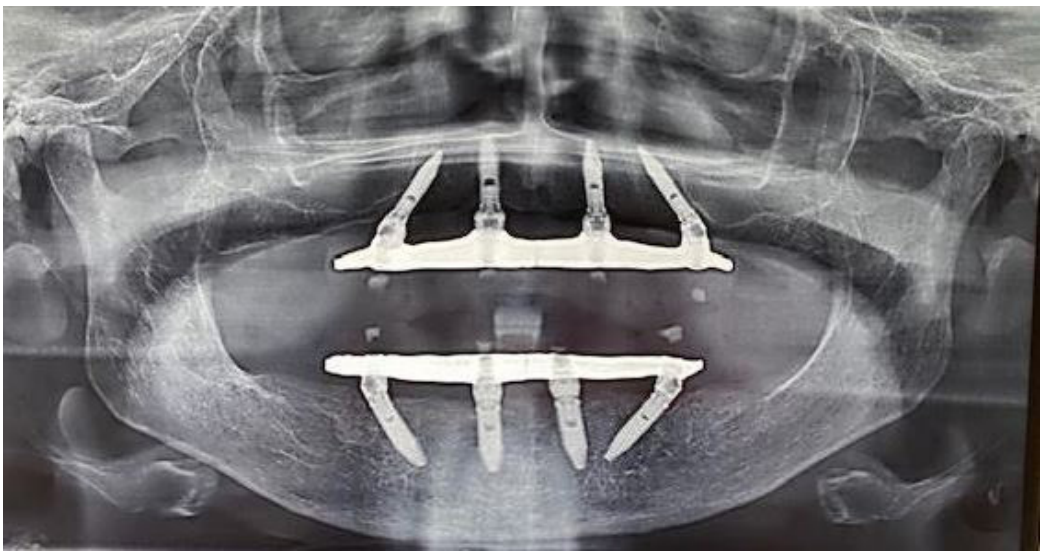

Fig. 15. *Final orthopantomography.*

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Comparison of hygiene levels in metal-ceramic and stratified zirconia in prosthetic rehabilitation on teeth and implants: a retrospective clinical study of a three-year follow-up

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The aim of this retrospective clinical study was to evaluate and compare oral hygiene levels in patients subjected to fixed metal-ceramic or stratified zirconia prostheses, either on teeth or on dental implants. Twenty patients, including 10 with metal-ceramic prostheses and 10 with stratified zirconia, were engaged for the study. Considering the prosthesis positioning phase as zero time, all patients were examined twice a year for a follow-up period of 3 years. During each session, to assess oral cavity state of health, both the Plaque Index (IP) and the Bleeding Index (BOP) were recorded. All patients were instructed in home hygiene maintenance and subjected to professional oral hygiene sessions customized according to prothesis type (on natural teeth or dental implants) and materials (metal ceramic or stratified zirconia). Statistically significant evidence was found in IP values, with an increase in the initial stages in zirconia prostheses and in the final stages in metal-ceramic ones. BOP levels showed a reduction during the follow-up period, but no statistically significant differences were found between examined groups. An adequate patient education in hygiene maintenance associated with professional oral hygiene sessions with special tools could positively affect fixed prostheses' maintenance, both on natural teeth and on dental implants.

In case of tooth compromise, based on quality and quantity of residual dental substance, fixed dental prothesis or implant-supported fixed prothesis could be considered as possible alternatives (1-2).

As suggested by several Authors long-term success and patients' satisfaction could be obtained both in osteo integrated dental implants or in dental supported fixed prosthesis (3-5). Several materials as metal-ceramic or zirconia could be applied for fixed prosthodontic treatment such as single crowns or full arch rehabilitation. As traditionally the first material was considered as gold standard, metal-free restorations were increasingly required, both for biocompatibility and mechanical and aesthetic properties (6, 7). Long term complications could occur in both restorations, either on teeth or on implants (8), such as ditching of cement margin, screw loosening, prosthetic cracking or fracture could be defined as technical complications, also biological issues as periodontal diseases could compromise prosthodontic treatment (9, 10).

Although periodontitis could be defined as multifactorial pathology, bacterial plaque could be considered as main biological cause (11). As

Key words: prosthetic rehabilitation, oral hygiene, zirconia protheses

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dental plaque could accumulate either on tooth crown or under gum margin, that is in subgingival area of the sulcus or pocket, professional hygiene sessions based on specific devices used according with rehabilitation type could be considered as gold standard so as to prevent occurrence and progression of mucositis, peri-implantitis, bleeding on probing (BOP), and deep probing pocket depth (PPD) (12, 13). Oral hygiene instructions provided by dental professionals, in association with patient compliance, seems to have a key role in the success of prosthetic rehabilitation, both on natural teeth and on dental implants (14, 15).

The aim of this retrospective clinical study is to evaluate and compare oral hygiene levels in patients subjected to fixed metal-ceramic or stratified zirconia prostheses, either on teeth or on dental implants, to prove role of oral professional hygiene sessions and patients' education and monitoring in different prosthetic rehabilitation.

MATERIALS AND METHODS

From November 2017 to December 2020, twenty patients, without distinction between men and women, were engaged in this study in the Dentistry Department of San Raffaele Hospital (Milan, Italy). Patients with uncontrolled systemic diseases, smokers or taking plaque-building drugs or anticoagulants, which could promote bleeding, were excluded from research. All patients were evaluated with careful objective, radiological and functional initial examination.

The patients received a prosthetic or implant-prosthetic rehabilitation designed and finalized according to the actual protocols and in compliance with the aesthetic and functional plans of the patient. A correct evaluation of the present bone structure, of the residual natural elements and of the occlusal planes was performed (16). The aesthetic-functional needs of the patient were also taken into consideration.

All patients were designed using traditional and digital methods to support them: the functional aesthetic design subsequently guided both the provisional and definitive planning phases (17, 18). In according to the reduction of the existing bacterial load, all the patients were subjected to chlorhexidine rinses (19, 20). Furthermore, the respect of the tissue healing based on a correct initial evaluation of the healing state of the tissue of the patient, especially in the pandemic actual situation, is necessary to evaluate the inflammatory state of the oral cavity before a prosthetic or surgical treatment (21, 22).

The sample was divided into two groups: the first group consisted of ten patients with zirconia prostheses, the second of as many subjects with metal-ceramic prostheses. For each subgroup five had prosthetic restorations on implants and five on natural teeth. Patients taking plaque-building drugs or anticoagulants, which could promote bleeding, were excluded from research. All patients recruited for this study have been visited twice a year from December 2017 to November 2020, starting from the first day the prosthesis was placed.

During every check, using special tools such as Teflon curettes for implant instrumentation, peek inserts for ultrasonic scalers, powders with low particle size applied for air-polishing and super-floss for cleaning under prosthesis and around implant' or teeth' sites, professional hygiene was performed.

Two clinical indices were recorded during each session: Plaque Index (PI) and Bleeding Index (BOP). For the detection of Plaque Index (IP), fluorescein was used, a plaque detector that is applied to all prosthetic surfaces with the aid of a micro-brush. Through the chemical process given by the reaction of the dye in contact with the bacterial plaque and thanks to the use of a blue light LED lamp; we can observe the areas with the greatest presence of soft deposits. The Plaque Index as a percentage was obtained using the Plaque Control Record technique, which allows the registration of bacterial plaque on the individual prosthetic surfaces, dividing the tooth into four zones: vestibular, palatal/lingual, mesial and distal.

After examining and recording all the surfaces, the index is calculated by dividing the number of surfaces with the presence of plaque by the total number of available surfaces. The bleeding index (BOP) was obtained by examining the presence or absence of bleeding on the four surfaces described

above, following the passage of the periodontal probe in the gingival sulcus. After examining and recording all the surfaces, the index was calculated by dividing the number of surfaces with bleeding by the total number of available surfaces. After the acquisition of clinical indices and therefore after noting the improvement or worsening of the patient's level of health; detailed and individualized instructions were provided for each patient on the use of home aids such as manual toothbrush with soft bristles, electric toothbrush with soft bristle head, Super-floss dental floss for cleaning the implants and the spaces under the prosthesis and interdental brushes specific for each patient. The instructions that were given to patients were always accompanied by a reinforcement of motivation to carry them out.

In each recall session, the patient was advised to go to the clinic with their home aids, in order to monitor their use by the same. The plaque index value and any negligence with respect to the correct use of home aids, led us to perfect the maneuvers performed by the prosthetically rehabilitated patient. At the end, patients were advised not to consume too hard foods in order not to risk fracturing or chipping the prosthesis, causing damage as well as aesthetic and functional damage. Another category of foods to be taken with care are chromogenic ones such as: coffee, tea, red wine, which would pigment the prosthetic material, creating aesthetic damage.

RESULTS

Plaque Index (IP)

Plaque Index results were recorded every 6 months for a 3-year follow-up period both for the first group, i. e. patients with zirconia prostheses (Table I), and for the second, i. e. with metal-ceramic devices (Table II).

A Multivariate Analysis of Variance (MANOVA) revealed a statistically significant difference, over time, in the trend of the IP values in the two groups, F=2.79, p=.022 (Fig. 1). In particular, the IP values

Table I. *Average values of Plaque Index (IP) detected every 6 months for 3 years in zirconia rehabilitations.*

	Average	*Standard deviation*
IP0	27.80	6.72
IP1	28.00	6.12
IP2	27.20	4.51
IP3	22.40	3.09
IP4	21.60	6.20
IP5	15.70	3.91

Table II. *Average values of Plaque Index (IP) detected every 6 months for 3 years in metal-ceramic rehabilitations.*

	Average	*Standard deviation*
IP0	27.80	7.34
IP1	25.60	4.99
IP2	24.70	4.02
IP3	23.20	4.26
IP4	21.10	3.87
IP5	19.60	3.80

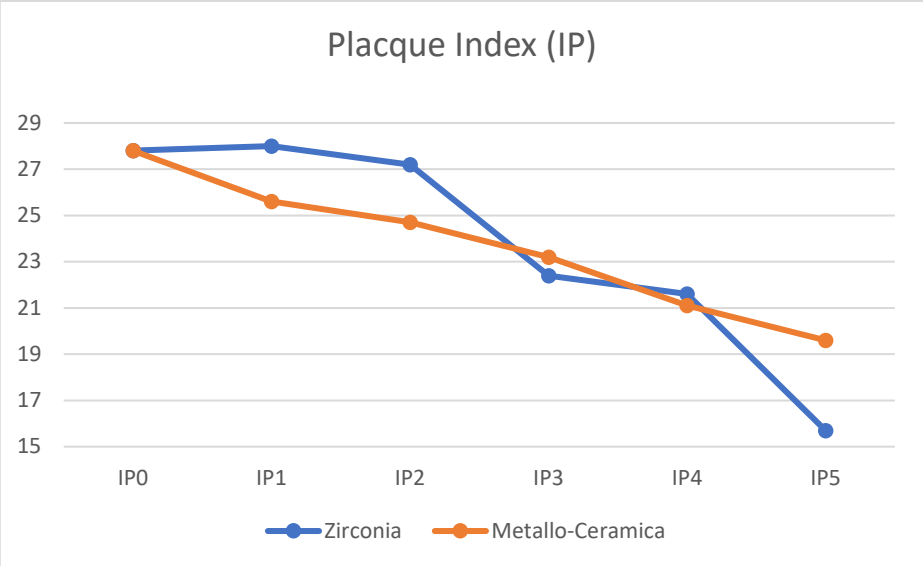

Fig. 1. *Trend of the average values of the Plaque Index (IP) in zirconia vs metal-ceramic restorations over 3 years.*

Table III. *Average values of Bleeding Index (BOP) detected every 6 months for 3 years in zirconia rehabilitations.*

	Average	*Standard deviation*
BOP0	7.20	3.59
BOP1	5.60	2.06
BOP2	4.90	1.93
BOP3	2.90	1.62
BOP4	6.00	1.74
BOP5	2.50	1.02

detected in the Zirconia group are greater than those detected in the Metal-Ceramic group in the initial stages; these values are inverted, however, in the final survey phase.

Bleeding Index (BOP)

Bleeding Index (BOP) results were recorded every 6 months for a 3-year follow-up period both for the first group, i.e., patients with zirconia prostheses (Table III), and for the second, i.e. with metal-ceramic devices (Table IV).

A Multivariate Analysis of Variance (MANOVA) revealed a statistically significant difference in the trend of BOP values over time, F=4.49, p=0.048 (Fig. 2), without however highlighting appreciable differences between the two groups. In other words, BOP significantly decreases, over time, in both groups.

DISCUSSION

Clinical application of fixed prostheses, both on natural teeth and on implants, could be a valid therapeutic alternative to removable prostheses (1, 2). To evaluate teeth maintenance, several criteria as residual coronal substance, abutment's retention and resistance, periodontal attachment loss and furcation involvement, residual probing pocket depth,

Table IV. *Average values of Bleeding Index (BOP) detected every 6 months for 3 years in metal-ceramic rehabilitations.*

	Average	*Standard deviation*
BOP0	13.30	3.59
BOP1	9.20	2.06
BOP2	9.90	1.93
BOP3	10.90	1.62
BOP4	6.90	1.74
BOP5	3.40	1.02

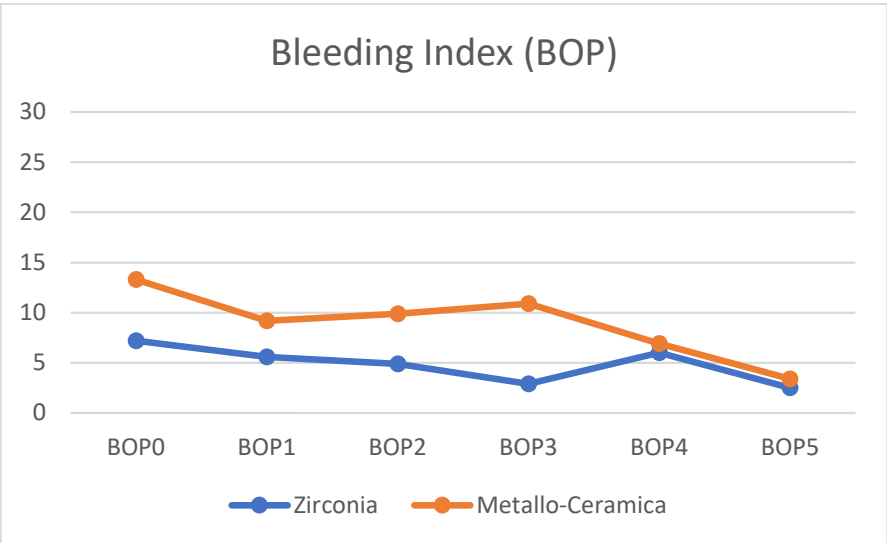

Fig. 2. *Trend of the average values of the Bleeding Index (BOP) in zirconia vs metal-ceramic restorations over 3 years.*

absence of clinical signs and symptoms or periapical radiolucency in endodontic treated elements, and contraindications in implants placement, could be considered (23-27). In case of tooth loss or need of tooth extraction, osteo integrated dental implants could represent a possible alternative for replacing missing teeth, restoring loss function (28).

Long-term success criteria of fixed prosthetic rehabilitation product could be summarized as follows: ability to reproduce the dental function, good aesthetics, accessibility at every point for hygienic maintenance by the patient and the dental hygienist, no interference with techniques cleaning of the remaining natural teeth, respect for oral tissues and acceptable aesthetics (29-31). Interproximal spaces should be broad enough to allow patients to introduce devices for interproximal hygiene (32).

Prosthetic margins should reproduce those of the underlying tooth, or to provide better access if it was not originally present (33). The prostheses should have adequate construction characteristics in order to allow self-cleansing and oral hygiene at home (34).

Long-term success could be associated both with prothesis features and with periodontal health (35), as well as stabilization of function with proper occlusal balance. As inflammatory process as gingivitis,

mucositis and periimplantitis could be considered as the most common biological complications of fixed dental prosthesis, both in provisional and definitive phase, several conditions as plaque accumulation and inflammation signs should be early intercepted (36-38).

Subjecting patients to a monitoring protocol and professional oral hygiene sessions could be the key to the success of fixed prosthetic restorations, both on natural teeth and on implants (14).

During professional oral hygiene sessions, the use of specific clinical parameters and devices customized according to the type of rehabilitation, could reduce risk of prosthetic failure (39-41).

Clinical parameters as Plaque Index and Bleeding Index, could allow both to early identify the accumulation of bacteria potentially harmful to the periodontium in natural teeth and in the peri-implant area, and to intercept possible inflammatory state of evaluated sites (42, 43).

As decompensated systemic diseases could interfere both with long-term fixed prosthetic success, predisposing patients to inflammatory reactions, the exclusion of these subjects from fixed rehabilitation could be essential (44, 45). However, if these pathologies are stably controlled, no statistically significant differences were found between sick patients and healthy patients in detection of clinical parameters considered (46, 47). Another factor that could adversely affect the long-term success of fixed rehabilitations is adequate patient education by the dental hygienist and proper compliance and ability in cleaning dental and gingival surfaces surrounding prosthetic crowns (48, 49). Maintain a continuous control regime over time, intercept any anomalies or inadequate oral hygiene conditions in the bud, so as to be able to intervene promptly to recreate the optimal conditions for prolonging prosthetic success (50). Failure to comply with these rules, even in the presence of a perfect prosthetic rehabilitation, could inevitably lead to the reduction of its survival in the oral cavity, leading to patients' dissatisfaction and discomfort.

Following the statistical analysis of the data collected, a progressive and continuous improvement of the clinical indexes detected in the 3 years on prosthetically rehabilitated patients could be evident. In detail, it could be seen how the Plaque Index (IP) in both materials starts with similar values while at the time of the last visit the rehabilitations on zirconia achieve better results. As for the Bleeding Index (BOP), however, zirconia maintains, albeit slightly, lower and lower values than metal-ceramic, without however highlighting appreciable differences between the two groups. The difference between implant rehabilitation vs rehabilitation on a natural element was found through the observation of the IP and BOP indices collected during the sessions, a continuous improvement in both rehabilitations, following each six-month visit over the three years. Following the indices' collection, in the last visit the values were slightly lower in the rehabilitations on natural teeth; however, it should be considered that the study was carried out on a small number of samples, therefore the specific analyzes on the comparison of the level of hygiene between implants rehabilitation comparison natural tooth would deserve further study.

Within the limitations of this study, based on obtained results, the authors agree professional and home oral hygiene maintenance, in association with constant monitoring through clinical parameters, could be considered essential for long-term success on both zirconia and metal-ceramic prosthetic products. Of great importance was certainly the continuous and in-depth education provided to patients at each visit, in conjunction with periodic motivational reinforcement.

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The efficacy of the diode laser at 800–980 nm as an aid to non-surgical therapy in periodontitis treatment: a review of literature

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The aim of this literature review is to assess the effectiveness of diode laser at a wavelength of 800-980 nm in addition to non-surgical periodontal therapy in periodontitis treatment. The authors performed an electronic research on Pubmed inserting as keywords: (laser OR laser therapy OR diode laser) and (periodontitis OR periodontal disease). The field has been narrowed to select only Randomized controlled clinical trials (RCT) performed from 2010 to 2020. The result of this research was 84 articles, of which eight were included in the review because they respect the inclusion criteria. The clinical, immunological, and microbiological parameters studied in the various clinical random trials were analysed. It has been shown that four out of eight studies have achieved greater benefits, in terms of clinical parameters, with the use of diode laser compared to Scaling and Root Planing. However, the greater increase in clinical parameters in diode laser-treated patients compared to the control group was mainly detected in the short term rather than in the long term. In terms of microbiological parameters, no improvement was detected after six months. Only one study reported six-month improvements in immunological parameters in patients treated with DL compared to the Scaling and Root Planing only group. In conclusion, considering the limitations of this review of literature, there is no evidence that the diode laser at 800-980 nm in addition to non-surgical periodontal therapy is more effective than SRP alone in the long term.

The purpose of the following narrative review of the literature is based on the hypothesis that diode laser at 800-980 nm in addition to non-surgical periodontal therapy in periodontitis treatment could be more effective than non-chemical therapy alone. Therefore, the hypothesis is exactly that the diode laser could be an effective aid to scaling and root planning in the treatment of the periodontitis. In literature, laser's employment is a very discussed theme because of the difference between the results of the studies, these differences are due to the several lasers and wavelength type. Therefore, in this review have been included only studies regarding the diode laser at 800-980 nm, to ensure the homogeneity of the results. Periodontitis is a chronic multifactorial disease that affects the supporting tissues of the tooth. Periodontal tissues are constantly exposed to various bacteria that can alter many local cellular functions (1).

Periodontitis occurs when untreated gingivitis progresses to the loss of the gingiva, bone and ligament, which creates the deep periodontal

Key words: diode laser; periodontitis; non-surgical therapy; scaling and root planing

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'pockets' that are a hallmark of the disease and can eventually lead to tooth loss. It has been widely demonstrated that the bacteria forming the dental biofilm are the main causative factor of the periodontal disease (2). In fact, the tissues respond to the bacterial attack by implementing an inflammatory process that protects the structures from the bacterial biofilm; the consequence, however, is that a part of the tissues is destroyed during this process (3). The extent and severity of the damage as an evidence of this project may vary from individual to individual. This variation in disease expression is the result of the interaction of host genetics and environmental and microbial factors (4).

In addition to limiting damage to the local level with non-surgical therapy, it could be hypothesized with further studies whether laser in its biomodulative action can stimulate the numerous populations of mesenchymal stem cells isolated from oral tissues (DPSCs, SHEDs, PDLSCs, DFSCs, SCAPs, hPCy-MSCs) to maintain proliferation and multipotency capacities (5). In fact, the scientific community is focusing on the ability of these cells to regenerate tissues through the production of MSC secretomes or with an immunomodulatory activity towards cells of the first immune response (6-7).

A key role in inflammatory response is also played by cytokines, specifically by two families of growth factors-such as transforming growth factor-Bl (TGF-PI) and vascular endothelial growth factor (VEGF) a. In fact, some results obtained suggests, that these two factors play a key role in regulating the immune response which is directly related to the evolution of periodontal disease (8). The therapy is mainly based on the mechanical plaque removal by Scaling and Root Planing (SRP) which in fact are considered a gold standard in periodontal therapy (9). It has also been shown how periodontal therapy affects the improvement of disorganized endothelial vascular structure associated with periodontitis, this because the gingival microcirculation undergoes a change as a result of inflammation progression (10).

Another parameter to consider, although it does not yet have much scientific evidence, is the reduction of mobility as evidence of scaling and root planing. However, it is important to note that non-surgical periodontal instrumentation has some limitations that are the long-term maintainability of the deeper periodontal pockets and the risk of recurrence, and the success of this therapy depends very much on the operator's dexterity (11).

