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3D Technologies In Oral And Dental Prostheses

Use of 3D technologies for planning extra-short implants insertion.

One stage technique vs two stage technique: a multicentre study.

Giulia Ambrogio

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Supervisors

Prof. Stefano Carossa, Supervisor
Prof. Elio Berutti, Supervisor
Dott. Federico Mussano, Co-Supervisor

Doctoral Examination Committee:

Prof. Paolo Pera, Referee, University of Genova

Prof. Santo Catapano, Referee, University of Ferrara

Prof. Massimo Corsalini, Referee, University of Bari

Politecnico di Torino
May 31, 2021

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Giulia Ambrogio
Turin, May 31, 2021

Summary

3D technologies in the dentistry have developed in recent years, bringing improvements in all fields.

The use of implant planning software allows a predictable and simplified approach to the surgical phase and subsequent prosthetic phases, even in complicated anatomical situations.

The aim of this dissertation is to present a surgical and prosthetic protocol to be applied in situations of important bone resorption, without using surgical techniques that are difficult to learn, but using extra-short implants and modern technologies to achieve a clear and simplified planning.

This virtual planning protocol can be used to plan surgery in all anatomical situations, from single tooth rehabilitation to full arch cases.

The extra-short implants have shown long-term results of implant stability absolutely comparable to conventional length implants, providing a valid alternative to complex bone regeneration techniques.

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A special thanks to my parents and all my family for the essential support.

To my family

What we think, we become.

Buddha

Contents

Summary ---------- 1
Acknowledgement ---------- 2
List of Tables ---------- 6
List of Figures ---------- 7
Introduction ---------- 7
1.1 3D technologies in dentistry ---------- 7
1.2 3D implant planning ---------- 7
1.3 Precision and accuracy ---------- 8
1.4 Definition of extra-short implants ---------- 8
1.5 Indications for the use of extra-short implants ---------- 9
1.6 Comparison between one-stage and two-stage technique ---------- 10
Purpose of the study ---------- 12
2.1 Null hypothesis ---------- 12
Materials and methods ---------- 13
3.1 Patient recruitment ---------- 13
3.1.1 Inclusion criteria ---------- 13
3.1.2 Exclusion criteria ---------- 13
3.1.3 Type of implant inserted ---------- 13
3.2 Virtual planning and evaluation of bone densitometry ---------- 14
3.3 Surgical protocol ---------- 15
3.4 Prosthetic protocol ---------- 17
3.5 Radiographic measurements ---------- 18
3.6 Evaluation of implant stability ---------- 20
3.7 Evaluation of periodontal indexes ---------- 21
3.8 Statistical analysis ---------- 21
Results ---------- 22
4.1 Bone resorption ---------- 22
4.2 Implant stability ---------- 23

4.3 Periodontal indexes ---24
Discussion and conclusions ---26
References ---28

List of Tables

Tab. 1 Bone resorption: Control group (two stage) vs Test group (one-stage).....22
Tab. 2 Implant stability: Control group (two stage) vs Test group (one stage). 23
Tab. 3 Periodontal indexes: Control group (two stage) vs Test group (one stage). 24

List of Figures

Fig. 1 Extra-short BTI implant. 13
Fig. 2 Virtual planning with BTI Scan®..14
Fig. 3 Hounsefield scale with BTI Scan ®. 14
Fig. 4 Implant milling sequence (from BTI manual)..16
Fig. 5 First Stage surgery. 16
Fig. 6 Multi-Im from BTI catalog. 17
Fig. 7 Gum healing and prosthetic rehabilitation. 18
Fig. 8 Example of radiographic measurement from Adobe Photoshop CC 2019® software. 19
Fig. 9 Example of radiograph T0, T3, T6, T12..19
Fig. 10 The ISQ scale (from Osstell®). 20
Fig. 11 Example of use of Osstell®: a. SmartPeg screwed to the implant, b. magnetic pulsations, c. Osstell® monitor. 21
Fig. 12 Histogram of bone resorption values in the two groups in comparison ...23
Figura 13 Histogram of ISQ values in the two groups in comparison 24
Figura 14 Histogram of PD values in two groups in comparison. 25

Introduction

1.1 3D technologies in dentistry

In the last few years, various technologies useful for clinical practice have developed in the dentistry: from intraoral scanners for digital impression to software for the design of prosthetic products, allowing a fluid and simplified digital workflow.

In all fields of dentistry, useful software for clinical practice are being developed: in Endodontics the use of three-dimensional imaging through Cone Beam to plan the correct treatment plan, as well as the printing of 3D models for teaching, has become of fundamental importance[1]; in orthodontics it is possible to view the result of the orthodontic treatment starting from the digital impression and print the treatment templates (Invisalign®).

In implantology, it has now become essential to be able to plan surgery correctly through software that reconstructs three-dimensional models from DICOM files obtained from a simple CBCT. It is of fundamental importance to identify the vital anatomical structures, to correctly measure the bone thickness and to be able to analyze the bone quality before performing the surgery, so as to be able to adapt the surgical technique to the individual case and choose the best implant line. The practice of "guided surgery" is developing more and more: templates obtained from virtual planning allows optimal insertion of the fixtures with flapless technique[2].

Finally, with 3D printing technology it is now possible to reproduce anatomical structures useful for didactic purposes or in maxillofacial surgery for post-trauma reconstruction interventions or in cancer patients[3-4].

1.2 3D implant planning

The first step in implant rehabilitation involves proper planning of the surgical procedure through a careful study of patient's radiographic examinations. Modern technology is an important aid because it allows the patient's CBCT DICOM files to be uploaded to software able to reconstruct the bone volumes to be analyzed in three dimensions. The clinician has the opportunity to evaluate not only the bone

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[1] Pratik Shah, B S Chong . 3D imaging, 3D printing and 3D virtual planning in endodontics. Clin Oral Investig. 2018 Mar;22(2):641-654.