SRP can be accomplished by non-surgical or surgical approach. However, it has been seen how SRP, being an invasive therapy, can cause wounds inside the tissue of the periodontal ligament, being this already compromised, and as the healing depends a lot on the individual cellular response (12). In addition, often there is a tendency to prescribe antibiotics, like tetracycline, nitroimidazoles, fluoroquionolones and macrolides, to patients as an additional therapy for the complete eradication of the pathogenic periodontal bacteria present within the pockets, this methodology however increases the bacterial resistance (13) and therefore, more and more experts have started to look towards new therapies that can further improve periodontal therapy and minimize side effects. The use of diode laser seems to be an excellent addition to non-surgical periodontal therapy because the specific wavelength of the laser affects the bacteria especially gram-negative anaerobic ones, first responsible for periodontitis (14). It has also been demonstrated that laser has properties that can stimulate cell proliferation, reducing inflammation and increasing the production of fibroblasts and consequently the improvement of periodontal tissue (15) and that diode laser can be selectively absorbed by tissues and blood and is widely used in soft tissues, especially in areas where there is an inflammatory process (16); although for the time being no faster resolution of gingival edema has been noted following tissue biostimulation by diode laser (17).

In the consensus report of the sixth European workshop on periodontology, there was no suitable demonstration that could ascertain the lasers' clinical effectiveness applied in SRP (18). But in 2018 it was highlighted by the American academy of periodontology best evidence consensus meeting (AAP BEC) that the confined well-crafted studies applying lasers in periodontal treatment demonstrated moderately greater improvements compared with conventional SRP (19). From the

systematic review of 2016 performed by T. Qadri et al. it was found that in sites with 5 mm deep pockets the therapy with SRP plus LD (800-980 nm) is more effective than the SRP alone (16). In contrast, in the systematic review of D. E Slot et al. no benefits in terms of Clinical Attachment Level (CAL) and Probing Pocket Depth (PPD) were observed between sites treated with DL (808-980 nm) + SRP and those treated with SRP only, however a greater reduction of the BS is evidenced in the group dealt the diode laser (20). Finally, in a meta-analysis carried out by F. Sgolastra et al. no statistically significant reduction of clinical parameters in sites treated with DL+SRP has been highlighted compared to sites treated with SRP only (21). In the study carried out by H. Gou et al. the effectiveness of the addition of laser therapy in the regulation of periodontal tissue vessels was also evaluated, however, in this study the laser did not provide any additional benefit compared to non-surgical periodontal therapy alone (10). As the previous revisions cited implies, there is a persistent debate regarding the efficacy of dental lasers in the treatment of periodontitis or periodontal maintenance therapy. So, the goal of this literature review is to evaluate the effectiveness of the diode laser at 800-980 nm in addition to scaling and root planning.

MATERIALS AND METHODS

Search strategy and selection criteria

Three of the authors performed an electronic research on Pubmed inserting as keywords: (laser OR laser therapy OR diode laser) and (periodontitis OR periodontal disease). The field has been narrowed to select only Randomized controlled clinical trials (RCT). All studies analyzed are not older than ten years. The search was limited to human subjects and studies that adhered to other eligibility criteria. Only studies using diode laser at 800-980 nm on patients diagnosed with periodontitis were selected. In Table I, the inclusion and exclusion criteria have been included.

Titles and abstracts of studies that accomplish the inclusion criteria were examined and valued. Data were obtained from the included studies according to the following parameters: author/country, study design (RCTs), subjects (sample size; mean and age range in years), inclusion of confounders, periodontitis diagnostic criteria, study groups, study outcome, and follow-ups. Moreover, methodological quality and the features of laser were evaluated.

Risk of bias

A limit of this literature review is that the electronic search was performed using only the PubMed search

Table I. *Inclusion and exclusion criteria.*

INCLUSION CRITERIA	EXCLUSION CRITERIA
In vivo studies	In vitro studies
Randomized controlled clinical trials (RCT)	Non-randomized controlled clinical trials (NRS); Review articles
Studies involving human subject	Animal studies
Patients diagnosed with periodontitis	Studies with patients diagnosed with peri-implant mucositis or peri-implantitis
800-980 nm diode laser	Diode laser > 800 nm
	Studies with patients suffering from systemic disease (like diabetes)

engine. The data that can constitute a risk of bias are the parameters regarding the energy fluence, the power output, the power density and the optical fiber used during the laser session that vary a lot between the various studies included. In addition, some studies performed different numbers of laser sessions and the duration of irradiation per tooth varies depending on the study. Due to the variation of all these parameters, it was not possible to perform a meta-analysis and therefore a statistical analysis of the data

RESULTS

Study selection

Based on titles and abstracts search, initially 84 studies were identified. Later, after examining the abstract, 52 studies were removed as the topic was not inherent in the objective of this review. There were 32 articles available in full text, of which 16 were excluded because they did not meet the inclusion criteria: 5 studies included in the sample patients with systemic diseases, 5 studies included in the sample patients with diagnosis of peri-implants mucositis or peri-implantitis and 7 studies used diode laser at wavelengths less than 800. The final selection included 8 articles. Fig. 1 shows the flow diagram of study selection process and results of the literature search according to PRISMA guidelines (22).

Characteristics of included studies

All studies are RCT (23-30). Five of these split mouth Random clinical trials (24-27, 30). Trials originated from Turkey (23, 25, 28), Brazil (27), Italy (24), Greece (26) and Serbia (29). In all studies the number of participants is between 19-31 with an average age ranging from 34.9-48.5 years. The presence of confounders, such as

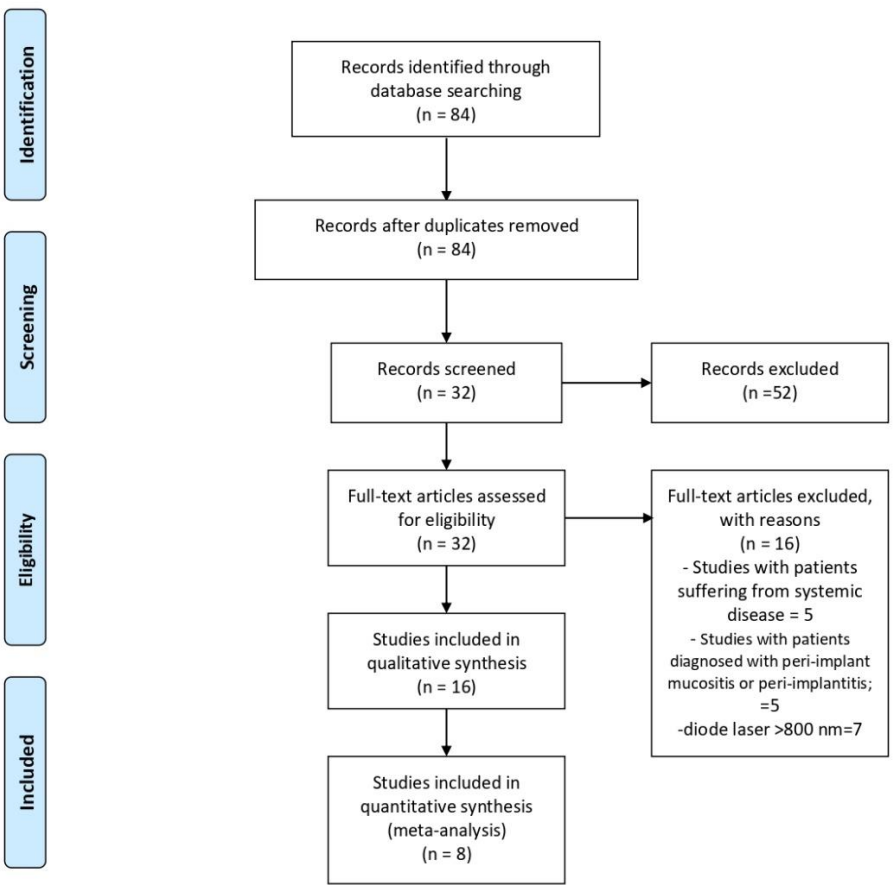

Fig. 1. *Study selection process and results of the literature search (PRISMA flow diagram).*

smokers, were included in two studies (26,28). All of the studies used the combined approach LD+SRP in the test group and SRP alone in the control group. The follow-up period for all of the studies ranged from 4 to 48 weeks. Among the studies analyzed in the review, only one study has performed a follow up of 4 weeks (29) and another of 6 weeks (26), five studies have performed a follow up of 24 weeks (23, 25, 26, 28, 30) while only one of 48 weeks (24). All studies performed the laser session following scaling and root planning except one study (25) which performed the laser session prior to non-surgical periodontal therapy (Table II).

Table II. *General characteristics of the included studies.*

Investigators & Country	Study design	Sample size, mean age in years (range)	cofonders	Periodontitis diagnostic criteria	Study groups		Follow up (week)	study outcome	funding source
					test (n)	control (n)			
M. Saglam et al; Turkey 2014 [23]	RCT	30, 41.48 (32-57)	Excluded	14 teeth with at least two teeth with ≥5 mm probing depth at each quadrant	SRP+DL (15)	SRP (15)	24	Test group showed a significant improvement in clinical periodontitis parameters as compared to control group at follow-up, but immunological outcomes were comparable for both groups at follow up	Not reported
G. Matarese et al; Italy; 2017 [24]	RCT, Split mouth	30, 34.9	Excluded	Radiographic evidence of interproximal bone loss exceeding ≥50% of the root length, a probing depth (PD) >5 mm at more than eight sites per quadrant, >30 years old or <40 years old with a rapid bone loss as shown by radiographs, a minimum of six teeth per quadrant, respectively, and a concentration of more than 104 colony-forming units/mL of Actinobacillus actinomycetemcomitans.	SRP+DL (30)	SRP (30)	48	Clinical outcomes were significantly better for the test group compared to the control group at follow up, but microbiological and immunological outcomes were comparable for both groups at follow up	Reported
K. Ustun et al; Turkey;2014 [25]	RCT, Split mouth	19, 40.23 (22-55)	Excluded	least two incisor or canines at two quadrant with periodontal pockets depth between 4 and 7 mm	SRP+DL (19)	SRP (19)	24	Clinical and immunological outcomes were significantly better for the test group compared to the control group at follow up	Reported
F. Katsikanis et al; Greece; 2019 [26]	RCT, Split mouth	21, 48.2	Light to moderate smokers	3 o more quadrants each containing at least three sites with periodontal pocket depht (PPD) of ≥ 5 mm	SRP+DL (21, 448 sites)	SRP (21, 389 sites)	24	Clinical and immunological outcomes were comparable for both groups at follow up	Not reported
G. De Micheli et al; Brazil,2009 [27]	RCT, Split mouth	27, 48.5	Excluded	Presence of a pair of single rooted controlateral teeth with a clinical probing depth ≥ 5 mm	SRP+DL (27)	SRP (27)	6	Clinical, immunological and microbiological outcomes were comparable for both groups at follow up	Not reported
G. Aykol et al; Turkey;2011 [28]	RCT	36, 42.89 (31-58)	Smokers	Presence of probing depth with PD ≥ 4 mm to PD ≤ 10 mm	SRP+LD (18)	SRP (18)	24	Clinical and immunological outcomes were comparable for both groups at follow up	Reported
MS Petrovic et al; Serbia,2017 [29]	RCT	60, 40	Excluded	Presence of CAL ≥ 3 mm at ≥ 30% of sites	SRP+DL (30)	SRP (30)	4	Clinical and microbiological outcomes were significantly better for the test group compared to the control group at follow up	Not reported
V. T. Euzebio Alves et al; Brazil;2011 [30]	RCT, Split mouth	36, 46.8 (37-64)	Excluded	Minimun probign depth (PD) of 5 mm	SRP+DL (36)	SRP (36)	24	Clinical, immunological and microbiological outcomes were comparable for both groups at follow up	Not reported

Laser parameters

All the studies used diode lasers. The wavelengths of different lasers used in the included studies ranged between 810 and 980 nm. Six studies have not defined the energy fluence (J cm-2) (25-30), while the power output varies from 250 to 2500 mw. Only three studies reported power density (W cm-2) (26, 27, 30), ranging from 1193.7 to 2831 W cm -2. Four studies reported that the duration of irradiation was 20 seconds per tooth (23, 24, 27, 30), one study specified that the duration of irradiation was 10 seconds for incisors and premolars and 20 seconds for molars (28), two studies exposed teeth to laser for 30 seconds (26, 29) and only one study used the laser for 80 seconds per tooth (25). Two studies didn't mention the diameter of the optical fiber used (28, 29), while in the remaining studies three used an optical fiber with a diameter of 300µ (23, 24, 26), one study used an optical fiber with a diameter of 320µ (25) and one study used a diameter of 400µ (27). The total number of laser applications is only once in five studies (23-25, 28, 29), two in two studies (27, 30) and three in one study (26). Only two studies specified that the laser sessions were all performed by the same clinician for all patients (26, 28) (Table III).

Main outcomes of the studies and microbiological findings

Only four studies, among those considered, also examined microbiological parameters (24, 27, 29, 30). One of these examined patients with a single follow-up after one month, resulting in a decrease in all microbiological parameters: a decrease in the prevalence of bacteria after treatment in the DL+SRP group was observed for *Aggregatibacter actinomycetemcomitans* and *P. intermedia* and *P. gengivalis* (29). In the other studies have shown a lower level of *Aggregatibacter actinomycetemcomitans*, *P. gingivalis, T. forsythia, T. denticola* and a lower number of colony-forming units (CFU) in the test group than in the control group, during the follow-up to 6 weeks (24, 27, 30). In contrast, during the 6-month follow-up, no statistically relevant differences were found in the microbiological indices between the two groups (24, 30).

Clinical findings

The only included study that saw patients with a one-year follow-up found an improvement in clinical attachment level (CAL) (3.44 mm±0.28 in group DL+SRP *vs* 4.23 mm±0.21 in group with SRP only), an improvement in probing depth (PD) (2.56 mm±0.44 *vs* 3.36 mm±0.51 respectively) and a decrease of percentage of bleeding on probing (BoP) (26.16±2.4 *vs* 32.26±3.1) largest in the group that received diode laser therapy after one year, while after six months it did not detect any difference between the two groups except in the BoP (22.79±4.2 *vs* 24.67±3.2) (24). Five studies examined patients at a six-month follow-up (23, 25, 27, 28, 30) and only two (23, 25) of these obtained significant differences

Table III. *Laser parameters of the included studies.*

Investigators	type of laser	Wavelenght (nm)	Energy Fluence (J cm $^{-2}$)	Power output (mW)	Power density (W cm $^{-2}$)	Duration of irradiation (sc/Tooth)	Optic fiber diameter (µm)	Number of laser session
M. Saglam et al; Turkey 2014 [23]	Diode laser	940	15	1500	N.A.	20	300	1
G. Matarese et al; Italy; 2017 [24]	Diode laser	810	28,84	1000	N.A.	20	300	1
K. Ustun et al; Turkey;2014 [25]	Diode laser	810	N.A	2500	N.A.	80	320	1
F. Katsikanis et al; Greece; 2019 [26]	Diode Laser	940	N.A.	2000	2831	30	300	3 (Every laser session was performed by the same clinician)
G. De Micheli et al; Brazil,2009 [27]	Diode laser	808	N.A.	1500	1193,7	20	400	2
G. Aykol et al; Turkey;2011 [28]	Diode laser	808	N.A.	250	N.A.	10 (incisors and premolar) 20(molars)	N.A.	1 (Every laser session was performed by the same clinician)
MS Petrovic et al; Serbia,2017 [29]	Diode laser	980	N.A.	200	N.A.	30	N.A.	1
V. T. Euzebio Alves et al; Brazil;2011 [30]	Diode laser	808	N.A.	1500	1193,7	20	400	2

NA: not available.

in CAL and PD between the two groups in favor of the test group. The other studies that examined the patients after six months (26, 28, 30) did not find any improvement in terms of clinical and immunological parameters for follow-up purposes. However, three months later, in the study carried out by F. Katsikanis et al (26), an increase of CAL (5.22 mm±1.17 *vs* 6.61 mm±2.35) and PD (3.42 mm±0.97 *vs* 4.25 mm±1.57) in the Deep pockets (7 mm≤PD≤9 mm) as noted in favor of the diode laser group. No study found differences between the two groups in the plaque index (PI) values at 6 months. A 1-month follow-up study was also included which resulted in an improvement of all clinical parameters, CAL (3.32 mm±0.63 in group DL+SRP *vs* 3.77 mm±0.73 in group SRP only) PI (0.68±0.31 *vs* 1.01±0. 49) and bleeding index (BI) (0.16±0.29 *vs* 0.58±0.66) in patients treated with diode lasers (29) The only included study that followed patients at a maximum of 6 weeks (27) found no difference between the control group and the test group except for CAL. In one study, smokers were also compared with non-smokers and no difference was noted between the two types of patients in terms of clinical parameters (28) In the other study, which also included light or moderate smokers in the results, it was not specified whether a difference was found between smokers and non-smokers (26).

Inflammatory findings

At the level of inflammatory parameters only one study produced better results in the DL+SRP group than the group with SRP only, IL-1β (0.09±0.14 *vs* 0.18±0.18) gingival crevicular fluid (GCF) (13.56±14.85 *vs* 28.07±31.23), after six months (25). In the study carried out by G. Matatrese et al. (24) there was a significant decrease in levels of IL-1β after 15 and 30 days (11.67±5.36 *vs* 9.36±8.12) in the diode group more SRP than in the SRP-only group.

DISCUSSION

This literature review is based on the assumption that the use of diode laser at 800-980 nm in combination with SRP is more effective than SRP alone in the treatment of periodontitis. The wide methodological heterogeneity of the various studies present in the literature makes difficult to interpret the results obtained, that is why this literature review has tried to focus on a certain type of laser at a certain wavelength. The optimal goal of periodontal therapy is to minimize or avoid invasive procedures while achieving a stable and lasting improvement of periodontal health and increasing the quality of life of the patient, avoiding the use of local or systemic antibiotics in a widespread way, in order to prevent the selection of resistant microbial stocks (31).

It was found that SRP are effective in periodontitis treatment however in some cases, where it is difficult to get the instrumentation, this technique may not completely remove the bacteria present in the periodontal pockets (32). It has been seen how non-surgical periodontal therapy becomes less effective when performed inside pockets with a depth of >5 mm (33). In addition, single-root teeth and rear teeth with intact furcation respond better to SRP than multi-root teeth and molars with invasions of bifurcations (34). Therefore, it seems useful to try alternative therapies that can face the limits of periodontal therapy, such as the use of 0.20% Chlorhexidine (CHX) which would seem to help to have good control over clinical indices and in particular the bleeding index (35).

Laser treatment has been proposed in addition to non-surgical periodontal therapy because the laser has shown beneficial effects against pathogenic periodontal bacteria, but the actual effectiveness of the laser in addition to SRP is still unresolved (36). Diode lasers are among the most efficient converters of electric energy into coherent radiation. Diode lasers employ semiconductor crystals as active media, which, after excitation, will emit coherent radiation in the VIS or IR region (typical medical diode lasers range between 630 and 980 nm), which can be easily transmitted via optical wave guides to the patient (37). The advantage of laser in the treatment of inflammatory diseases, such as periodontitis, is its ability to stimulate various biological mechanisms (38). It can be said, based on some studies, that regenerative repair can be greater thanks to laser-assisted stimulation; however, an exact frequency has not yet been established

(39). The advantage of laser in the treatment of inflammatory diseases, such as periodontitis, is its ability to stimulate various biological mechanisms (40). In July 2015, the Journal of the American Dental Association (JADA) published a systematic review with meta-analysis and evidence-based practice guidelines on the treatment of periodontitis by SRP with and without adjunctive therapies. In this systematic review it was seen that the diode laser in addition to the non-surgical periodontal therapy did not bring any more benefits than the SRP alone (41). The results obtained in the meta-analysis of C. Ren (42) may suggest that the addition of the laser to scaling and root planning is more effective in the short term than in the long term. All studies included in this review have shown an improvement in clinical parameters in patients treated with diode laser. In no study patients reported adverse effects such as discomfort, dentin hypersensitivity, burning sensation or pain associated with laser irradiation. Four studies included in this review have achieved better results in the test group than in the control group (23, 24, 25, 29).

An interesting finding in most studies is that there was an improvement in clinical parameters during follow-up before three months in favor of the Diode Laser Group. Therefore, it was noted, analyzing the results of the various studies in terms of clinical parameters, that the laser could bring benefits to the non-surgical periodontal therapy especially in the short term rather than in the long term. In the systematic review performed by S. Mokeen in 2018 (43) from the results obtained, it was observed that the laser could be a valid addition to scaling and root planning. In the meta-analysis performed by L. Jia et al. (44) it was found that diode laser could be the best additional therapy for periodontitis treatment. This result was achieved by looking at the gain of CAL in studies with a follow-up of 3 to 6 months. In contrast to the review by C. M. Cobb (45), which says that current evidence on the use of diode lasers, both as monotherapy and as additional scaling therapy and root planing, shows that it provides minimal benefits. The rational use of laser in the treatment of periodontitis is given by its anti-infective, physical and ablative properties (46). A key role in the etiology and progression of periodontitis is played by the subgingival microbical biofilm (47). Given the important role played by bacterial biofilm, periodontal therapy should aim at preventing immune response and thus reducing these active microbial factors (48). However, the ability of the laser to act against bacteria within periodontal pockets varies greatly depending on the wavelength and power used (49). The in vitro study performed by X. Song et al did not observe any relevant anti-bacterial effect following a diode laser session at 800-980 nm, always taking into account the limitations of this study (50). In the studies included in this literature review no improvement of microbiological parameters was observed after six months of follow-up (24-30) In the short term it was noticed an improvement of all microbiological parameters especially was observed a reduction of the bacteria of the red complex of Socranski during the first weeks of follow-up. This data would seem to indicate, as mentioned above, that the benefits of laser are more in the short term than in the long term. At the level of inflammatory parameters, it is known as IL-1β plays a role in multiple biological activities and regulates several genes expressed during inflammation (51). One of the randomized clinical trials in the literature performed by D. Sezen et al noted a decrease in levels of IL-1β greater in the laser-treated group than in the control group. However, the previous study used a different type of laser than diode laser (52). Speaking instead of the immunological and inflammatory parameters in the review performed by S. V. Kellesarian the results of the various studies considered were too inconsistent with each other with regard to the levels of pro-inflammatory cytokines (53). Analyzing the data obtained from this review of the literature only one study has noticed lower levels of IL-1β and GCF at six months (25) and another study (24) has instead always noticed a decrease in levels of IL-β 30 days later, however, in the latter study it was also seen that, on the contrary, the levels of IL-10 were higher in the diode laser group than in the control group. All other included studies that examined immunological and inflammatory parameters have not found differences between the test group and the

control group (26, 27). It is not yet clear how the laser can act in the modulation of these parameters; we have already discussed an immunomodulatory effect of the laser, but we do not have sufficient data to say that there is definitely a decrease in the level of inflammation in laser-treated patients, so further studies are needed.

As noted by S.G. Grossi (54) smokers have a worse recovery, both in terms of clinical parameters and microbiological parameters, following non-surgical periodontal therapy. In the only study (28) included in the review that also compared smokers' patients to no smokers' patients, no differences in clinical parameters were found in both groups. However, care should be taken to consider the data from this literature review since there are limits. First of all, there are differences regarding the power output and the different optical fiber used in the various studies. In addition, some studies have not reported the energy fluence (25-30) or power density used (22, 24, 25, 28, 29). It is known that fiber diameter influences the overall power density and energy output during laser therapy and can modify the actual amount of energy released during the process, potentially affecting the antimicrobial efficacy of laser therapy (55). Finally, the diode laser therapy can be a good alternative for the current period, to minimize the production of aerosol and droplets especially in patients with chronic viral and autoimmune diseases (HIV, HCV, Sjogren's etc.) (56-60). Although attempts have been made to take studies that used only a certain laser wavelength to minimize the heterogeneity of the various studies, there are many other factors that affect the results. It should be remembered that some studies have also performed more than one session of diode laser therapy (26, 28, 30).

Although this review of the literature included studies that performed a different number of laser sessions, analyzing various results of studies that performed multiple sessions with those that performed only one, it would seem that the number of sessions carried out do not have a particular effect on the outcome of the therapy. Due to the heterogeneity of the various data taken from the analyzed studies and the different laser parameters used it was not possible to perform a meta-analysis and therefore a statistical analysis of the data; For the presence of these variables, it was possible to perform only a review of the literature. It should also be considered that only the PubMed search engine has been used to carry out this review of the literature, and this also implies a limit to be taken into account during the discussion of the results.

Considering the limitations of this review of literature, it would seem that the diode laser at 800-980 nm + SRP is effective in periodontitis treatment only in the short term or in any case bring minimal benefits. However, it should also be remembered that in the literature there are not many studies that show the results after a year or more, most of them follow patients only to a maximum of six months. So, in the future, you'd need more Random clinical trials with more follow-up to see the real long-term effectiveness of the laser.

Talking about diode lasers, there are many variations to consider in order to assess its actual effectiveness, so within the limits of our study no evidence was found that the addition of diode laser at 800-980 nm in non-surgical periodontal therapy may be more effective than long-term SRP alone. The main benefits of using diode lasers were found in the short term, from 4 weeks to 12 weeks, rather than six months of follow-up. This may suggest that diode laser is more effective in the short term rather than in the long term. In the future, more follow-up studies will be needed for patients over six months to assess their actual effectiveness. The results of this literature review should be considered preliminary and further, more robust, well-designed studies with long-term follow up and standardized comparators with laser parameters are warranted.

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approval; G. Rellandini contributed to acquisition, analysis, or interpretation, drafted the manuscript and gave final approval; E. Polizzi contributed to conception and design, critically revised the manuscript and gave final approval.

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Role of mast cells in oral inflammation

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Mast cells play important roles in the maintenance of many physiological functions as well as in the pathophysiology of diseases. Mast cells are involved in the inflammatory mechanisms of many systemic diseases. In this pandemic period, their role in physiological and pathological host inflammatory reactions in tissue disruption following SARS-CoV-2 infection has been stressed. A review of the literature was carried out by entering the key words "Mast Cells" AND "Oral Diseases" and "ROLE OF MAST CELLS IN PERIODONTITIS". The results show us that mast cells are definitely involved in many oral diseases including periodontitis. Further in vivo and in vitro studies are needed to further investigate the specific role of the cells in physiological and pathological inflammation.

Mast cells (MCs) are important cells of the immune system, of hematopoietic lineage and present in connective tissues throughout the body. Mast cells play important roles in the maintenance of many physiological functions as well as in the pathophysiology of diseases (1). Mast cells are involved in the inflammatory mechanisms of many systemic diseases. In this pandemic period, their role in physiological and pathological host inflammatory reactions in tissue disruption following SARS-CoV-2 infection has been stressed (2, 3); mast cells intervene, as effector cells, in allergic and anaphylactic reactions, asthma, autoimmune diseases and cancer. In dermatitis, activated MCs release inflammatory chemical mediators and secrete pro-inflammatory cytokines, including interleukin (IL)-1, TNF, and IL-33 (2, 4). In fact, their role in viral infections had already been highlighted in the literature, for example in advanced stage of chronic hepatitis C (5, 6).

In the oral tissues, MCs release different pro-inflammatory cytokines and tumor necrosis factor-alpha that promote leukocyte infiltration in various inflammatory states of the oral cavity. These cells play a key role in the inflammatory process and, consequently, their number changes in different pathologic conditions of the oral cavity, such as gingivitis and periodontitis, periapical diseases and pulp inflammation (7). These cells may become therapeutic targets by understanding their role in the host inflammatory response, improving prognosis. In this review we emphasize the important role of mast cells in oral cavity diseases and in periodontitis (Fig. 1).

Mast cells and oral cavity

A MEDLINE (NCBI PubMed and PMC) database was employed in order to obtain information sources. An electronic search was performed to select articles regarding role of Mast Cells (MCs) in oral diseases'

Key words: mast cells, inflammation, oral diseases, periodontitis, SARS-CoV-2

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development. The following terms were applied: "Mast Cells" AND "Oral Diseases".
In absence of selection criteria, 406 results were obtained. Only papers published in last 10 years were considered, for a total of 212 studies. Several exclusion criteria such as no full text available and no relevance to the research topic were applied. Papers related to other medical branches than dentistry (immunology, allergology, dermatology, pneumology, neurology, cardiology) or to maxilla-facial district but not specifically to the oral cavity (for example: salivary gland or tonsils' pathologies) or to periodontal diseases were excluded, for a total of 46 results.

Papers not specifically focused on role of MCs in pathogenesis of oral bone or soft tissues diseases, studies in which mast cells were mentioned among the possible causes but were not the subject of the analysis, papers specifically referred to selected patients' category as affected by mastocytosis or organ-transplanted children, immunohistochemical analysis of oral disease in which MCs were not recorded and studies in which full text was not available were excluded as not pertinent, for a total of 17 results considered.

MCs could have a significant role on several oral bone and soft tissues diseases 'pathogenesis and development such as odontogenic osteolytic lesions, premalignant lesions as oral lichen planus, oral submucous fibrosis, other chronic inflammations as oral lichenoid mucositis, oral squamous carcinoma, inflammatory periapical and gingival conditions, oral reactive hyperplastic lesions such as pyogenic granuloma, peripheral giant cell granuloma, peripheral ossifying fibroma and irritation fibroma, inflammatory and reactive lesions of pulp, periapical area and periodontium, odontogenic cysts could be considered as most common osteolytic neoformations of jaws; MCs perform their function through angiogenesis, immune modulation and tissue remodeling (8).

As cyst expansions could be related with intra-luminal hydrostatic pressure increase and a subsequent bone resorption, MCs could play a

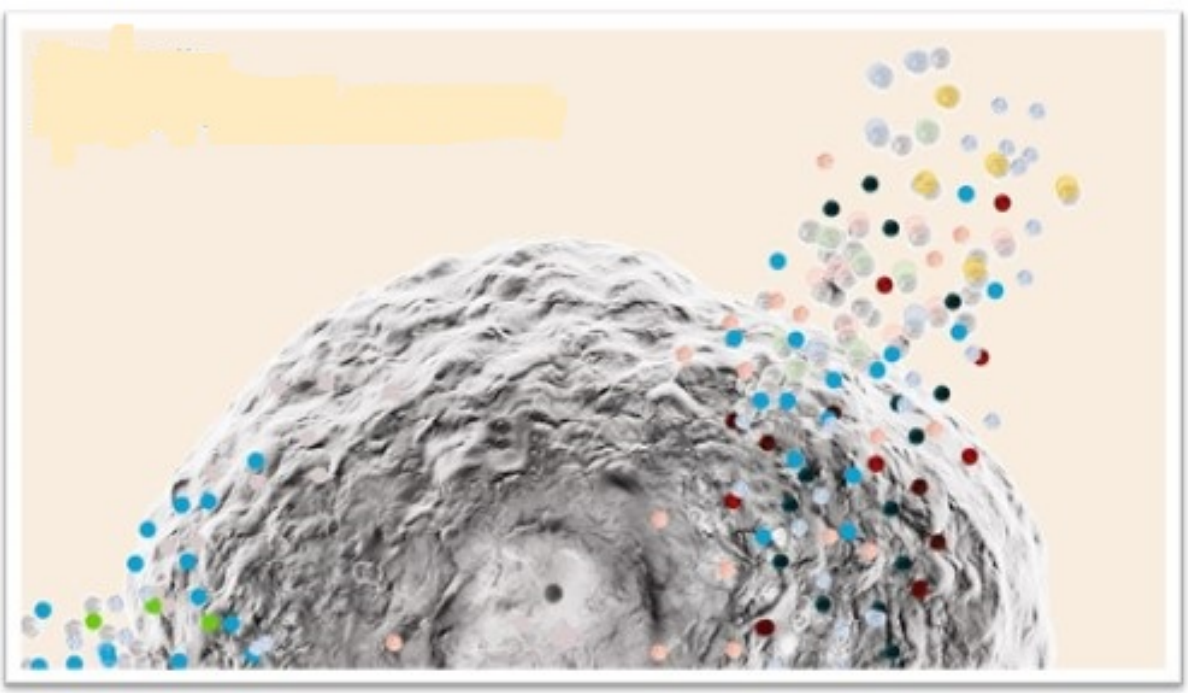

Fig. 1. *Mast cells and their release of granules.*

significant role in these events: the heparin release could influence intra-luminal osmotic pressure, hydrolytic enzymes could degrade extracellular matrix components of cyst capsule, histamines could increase vascular permeability and prostaglandin could promote bone resorption (9). These statements could be confirmed by a significant density of MCs in fibrous walls of radicular and dentigerous odontogenic cysts and keratocysts (10).

Despite the studies analyzing the contribution of MCs in odontogenic lesions, its biological behavior in ameloblastomas (AMBs) and odontogenic keratocysts (OKCs) remains unclear; therefore, a total of 40 odontogenic lesions were analyzed and MCs were observed in 60% of OKCs, and 35% of AMBs (11). A possible implication of MCs could be recorded also in oral lichen planus and oral lichenoid mucositis. The number of mast cells increases as demonstrated by the histology of oral mucosal lesions (12-13). MCs increase in oral lichen planus could be associated with histamine4 receptor decrease. As H4r could be related with healthy human oral mucosa, the reduction of these receptors, according with MCs degranulation and histamines release, could be related with epithelial barrier impairment (14-15). A significant density of MCs could be recorded also in oral submucous fibrosis area. If compared with normal buccal mucosa, mast cells density could gain according with progression of mucosa alteration (16). Development of oral submucous fibrosis and malignant transformation of the overlying epithelium, could be associated with MCs' tryptase and chymase release. (17)

An increased density of MCs was recorded as well as in oral lichen planus and oral submucous fibrosis also in oral leucoplakia and oral squamous carcinoma. As all these diseases, even in different stages, could be associated with a chronical inflammation condition, MCs could play an active role in their evolution (18-19). In case of oral squamous carcinoma, extracellular matrix degradation mediated by tryptase and chynase release could indirectly promote angiogenesis, favoring primary tumor development, tissue invasion and metastases (20). Mast cells have an angiogenic capacity that promotes tumor formation when the lesion is premalignant, therefore their increased presence is a negative prognostic factor (21).

A significant gain in MCs density could be recorded also in periapical and gingival inflammatory lesions such as periapical granuloma, periapical cyst, in inflammatory gingival hyperplasia and pyogenic granuloma, suggesting their possible role in initiation, development, and progression of these inflammatory conditions (22-23). The same results were obtained in histological evaluation of oral reactive hyperplastic lesions as pyogenic granuloma, peripheral giant cell granuloma, peripheral ossifying fibroma and irritation fibroma. As MCs degranulation could promote fibroblast growth factors and angiogenetic factors release, they could play a significant role in all this fibrosis (24-25). According with increased intensity of inflammation MCs density could be greater in irritation fibroma and pyogenic granuloma than in other oral reactive hyperplastic lesions (26).

Mast cells and periodontitis

A MEDLINE (NCBI PubMed and PMC) database was employed in order to obtain information sources. An electronic search was performed to select articles regarding role of Mast Cells (MCs) in oral diseases' development. The following terms were applied: "ROLE OF MAST CELLS IN PERIODONTITIS". In absence of selection criteria, 60 results were obtained. Several exclusion criteria such as no full text available and no relevance to the research topic were applied. Papers related to other medical branches than dentistry (immunology, allergology, dermatology, pneumology, neurology, cardiology) were excluded, for a total of 32 results.

Nowadays, several studies have focused on the role of the immune system in the development of periodontal disease, indicating that bacterial antigens trigger an immunopathologic reaction, so periodontal disease is not caused only by bacterial agents (27).

Periodontitis is not unidirectional, but rather it is interactive; the same cells that produce the destructive pro-inflammatory cytokines can also produce mediators that activate the healing process (28). Mast cells would be involved in the transition

from gingivitis to periodontitis precisely because of the presentation of antigen to T cells and the resulting release of inflammatory cytokines and chemokines that attract cells and factors that mediate the destruction of periodontal tissue (29). An in vivo study aimed to examine the expression and analyze the quantification of TIM-1 on tryptase-positive MCs in different stages of human chronic periodontitis using double immunofluorescence staining. An increase in tryptase-TIM-1 double-positive MCs directly proportional to increasing periodontitis severity was observed (30).

As suggested by several Authors, MCs can lead to increased vascular permeability, angiogenic response, collagen synthesis, regulation of inflammation, bone resorption and destruction of extracellular matrix. Thus, participating in the pathogenesis of chronic inflammatory diseases, such as periodontitis. moreover, in the same review it is emphasized that they are present in older people in greater numbers and in anterior lesions of the oral cavity (31). In an in vivo study comparing 40 patients with healthy periodontium and 40 with chronic periodontitis, it was found that a higher number of mast cells correlated with a higher PPD (pocket depth) value (32). Another important data is the number of mast cells in the oral cavity is even higher in patients with HIV. Periodically, however, the balance in oral cavity may be disturbed, either by the increased strength of the attack or the decreased defense of the host, and progressive loss of gingival and periodontal tissue may occur (active periodontitis or necrotizing periodontitis) (33). In fact, findings suggest that low-level inflammation induced by HDP/MRGPRX2-mediated mast cell degranulation contributes to gingival homeostasis but that sustained inflammation due to elevated levels of both HDPs and MRGPRX2-expressing mast cells promotes periodontal disease. Furthermore, differential regulation of HDP-induced mast cell degranulation by PgLPS1690 and PgLPS1435/1449 may contribute to the modulation of disease progression (34). However, in an in vivo animal study following the development of periodontitis, the number of mast cells decreases and the number of MMP9 increases (35). Thesis confirmed by another in vivo study where the number of mast cells was not correlated with an increase in the density of new vessels (36). However, it is clear that mast cells play a key role in the progression of periodontitis, it is not yet clear how and it would be interesting to know to identify possible targets for therapies.

A dentist or dental hygienist, waiting for the scientific evidence to become clearer, must provide for the patient's oral health with different domiciliary and professional care strategies. For example, professional care strategy is a laser therapy. In fact, the evidence says diode laser therapy is a valid support of traditional treatment of initial gingivitis (37). Another comparative study assessed the effect of PhotoBioModulation (PBM) versus conventional therapy, and investigated biomarkers involved in the healing process; The test group comprised twenty systemically healthy non-smoking subjects with chronic periodontitis with the presence of two matched contro-lateral premolar sites (probing depth > 5 mm); twenty subjects without chronic periodontitis (CP) served as control group. Patients were treated at baseline, either with scaling and root planing (SRP group) or with a procedure entailing SRP supported by PBM (PBM group); The results confirmed that PBM have beneficial effects in the early phases of the healing process playing a role in modulation of BK, EGF, and VEGF in gingival crevicular fluid levels (38-39). Obviously, the patient will have to respect the professional treatment and have a correct home hygiene with use of floss and rinses with mouthwash (40).

This review lays the foundation for further studies maybe in vivo and in vitro that could identify the biological role of mast cells and identify possible therapeutic targets.

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Minimally invasive digital implant-prosthetic procedure in "all on 4" rehabilitation in patients with special needs: a three-year follow-up.

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The present study describes an innovative procedure for resolving implant-prosthetic cases in patients with edentulous special needs. In 2017 a 56-year-old female patient came to the Department of Dentistry of Vita-Salute San Raffaele Hospital, Milan, Italy, requiring implant-prosthetic rehabilitation of the dental arches given the difficulty in wearing removable prostheses. The first level radiological examinations were evaluated, two technical photographs were taken with specific reference, the 2D Digital Smile Design (Smile Design) was then carried out, the provisional prosthesis was performed and the CBCT requested with repere and provisional prostheses to realize the computerized implant project and an atraumatic flapless guided surgery. Professional oral hygiene sessions were performed quarterly, and the 3-year follow-up revealed no complications affecting the prosthetic or implant component. We can therefore conclude that the proposed method, exploiting digital technologies and flows and minimally invasive flapless surgical methods, can be considered elective in the treatment of patients with special needs.

The present study describes an innovative procedure for resolving implant-prosthetic cases in patients with edentulous special needs. The aim of the research is to create fixed prosthesis to support the implants. These can be used as "immediate loading" after minimally invasive surgical procedures. In recent years, these goals have been at the center of implant and prosthetic studies due to the need to offer patients an alternative to often unstable and retentive tissue-supported dentures (1, 2). Subjects who lack bone support for the dental arches caused by a high degree of maxillary atrophy are more likely to have difficulty using removable dentures. This is due to a reduced stability and retention of the prosthesis (3, 4, 5). The possibility of creating a unified implant and prosthetic project meets the increasing need felt by dental practitioners to reduce the time and costs of therapies until a few years ago onerous and prolonged (6). In addition to the restoration of aesthetics and function, the patient after an implant rehabilitation also improves the general state of health which is related to an increase in the quality of life (7).

It is evident that the state of health of patients directly and indirectly impacts implant rehabilitation as osteointegration is favored precisely by the first phases of physiological inflammation and healing (8); however, due to a constantly improving health care with increased life expectancy and new indications for immunosuppressive treatments, oral and maxillofacial surgeons are facing an increasing number of patients who are immunocompromised or have immunosuppression in their medical record (9). Not only that, but everyday surgeons also have to deal with a particular category of patients with "special needs" that represent an increasing category of people who require implant rehabilitation (10, 11).

The option of implant therapy needs to be considered in the growing population of patients undergoing immunosuppressive therapy that prevents or attenuates common chronic diseases, treats HIV, HCV, and cancer,

Key words: "All on 4", prosthetic rehabilitation, tilted implant, implant prosthetic rehabilitation

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or after transplantation (12). Given the wide range of indications for glucocorticoid therapy such as asthma, rheumatism, and connective tissue disorders, it is almost certain to meet a patient on corticosteroid therapy who needs implant-based rehabilitation (13-15).

In recent years, the development of new surface treatments for titanium and innovative morphologies of fixtures have made it possible to develop new implant techniques to support "Toronto" or "Full-arch" prostheses. Using a limited number of pillars and specific implant-prosthetic connections, we can successfully achieve fixed rehabilitations, that cannot be removed from the patient (16).

Today, the therapeutic efficacy of rehabilitation treatment plans based on the use of fixed dental prostheses supported by a reduced number of implants with a high aesthetic and functional performance is universally recognized. The literature has already highlighted these treatments with a considerable number of retrospective publications (17-19). The workflow proposed in the present study deals analytically and in detail with each clinical and project phase, starting from the clinical examination performed during the surgical examination which must include an inspection to evaluate the presence of the mucosa, its extension, and the height of the remaining ridges. These surveys, although accurate and carried out by experienced operators, do not provide a detailed analysis of bone structure and anatomy of the site. After the clinical examination, the issue of instrumental indispensable investigations is addressed to deepen the study of the patient's surgical and topographic anatomy. An important role in this diagnostic phase is Second Level Dental Radiology (20). These surveys, such as CBCT, allow to be combined with other digital imaging files, thus allowing an overview of the pre-surgical situation, and favoring the design of prosthetic rehabilitation (21-23).

An extensive discussion on how to select and collect data in a three- dimensional virtual environment allows us to know in detail all the operational sequences to treat a clinical case through the so-called Computer Aided Rehabilitation (24-29).

MATERIALS AND METHODS

In 2017, a 56-year-old female patient came to the Department of Dentistry of Vita-Salute San Raffaele Hospital, Milan, Italy, requiring implant-prosthetic

Fig. 1. *Initial clinical case: frontal view.*

Fig. 2. *Initial clinical case: lateral view.*

rehabilitation of the dental arches given the difficulty in wearing removable prostheses. The patient was suffering from Sjogren's Syndrome, resulting in a reduction in the activity of the salivary glands and keratoconjunctivitis sicca as severe symptoms of the disease, rheumatoid arthritis and psoriasis, thus falling into the category of patients suffering from chronic autoimmune diseases and therefore definable as special needs. The patient was on corticosteroid therapy.

On clinical examination, he presented complete edentulousness of the dental arches, associated with severe atrophy of the bone bases and relative reduction in the volume of soft gingival and mucous tissues. The patient was wearing removable prostheses in the upper and lower arch. She presented a reduction in the vertical dimension, an incongruity of the profile due to insufficient mucous support offered by the incongruous prostheses, a convexity of the profile, a volumetric reduction of the lower third of the face and relative imperfections associated with the problems (Fig. 1-4). The total prostheses had respect for the parallelism with the bipupillary line (horizon line) and sufficient coherence with the midline of the face even in the presence of slight asymmetries of the face. horizon) and sufficient coherence with the midline of the face even in the presence of slight asymmetries of the face. After the clinical-objective examination, the first level radiological examinations (initial orthopantomography) were evaluated.