[2] Jan D'haese, Johan Ackhurst, Daniel Wismeijer, Hugo De Bruyn, Ali Tahmaseb. Current state of the art of computer-guided implant surgery. Periodontol 2000. 2017 Feb;73(1):121-133.

[3] A Dawood , B Marti Marti , V Sauret-Jackson, A Darwood. 3D printing in dentistry. Br Dent J. 2015 Dec;219(11):521-9.

[4] Norman Moser, Petra Santander, Anja Quast. From 3D imaging to 3D printing in dentistry - a practical guide. Int J Comput Dent. 2018;21(4):345-356.

quantity but also the quality, to carefully measure the length of the appropriate implant fixture, in full compliance with the vital anatomical structures, and to simulate its insertion.

The correct insertion of implants in order to obtain the best result both from a functional and an aesthetic point of view has always been the most critical step in all implant-prosthetic rehabilitations. The introduction of software for 3D visualization and simulation of implants positioning has led to a simplification in the design and an increased safety in precision during the surgical procedure[5].

1.3 Precision and accuracy

Despite possible errors can occur and accumulate during the various steps, recent studies have shown that computer-guided implantology is highly precise with minimal discrepancies between planning and reality:

• At the level of the implant head, the deviations are 0.43mm in the buccal-lingual direction, 0.46mm mesio-buccal and 0.53mm crown-apical;

• At the level of the apex of the implant they are slightly higher: 0.7mm buccal-lingual, 0.63mm mesio-distal, 0.52mm coronal-apical;

• The angular deviation is 3.53 °.

There was no statistically significant difference between upper and lower jaw[6].

Finally, although the procedure is very safe, there are in vitro studies that show that guided implant insertion is statistically less accurate if performed by operators with minimal experience compared to experienced surgeons. It can be concluded that this apparently simple technique actually requires an excellent knowledge of surgical and implant procedures[7].

1.4 Definition of extra-short implants

Due to an important bone resorption, the amount of residual bone is often inadequate for the ideal insertion of an implant. Several techniques have been developed over the years, including guided bone regeneration (GBR), block grafts, sinus lifts and bone distractions, to increase the bone vertically and horizontally. However, all these procedures are not widely adopted by clinicians because they are technically difficult and involve an increase in morbidity for the patient and a lengthening of the intervention times, as well as an increase in costs, all related to a poor predictability and high failure rate . As a result, simplified therapeutic

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[5] Vasak C., Kohal R.J., Lettner S., Rohner D., Zechner W. Clinical and radiological evaluation of a template-guided (NobelGuide) treatment concept. Clinical and Oral Implant Research 2012; 0: 1-8.

[6] Vasak C., Watzak G., Gahleitner A., Strbac G., Schemper M., Zechner W. Computed tomography-based evaluation of template (NobelGuide™)-guided implant positions: a prospective radiological study. Clinical and Oral Implant Research 2011; 20: 1-7.

[7] Cushen S.E., Turkyilmaz I. Impact of operator experience on the accuracy of implant placement with stereolothographic surgical templates: an in vitro study. The Journal of Prosthetic Dentistry 2013; 109: 248-254.

alternatives have been developed, such as the use of short and extra-short implants or tilted implants[8].

Dental implants can be classified according to their length:

- Extra-long: ≥ 20 mm
- Long: 15-18 mm
- Medium: 10-13 mm
- Short: 6.5-8 mm
- Extra-short: ≤ 6.5 mm

They can also be classified by diameter:

- narrow platform: ≤ 3,5mm
- regular platform: 3.8 - 4.2 mm
- wide platform: ≥ 4.5 mm

It has been scientifically proven that implants with a larger diameter, for the same length, are able to better withstand chewing loads and, by increasing the contact surface with the bone, better distribute the forces on the peri-implant bone[9]. This may be more important in short implants to achieve good long-term clinical results[10].

1.5 Indications for the use of extra-short implants

The use of extra-short implants is recommended in case of important vertical bone resorption but in the presence of a good width, which allows the insertion of the fixture inside the crestal bone while maintaining a portion of circumferential bone to the implant of 1,5mm.

The study of Ivanoff (1997)[11] showed that for osseointegration the diameter of the implant is a more important factor than the length, measuring osseointegration as a counter-tightening force. Many studies based on FEM (Finite Element Analysis) have also highlighted how the bulk of the masticatory forces are distributed to the

[8] A. Monje, Jia-Hui Fu, Hsun-Liang Chan, F. Suarez, P. Galindo-Moreno, A. Catena, Hom-Lay Wang. Do Implant Length and Width Matter for Short Dental Implants (<10 mm)? A Meta-Analysis of Prospective Studies. J Periodontol 2013; 84: 1783-1791.

[9] Sato Y, Shindoi N, Hosokawa R, Tsuga K, Akagawa Y. A biomechanical effect of wide implant placement and offset placement of three implants in the posterior partially edentulous region. J Oral Rehabil 2000; 27: 15-21.

[10] Anitua E, Tapia R, Luzuriaga F, et al. Influence of implant length, diameter and geometry on stress distribution: A finite element analysis. Int J Periodontics Restorative Dent 2010;30:89-95.

[11] Ivanoff CJ, Sennerby L, Johansson C, Rangert B, Lekholm U. Influence of implant diameters on the integration of screw implants. An experimental study in rabbits. Int J Oral Maxillofac Surg. 1997; 26(2):141-8.

first turns of the implant, in particular after the first 3 turns the concentration of forces decreases significantly[12].

The results of these studies initially met with a lot of skepticism. In particular, there were (and are) the most contested aspects: the unfavorable crown-to-root ratio and the very high Crown Height Space (CHS).

Indeed, the study of Anitua (2014)[13] highlighted how a high crown-to-implant ratio can lead to a greater bone loss when associated with a high CHS. However, the crown-to-implant relationship alone is not directly correlated with less or greater bone loss. On the other hand, it would be a mistake to think that in implant-prosthesis the minimum crown-root proportions of the prosthesis on a natural tooth must be respected, of 1: 2 if it is a bridge abutment or 1: 1 in single element. In fact, the attachment to the bone of an implant is completely different, as it does not have the interposition of the periodontal ligament, which allows the transmitted forces to be attenuated along the entire root. In the case of the implant, this does not happen, as it is rigidly anchored to the surrounding bone, and therefore the forces are discharged more in the first threads, as amply demonstrated by FEM studies. This would lead to increase the crestal bone resorption in standard diameter implants, but by increasing the diameter it is possible to significantly decrease the tension. That is: we can compensate for the increase in the vertical crown-to-implant ratio by increasing the implant diameter (obviously within certain limits).

The Crown Height Space is different: that is the distance between the bone crest and the occlusion plane, and represents the needle in the balance for the choice or not to use short or extra-short implants. The study showed that CHS values greater than 16 mm lead to significantly greater bone loss than in the lower values.

1.6 Comparison between one-stage and two-stage technique

When planning an implant surgery, the surgeon can adopt two different techniques for the healing of the gingiva around the implant fixture:

- One-stage technique: at the end of the operation, a healing cap of variable height (based on the thickness of the mucosa) is screwed onto the head of the implant, which allows the gingiva to heal during the osseointegration phase, without the need for other surgery before the prosthetic phase.

- Two-stage technique: at the end of the operation a cover screw is screwed onto the head of the implant and the gingiva is sutured above, the "submerged" fixture undergoes the osseointegration phase. After the healing period, the so-called

[12] Anitua E, Orive G. Finite Element Analysis of the Influence of the Offset Placement of an Implant-supported Prosthesis on Bone Stress Distribution. J Biomed Mater B Apple Biomater. 2009; 89:275-281

[13] Anitua E, Alkhraist MH, Piñas L, Begoña L, Orive G. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. Int J Oral Maxillofac Implants. 2014; 29(3):682-9.

"second surgical stage" is carried out, which involves reopening the gum to expose the implant head, screwing the healing cap.

A randomized case-control study of 140 patients (Gheisari et al, 2017) . establish that, although the one stage technique appears to ensure better aesthetic and functional results, there are no statistically significant differences between the two techniques as regards bone loss[14]. A systematic review (Gerard Byrne, 2010) concludes that there are no statistically significant differences between the two techniques.[15]. In another systematic review, Esposito comes to the same conclusions.[16]. These studies all referred to conventional length implants.

From the various studies it can be concluded that the one-stage technique is preferable to the two-stage one, in order to avoid a second surgery. The clinician will have to carry out a careful and correct planning of the surgery: the initial incision will have to be made by evaluating the thickness and quality of the gingival, to allow ideal healing around the healing abutment.

[14] Gheisari R, Eatemadi H, Alavian A. Comparison of the Marginal Bone Loss in One-stage versus Two-stage Implant Surgery. J Dent (Shiraz). 2017; 18(4):272-276.

[15] Byrne G. Outcomes of one-stage versus two-stage implant placement. J Am Dent Assoc. 2010; Oct;141(10):1257-8.

[16] Marco Esposito, Maria Gabriella Grusovin, Yun Shane Chew, Paul Coulthard, Helen V Worthington. One-stage versus two-stage implant placement. A Cochrane systematic review of randomised controlled clinical trials. Eur J Oral Implantol. Summer 2009;2(2):91-9.

Purpose of the study

The pre-surgical evaluation using 3D software is essential to plan a correct implant insertion, even without necessarily using a flapless guided surgery technique. Our goal is to leverage new technologies to try to simplify surgical and prosthetic protocols. To date, the critical points in an implant rehabilitation in our opinion are:

- How to deal with cases with important vertical bone resorption in a simple and predictable way

- How to minimize patient morbidity

For this reason, we decided to study a protocol with digital planning for the insertion of extra-short implants, comparing the one-stage and two-stage techniques.

The aim of the study is to evaluate if there are statistically significant differences at 1 year of follow-up in terms of stability, bone resorption and peri-implant indixes between extra-short BTI implants, inserted with one-stage or two-stage technique and loaded after three months with metal-composite screwed bridge.

2.1 Null hypothesis

There are no statistically significant differences in terms of stability, bone resorption and peri-implant indices between implants inserted with one stage or two stage technique. What has been seen in the literature for conventional implants is also valid for implants with a length of less than 6.5[17].

[17] Gabriel Hernández-Marcos, Mariela Hernández-Herrera, Eduardo Anitua. Marginal Bone Loss Around Short Dental Implants Restored at Implant Level and with Transmucosal Abutment: A Retrospective Study. Int J Oral Maxillofac Implants. Nov/Dec 2018;33(6):1362-1367.

Materials and methods

3.1 Patient recruitment

Patients were recruited from the Prosthetics Department of the Dental School of Turin and the Prosthetics Department of the University of Genova. Since December 2018, 20 patients have been recruited (8 men and 11 women), aged between 48 and 81 years.

All the patients recieved 2 implants, one with one stage technique (considering the test implant) and one with two stage technique (considering the control implant).

The assignment of the implant site to the surgical technique was random.

3.1.1 Inclusion criteria

Patients had to have unilateral or bilateral distal edentulism (Kennedy class I or II) of at least two teeth.

3.1.2 Exclusion criteria

Patients did not have to have systemic contraindications to surgery.

3.1.3 Type of implant inserted

Extra-short BTI implants (5.5 or 6.5 mm length, 5 or 5.5 mm diameter) were used(FIG.1).