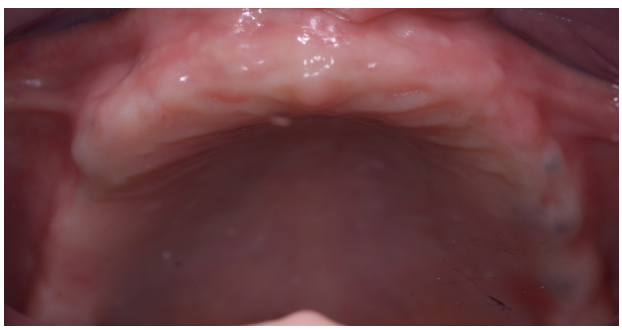

Fig. 3. *Upper edentulous saddle.*

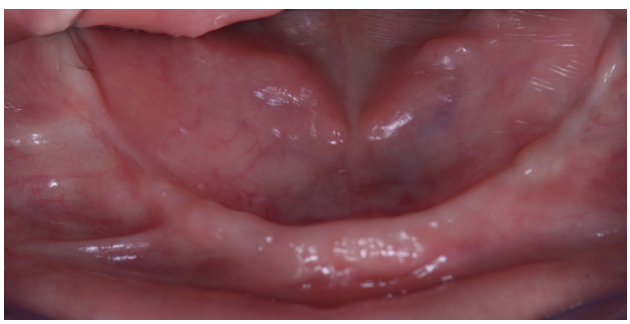

Fig. 4. *Lower edentulous saddle.*

Fig. 5. *Technical photo with landmark for digital project.*

Two technical photographs were taken with specific reference to the patient, useful for the improvement of the diagnostic process, used as a two-dimensional digital diagnosis tool. The first photograph was taken by portraying the patient's smiling face and the second by portraying the patient's face while wearing a mouth opener. The photographs were taken from the same distance and from the same position, to be superimposed. During the two shots a special calibrator was used, containing two squares inside, thanks to which it was possible to identify landmarks of a known size, to obtain accurate measurements (Fig. 5). The 2D Digital Smile Design (Smile Design) was then carried out using specific software [Digital 2D Drawing software (Smile Lynx, 3D-Lynx, 8853 Spa, Pero-MI)].

This computerized design method allows to broaden the diagnostic view and help the dental team to evaluate the limitations and risk factors of a case, including asymmetries, disharmonies, and alterations of aesthetic principles, also allowing the realization of a more accurate treatment.

The "before" and "after" images of the digital project are useful for better communication with the patient. The patient presented with systemic pathologies that made us prefer a minimally invasive and atraumatic implant-prosthetic rehabilitation treatment, which exploited the "All on 4" implant protocol in guided surgery. Once the virtual project was created, a physical model and the surgical guide with mucous support were produced with digital CAM technology, which will guide the implant positioning. To obtain a prosthetically guided surgery we followed the following protocol:

Realization of provisional prostheses

A provisional prosthesis was performed using a traditional method, taking an alginate impression, creating the wax valleys on a rigid base, tested, and adapted from an aesthetic-functional point of view to the patient's facial planes, performing a teeth test and finalizing the prostheses which are called diagnostic.

Indirect rebasing

The indirect relining of the patient's diagnostic prostheses was performed by means of a polysulfide impression, after the adaptation of the same for 30 days, we then obtained a plaster model of both the upper and lower edentulous arch, and we requested the dental laboratory for the rigid relining of temporary diagnostic prostheses (Fig. 6).

Radiological REPERE

We also created a rigid radio-transparent relined plate in transparent silicone between the 2 relined mobile prostheses and therefore extremely stable, with radiopaque extraoral radiological marker (Evobite equipped with 3D Marker).

Fig. 6. *Diagnostic prosthesis.*

Scans

The laboratory was asked to provide:
- the scan of the prosthesis on the plaster model with radiopaque extraoral radiological landmark positioned on it
- the scan of the prosthesis on the plaster model
- the scan of the edentulous plaster model.

CBCT with REPERE

We requested the CBCT of the patient with the relined total prostheses and of the specific reference placed between the arches (Evobite equipped with 3D Marker). The STL files of the optical scans and the DICOM files of the CBCT were imported into an implant design software (Real Guide 5.0-3Diemme, Cantù-Italy). The overlay of the STL files of the optical scan of the model equipped with Repere (3Dmarker) is based on the software's recognition of the volumetric element present both in the volume of the CBCT and in the optical scan.

The result obtained is a complete anatomical virtual working model: the teeth and mucous membranes of the CT image are replaced with much more defined surfaces from the optical scan of the model (Fig. 7, 8). This virtual model facilitates implant planning, because it displays a faithful and realistic virtual model of the bone volumes, mucous thickness and morphology of the diagnostic prosthesis or residual dental elements. The Computerized implant project was then carried out, exploiting the DICOM data of the required CBCT and, therefore, to obtain the correct positioning of the fixtures in the patient's residual basal bone.

The result obtained is a complete anatomical virtual working model: the teeth and mucous membranes of the radiological image are replaced with much more defined surfaces coming from the optical scan of the model.

This virtual project facilitates implant planning, as it displays a faithful and realistic virtual model of the bone volumes, mucous thickness and morphology of the diagnostic prosthesis or residual dental elements. At this point, the number and position of the implants were programmed, and the implant positioning was also guided by the position of the prosthetic elements. The emerging portion of the fixtures was then modified in relation to the relationship of the inserted abutments with the soft tissues and with the prosthetic component. The project was sent to the production center where an anatomical model in resin with CAD / CAM technologies and the relative surgical guide are made (Fig. 9-13).

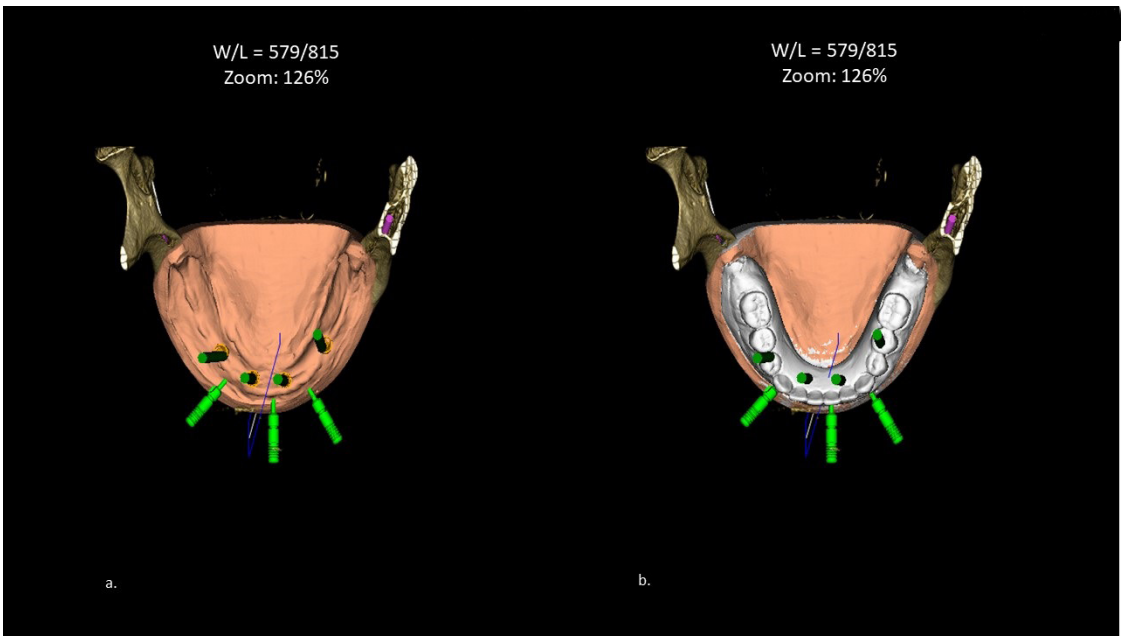

Fig. 7. **a**: *3D maxillary view with overlay of the STL file of the edentulous model, for visualization of the mucosa and prosthetic emergencies;* ***b****: 3D view of the maxilla with superimposition of the STL files of the edentulous model and the diagnostic prosthesis.*

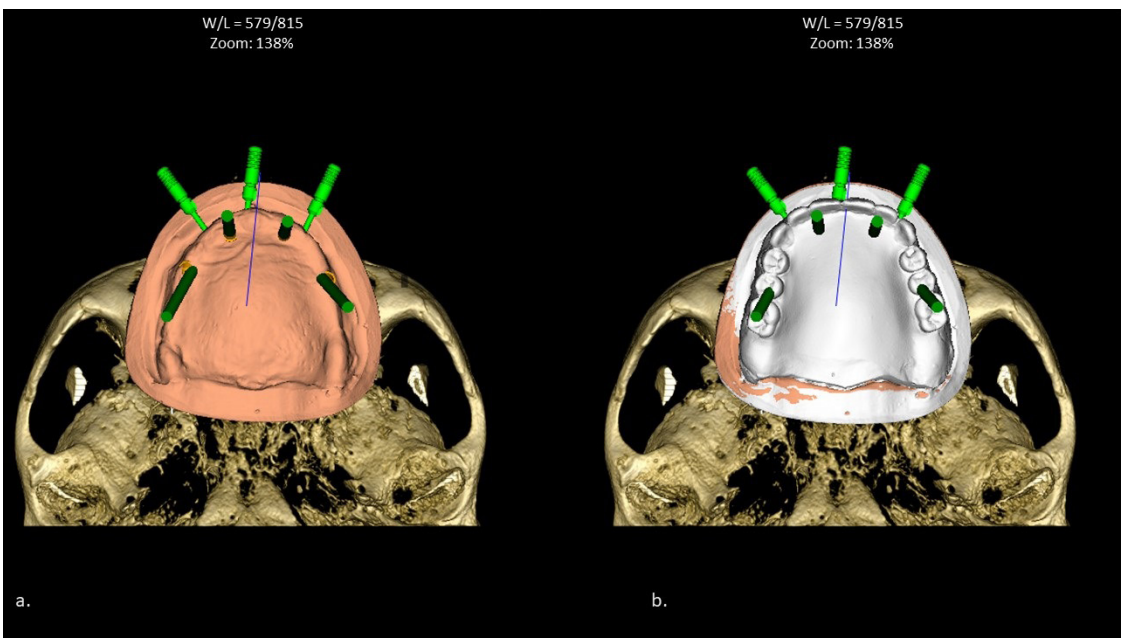

Fig. 8. **a**: *3D view of the mandible with superimposition of the STL file of the edentulous model, for visualization of the mucosa and prosthetic emergencies;* ***b****: view of the 3D mandible with superimposition of the STL files of the edentulous model and of the diagnostic prosthesis.*

Surgical procedure

Given the global pandemic situation, it is even more important for us as dentists to monitor the oral health of our patients, specifically the level of inflammation, before proceeding with any rehabilitation treatment (8, 13). After patient preparation, povidone and chlorhexidine rinsing was performed and local anesthesia was administered (30, 31). The implant surgery involves infiltration with anesthetic in the vestibular areas at the fornix level, then the surgical guide is positioned using a bone anchoring pin. The palatine fibro-mucosa is then infiltrated with local anesthesia through the appropriate holes on the same template. The support of the template repeats exactly that of the diagnostic prosthesis, in such a way as to avoid tilting which would cause a bad positioning of the implant fixtures and a consequent discrepancy with the computer-assisted project (Fig 14).

Having ascertained the correct positioning of the template, osteotomic drills are used which must be inserted up to the stop in the guide cylinders on the vestibular side, thus allowing the possibility of positioning the pins with digital pressure. The presence of the pins guarantees the stability of the template throughout the surgery. The steps after positioning the template are standardized and must follow a pre-ordered sequence with dedicated drills for each implant size and diameter. After the mucotomy through the surgical guide, we proceed with the sequence of drills calibrated for diameter and length until the creation of the correct neo-alveolus that will house the fixture, considering the horizontal under-preparation to ensure adequate primary stability, thus guaranteeing the immediate loading (Fig. 15). The implants using a specific mounter are inserted into the neo alveoli using a contra-angle and brought to the end of the stroke using a torque wrench, making sure that the hexagon of the mounter coincides with the hexagon of the guide cylinder. This expedient allows to facilitate the positioning of the prosthetic connection in a way that coincides with the initial prosthetic project (Fig 16, 17). The mounters and the fixation pins are then removed, the surgical guide can be extracted, and the prosthetic components (Extreme abutment) can be assembled as per the digital project. After surgery, a low-level laser therapy protocol was performed with a 645 nm diode laser to reduce inflammation of the tissues and to improve the healing phase of the tissues

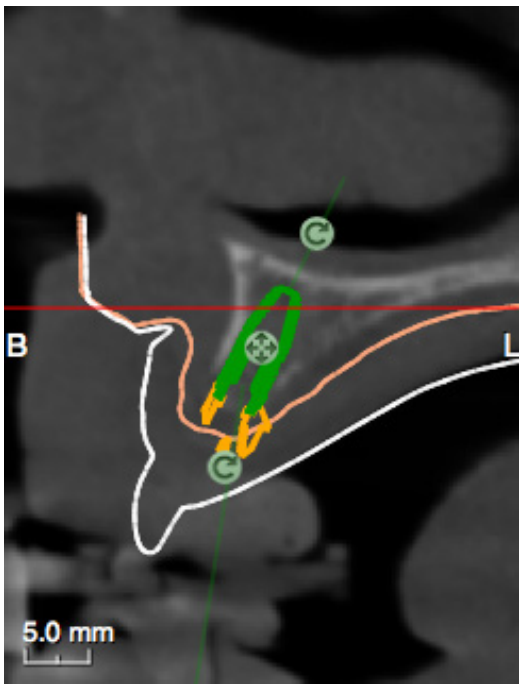

Fig. 10. *Cross-section showing the relationship between the bone volume, the virtual positioning of the implant and the prosthetic component.*

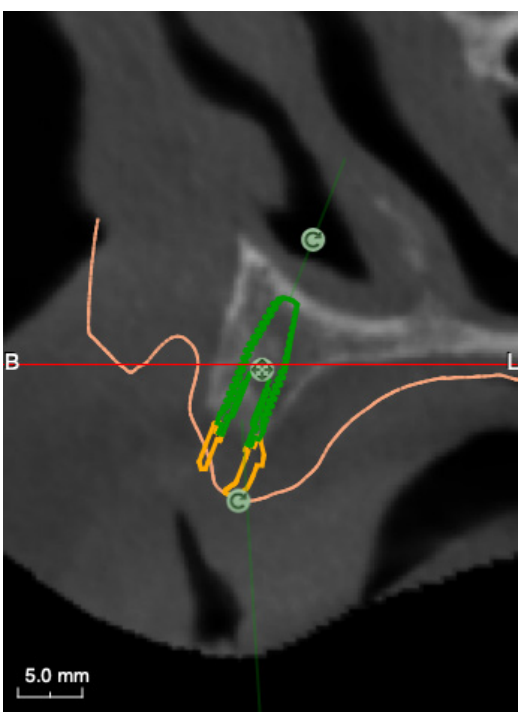

Fig. 9. *Cross-section showing the relationship between bone volume and virtual positioning of the implant and soft tissues.*

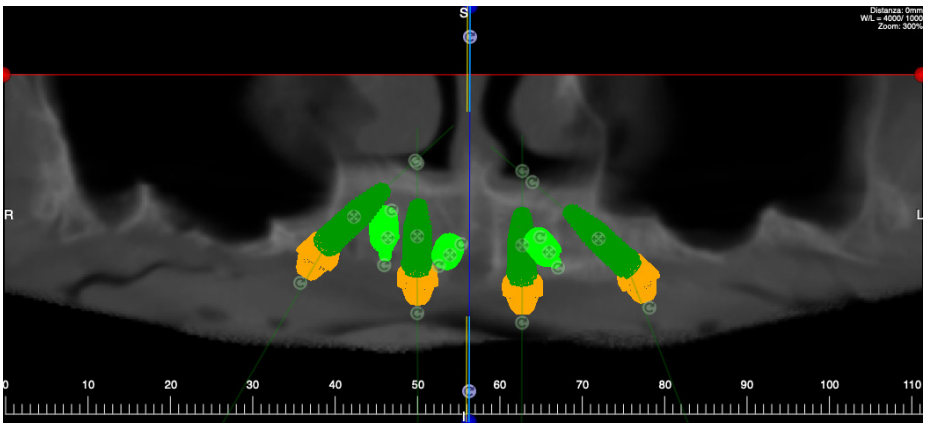

Fig. 11. *Jaw-like panoramic with virtual positioning of the implants.*

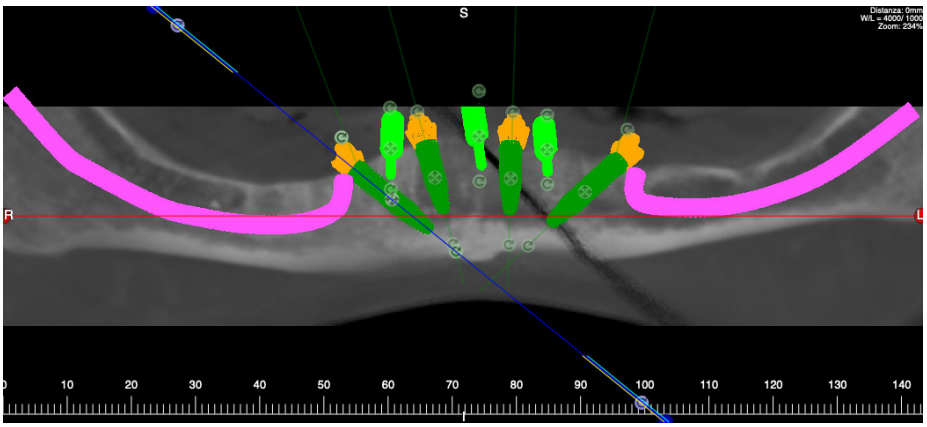

Fig. 12. *Mandibular panoramic-like with virtual positioning of the implants.*

Fig. 13. *Stereo-lithographic model and surgical guide.*

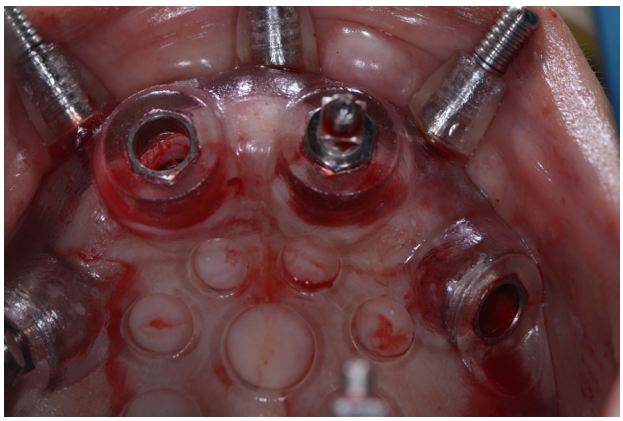

Fig. 14. *Surgical guide positioned in the oral cavity and stabilized by means of fixation pins.*

Fig. 15. *Ratio between the drill guide cylinder and the guide cannula*.

(diode laser, 645 nm, 0, 6 Watt) (EGG Laser, DMT, Lissone, Italy) (32-34). The fixtures are then immediately loaded using the temporary prosthesis made in compliance with the aesthetic-functional criteria described and the specific loading cannulas that are positioned on the EAs.

The following method involves the immediate loading of the temporary prosthesis; however, it is necessary to have applied an implant insertion torque of at least 35 Ncm for each implant (35).

We then proceed initially with the positioning of the abutments on the implants and any angulation correctors to obtain the parallelism of the abutments themselves. The temporary prosthesis is positioned by checking that the holes opened during the drilling phase for the passage of the implant components are correct and, if necessary, any slight changes are made. Once it is determined that the temporary prosthesis is correct, it is repositioned, locked onto the implant components, and directly relined in the patient's mouth using self-curing resin, and then finished in the laboratory (Fig. 18). The immediate provisional prosthesis was delivered 1.5 hours after surgery and occlusal contacts were maintained in maximum intercuspation between the anterior teeth as described in the original protocol (36-38). After the post-surgical visit, occlusal balancing was performed, and a control recording was made after 3 months to verify functional fit (36, 39) (Fig. 19).

The provisional prosthetic artifact is monitored periodically, until it is replaced with the definitive artifact 6 months after surgery (40, 41). The prosthetic artifact was made using a mixed method: the metal alloy bar was milled from a digital project, to have an increase in the rigidity and resistance to fracture of the artifact itself, while the aesthetic part of the definitive prosthesis was made using the use of acrylic resins, a biocompatible

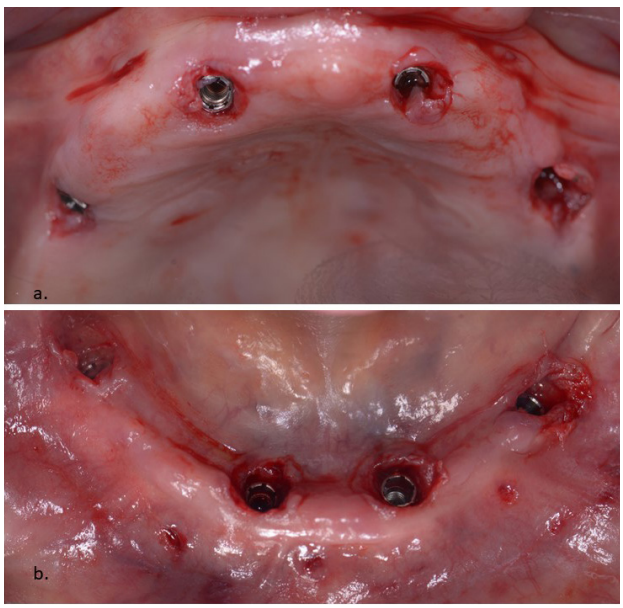

Fig. 16. ***a****: post-surgery sup;* ***b****: post-surgery inf.*

Fig. 17. *Positioning of the cannulas for immediate loading.*

material with good mechanical and aesthetic properties (42, 43) (Fig. 20-25). Professional oral hygiene sessions were performed quarterly, and the 3-year follow-up revealed no complications affecting the prosthetic or implant component (44) (Fig. 26, 27).

DISCUSSION

Dental implant rehabilitation 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 could be directly linked to an improvement in general health and a higher quality of life (45). However, it is indisputable that the patient's medical status has a great influence on the success rate of dental implants. Impaired health conditions and the relative lack of adequate host healing are among the most important conditions explaining implant failure (46, 47).