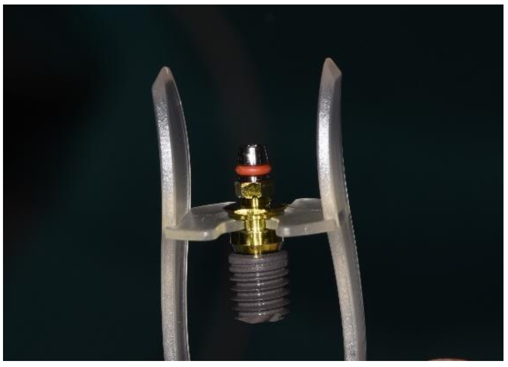

Fig. 1 Extra-short BTI implant.

3.2 Virtual planning and evaluation of bone densitometry

Before surgery, a virtual surgical planning was created using the BTI Scan® software, which allows you to simulate the insertion of different types of implants, taken from a virtual library, loading the patient's CT Dicom files. This planning served as a model in the surgical phase (FIG.2).

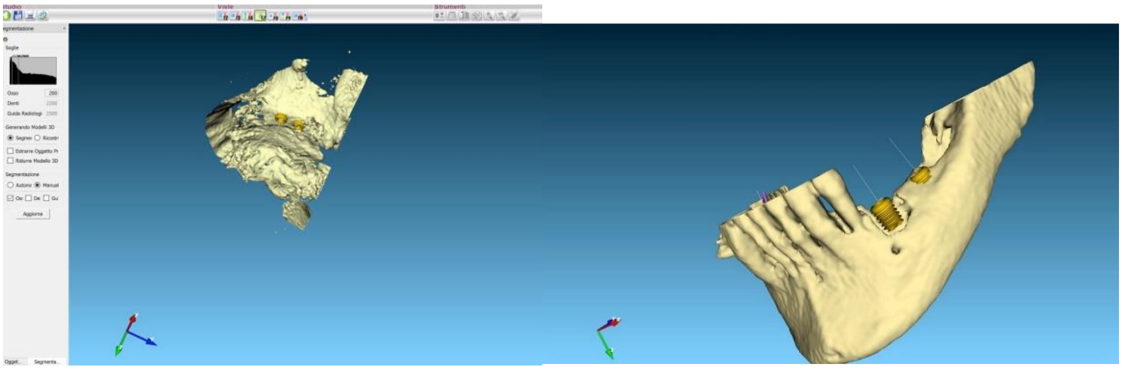

Fig. 2 Virtual planning with BTI Scan®.

It is possible to measure the Hounsefield density of the implant site (FIG.3), that allows you to modify the drilling protocol in relation to the type of bone. At the time of surgery, the bone quality of the site is assessed by the surgeon by comparing the data obtained from the software with the surgeon's manual perception.

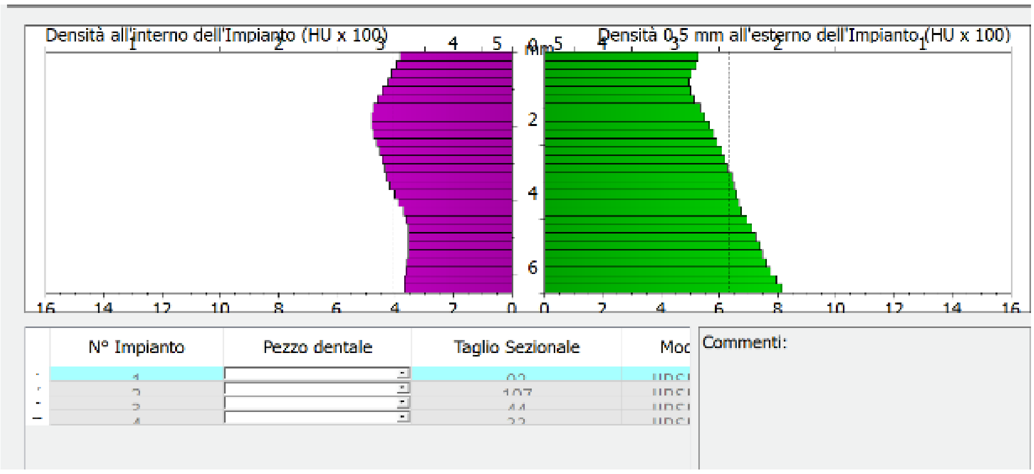

Fig. 3 Hounsefield scale with BTI Scan ®.

Finally, it is possible to print the three-dimensional models of the edentulous crests for a simulation of the intervention for didactic purposes and to test the operative sequences.

3.3 Surgical protocol

The protocol for the insertion of extra-short BTI implants is characterized by a biological milling: except for the first drill, all subsequent ones of increasing diameter are used at low speed without irrigation, collecting the residual bone between the blades. The collected bone is then placed in the implant site to promote healing. For drilling without irrigation, the number of revolutions should be approximately 125 rpm.

Another characteristic is the frontal cutter, the last to be used, at a working length of 1-2 mm less than the length of the implant. It is a cylindrical cutter with a non-cutting tip. The diameter to be used depends on the diameter of the implant and the bone type: the lower the bone density, the greater the difference in diameter between the last cutter used and the implant must be, so that the implant must exercise greater compression to have primary stability.

To establish the diameter of the frontal cutter to be used, it refers to the classification of bone density developed by Anitua in 2014[13], which incorporates the classification of Lekholm and Zarb of 1985, adding two further types of bone in addition to the four of the previous classification.

We have 6 categories:

- Type 0: from 1400 to 1200 U.H.

- Type I: from 1200 to 1000 U.H.

- Type II: from 1000 to 850 U.H.

- Type III: 850-500 U.H.

- Type IV: 500-400 U.H.

- Type V: 350-100 U.H.

In types 0 and I (bone quality 1), the gap between the frontal cutter and the implant to be inserted will be 0.2-0.5 mm; in types II and III (bone quality 2), 0.5-0.75 mm; in types IV-V (bone quality III), 1-1.5 mm (FIG.4).

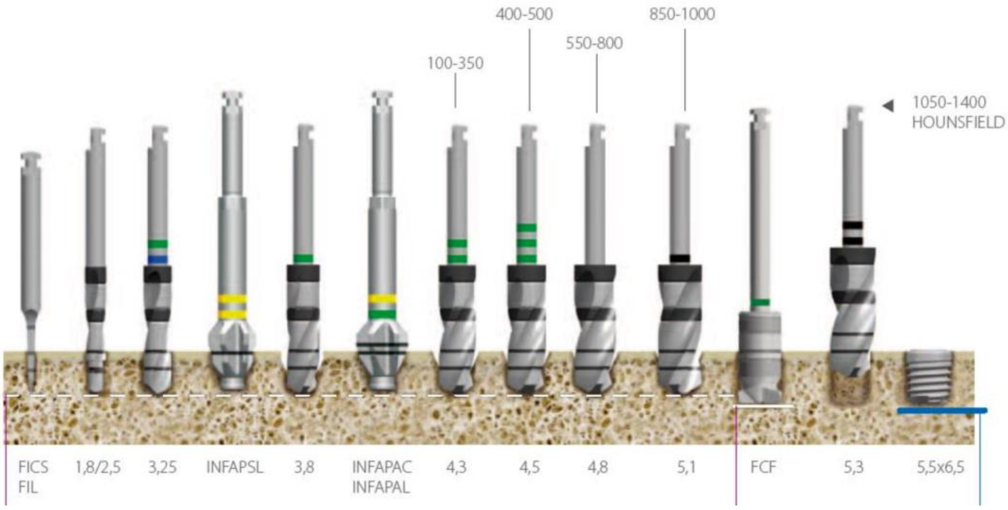

Fig. 4 Implant milling sequence (from BTI manual)

The minimum tightening torque to include the patient in the study is 20 Ncm[18].

As previously explained, one implant is randomly inserted with one stage technique immediately screwed with the Multi-Im, while the second one with two stage technique and then submerged (FIG.5).

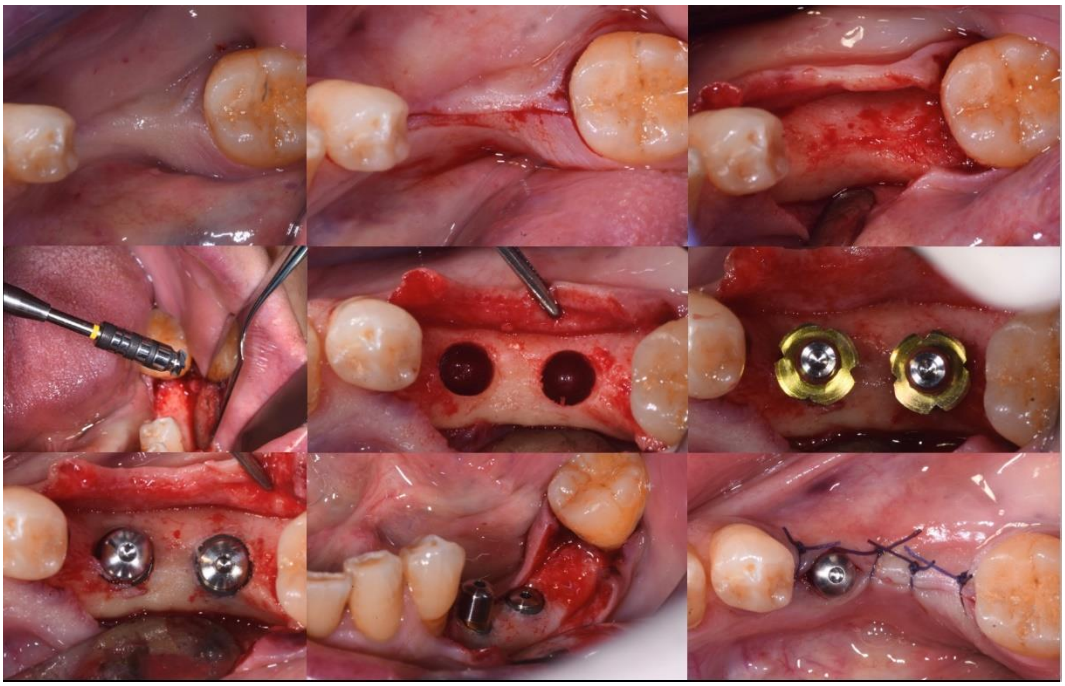

Fig. 5 First Stage surgery.

[18] Schrott A, Riggi-Heiniger M, Maruo K, Gallucci GO. Implant loading protocols for partially edentulous patients with extended edentulous sites-a systematic review and meta-analysis. Int J Oral Maxillofac Implants 2014; 29 (suppl):239-255.

Three months after surgery, it is uncovered with a second stage surgery.

3.4 Prosthetic protocol

The implants used in the study have an internal “quadrilobate” connection, on which a transepithelial component (Multi-Im®, FIG.6) has been screwed to create the Bioblock® concept created by Anitua. The Bioblock® concept is based on three basic pillars:

1. The union of the implant to the prosthesis is achieved through an intermediate element: a transepithelial component screwed to the implant called Multi-Im®.

2. A perfect hermetic seal is obtained between the implant platform and the intermediate transepithelial component, removing the presence of possible gaps that would generate microenvironments conducive to anaerobic bacterial proliferation.

3. The surface of each element that makes up the Bioblock® adapts specifically to the various tissues in contact (bone and soft tissue) to maximize the amount of biologically active surface.

Fig. 6 Multi-Im from BTI catalog.

It is necessary to select the Multi-Im® depending on the gum height and the aesthetic impact. The first option is to always insert them 0.5 mm supragingival. In the case of aesthetic needs, they can be positioned at the juxtagingival level. At the time of implant insertion, a tightening torque of 35 Ncm is applied to ensure proper tightness.