Today, clinicians are confronted with the needs of edentulous patients and with responsible decision making based on the medical status and history of treated patients. Implant-based dental rehabilitations are obviously an elective treatment. Consequently, it is mandatory to identify and exclude patients with local or systemic contraindications to ensure the success of implant therapy without endangering patients' health (48). Proper

Fig. 18. *Immediate loading performed using the diagnostic prosthesis.*

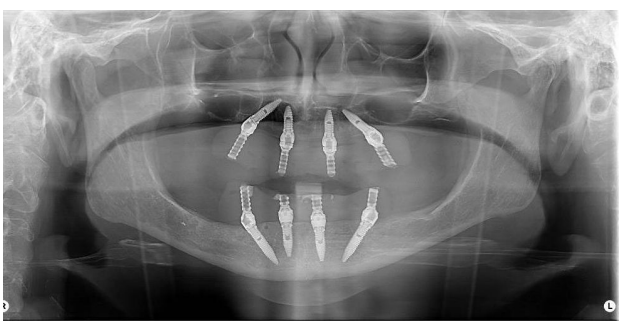

Fig. 19. *Radiographic control following implant surgery and immediate loading.*

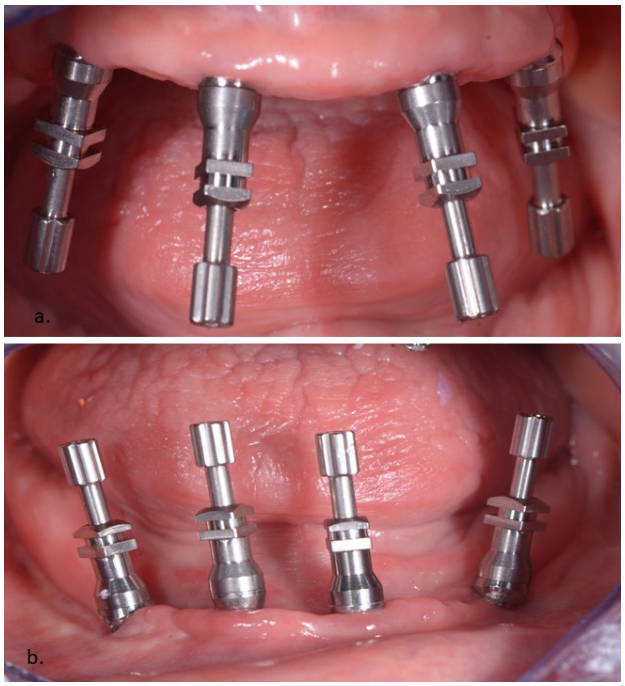

Fig. 20. ***a****: positioning of the transfers to take the definitive impressions: upper arch;* ***b****: positioning of the transfers to take the definitive impressions: lower arch.*

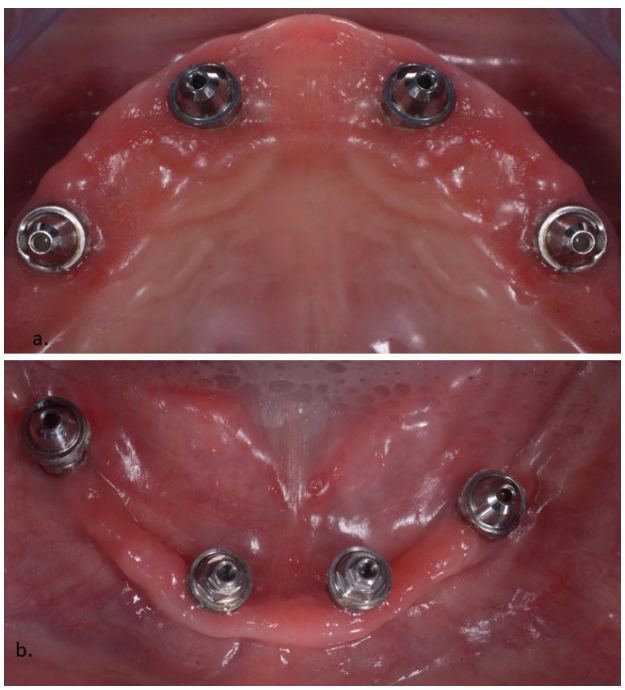

Fig. 21. ***a****: Healing at 6 months of the upper arch;* ***b****: healing at 6 months of the lower jaw.*

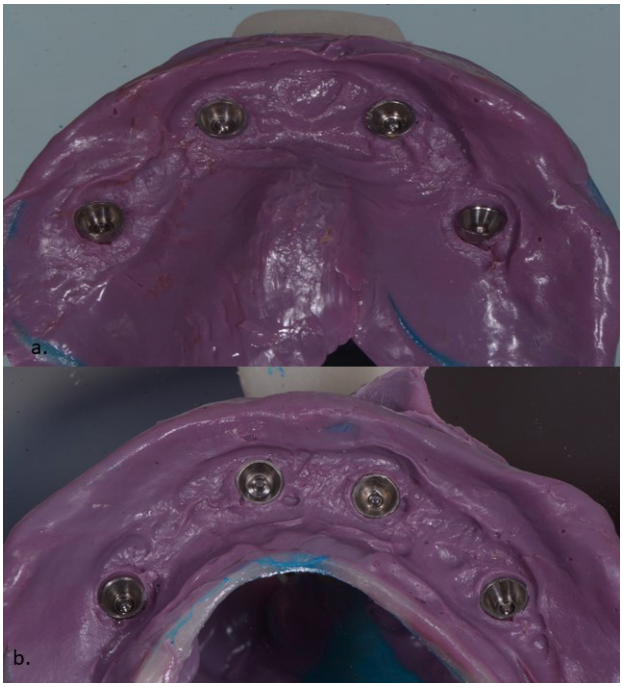

Fig. 22. ***a****: Monophasic impression of the upper arch using an individual tray and polyether;* ***b****: monophasic impression of the lower arch using an individual tray and polyether.*

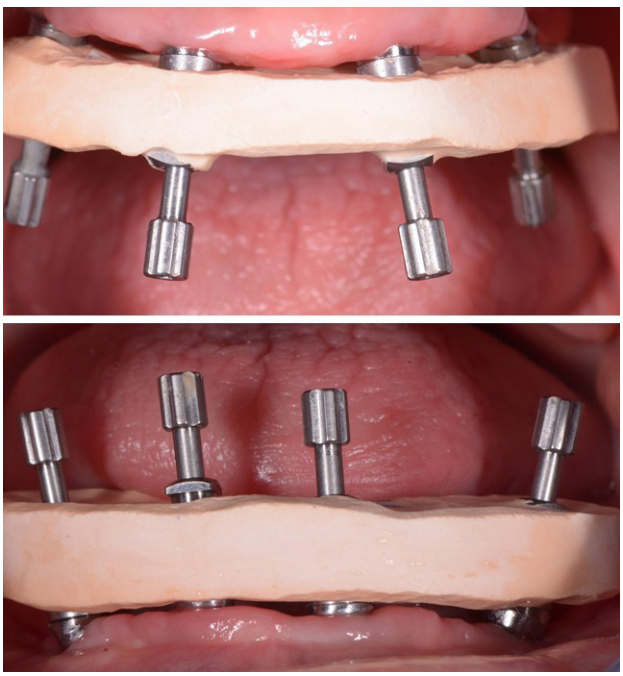

Fig. 23. ***a****: Try-in plaster bar and transfer: upper arch;* ***b****: try-in plaster bar and transfer: lower arch.*

functioning of the immune system is a prerequisite for any non-mandatory surgery, and the inflammatory response of the immune system also plays a key role in targeting

Fig. 24. *Aesthetic test.*

Fig. 25. *Delivery of the final artifact.*

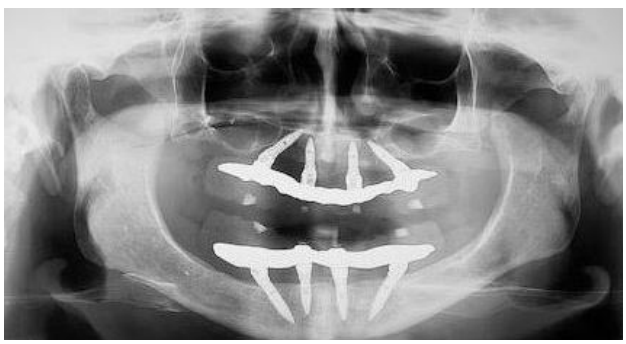

Fig. 26. *Final radiological control.*

infections and orchestrating healing processes (49, 50).

In the recent systematic review, Duttenhoefer F. describes the implant survival rate of the patients examined, including autoimmune diseases polymyalgia rheumatica, pemphigus vulgaris, scleroderma, Sjogren's syndrome and systemic lupus erythematosus. The survival rate was 100% during the follow-up periods ranging from 4 to 13 years (9).

Numerous authors have evaluated implant survival in subjects with multiple autoimmune diseases and concluded that no influence of the above diseases on the overall survival rate of dental implants (Sjogren's syndrome, dermatological myositis, rheumatoid

Fig. 27. *Final clinical case.*

dermatitis) was found (51-58). The digital planning of an implant-prosthetic rehabilitation begins with the use of Smile Design, which allows for a two-dimensional project of the patient's future smile. This allows for proper planning of rehabilitation in aesthetic terms, improves interaction between specialists and communication with the patient and therefore allows for a higher quality of treatment, as already described by Coachman et al. in 2017 (59). Tracing reference lines and shapes over intra- and extraoral digital photographs with a determined sequence can broaden the diagnostic view and help the dental team to assess the limitations and risk factors of a case, including asymmetries, disharmonies, and alterations in aesthetic principles. Thus, allowing the realization of a more accurate treatment (59-60).

Patient appreciation of digital aesthetic planning has also been described by Cattoni et al. in 201665, using a VAS-type scale, for what concerned the creation of crowns and veneers of the front teeth (61). Today it is possible to use specific software that allows the transition from the two-dimensional pre-visualization of the smile to a three-dimensional study, allowing a CAD-CAM processing for the realization of the prosthetic product. It was reported in the literature in 2014 by Kapos et al. that the survival rates of crowns, abutments and superstructures made with the CAD-CAM method are like those of the same ones manufactured with traditional methods (62). The digital prosthetic realization can be combined with the digital planning of the surgical intervention, thanks to the matching between the data of the prosthetic project and the data obtained from the CBCT, as described by various authors (63, 64). Schneider et al. in 2009, as well as other authors, showed the effectiveness and accuracy of computer-assisted implant surgery in this regard. The superposition of intra- and extra-oral photographs, models, intraoral scans and CBCT is recognized as a reliable procedure by the 5th Consensus Conference of the European Association of Osseointegration in 2015 (65, 66).

Meloni et al. in 2010, in a retrospective analysis conducted on 15 patients, described the possibility of planning implant surgery in a guided and flapless manner and with immediate loading. This has also been confirmed by other authors such as Komiyama et al. in 2012 (67, 68). The main advantages of computer-assisted implant surgery, as already described by Hultin et al. in 2012, are the significant reduction of pain and post-operative discomfort for the patient and the possibility of making a temporary prosthesis to be used for the immediate functionalization of the implants (69). The levels of peri-implant bone loss obtained in the present study proved to be like those reported by other authors in the literature, both for the group of patients treated with traditional surgery and for that treated with guided surgery (70-73).

We can therefore conclude that the proposed method, exploiting digital technologies and flows and minimally invasive flapless surgical methods, can be considered elective in the treatment of patients with special needs.

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A simplified digital workflow for the prosthetic finishing of implant rehabilitations: a case report

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The aim of this article is to describe how, during the provisional and definitive prosthetic phases, using new digital technologies, it is possible to improve the ergonomics of the prosthetist's work and reduce the discomfort of patients, subjecting them to the fewest possible appointments at the dentist. The proposal of a full digital protocol, described by the following case report, for the realization of a definitive prosthetic rehabilitation supported by a reduced number of implants, in fact, allows to considerably reduce the number of appointments and reduce any bias. A 67-year-old male patient presents for the first visit to the Department of Dentistry of the San Raffaele Hospital, wearing a removable upper prosthesis and with the request to heal the aesthetic and functional situation through prosthetics fixed. An initial panoramic radiograph was performed, intra and extra oral photos were taken and also intraoral impressions. A stereo-lithographic models are obtained from intraoral scans, and two total prostheses, upper and lower, were packaged for the provisional post-surgical phase was performed. In accordance with the All-on-4 method 8 implant fixtures were placed. For the final prosthetic phase, the patient underwent only two operative sessions. In the first session, scans were taken with the provisionals in situ, of the patient's mucous membranes and with the Scan-abutments in place. In the second session using specific CAD-Software the matching of the STL files of the three scans were created, the opposing arches of the patient were related on a digital articulator, and the milled titanium bars were immediately constructed and finished with the resin. Finally, the definitive prostheses were delivered to the patient without any other test. Digital technology has allowed a clear reduction in working times and costs and has allowed the reduction of stress for patients who undergo invasive and extensive treatments to recover aesthetics and function, and for clinicians who must manage complex cases with fewer appointments possible.

The implant-prosthesis in dentistry deals with the morphological, functional, and aesthetic restoration of the original lost and/or compromised teeth (1). The aim is to rehabilitate the dental arches when the dental elements have been lost and an occluded-functional and aesthetic restoration of the oral cavity is required (2). In the modern era, the life expectancy of a patient has increased considerably and with it the need not only functional but above all aesthetic: the need for a harmonious and satisfying smile, in fact in many subjects has priority (3-5). As regards edentulous patients, techniques have been introduced that allow the creation of a screw-retained prosthesis on a small number of osseointegrated implants, which allows to maintain a high aesthetic and functional value (6-9).

One of the most widely used protocols to date

Key words: implant rehabilitation, implant-prosthesis, All-on-4, digital dentistry

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is the "All-on-4": the goal is to make the most of the residual basal bone available in the atrophic jaws, allowing immediate operation and avoiding invasive regenerative procedures. This protocol is based on the use of four implants that support a fixed temporary prosthesis with immediate loading. The two anterior implants are positioned axially, while the two posterior ones are positioned distally and angled to minimize the length of the cantilever and to allow the application of prostheses up to 12 teeth, thus improving masticatory efficiency (10, 11).

Immediate loading procedures have become one of the most frequent requests of patients. The low incidence of complications also demonstrates the predictability of implant treatment and its success over the years (12-14). The most recent literature confirms the same survival and success rate of the implant also in patients with systemic diseases (HIV, HCV, SJOGREN) (15-20). In the twentieth century, both dental materials and technologies for manufacturing any prosthetic product have advanced considerably (21, 22).

Digital dentistry has become a reality: in recent years there has been a growing use of new digital devices from diagnosis to virtual planning to achieve complete implant-supported rehabilitation (23-26). First and second level radiographic instrumental examinations, intraoral scanners (IOS) and laboratory scans are now a custom: the opportunity to use these new techniques in symbiosis has allowed us to optimize not only the quality but also the time of work (27-29).

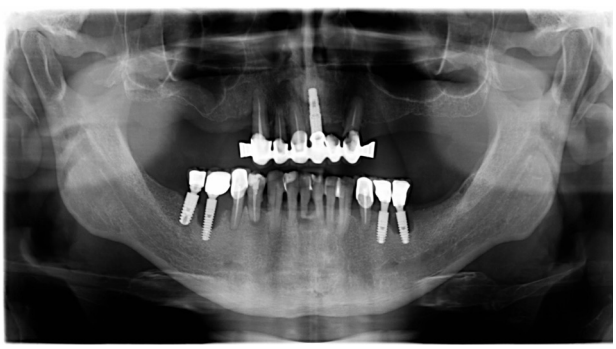

Fig. 1. *Initial orthopantomography.*

Fig. 2. *Initial clinical case: smile.*

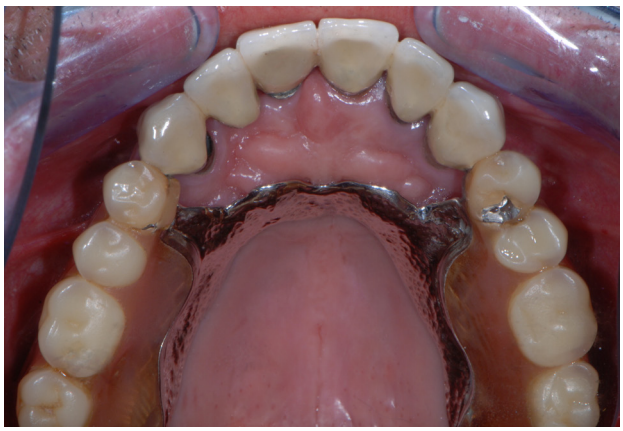

Fig. 3. *Initial clinical case: upper occlusal arch.*

Fig. 4. *Initial clinical case: lower occlusal arch.*

Fig. 5. *Initial clinical case: frontal intraoral vision.*

The aim of this article is to describe how, during the provisional and definitive prosthetic phases, using new digital technologies, it is possible to improve the ergonomics of the prosthetist's work and reduce the discomfort of patients, subjecting them to the fewest possible appointments at the dentist. The proposal of a full digital protocol, described by the following case report, for the realization of a definitive prosthetic rehabilitation supported by a reduced number of implants, in fact, allows to considerably reduce the number of appointments and reduce any bias (30).

MATERIALS AND METHODS

In 2020, a 67-year-old male patient presents for the first visit to the Department of Dentistry of the San Raffaele Hospital, with a compromised periodontal and dental situation, wearing a removable upper prosthesis and with the request to heal the aesthetic and functional situation through prosthetics fixed.

An initial panoramic radiograph was performed (Fig. 1), intra and extra oral photos were taken (Fig. 2-5) and intraoral impressions were taken with a specific scanner (3Di TS, MYRAY, CEFLA sc, Imola- BO-Italy) for the initial case study.

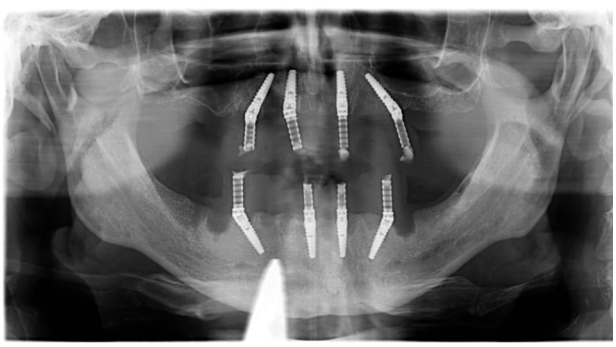

Fig. 6. *Post-surgery radiological control with provisionals in situ.*

Fig. 7. *Clinical case in provisional phase: smile.*

Fig. 8. *Clinical case in provisional phase: frontal intraoral vision.*

After the preliminary study of the case, the residual dental elements were considered unrecoverable, and a fixed rehabilitation was proposed on a reduced number of implants for both the upper and lower arches.

Surgical phase

Stereolithographic models are obtained from intraoral scans, and two total prostheses, upper and lower, were packaged for the provisional post-surgical phase before the operation was performed. After seating the patient, he was rinsed with 0.2% chlorhexidine and povidone for one minute (31, 32).

Local anesthesia with articaine 1:100,000 was administered and tooth extractions performed. After detachment of the full-thickness flap, an ostectomy was performed to adjust the edentulous ridges and the preparation of the implant sites in accordance with the All-on-4 method. 8 implant fixtures with insertion torque greater than 30 Ncm and prosthetic posts for the correction of the implant angulation (Extreme abutment) were placed.

After the surgery, a Low-level-laser Therapy Protocol with a 645 nm Diode Laser was performed to reduce tissue inflammation and to improve the tissue healing phase (Diode Laser, 645 nm, 0,6 Watt) (EGG Laser, DMT, Lissone, Italy) (33-35). Given the primary stability of the implant posts, the temporary prostheses with immediate loading were delivered immediately after the surgical phase and the relative radiological control was performed (Fig. 6). Bite registrations were performed, in accordance

with the original All-on-4 protocol, with maximum intercuspation from canine to canine (36, 37). After the healing phase, occlusal balancing was done after 3 months (Fig. 7, 8).

Stages of definitive restoration

The fundamental objective for the prosthetist is to find the simplest techniques, which allow to reduce the time spent in the chair and the patient's discomfort, while keeping his work accurate and predictable.

For the final prosthetic phase, the patient underwent only two operative sessions. In the first session, scans were taken with the provisionals in situ, trying to detect as much as possible the soft tissues adjacent to the prostheses themselves: the palatal and vestibular areas above while the lingual, vestibular and retromolar tissue below. Also, with the provisional rehabilitations in situ, the chewing between the two arches was detected. Subsequently, after the removal of the temporaries, scans of the patient's mucous membranes and scans with the Scan abutments in place were taken. After this single session, the scans detected were sent to the laboratory (Odontotecnica Lazetera Savona, Savona, Italy) which proceeded with the construction phase of the final artifacts.