Two weeks after the second surgery to uncover the submerged implant, the position impression was taken with transfers screwed onto the Multi-Im®.

Finally, the implants were loaded with screw-retained metal-composite splinted rehabilitation (FIG.7).

Fig. 7 Gum healing and prosthetic rehabilitation.

3.5 Radiographic measurements

To evaluate bone resorption, an x-ray was taken immediately after surgery, and the subsequent ones at 3-6-12 months and then annually. The radiographs were performed with a Rinn centering device respecting the following parameters: 0.250 sec, 63 kV, 8 mA. Due to the difficulties in the construction of a customized bite on an edentulous area, which would not have been reusable once the implants were rehabilitate with crowns, a customized silicone device was not created for the standardized reproduction of radiographs.

Each radiograph was performed faithfully following the parallel beam technique, in order to minimize possible errors due to different inclinations of the X-ray tube from one appointment to the next. The analog film radiographs were subsequently scanned to obtain a JPEG equivalent file. The measurements were subsequently performed using Adobe Photoshop CC 2019® software.

There are several articles in which the authors used this software (in its various versions) to perform measurements on digital or analogue intraoral x-rays subsequently digitized. In the study of David Peñarrocha-Oltra of the University of Valencia, the accuracy and dispersion of the results in the calculation of bone resorption of two different software, ImageJ and Adobe 15 Photoshop®, were compared, using a software considered as a control for its high precision, 3D DicomViewer®[19]. ImageJ is an opensource software widely used in the medical and dental field to perform different types of measurements[20-21]. The study showed that both software represent valid methods for calculating bone resorption, and that there are no statistically significant differences. Nonetheless, ImageJ was slightly more accurate than Adobe Photoshop® (in the order of hundredths of a millimeter), but with a greater dispersion of the results. Since, for anatomical reasons, it was not possible to create bite devices for the standardization of the geometric projection

[19] Peñarrocha-Oltra D, Palau I, Cabanes G, Tarazona B, Peñarrocha-Diago M (2018). Comparison of digital protocols for the measurement of peri-implant marginal bone loss. J Clin Exp Dent.10(12):e1216-e1222.
[20] Dias DR, Leles CR, Lindh C, Ribeiro-Rotta RF (2015). The effect of marginal bone level changes on the stability of dental implants in a short-term evaluation. Clin Oral Implants Res.10:1185-90.
[21] Romeo E, Lops D, Margutti E, Ghisolfi M, Chiapasco M, Vogel G (2003). Implant-supported fixed cantilever prostheses in partially edentulous arches. A seven-year prospective study. Clin Oral Implants Res. 14:303–11.

during the execution of the x-ray, Adobe was preferred precisely because of its lower dispersion of the results.

In the 2017 study by Gheisari et al. , precisely on the comparison between the one-stage and two-stage techniques in the insertion of conventional implants, the researchers used Adobe Photoshop CS5® to establish bone resorption, using the length of the implant as a known measure and calibrating the following[22].

Using the various functions of the program, the profile of the bone crest and the position of the implant head were outlined. The distance between the head of the implant and the bone level at the point where it intersected the implant was measured, comparing the measurements with the known length of the implant (FIG.8).

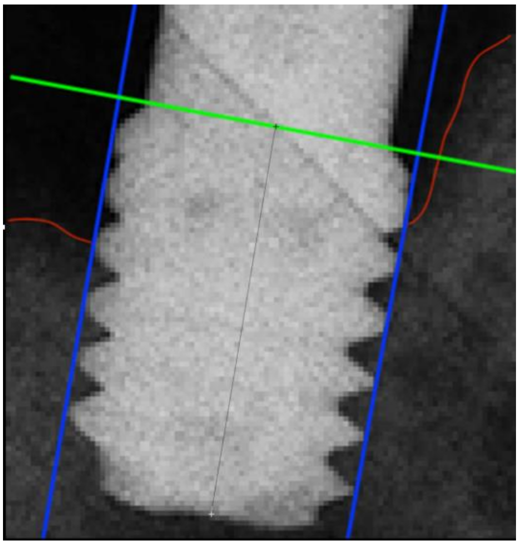

Fig. 8 Example of radiographic measurement from Adobe Photoshop CC 2019® software.

Comparing the subsequent radiographs with the first at t0 (date of surgery), mesial and distal bone resorption was measured. The measurement of resorptions was performed at 3-6-12 months in the implants inserted with the one stage technique on the one hand, and those inserted with the two stage technique on the other (FIG.9).

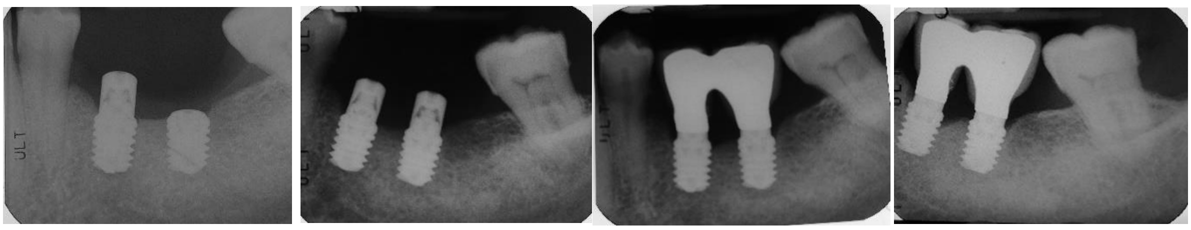

Fig. 9 Example of radiograph T0, T3, T6, T12.

[22] Gheisari R, Eatemadi H, Alavian A (2017). Comparison of the Marginal Bone Loss in One-stage versus Two-stage Implant Surgery. J Dent (Shiraz). 18(4):272-276.

3.6 Evaluation of implant stability

The ISQ (Implant Stability Quotient) is a measuring scale based on the Resonance Frequency Analysis (RFA) to determine the stability of an implant and the degree of osseointegration; it is expressed on a clinical scale calibrated from 1 to 100 ISQ. The ISQ scale is in perfect correlation with the measurements of the micro movements: the higher is the ISQ value, the greater is the implant stability.

In recent studies and systematic reviews of the literature, it has been shown that the ISQ is closely related to the insertion torque (IT) of the implant and is a fundamental value for evaluating the primary stability of the implant fixture and the secondary stability given by the implant osseointegration in the months following the surgery[23-24-25].

The Osstell ISQ® measurement tool stimulates the SmartPeg (a metal device that is screwed to the implant) by emitting magnetic pulsations. The SmartPeg, being provided with a magnet, begins to vibrate with a frequency proportional to the implant stability, which is detected and digitized. The corresponding ISQ value is then shown on the monitor.

In particular, the results can be divided into three reference ranges (FIG. 10):

- for values below 60, implant with low stability;

- for values between 60 and 70, medium stability;

- for values above 70, high stability.

Fig. 10 The ISQ scale (from Osstell®).

Since the insertion of the SmartPegs inevitably involves the removal of the Multi-Im®, which guarantee the tightness of the connection and on which the connective fibers of the soft tissues are anchored, the ISQ measurement was taken at 0, 3 and

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[23] Lages FS1, Douglas-de Oliveira DW1, Costa FO1. Relationship between implant stability measurements obtained by insertion torque and resonance frequency analysis: A systematic review. Clin Implant Dent Relat Res. 2018 Feb;20(1):26-33.

[24] Alberto Monje, Andrea Ravidà, Hom-Lay Wang, Jill A Helms, John B Brunski. Relationship Between Primary/Mechanical and Secondary/Biological Implant Stability. Int J Oral Maxillofac Implants. 2019 Suppl;34:s7-s23.

[25] Huang H, Wu G, Hunziker E. The clinical significance of implant stability quotient (ISQ) measurements: A literature review. J Oral Biol Craniofac Res. Oct-Dec 2020;10(4):629-638.

12 months, and not at 6 months as for the other measurements, in order to guarantee an adequate seal against bacterial infiltration.

Two ISQ values were measured for each implant: one referred to the stability in the mesio-distal direction, and one referred to the stability in the buccal-lingual or buccal-palatine direction (FIG.11).

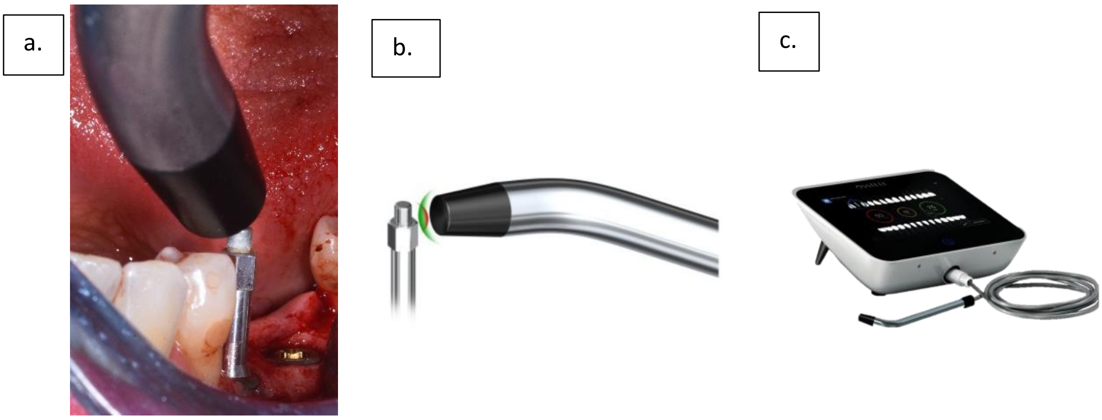

Fig. 11 Example of use of Osstell®: *a*. SmartPeg screwed to the implant, *b*. magnetic pulsations, *c*. Osstell® monitor.

3.7 Evaluation of periodontal indexes

Finally, the plaque index (PI) and the bleeding on probing (BOP) on 4 sites (mesial, distal, vestibular, palatine/lingual) were measured using the dichotomous index (values 0 and 1) and peri-implant probing on 6 sites (M/V, C/V, D/V, M/P, C/P, D/P), fundamental for the evaluation of gum health and the success of implant rehabilitation[26].

3.8 Statistical analysis

Mean with standard deviation were reported for quantitative characteristics.

Longitudinal assessment of ISQ, torque insertion, bone resorption, PD, BOP and PI during follow-up was performed using a linear mixed model with random intercept after visual inspection of their probability distribution. In all these regression models the dependent variable was the outcome and the independent variables were the time indexes, the treatment group and their interaction. A significance level of 5% was adopted in all tests and SPSS IBM (version 25) was used.

[26] Saso Ivanovski, Ryan Lee. Comparison of peri-implant and periodontal marginal soft tissues in health and disease. Periodontol 2000. 2018 Feb;76(1):116-130.

Results

19 patients were included in the study (10 patients from Turin, 9 patients from Genova; mean age 62, range 38-82) and 38 short implants were inserted. During the follow-up of 1 year, no drop-outs or implant failures were registered in order to obtain 100% CSR (cumulative survival rate).

4.1 Bone resorption

The bone resorption for each implant is the average of mesial and distal bone level (Tab.1).