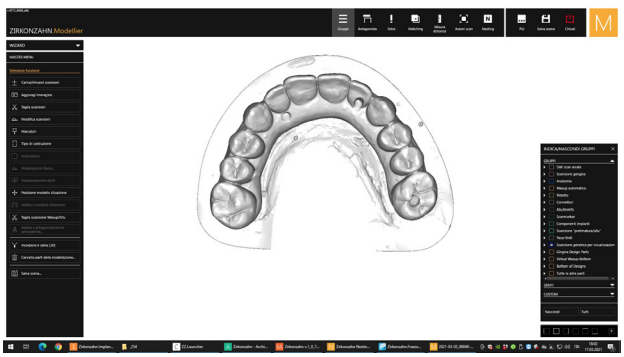

Fig. 9. *Provisional prosthesis scan in upper position.*

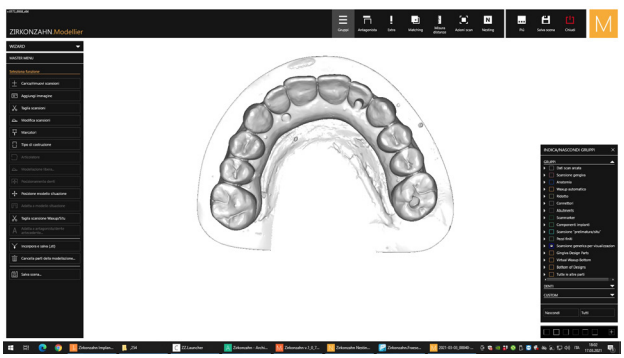

Fig. 10. *Provisional prosthesis scan in inferior position.*

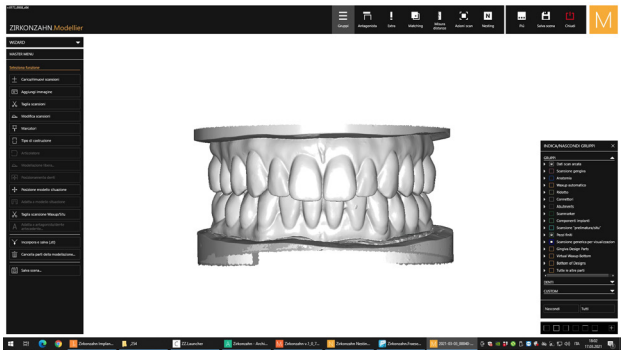

Fig. 11. *Provisional prosthesis scan in patient occlusion.*

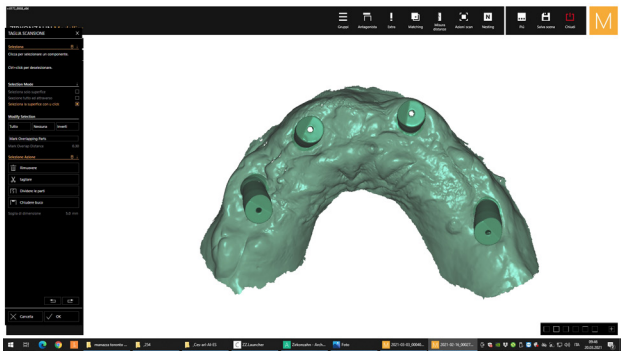

Fig. 12. *Digital scan with mucous membranes and Scan-abutment: superior occlusal view.*

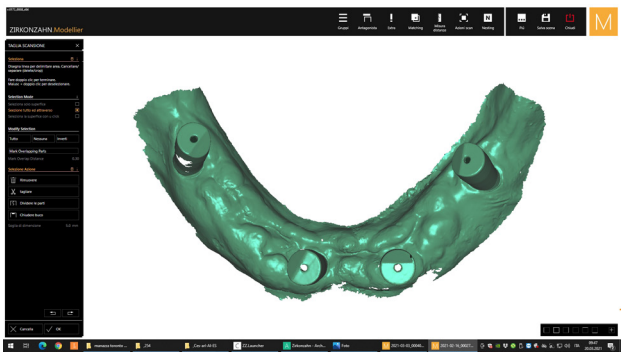

Fig. 13. *Digital scan with mucous membranes and Scan-abutment: inferior occlusal view.*

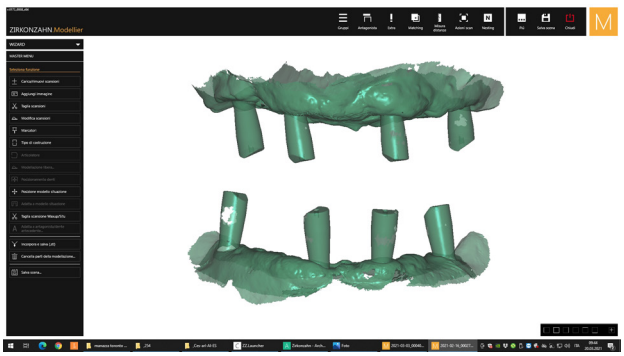

Fig. 14. *Digital scan with mucous membranes and Scan-abutments: inter-arch relationships.*

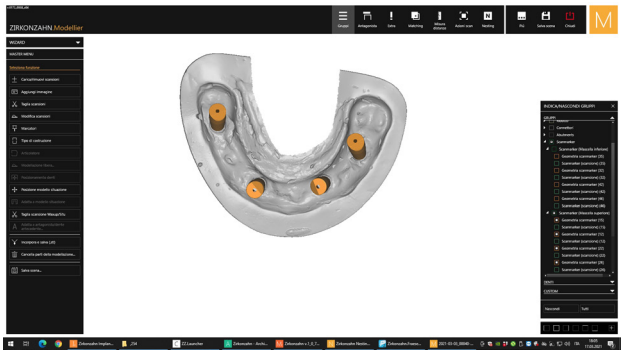

Fig. 15. *Digital model with virtual Scan-Abutment coupling: superior occlusal view.*

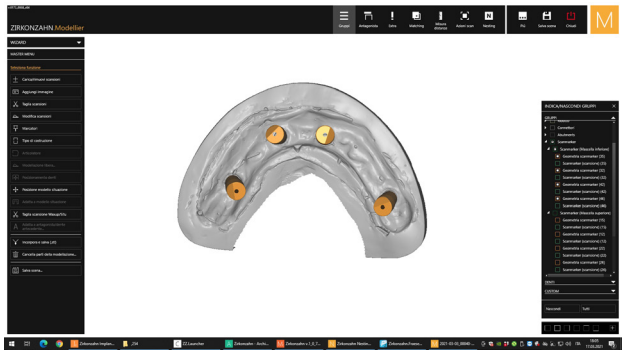

Fig. 16. *Digital model with virtual Scan-Abutment coupling: inferior occlusal view.*

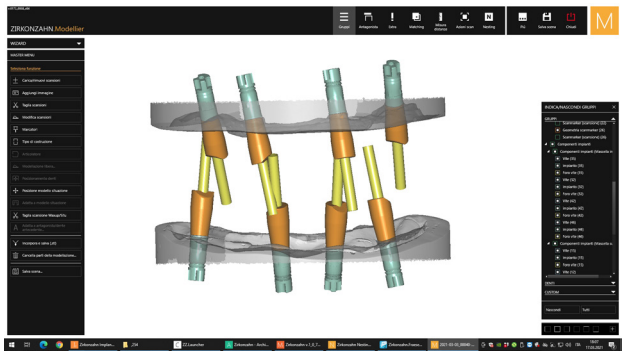

Fig. 17. *Digital model with virtual Scan-Abutment coupling: inter-arch relationships.*

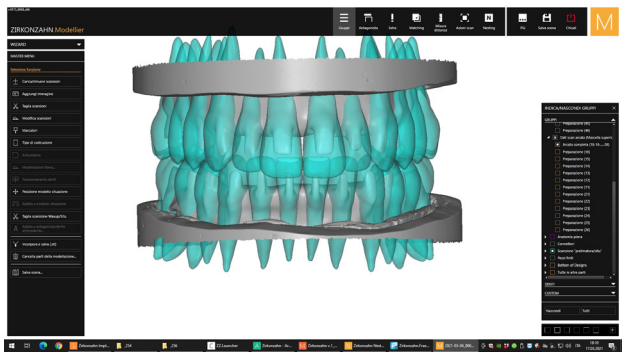

Fig. 18. *Virtual mockup: front view.*

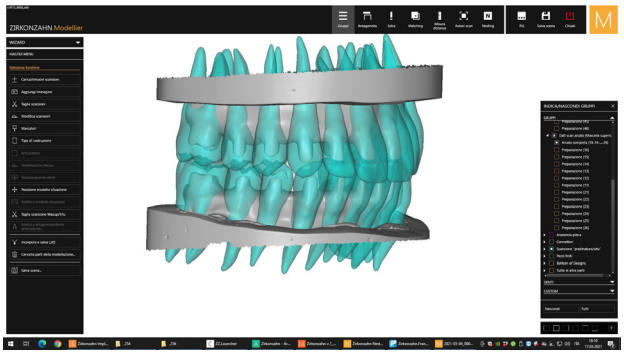

Fig. 19. *Virtual mockup: side view.*

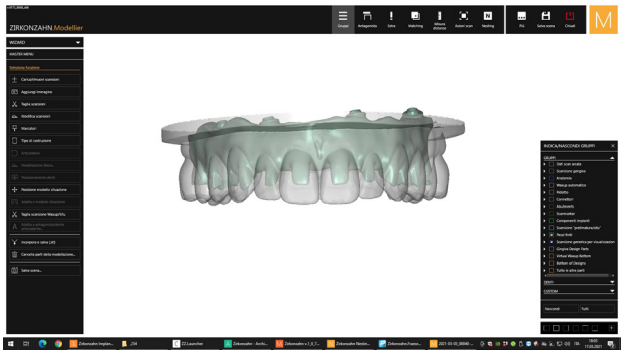

Fig. 20. *Virtual design of the titanium bar by reducing the shapes starting from the Mock-up: superior front view.*

Using specific CAD software (Zirkonzahn.Modellier, Bolzano, Italy), the matching of the STL files of the three scans were created: scans of the shapes of the temporary prostheses (Fig. 9-11), scans of the soft tissues and scans with scan abutment in situ (Fig. 12, 13); in this way the opposing arches of the patient were related on a digital articulator (Zirkonzahn.Modellier, Bolzano, Italy) (Fig. 14).

The virtual implant analogues were positioned (Fig 15-17), the aesthetic design of the rehabilitation was then designed (Fig. 18, 19) taking up the CAD drawing of the shapes initially established in the provisional phase (CAD waxing), by subtraction and the design of the metal structures of the definitive prostheses was created (Fig. 20-23).

The milled titanium bars were immediately constructed, made with the CAM method, to which the abutments for the fixation of the prostheses and the resin dental elements milled from solid individualized for the occlusion of the individualized were cemented (with specific adhesive cementation) patient.

For these phases of finishing with the resin, the dental technician created plaster models on which to place the

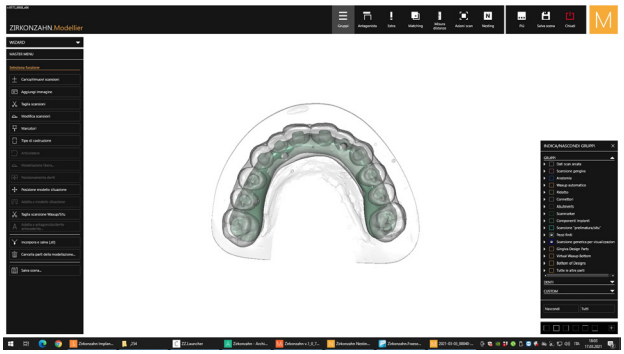

Fig. 21. *Virtual design of the titanium bar by reducing the shapes starting from the Mock-up: superior occlusal view.*

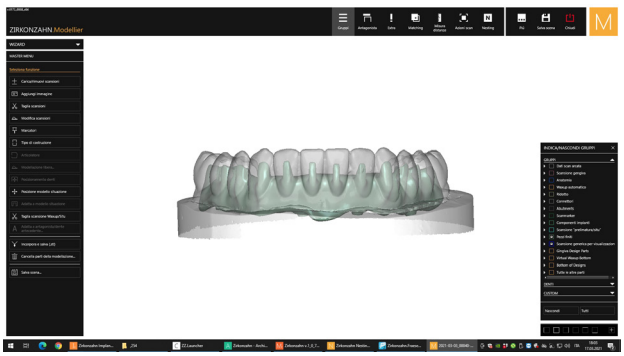

Fig. 22. *Virtual design of the titanium bar by reducing the shapes starting from the Mock-up: lower front view.*

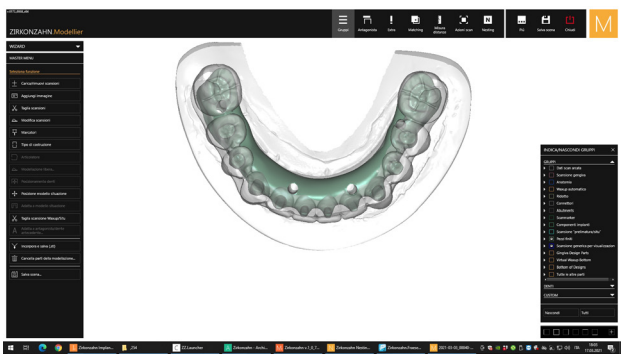

Fig. 23. *Virtual design of the titanium bar by reducing the shapes starting from the Mock-up: inferior occlusal view.*

Fig. 24. *Gingival modeling with resin elements glued to the bar.*

bars for ergonomics in the work (Fig. 24), obtained by placing the laboratory analogues on the bar itself. 15 days after the first appointment, the definitive prostheses were delivered to the patient, the aesthetic and occlusal check was performed, and the final panoramic radiograph was performed to verify the precision of coupling between prostheses and implant components (Fig. 25-29).

DISCUSSION

The purpose of this work is to describe a procedure for the prosthetic restoration of implant rehabilitations, relying on digital technologies to minimize the patient's appointments in the chair. In the clinical case described, the All-on-4 technique was used as a rehabilitation choice, the effectiveness of which has already been confirmed by a considerable number of previous studies. This does not exclude the possibility of applying this protocol also in other types of simple and complex implant restorations (38-40).

Before any surgical and prosthetic treatment, especially in the current pandemic situation, the assessment of tissue healing is necessary, it is necessary to evaluate the inflammatory state of the oral cavity (41-43). The evolution of dentistry has always been gradual and constant, driven above all by innovations and new treatment protocols that have changed previous knowledge.

The last major change was the digital revolution: in recent decades, the increase in these new technologies in terms of software, scanners, and the possibility of manufacturing products, is leading to a gradual but constant modification of traditional dentistry (44, 45). One of the main factors on which the prosthetic finalization of an oral rehabilitation depends is the relief of the impression (46, 47).

Within the traditional protocols validated by the international bibliography of recent decades, digital technologies are today a valid alternative and aid in the relief of footprints on natural elements and plants (48-50). The development of new technologies in recent years is totally changing the concept of dentistry: the introduction of digital scanners (IOS), in fact, is leading to a modification of the working protocols of both the dental technician and the

clinician, eliminating micro-inaccuracies. due to human error, reducing the technical variables and those related to the materials, obtaining a greater standardization of the procedures and therefore a better effectiveness of the restorations (51-53).

The CAD / CAM "computer-aided design" and "computer-aided manufacturing" techniques have also been developed with the aim of reducing the deficits of traditional techniques and automating the production process for restoration quality and flow efficiency of work (54, 55). Digital dentistry and CAD / CAM restorations are now setting the standards of modern dentistry in terms of precision, predictability, and simplicity of production (56, 57). Modern dentistry is therefore an aesthetic, minimally invasive and digital dentistry. Achieving "beauty" with minimal invasiveness increasingly passes through a "dental digital workflow", that is the adoption of modern principles and digital protocols in daily clinical practice (58, 59).

The present study, in the description of the case report shown, proposed a therapeutic process in which, after the surgical part, a digitized protocol was used to reduce the time and number of working sessions and improve patient comfort, while maintaining the type of desired result.

Digital technology has allowed a clear reduction in working times and costs and has allowed the reduction of stress for patients who undergo invasive

Fig. 25. *Final prosthesis in situ: superior occlusal view.*

Fig. 26. *Definitive prosthesis in situ: inferior occlusal view.*

Fig. 27. *Definitive prosthesis in situ: inter-arch relationships.*

Fig. 28. *Final prosthesis in situ: front view.*

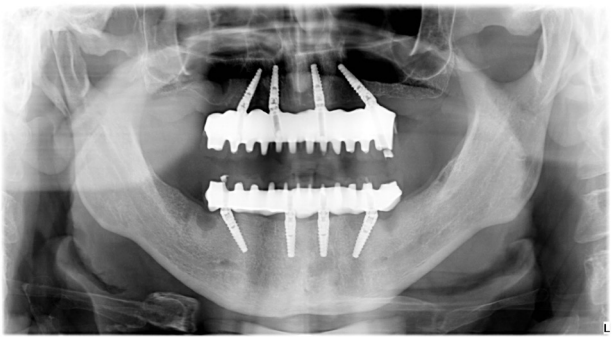

Fig. 29. *Final orthopantomography.*

and extensive treatments to recover aesthetics and function, and for clinicians who must manage complex cases with fewer appointments possible. These results can be obtained thanks to an accurate initial aesthetic and functional planning that, once obtained in the provisional phase, is not lost in the definitive one: therefore, an accuracy of all the steps is essential.

Finally, we must not forget the importance of a team: the communication between clinician and dental technician through the digital workflow will further reduce errors and obtain an optimal final prosthesis. It will be interesting to evaluate the accuracy and reproducibility of this workflow with a reduced number of appointments on a greater number of cases.

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Implant rehabilitation of edentulous jaws with predominantly monolithic zirconia compared to metal-acrylic prostheses: a 2-year retrospective clinical study

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Limited data are available on the clinical outcomes of patients with edentulism treated with predominantly monolithic zirconia fixed complete dentures (FCDs) compared to traditional restoration materials. The purpose of this study was to analyze the differences in terms of complications and failures of definitive full-arch implant rehabilitations made in metal-acrylic versus those made in monolithic zirconia with porcelain veneering limited to non-functional areas. This retrospective clinical study included 50 patients treated between January 2015 and December 2018, with 222 implants inserted in fifty edentulous jaws. All patients were treated with immediately loaded full-arch fixed prostheses (22 maxillary; 28 mandibular) each supported by four to six implants (two/four axial, two distally tilted). All 25 zirconia prostheses were predominantly monolithic with ceramic veneering limited to non-functional areas. The primary outcome measures were prosthetic success of the definitive restoration and implant survival. The secondary outcome measures were full mouth plaque score, full mouth bleeding score, peri-implant probing depths and peri-implant keratinized tissue. All implants and prostheses analyzed had a minimum of 2 years of follow-up. No chipping of the veneered facial porcelain or other technical complication was observed over the study period achieving a prosthesis survival and success rate of 100%. No implants were lost, achieving a 100% survival rate. Bleeding on probing was positive in 33% and 13% of probing sites for metal-acrylic prosthesis and zirconia prosthesis, respectively (p = 0.0445). Plaque index was positive in 76% and 53% of probing sites for metal-acrylic prosthesis and zirconia prosthesis, respectively (p = 0.0491). Mean probing depth was 1.74mm (SD 0.89mm) for the 106 implants supporting metal-acrylic prosthesis and 1.52mm (SD 0.63mm) for the 116 implants supporting zirconia prosthesis (p=0.0412). No other statistically significant differences were found between the two groups. The results of this retrospective evaluation showed that predominantly monolithic zirconia is a feasible alternative to the conventional metal framework acrylic for full arch implant-supported prosthesis. The restauration material did not influence the failure rate and complication risk of both prosthesis and implants.

Fixed complete dentures (FCDs) are a clinically proven treatment for edentulism (1-3) with an implant survival rate well above 90%. The long-term outcome of full-arch dental implants has been widely demonstrated. Clinical studies (4, 5) and systematic reviews (6) report an implant-survival rate of more than 90% after a follow-up period of at least 5 years. Nevertheless, a certain resonance should be also given to restorative material selection, manufacture and design of the supporting framework and handling of the veneering material in full-arch rehabilitations (7-10).

Key words: monolithic zirconia, metal-acrylic restorations, CAD-CAM, edentulism, fixed complete denture

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Many prosthetic designs and materials have been described (11, 12). FCDs are traditionally made of a metal framework with acrylic resin and denture teeth as veneering materials (13). These implant-supported hybrid prostheses (metal-acrylic resin) are associated with a high success rate (14). However, the high rate of prosthetic complications related to this kind of restoration has been reported over short- and long-term periods (15-17).

New ceramic materials, especially zirconia, have been recently introduced as an alternative to metal frameworks in full arch rehabilitations to improve the mechanical stability, biologic properties and aesthetic implications (18-21). This high-strength oxide ceramic presents a good dental and gingival aesthetics (22) due to its natural white color. The reduced plaque accumulation and favorable soft tissue response makes zirconia an excellent choice for implant-retained superstructures (23). In addition, the fabrication of zirconia restorations requires CAD/CAM technology that allows a better marginal fit and control of distortion which is introduced by conventional casting procedures (24, 25).

The combination between intraoral scanning and CAD/CAM procedures results in a fully digital workflow in which zirconia exhibits an excellent behavior being a high-quality core material (26).

Many studies providing ceramic veneered zirconia restorations have shown promising short-term clinical results with a prosthetic survival rate of almost 99% (27-29). In a prospective study by Mendez Caramês, out of the total 77 restorations, only one framework fracture was observed during the follow-up period, resulting in a survival rate of 98.7% for the zirconia framework veneered with feldspathic porcelain (30). Nevertheless, one of the most frequently reported complications of these prostheses is chipping, due to the dissimilar framework-veneering interface (31). In a recent systematic review, short-term results from a combined 223 patients with 285 one-piece zirconia FCDs showed a mean failure rate of 1.4% due to fracture of the zirconia framework and a 14.7% of minor complications exclusive to fracture of veneered porcelain (31). The same results are confirmed by Sailer (32) and Pieralli (33). In the first systematic review by Sailer (32) et al. the comparison between metal-ceramic and zirconia-ceramic for multiple-unit fixed dental prostheses resulted in a cumulative 5-year ceramic fracture or chipping of 11.6% for the first group and 50% for the second group. In the other review by Pieralli (33), chipping of the veneering ceramic was frequent, resulting in estimated 5-year complication rated of 22.8% for partial fixed dental prostheses and 34.8% for full-arch fixed dental prostheses. To minimize these complications, monolithic zirconia was developed and introduced (34). Being monolithic, its constituent does not present dissimilar interfaces. This allows to almost avoid any fracture and/or chipping events since it represents a greater bulk of material that improves the structural properties (35).

In a recent systematic review by Abdulmajeed, monolithic zirconia in complete-arch implant-supported fixed dental prostheses was evaluated (36). It resulted that only nine studies with a mean follow-up of at least 1 year were included in the review due to lack on the long-term outcome (36).
All the analyzed reviews suggest the need for more long-term studies on all-ceramic complete-arch fixed implant prostheses focusing especially on monolithic zirconia. In fact, there is lack of published RCTs comparing various restorative materials (37).

The aim of the present short-term study is to report the clinical performance of predominantly monolithic zirconia used for full-arch rehabilitations compared to the conventional cast metal-acrylic prostheses. Fixed complete dentures supported by 4 to 6 implants were retrospectively followed up for 2 years.

MATERIALS AND METHODS

Patient selection

This study was conducted in accordance with the tenets of the Declaration of Helsinki and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies (http://www.strobe-statement.org). This single-centre retrospective study was performed at the Department of Dentistry, IRCCS San Raffaele Hospital, Milan, Italy. All the records of single arch edentulous patients treated from January 2015 to December 2018 were reviewed. The principles were in accordance with Helsinki Declaration

and Italian Law.

Patients rehabilitated with four to six implants supporting an immediate loading metal-acrylic or monolithic zirconia prosthesis according to the all-on-four technique were selected.

Inclusion criteria:
- age > 18 years
- total or partially edentulous in one arch
- adequate bone volume (divisions A, B or C based on the Misch classification of bone available (38)
- appropriate bone density (class D1, D2 or D3 based on the Misch classification (39)
- implant occlusal loading with a provisional prosthesis of at least 4 months

Exclusion criteria:
- severe immunodeficiency with a high recurrence of opportunistic infections
- uncontrolled diabetes
- severe malocclusion
- severe parafunction (bruxism)
- inadequate bone volume (division D based on the Misch classification (38)
- inadequate bone density (class D4 based on the Misch classification (39)
- disorders for which surgical procedures were contraindicated
- lack of collaboration
- lack of oral hygiene
- patients receiving bone grafts
- patients participating in other clinical studies that could affect either the design of the prosthesis or the follow-up protocol
- patients with distal cantilever more than 10mm
- heavy smokers (>10 cigarettes per day).

Pre-treatment

All diagnoses were made clinically and radiographically. All patients gave their written informed consent for immediate implant loading and professional oral hygiene was provided before surgery. The local ethical committee approved the study. Conventional impressions were taken for study casts and provisional prostheses; to assess bone volume (according to Cawood and Howell classification (40)) and bone density in each patient, the diagnosis was conducted as first level with panoramic radiography and at second level with cone beam computed tomography (CBCT).

Surgical procedure

All surgeries were performed by a single experienced surgeon. On the day of surgery, implants were positioned after antibiotic prophylaxis with 2 g amoxicillin and clavulanic acid (Augmentin, GlaxoSmithKline, Brussels, Belgium), which was administered 1 hour prior to surgical incision. After preparation of the patient, a povidone and chlorhexidine rinses were performed (41, 42). Implant surgery was performed under local anaesthesia (optocain 20 mg/mL with adrenaline 1:80,000; Molteni Dental, Firenze, Italy).

In edentulous mandibles, a crestal incision with bilateral releasing incisions was made from the first molar region to the contralateral side. Sub periosteal dissection was performed on the lingual and vestibular surfaces; a full- thickness buccal flap was raised, exposing the buccal bone wall and allowing detection of the mental foramina. In edentulous maxillae, a crestal incision was performed on the alveolar crest from the pterygomaxillary region to the contralateral side with bilateral releasing incisions; a mucoperiosteal buccal flap was elevated, exposing the vestibular bony wall. Residual hopeless teeth were automatically extracted before implants insertion to preserve the alveolar ridge.

The two posterior implants were placed bilaterally immediately anterior to the mental foramina in edentulous mandibles; following the anterior sinus wall in edentulous maxillae, the implants were distally tilted at approximately 30 to 45 degrees relative to the occlusal plane, emerging at the second premolar position to shorten the cantilever length and maintain a large inter-implant distance (3). The two to four anterior implants always followed the jaw anatomy in direction. Bone density was assessed by CBCT as previous described, during the early phase of drilling by the clinician's experience and sensation and scored in accordance with the Lekholm and Zarb classification (43).

The diameter of the final drill was chosen based on bone quality to optimize implant stability. The insertion of the implants followed standard procedures, although under-preparation was used in soft bone to achieve an insertion torque ranging between 30 and 40 N·cm before final seating of the implant, thereby obtaining

high primary stability and immediate function. A manual wrench was also used when incomplete seating of the implant occurred. The implant neck was aimed to be positioned at bone level, and bicortical anchorage was established whenever possible (3).

Surgical placement of the implants always aimed to achieve ideal prosthetically driven implant positioning; therefore, to allow optimal prosthetic screw access and placement of holes in an occlusal or lingual location, angulated abutments for anterior implants were set at 17 degrees, and those for posterior implants were set at 30 degrees to compensate for the lack of parallelism between implants. Flap adaptation and suturing were performed with 4-0 non-resorbable suture (Vicryl; Ethicon, Johnson & Johnson, New Brunswick, NJ, USA).

After surgery, a Low-level-laser Therapy Protocol with a 645 nm Diode Laser was performed to reduce tissue inflammation and to improve the tissue healing phase (Diode Laser, 645 nm, 0,6 Watt) (EGG Laser, DMT, Lissone, Italy) (44,45,46).

Post-surgical instructions

After surgery, mouth rinsing with a chlorhexidine digluconate-containing solution (0.12% or 0.2%), twice per day for 10 days, was prescribed in addition to the recommended standard post-surgical medication: amoxicillin and clavulanic acid (Augmentin, GlaxoSmithKline) 1 g, two times per day for 7 days after surgery, and non-steroidal anti-inflammatory drugs (ibuprofen 600 mg, Brufen, Abbott Laboratories, Chicago, IL, USA) as needed. All patients were instructed to avoid brushing and any trauma to the surgical site, and were recommended to follow a soft diet (avoiding bread and meat) for 2 months. One week after implant placement, sutures were removed.

Prosthetic protocol

According to the direct provisionalization technique (47), the interim restorations were properly intraorally relined with autopolymerizing polyurethane resin (Voco, Fort Mill, SC, USA) including the straight titanium cylinders screwed to the angulated abutments (47-49). The vertical dimension was established and corrected using facial reference marks recorded prior to surgery.

No more than 3 hours after surgery, provisional complete-arch all-acrylic resin prostheses were delivered to all patients based on preliminary impressions and diagnostic set up. On this screw-retained prosthesis, only 10 teeth were mounted, no cantilevers were used (3). An interocclusal registration was then performed using the prefabricated prosthesis, and panoramic radiographs were obtained. The torque for tightening the prosthetic screws was 20 N. Screw access holes were covered with provisional resin (Fermit, Ivoclar Vivadent, Naturno, Bolzano, Italy).

Following the immediate provisional prosthetic protocol (47), centric and lateral contacts were limited to the intercanine area and modified where needed using an articulating paper (40 μm Bausch Articulating Paper, Nashua, NH, USA). Passive fitting was also checked. After the post-surgical visit, occlusal balancing was made and after 3 months, a control recording was made to verify functional adaptation (50).

After a healing period of 4 months, open tray impressions were taken for the realization of the definitive prosthesis. Integral pick-up impression copings were screwed over the fixtures and splinted together using orthodontic wire and composite resin, that has been gradually polymerized in order to reduce and avoid its shrinkage. The impression material used for all patients was gypsum (Éclair Class II, Ultima, Angers, FRANCE). After obtaining the impression, it was necessary to attach the implant analogs to the copings and then realize a stone model to replicate the exact position of the implant in the cast.

Monolithic zirconia restaurations

Once the definitive cast had been fabricated, a 3D laboratory scanner (Optical scanner S600 ARTI, Zirkonzahn) was used to obtain the virtual model of the considered jaw and begin the CAD-CAM procedure. The stone cast model of the opposing arch was scanned with the same procedure. In addition, the virtual model of the temporary prosthesis, attached to implant analogs, was extraorally acquired through the same laboratory scanner. Subsequently, the scans have been digitally overlapped with a laboratory software (ImplantPlanner, Zirkonzahn) for each patient. The resulting 3D scans were then exported in the standard tessellation format (.stl).

Once the virtual model is created with the dental implant in position, virtual digital creation of the zirconia frameworks from the scanned interim restoration can be designed through the CAD software (Exocad software,

Darmstadt, Germany). A limited digital cut-back procedure was done to provide adequate space for the feldspathic veneering in the facial areas. The definitive restoration is ready to be milled from monolithic zirconia. The milling (CAM) process of the zirconium oxide blank (Prettau Zirconia, Zirkonzahn) was carried out on the basis of this computer designed project (CAD data) using standardized fabrication protocols recommended by the manufacturer (Zirkonzahn). The CAD/CAM system was CAD/CAM 5-Tech, Zirkonzahn.

To finalize the rehabilitation after milling, the monolithic zirconia prosthesis underwent the sintering process. The resulting monolithic zirconia full-arch fixed rehabilitation was then hand veneered with a reduced amount of feldspathic porcelain (ICE Zirkon Ceramics, Zirkonzahn) limited to nonfunctional facial areas of the prosthesis. For this reason, the restoration is considered mainly monolithic. The prostheses were luted with adhesive cement (Panavia F 2.0; Kuraray) to prefabricated titanium abutments in order to have a titanium-to-titanium connection at the implant-level.

Metal-acrylic restorations

After realization of the stone model, the technician followed the conventional procedures for the fabrication of a metal framework up to the completion of the try-in of the tooth setup (51). A wax pattern was made on the stone model to reproduce the design of the final Co-Cr framework obtained through the traditional lost-wax casting technique. Thereafter, the metal framework was refined and polished by the technician, and after clinical try-in, the prostheses were completed by curing acrylic resin and composite teeth (Ivoclar Vivadent) to the metal frame, following standard procedures (51) used for conventional cast fixed full-arch prostheses. The prostheses, set up for the esthetic trial placement, were fabricated based on the provisional prosthesis, but refined in esthetics, function and in relation to soft tissue.

Both metal-acrylic and monolithic zirconia definitive prostheses were finally positioned and screwed onto dental implants. Sheffield test was carried out to check the precision of framework. The marginal fit of final prosthetic frameworks screwed onto the implants was checked by intraoral digital radiographic examination in both groups. Articulating paper (Bausch Articulating Paper, Nashua, NH, USA) was used to check the occlusion and adjust it, if necessary. In particular, static occlusion consisted of central contacts established on all masticatory units and dynamic occlusion included canine/premolar guidance, regardless of the opposite arch settings. Screw access holes were covered with temporary resin (Fermit, Ivoclar Vivadent, Naturno, Bolzano, Italy).

Primary outcome measures:

- Prosthetic success: defined as absence of failure and occurrence of technical complications. Failure consisted in fracture of any part of the full-arch prosthesis resulting in the need for a complete refabrication of the prosthesis. Technical complication is defined as an unanticipated event that affected any or all of the full-arch prosthesis and required maintenance services but without replacement with a new prosthesis.
- Implant survival: defined as presence of implant stability, absence of radiolucent zone around the implants, no mucosal suppuration or bleeding and no pain. Implant success was defined as implant survival plus marginal bone loss of less than 1.5mm after 1 year of loading and no more than 0.2mm loss between each follow-up appointment after the first year of function. The stability of each individual implant was assessed manually after 6 months and then annually from insertion by tightening the abutment screws with the removed prostheses.
- Peri-implant marginal bone levels: bone level measurements were performed on the mesial and distal aspect of each implant, using the implant-abutment junction as reference point (52); these were made perpendicular to the long axis of the implant with the long-cone parallel technique using an occlusal custom template to measure the marginal bone level. The difference in bone level was measured radiographically through custom software (DIGORA 2.5, Soredex, Tuusula, Finland). To adjust the dimensional distortion and enlargement on the radiographs, the software was calibrated for each image using the known implant diameter at the most coronal portion of the neck of the implant. The linear distance between the most coronal point of bone-to-implant contact and the coronal margin of the implant collar was measured to the nearest 0.01 mm at both the mesial and distal sides, and then averaged.

Secondary outcome measures:

- Full mouth plaque score (FMPS) calculated by dividing plaque presenting sites for all sites around implants (6 points per element) and expressed in percentage.
- Full mouth bleeding score (FMBS) calculated by dividing bleeding sites for all sites around implants (6 points per element) and expressed in percentage.
- Pocket probing depth (PPD) of implants supporting full-arch prostheses, expressed as a mean of all sites probed (6 points per element).
- Peri-implant keratinized tissue (KT) of each implant measured with a periodontal probe from free gingival margin to the mucogingival junction and expressed as a mean.

All outcomes are referred to the definitive restoration, inserted 4 months after surgery.

Follow-up

Follow-up visits that included clinical and radiological examination were performed at 4, 6, 12 and 24 months after implant placement. Appointments with a dental hygienist were also scheduled every 6 months during the follow-up. The maintenance protocol was conducted according to Jepsen et al. (53). As reinforcement for the home oral hygiene, patients were instructed on the proper use of aids such as interproximal brush, mono tuft toothbrush, and Super floss. Moreover, patients occasionally failed to visit the hygienist, but were always recalled for another appointment.

Radiographic examination

Radiographic evaluation was performed using panoramic radiographs obtained immediately after surgery and at each follow-up visit. The marginal fit precision of final prosthetic frameworks of both groups, screw-retained onto the implants, was checked by intraoral digital radiographic examination (DIGORA 2.5 software Soredex, Tuusula, Finland) immediately after placement.

Statistical analysis

A dedicated software (SPSS 11.5.0, IBM, Armonk, NY, USA) was used for all statistical analysis. Measurements of probing pocket depth (PPD) and peri-implant keratinized tissue (KT) are reported as mean ± standard deviation (SD). Full mouth plaque score (FMPS) and full mouth bleeding score (FMBS) are reported as percentages. Comparisons between zirconia and metal-acrylic supporting implants were made regarding PPD, FMPS, FMBS and differences in KT. Student's t tests were applied at a significance level of $P < 0.05$.

RESULTS

Data related to a total of 50 full arch prosthesis were analyzed in this study over the 2-year evaluation period. Fifty patients (31 men, 19 women, average age 64.8) were included in the present sample. All patients had only a single jaw rehabilitated. Of the 222 implants, 104 were placed in the maxilla and

Table I. *Diameters and lengths of implants placed in the maxilla and mandible.*

	Zirconia prosthesis	Metal-acrylic prosthesis	TOTAL
	9	13	22
	3	1	4
	13	11	24
	0	0	0
	25	25	50

118 were placed in the mandible. The majority of the implants (160) were 3.8mm in diameter, followed by 3.3mm implants (62) as shown in table I.

Thirty-nine patients were rehabilitated through four implants (156 implants, 39 full-arch prostheses) and eleven patients through six implants (66 implants, 11 full-arch prostheses), therefore 122 implants were placed axially and 100 were placed tilted to avoid anatomical structures. The prosthetic material of the full-arch prosthesis was metal-acrylic with denture teeth for 25 patients and predominantly monolithic zirconia for the others. The opposing dentitions (table II) were implant-supported prosthesis (22 patients), natural teeth (4 patients), or a combination of both (24 patients). No chipping of the veneered facial porcelain or other technical complication was observed over the 2-year study period achieving a prosthesis success rate of 100%. No implants were lost, achieving a 100% survival rate.

Bleeding on probing (BOP) was positive in 70 sites for metal-acrylic prosthesis and 30 for zirconia prosthesis leading to a FMBS of respectively 33% and 13% (table III). The difference was statistically significant ($p = 0.0445$). Plaque index (PI) was

Table II. *Status of the opposite jaw at the time of implant placement.*

	Implant diameter	Number of implants placed		
		11mm	13mm	15mm
Maxilla				
Axial (n=60)	3.8mm	12	26	0
	3.3mm	8	14	0
Tilted (n=44)	3.8mm	0	20	24
	3.3mm	0	0	0
Mandible				
Axial (n=62)	3.8mm	8	24	6
	3.3mm	2	18	4
Tilted (n=56)	3.8mm	0	22	18
	3.3mm	0	6	10

Table III. *FMBS and FMPS of implants supporting full-arch prosthesis.*

Periodontal Index	Zirconia prosthesis	Metal-acrylic prosthesis
Full-mouth bleeding score (FMBS)	13%	33%
Full-mouth plaque score (FMPS)	53%	76%

positive in 161 sites for metal-acrylic prosthesis and 123 for zirconia prosthesis leading to a FMPS of respectively 76% and 53% (table III). Again, the difference was statistically significant (p = 0.0491).

Probing depth (PPD) showed a mean value of 1.74mm (SD 0.89mm) for the 106 implants supporting metal-acrylic prosthesis and 1.52mm (SD 0.63mm) for the 116 implants supporting zirconia prosthesis resulting in a statistically significant difference (p=0.0412) (table IV).

No other significant differences were found between the two groups (Table V). In fact, the amount of keratinized tissue (KT) was similar between implants of metal-acrylic and zirconia prosthesis (p=0.1454). The prostheses in metal-acrylic group were fabricated with a framework of Cr-Co alloy and acrylic artificial teeth. All zirconia prostheses were bonded to prefabricated or custom metal cylinders (indirect interface) differently from the first-generation design of direct zirconia interface.

DISCUSSION

The current study shows the results obtained with predominantly monolithic zirconia used for fixed complete implant-supported dentures. It has some limitations because of its retrospective design but the presence of a control group (metal-acrylic full-arch prosthesis) allowed a comparison between materials. The surgical protocol adopted in this study, widely described, allows to simplify and shorten the implants rehabilitation for both patient and clinician (54). Patients experience a more comfortable post-surgical period since they wear a fixed prosthesis from the day of the surgery (54).

The most recent literature confirms the same survival and implant success rate also in patients with systemic diseases (HIV, HCV, SJOGREN) (55-58). Cattoni et al. in 2020 also evaluated a possible neuro-cognitive measure of how self-perception can change as a significant consequence of aesthetic prosthetic rehabilitation (59).

Table IV. *PPD of implants supporting full-arch prosthesis (mean ± standard deviation in mm).*

Framework material	Number of implants	Periodontal pocket depth (PPD) mean
Zirconia prosthesis	Axial (n=66)	1.40 ± 0.62
	Tilted (n=50)	1.63 ± 0.64
	Total (n=116)	1.52 ± 0.63
Metal-acrylic prosthesis	Axial (n=56)	1.73 ± 0.92
	Tilted (n=50)	1.74 ± 0.85
	Total (n=106)	1.74 ± 0.89

Table V. *KT around implants supporting full-arch prosthesis (mean ± standard deviation in mm).*

		Zirconia prosthesis	Metal-acrylic prosthesis
Peri-implant keratinized tissue (KT)	Axial	1.04 ± 0.71	1.07 ± 0.7
	Tilted	0.86 ± 0.78	1.18 ± 0.9
	Total	0.95 ± 0.74	1.12 ± 0.8

Choosing the right material is considered a determinant factor for the rehabilitation of the edentulous arch through dental implants (60). Factors as production and manipulation of the prosthetic material, the supporting framework and the veneering material should be evaluated (61, 62). Before the surgical and prosthetic treatment, especially in the pandemic actual situation, it is necessary, however, to evaluate the tissue healing and the inflammatory state of the oral cavity (63-65).

Both kinds of prosthetic materials gave optimal results when applied to full-arch rehabilitations (7). In particular, Malò (66) achieved a 100% survival rate in full-arch prostheses using reinforced composite resin and Tischler (28) achieved a 99.4% cumulative survival rate in full-arch prosthesis using predominantly monolithic zirconia over a 4-year period. Nevertheless, clinical data comparing the two materials are lacking. In a recent RCT study (37), Merli et al. compared ceramic vs composite veneering of full arch implant-supported zirconium frameworks reporting no difference between the two treatments in terms of complications, reduction of FMBS, patient preference and satisfaction. However, the comparison was limited to the same kind of zirconium framework. In order to compare restorations made with different framework materials, the present study evaluated various factors that can influence the clinical outcome of full-arch implant-supported prosthesis.

Despite the statistically significant differences concerning FMPS (p=0.0491), FMBS (p=0.0445) and PPD (p=0.0412) found between the two groups, implant survival rate seems not to be affected. As reported in literature, the prosthetic material does not influence implant stability and function (9-10). A recent study by Brignardello-Petersen showed a high survival of implants and fixed complete dentures after 3 years, regardless of material used to fabricate the implant-supported fixed complete dentures (69). Moreover, the mentioned differences did not influence the prosthetic survival and success rate of full-arch implant-supported prosthesis.

With the advent of CAD/CAM protocols, milled zirconia frameworks became quite popular in implant prosthodontics (11). Some authors noted a relative inaccuracy of metal frameworks fitting due to unprecise clinical or laboratory casting techniques (11). In the present study, even if the passive fit of the framework was not investigated primarily, no differences were found between CAD/CAM zirconia framework and metal framework in relation to implant and prosthetic survival. Prosthetic complications reported when speaking about full-arch implant-supported prosthesis are well known and include chipping of veneering material, prosthetic screw loosening or fracture, loss of retention, framework fracture and loss of access hole filling (32). Fracture or wear of the reconstruction materials were considered predictable risks when using resin-based supra-structure materials (5). In the present study the acrylic resin used as supra-structure wasn't affected by any of the cited complications probably thanks to the decennial experience of the team in full-arch rehabilitations.

In the last decade, many authors showed satisfactory treatment outcomes in the short-term for zirconia (26). In particular, the last studies focused on monolithic zirconia since the weak point of these rehabilitation appears to be the ceramic veneering. Being mostly monolithic, it is possible to restrict the veneering to nonfunctional area (26). This modification drastically reduced the incidence of ceramic chipping. In the current study, thanks to the limited veneering, it was achieved a 0% chipping rate reflecting the result obtained by Venezia in a recent retrospective study (27).

Even if the modern technologies would allow a fully digital workflow (70), the authors preferred a combined approach for the zirconia rehabilitation (23). This approach involved taking analogic impressions instead of using an optical scanner. The stone models are then digitalized through a laboratory scanner for zirconia rehabilitations as suggested by many authors (23). This method was chosen to standardize the clinical and laboratory procedures as much as possible.

In addition, the presence of a well-harmonized interface between soft tissues and implant abutments is necessary for the long-term survival of the implant and a successful prosthodontic treatment (71). Many authors compared different abutment

materials (72) but scarce data are provided on mucosal surfaces of the FCSs. From the current study, monolithic zirconia prosthesis showed a reduced plaque accumulation in comparison to metal-acrylic prosthesis. This result is consistent with published literature (73), especially with a recent RCT by Kanao in which resin surfaces obtained the worst result in terms of plaque accumulation (71). These findings may explain the other results of the present study, in fact, it is well known how plaque accumulation led to inflammation and tissue bleeding resulting in a greater PPD and FMBS for implants supporting metal-acrylic prosthesis compared to zirconia (74). Moreover, these results couldn't be explained by a difference in the width of the peri-implant keratinized mucosa as suggested by Schrott (75) since it resulted similar in both groups (p= 0.1454). Thus, oral hygiene must be considered when choosing a prosthesis material. To conclude, despite the present study showed stackable results between the two groups, further studies are necessary to confirm these promising data. An investigation regarding patient preference and satisfaction between the two restauration materials is missing. OHIP-21 and VAS questionnaires could be useful tools to perform this comparison.

Within the limitations of this short-term retrospective study, it can be concluded that predominantly monolithic zirconia is a feasible alternative to the conventional metal framework acrylic veneer in the realization of full arch implant-supported prosthesis. The rehabilitations with only facial porcelain veneering showed minimal biologic and mechanical complications demonstrating a 100% survival rate. Additional RCTs and long-term studies with at least 5 years of prospective follow-up are needed to validate these results.

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Anti-discoloration system: a new chlorhexidine mouthwash

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Chlorhexidine is defined as biocompatible, which is why it is used as a mouthrinse for the patient before starting dental procedures (2). It has the ability to bind well to teeth and mucous membranes and is released for twelve hours, which is why it is used as a treatment for gingivitis and also in post-operative wound healing. The long-term side effects of chlorhexidine are pigmentations. To remedy this, various types of anti-discoloration have been tried out over time. Nowadays there are other types of anti-discoloration systems such as, for example, in our study we used a test group containing an anti-discoloration system called SPPD. A single-center, prospective, double-blind randomized clinical trial on 84 patients. The investigated treatments consisted of 4 mouthwashes (CHX 0.12% SPDD alcohol free; CHX 0.20% SPDD alcohol free; CHX 0.12% alcohol free with ADS; CHX 0.20% alcohol free with ADS). Despite the limitations of the study, all the mouthwashes tested showed good efficacy in reducing the amount of plaque. Comparing the two experimental concentrations (0.12% and 0.20%) tested here demonstrates that the 0.20% chlorhexidine concentration slightly surpasses its 0.12% equivalent with regard to the PI and BI parameters. The SPDD is an innovative anti-discoloration system and gives the mouthwash a great taste.

Chlorhexidine is a microbial agent introduced for clinical use in the 1950s. It has the ability to destroy the bacterial membrane and is therefore also used for inanimate surfaces (1). Chlorhexidine is defined as biocompatible, which is why it is used as a mouthrinse for the patient before starting dental procedures (2). It can bind well to teeth and mucous membranes and is released for twelve hours, which is why it is used as a treatment for gingivitis and also in post-operative wound healing (3). However, according to the new scientific guidelines, Chlorhexidine alone is no longer sufficient for Covid-19, especially in the case of patients with previous chronic diseases of various origins (4-8). Indeed, chlorhexidine is a powerful antimicrobial but has a less effective effect on viruses; therefore, it is recommended to use another rinse with hydrogen peroxide or povidone iodine together with chlorhexidine as their actions become complementary and fully effective (4-9). However, further studies are needed to confirm this, and chlorhexidine even when combined with other mouth rinses should be used. However, the diatonic structure of chlorhexidine also has some side effects such as altered taste, and, above in particular, discoloration of the teeth and mucous membranes; the latter effect is the most commonly reported by long-term users of the chlorhexidine products (10-11). Therefore, in recent developments, some have added ADS, an anti-discoloration system that reduces side effects with a chemical formulation.

Key words: Chlorhexidine, mouthwash, discoloration, plaque, hydrogen peroxide, povidone iodine together

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Nowadays there are other types of anti-discoloration systems such as, for example, in our study we used a test group containing an anti-discoloration system called SPPD.

The aim of our study is to compare 4 types of mouthwash in two different chlorhexidine concentrations (0.12% and 0.20%) without alcohol and with ADS and SPPD. Firstly, the inflammatory indices were evaluated and then the level of discoloration.

Study design

A single-center, prospective, double-blind randomized clinical trial on 84 patients. The investigated treatments consisted of 4 mouthwashes (CHX 0.12% SPDD alcohol free; CHX 0.20% SPDD alcohol free; CHX 0.12% alcohol free with ADS; CHX 0.20% alcohol free with ADS). Each patient provided a written informed consent before participation. The protocol was approved by the Local Ethical Committee. Participants were chosen among patients seeking care at the Center for Dental Hygiene and Prevention at the Department of Dentistry, IRCCS San Raffaele Hospital, Milan, Italy. Patient admissibility for the study was determined based on the inclusion/exclusion criteria.

Patient selection

84 consecutive patients, 30 female and 54 males, aged between 20 and 45 years, were enrolled.
The inclusion criteria were:

- the absence of concomitant local or systemic pathologies.
- the absence of pregnancy.
- no medical history of allergy.
- no intake of substances (including hallucinogenic drugs) featured by a potential pharmacological interaction with the active ingredients to be tested.
- no intake of antibiotics and/or anti-inflammatory drugs in the 6 months prior to beginning of the study.
- no physical or mental disability such as might impair normal domestic oral hygiene practice.
- The exclusion criteria were:
- non-compliance with the inclusion criteria.
- smoking habit.
- the presence of fixed prostheses from upper right second premolar to upper left second premolar.
- the use of temporally prosthesis.
- the presence of orthodontic therapy.

The patients were randomly assigned to 4 groups, each of which consisted of 21 subjects. Assignment of the mouthwashes to the groups was randomized by a computer-generated sequence and double-blind. The concealment of the allocation was preserved by sequentially numbered sealed envelopes.

The Groups were as follows:

- Group 1: Chlorexhidine SPDD 0.12% without alcohol.
- Group 2: Chlorexhidine SPDD 0.20% without alcohol.
- Group 3: Chlorexhidine 0.12% without alcohol with ADS.
- Group 4: Chlorexhidine 0.20% without alcohol with ADS.

To provide standardization of home dental hygiene procedures, each patient was offered two 250 ml bottles of mouthwash, a medium-bristled toothbrush and a chlorhexidine-free toothpaste. Patients were instructed to wash their mouths with mouthwash for 1 minute twice a day half an hour after brushing their teeth. In order to avoid bleaching drinks and foods, they were also asked to abstain from consumption (3). At the first follow-up (T0), each patient filled out a medical history questionnaire and underwent a professional oral hygiene session, which revealed plaque and bleeding scores (O'Leary Plaque Index (PI), and Bleeding Index (BI) respectively) by means of a periodontal probe (DP-10, Hu Friedy, USA).

In order to follow the colour variations of the tooth surface during the test period, we verified the pre-treatment post-treatment colour of the maxillary right central incisor (the intrinsic technical characteristics of the spectrophotometer do not allow, due to its size and the alignment necessary to make the measurement, to operate on distal elements) by using a spectrophotometer (SpectroShadeTM MHT S.p.A. Medical High Technologies, Verona, Italy), which provides objective assessment of chromium, colour, value on the basis of the CIELAB system (Delta E). Successive follow-ups at 7 (T1), 14 (T2) and 21 (T3) days monitored plaque index (PI) and

bleeding index (BI) values, along with tooth colour.

During the entire duration of the study, all patients were supervised by a dental hygienist, who highly recommended proper oral hygiene at home and trained all patients on the appropriate use of their mouthwash. In addition, the conformity of the patients at home with the trial protocol was evaluated by questionnaires that the patients answered at each follow-up. Each one patient responded to questions on taste satisfaction.

Outcome measure

Outcome measure were assessed as primary outcomes PI and BI according to the Plaque Control Record and the Gingival Bleeding Index respectively.

Plaque Index (PI): it was assessed according to the Plaque Control Record. A dental hygienist, by means of a probe (PCP UNC 15, Hu Friedy, USA) detected the presence of plaque at six points on the tooth surface (disto-buccal, mesio-buccal, buccal and lingual, mesio-lingual, disto-lingual), revealed by plaque detector. The number of surfaces with plaque divided by the number of available tooth surfaces and multiplied by 100 expresses the percentage of plaque presence.

Bleeding Index (BI): index measuring the presence of gingival bleeding on gentle probing of six tooth surfaces (disto buccal, mesio-buccal, buccal and lingual, mesiolingual, disto-lingual). A dental hygienist, by means of a probe (PCP UNC 15, Hu Friedy, USA) assigned a positive score when bleeding happened within 10-15 seconds, running along the cervical surface of all teeth. The number of positive areas was divided by the number of areas tested, and the result was multiplied by 100 to express the index as a percentage. The absence/reduction of the gingival bleeding index was interpreted as an enhancement of the inflammatory status.

Delta E: the colour difference before and after treating the maxillary right central incisor, recorded according to the CIELAB system.

Randomization

A computer-generated list of random numbers was used to allocate participants to the four groups. The randomization sequence was generated by using specific statistical software (SPSS 17.0, SPSS Inc., Chicago, Illinois, USA). A dental hygienist (blinded and calibrated at baseline) carried out patient recruitment, professional oral hygiene procedures and outcome evaluation. Another dental specialist made the allocation to each group for mouthwash preparation; and each patient was given mouthwash in an unmarked bottle according to the randomization list.

Blinding

The treatment identity was blind to the practitioner who conducted patient recruitment and outcome evaluation, the data analysts, and the participants. Only the practitioner who performed the group allocation was conscious of the allocated group.

Statistical analysis

Dedicated software (SPSS 17.0, SPSS Inc., Chicago, Illinois, USA) was used to perform the statistical analysis. The data were subjected to the Kolmogorov-Smirnov test to assess the normality of the distribution. Subsequently, each of the study variables (PI, BI and Delta E) was subjected to multivariate analysis of variance and Tukey's post hoc test for multiple comparisons. For all statistical tests, statistical significance was set at α=0.05. The initial null hypotheses were "there is no association between the different mouthwash formulae used and the change in PI and BI; there is no associations between the different mouthwash product formulations used and the change in tooth colour".

RESULTS

Kolmorogov-Smirnov confirmed the normality of data distribution ($p>0.05$). There are no significant differences in modifications both of bleeding indices (in the statistical analysis); the are no significant differences in modifications of plaque indices; moreover, all patients report less long-term discoloration with the new SDPP system and a more pleasing taste

As show in Table I all the test formulations were efficient in enhancing the periodontal indices here analyzed. Mouthwashes that contain 0,20% chlorhexidine reduce BI more than 0,12 chlorhexidine,

with a medium reduction of 85% (table I); In fact, the group 1 and 2 achieve a better result in term of PI and BI, respectively 0.12% combination 49% and 0.20% combination 55% in PI and 0.12% combination 9% and 0.20% combination 87% in BI.

Furthermore, all mouthwashes can be defined as efficiency in terms of PI. The group 2 and 4 are more efficacy in term of BI. In general mouthwashes with SPDD have the better results but non significatively. Comparison of T1 with T0 data point out that all of the tested mouthwashes demonstrate the efficacy of the chlorhexidine molecule, in terms of reduction both in PI and BI. The group 2 mouthwash was the most effective in reducing PI and obviously its high ability in reducing BI.

The pre- and post-procedures data for pigmentation, which we take with a spectrophotometry, showed changes in Delta E, very similar between the 4 groups; moreover, the test groups (1 and 2) had better results in term of Delta E. Most pigmentations were found in the control groups (3, 4).

DISCUSSION

Despite the limitations of the study, all the mouthwashes tested showed good efficacy in reducing the amount of plaque. Comparing the two experimental concentrations (0.12% and 0.20%) tested here demonstrates that the 0.20% chlorhexidine concentration slightly surpasses its 0.12% equivalent regarding the PI and BI parameters. No statistically significant differences were found between the two types of mouthwash in terms of plaque and bleeding index, both alcohol-free.

There are differing views on alcohol-containing mouthwashes in the literature. Recent studies have shown that the high alcohol content in long-acting mouthwashes may potentially increase the risk of oral and oropharyngeal cancers (12-14). Indeed, chlorhexidine is considered the antibacterial "gold standard" and it is used in many fields of dentistry. Chlorhexidine is commonly used in non-causal therapy in the treatment of periodontitis and implant maintenance (15-17). Commonly used as a home oral hygiene aid and as a mouthwash of choice before starting oral hygiene procedures (18). However, considering that antiviral power of chlorhexidine is rather low, and that the literature stresses the involvement of the mouth in covid-19 pathology, it should be accompanied by another rinse (povidone iodine, hydrogen peroxide) before starting dental procedures for the safety of the patient and the operator (19-20).

However, in this study we analyzed two mouthwashes with chlorhexidine as an excipient with two different color protection systems; a control group (3-4) with ADS already described in the literature and the test group (1-2) with an innovative protection system and a very pleasant minty taste, as reported by the patients.

A meta-analysis shows that there is no significant effect of ADS on tooth stains in situations where mouthwash is used in addition to toothbrushing (21). While other authors point out that there are no statistically significant differences in terms of plaque and bleeding indices, but the test group with ADS had less staining than the control group during a 15-day period of use (22, 23).

This study lays the groundwork for further studies investigating the potential of the SPDD system, as it has been shown to be effective for pigmentations and to offer excellent patient-perceived taste.

Table I. *Test formulations for periodontal indices.*

Group	PI	BI
1 SPDD 0.12%	49%	9%
2 SPDD 0.20%	55%	87%
3 ADS 0.12%	48%	7%
4 ADS 0.20%	53%	82%

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How to consider implant-prosthetic rehabilitation in elderly patients: a narrative review

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With the beginning of the twenty-first century, population aging has emerged as a major worldwide phenomenon. The dentist must respond to this demographic change by taking into consideration the possibility of restoring oral function in the elderly patient with the use of dental implants. This article aims to provide a narrative review of the literature regarding the implant survival rate in geriatric patients and the relative importance and advantages of implant-prosthetic rehabilitation through a scientific analysis of the literature through online databases and dental journals. Tooth loss can have a significant impact on patients' oral function and significantly affects quality of life, self-esteem, and nutritional status. Although many studies in the past have reported that implant success is age-dependent, more recent studies suggest that they are safe and predictable for geriatric patients, improving quality of life, with similar results to those of younger age groups. Advanced age does not necessarily represent a contraindication for implant placement and osseointegration and success is influenced by patient and site-specific factors. Aging is a process that affects each patient differently, consequently, there should be a specific therapeutic approach for everyone, which must consider the functional and cognitive status of the patient, his medical condition, and his social situation-economic and motivational.

The elderly population in the world is significantly increasing (1). This occurrence could be associated with in-depth study of multiple diseases and drugs and consequent improvement of the general health conditions and medical assistance (2). However, recently this has changed profoundly globally due to the Covid-19 pandemic, and we should review the world data once it is over (3).

Aging involves anatomical-functional and cognitive changes that could also have impact on oral cavity, affecting dental treatments (4, 5). According with the increase of average age, partial or total edentulism' rehabilitation could represent a an increasingly common procedure (6). the covid-19 pandemic certainly did not favor this condition; in fact, a recent study points out that especially in the most severe cases, mostly elderly people, the salivary glands are affected by the new sars-cov-2. This causes an alteration in the normal function of the salivary glands, possibly resulting in a disruption of the salivary function that physiologically protects the oral cavity from external agents (7). The loss of dental elements determines the lack of a functional stimulus that is reflected on the jaw bones in terms of resorption (8, 9). As reported by Pietrokovski and Massler in 1967 and by Schropp in 2003, the process also occurs with the loss of the single element: the bucco-lingual/palatal dimension of the alveolar process is reduced by about 30% after 3 months and by 50%

Keywords: aging, dental implants, edentulous jaws, elderly patients, gerodontology, implant survival, survival rate.

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after 12. Furthermore, approximately one year later, at a vertical level there is a reabsorption of about 1.2 mm greater at the level of the vestibular wall, which is thinner, compared to the lingual/palatal one (10, 11).

In the case of total edentulism, the progressive reabsorption of the maxillary bones, which occurs in the centripetal direction in the upper jaw and in the centrifugal direction in the mandible, leads over time to an alteration of the inter-maxillary relationship and patient' vertical dimension (12).
In both cases, the loss of a single element, of more or of the entire arch, has an important impact both on the subject and on the rehabilitation difficulties of the dentist (13, 14, 15). The partially or totally edentulous subject is often induced to a reduction in social relations, caused by difficulties of a masticatory, phonetic and aesthetic type. From a rehabilitation point of view, the dentist should consider several factors: patient needs, degree of atrophy, inter-maxillary relationship, vertical dimension, and aesthetic appearance (16-18). Although the application of removable prostheses still represents a possible therapeutic alternative for replacing missing teeth, the use of fixed implant-supported restorations could be considered a possible alternative, giving the patient functional and aesthetic advantages (19).

The purpose of this study was to evaluate the importance of implant-prosthetic rehabilitation in geriatric patients, the advantages it entails on general health and their survival rates.

MATERIALS AND METHODS

The following review includes all the studies carried out on humans and referred to geriatric patients (≥ 65 years) with and without systemic conditions, undergoing rehabilitation with the aid of dental implants. The databases used for the bibliographic research were MEDLINE (PubMed), EMBASE and CENTRAL. Dental journals were searched for those articles that were not available on online databases. In addition, the ResearchGate research platform was used to maximize the number of significant studies. The results highlighted in this review were obtained from this literature search.

RESULTS

The importance of oral rehabilitation in geriatric patient

Although there have been advances in improving oral hygiene, both in patient education and motivation (20, 21), and in instrumental techniques (22, 23), restorative techniques (24) and health care improvement in developed countries, tooth loss is still frequent. For this reason, it is important to pay attention to the oral rehabilitation of the elderly patient, especially analyzing the possibility of considering implant-prosthetic rehabilitations as an effective therapeutic alternative (24). However, at present, dental implants in older people are minimally used.

Similar results were achieved in a study conducted in Switzerland on patients with an average age of 81, in which the attitudes of the elderly concerning dental implants were studied. The conclusion of the study was that the knowledge of dental implants by older people is limited, and the greatest concerns relate to the cost, the lack of perceived need and advanced age (25). Elderly patients, compared with younger patients, often place a different value on the potential benefits of treatment, based on medical, social, cultural, and economic considerations. It remains of fundamental importance to involve the patient in the therapeutic decision-making process as it increases the levels of satisfaction with the treatment (26). The real benefits of the treatments according to the patients could be evaluated with indices that allow to monitor improvement the quality of life in relation to oral health (OHRQoL). Compromised oral health affects self-esteem, self-image, causes other health problems, discourages social interaction, and leads to pain, stress, or depression, this can be measured (27).

The most used indices to measure the social impact of dental disease could be summarized as follows:
OHIP (Oral Health Impact Profile) questionnaire, used to assess the patient's perception of the social impact of poor oral health (28).
GOHAI questionnaire (Geriatric Oral Health Assessment Index), used to assess the impact of oral health problems in the elderly population (29).

As confirmed by OHRQoL it has been improved by providing elderly patients with rehabilitations with single crown prostheses, fixed partial prostheses, or fixed or removable total prostheses supported by implants (30, 31).

Implant prosthetic rehabilitation advantages

The advantages of implant-supported prostheses in elderly patients could be significant especially in completely edentulous individuals who have had traditional total prostheses for several years (32).

Over time, most edentulous patients with conventional total prostheses experience functional problems, especially this occurs at the level of mandibular prostheses. The same often report lack of stability and retention, as well as decreased chewing ability (33, 34). Numerous clinical studies have affirmed that patients with implant-supported mandibular overdentures are significantly more satisfied than patients with a conventional total prosthesis, equally in the short and long term (35, 36). The principles that allow the stability of the conventional total prosthesis (physical retention, muscle control and occlusal stabilization) are enhanced when a conventional total prosthesis is converted into an implant-supported overdenture (IOD) (37).

Studies of several populations have shown that quality of life levels could be significantly higher in patients with IOD (38). The additional retention and stability provided by the implants replace the need for muscle skill and prevent displacement of the prosthesis during speech and chewing. In addition to the greater retention and stability provided by implant-supported prostheses compared to conventional full dentures, there are other advantageous aspects to consider, such as prevention of bone atrophy, effectiveness of chewing and occlusal strength, nutritional status, aesthetic aspects, and psychosocial aspects (39, 40). With careful diagnosis and treatment planning, elderly patients could excellent candidates for dental implants (41). Although implants-prosthetic rehabilitation success could be influenced by patient-related and site-specific factors, Advanced age could be not a contraindication for dental implant placement and osseointegration (42).

Medical considerations on implant therapy in geriatric patients

Thanks to improvements in health care and medical advances, life expectancy has increased, even in the presence of chronic diseases, resulting in a higher incidence of elderly patients with multi-organ diseases (43). With advancing age, progressive biological and physiological changes influenced by psychosocial, genetic, functional, and nutritional factors, physical and mental disabilities and side effects of drugs administered to treat several medical conditions could occur (44).

As suggested by a cross-sectional study of more than 162.464 people of all ages, more than one in ten of the total study population had two or more chronic conditions such as diabetes and cardiovascular diseases, which increase proportionally with increasing age (45). The increases in life expectancy could be associated with several chronic diseases such as diabetes mellitus, cancer, mental disorders, cardiovascular and neurological pathologies (46). According with the increasing incidence of these chronic conditions and a multimorbidity associated with the enhancement of average age, the administration of multiple drugs is an increasingly common condition (47, 48).

A study points out that the European population takes on average 6 drugs a day the dentist is required to consider the presence of any systemic diseases and associated drugs and to adapt the therapy to the patient's needs, his ability to maintain hygiene and compliance (49). The degree of control of systemic diseases, rather than the presence of such conditions, is the most important consideration in implant therapy' success and survival; the real contraindications to implants placement in elderly patients could be considered acute or decompensated diseases (50). Indeed, many studies demonstrated an outstanding success rate in patients affected by systemic disease, like HIV positive ones and Sjogren Syndrome (51-54). Moreover, preimplant bone augmentation techniques have to be considered also in elderly patients, due to the increased success rate in patients with severe atrophic maxilla (55-58). In the same way, some papers hypothesized the further use of stem cells, reporting encouraging results (59,

60). In the end, immediate loading techniques must be considered, due to the reduction of time of treatments and, consequently, less invasiveness (61, 62).

Bibliographic data supporting implant-prosthetic rehabilitation in geriatric patients

Implant success and survival are well documented for younger age cohorts, but less is known about the effect of age on osseointegration and long-term implant survival (63). Malm et Al. in their retrospective case-control study shown several factors associated with implant failure. According with their results, systemic diseases, which could increase according with increasing age, could be considered as potential risk occurrence (64). Kondell and Al. compared the success rate of 284 implants in 53 elderly patients, with the success rate of 183 implants in 36 younger patients, aged 18 to 54 years. The implants mainly maintained partial or complete fixed prostheses and some overdentures. After an observation period of 1 to 6 years, the overall success rate in elderly patients was at least the same, even marginally better, than in the younger group (65). Boboeva et Al (66), in their retrospective cohort study compared implant survival rate in the older (≥65 years) and younger (<65 years) patients. A total of 628 implants in 308 older patients and 1904 implants in younger was evaluate. In addition to several conditions as smoking, systemic diseases and implants features were considered to obtain a uniform sample. At eleven years follow-up the implants survival rate was, in older and younger patients respectively, was 95.3% and 93.9%. No statistically significant differences identified between groups.

A retrospective study reported an implant survival rate of 95% over an observation period of up to 17 years for an elderly cohort (67). Etöz et Al. Reported an implant survival rate of 95.4% in the elderly population over a 5 to 11-years observation period (68). These implant survival rates in the elderly population could be compared to survival rates published by Yang et Al (69). As reported by Schimmel et Al. in their literature review, a high implant survival rate in geriatric patients aged 75 years or older could occur (70) 1- and 5-year survival rates are like those reported in younger cohorts (71, 72) regardless of clinical indication or loading protocol (73-76) 1-year survival rates relate to implants failing to osseointegrate and, therefore, it could be suggested that older age does not appear to adversely affect osseointegration.

CONCLUSION

With the limitations of this study, implant-prosthetic rehabilitation in geriatric patients could be considered a predictable treatment option with a high implant survival rate. The functional and psychosocial benefits of such rehabilitation should outweigh the relative risks associated with common medical conditions and their respective therapies. However, clinical decision making must not be based only on survival rate, but rather on the patient's subjective gains in quality of life, comfort and overall well-being which should outweigh the associated risks.

Implant rehabilitation needs to be assessed in a relevant manner. In fact, an implant can be perfectly osseointegrated, but a patient with complex implant prostheses who depends on help for the activities of daily life may not have adequate care, since management is too complex. This could not be considered an effective treatment in this type of patient.

Further studies on the combined effect of age and chronic disease would be needed, as knowledge of the interactions of old age, medical conditions and implant survival would be essential for clinical decision making and meticulous reporting of medical conditions. in participants in elderly studies, it should be encouraged for future implant survival studies.

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