Parameter	*Control Mean (SD)*	*Test Mean (SD)*	*Statistical significance*
Bone level T0	*0.09 (0.21)*	*0.12 (0.23)*	*p=0.6771*
Bone level T3	*0.35 (0.34)*	*0.37 (0.35)*	*p=0.8592*
Bone level T6	*0.45 (0.34)*	*0.53 (0.32)*	*p=0.4794*
Bone resorption T6-T0	*0.37 (0.38)*	*0.41 (0.28)*	*p=0.6945*
Bone level T12	*0.61 (0.34)*	*0.65 (0.38)*	*p=0.2050*
Bone Resorption T12-T0	*0.46 (0.41)*	*0.45 (0.38)*	*p=0.9417*

Tab. 1 Bone resorption: Control group (two stage) vs Test group (one-stage).

All the implants showed a normal bone resorption in one years follow-up. No statistically differences between the two groups were evidenced.

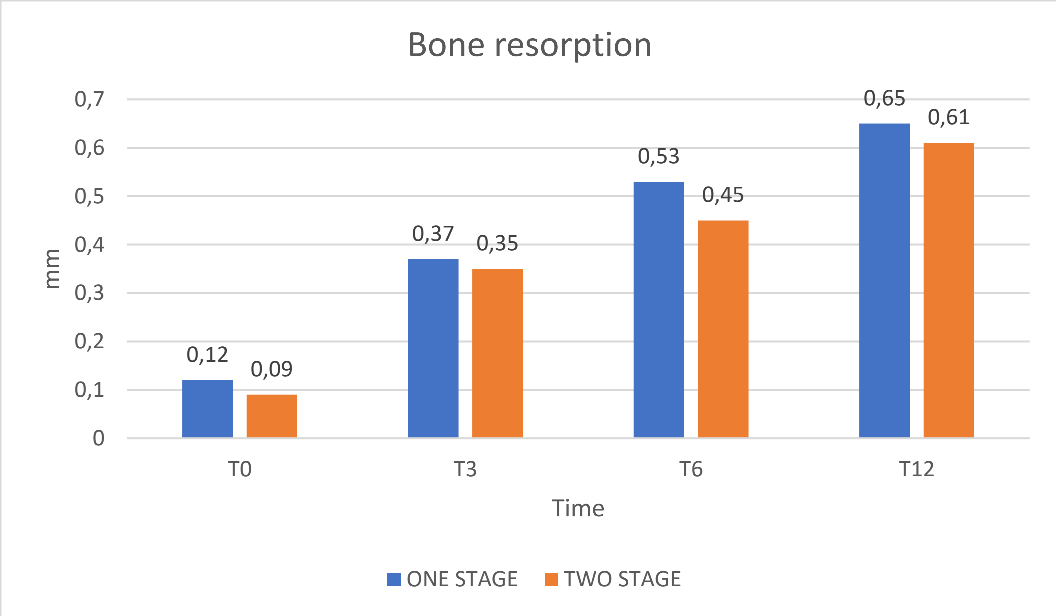

Fig. 12 Histogram of bone resorption values in the two groups in comparison

4.2 Implant stability

The implant stability for each implant is the average of two measurements: mesio-distal direction (MD) and bucco-lingual direction (BL) (Tab.2).

Parameter	*Control Mean (SD)*	*Test Mean (SD)*	*Statistical Significance*
ISQ T0	*67.53 (19.47)*	*66.53 (10.07)*	*P=0.8738*
ISQ T3	*78.26 (8.76)*	*79.26 (7.88)*	*P=0.7136*
ISQ T12	*81.1 (7.04)*	*81.39 (6.07)*	*P=0.9266*

Tab. 2 Implant stability: Control group (two stage) vs Test group (one stage).

The value of ISQ during the follow-up of 1 year increased in each group of implant but there is no statistically differences between the two tecniques (one-stage vs two stage) (ΔT0-T3 p-value=0,350; ΔT0-T12 p-value=0,757).

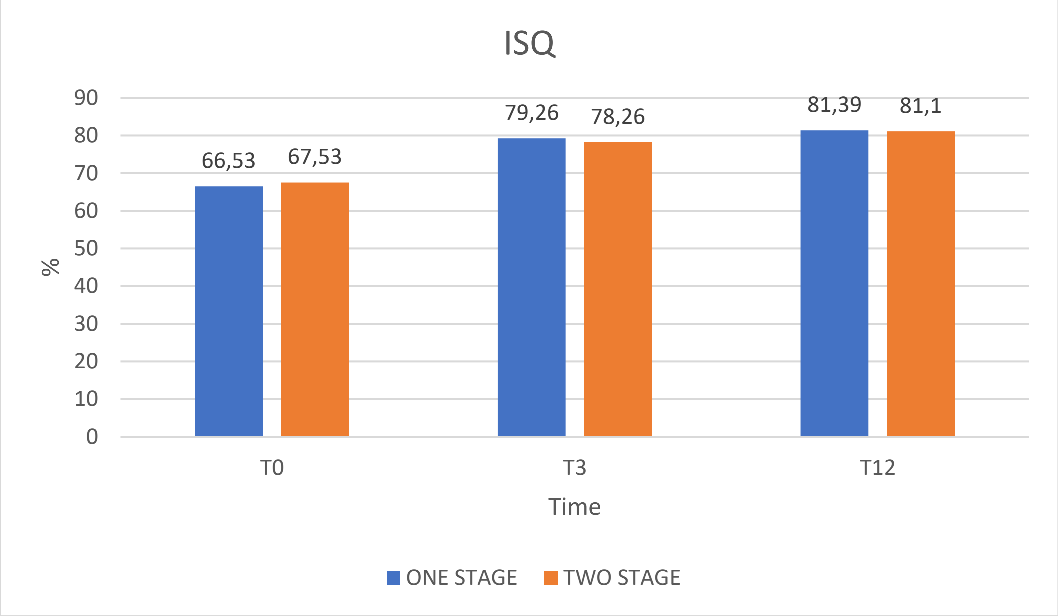

Figura 13 Histogram of ISQ values in the two groups in comparison

4.3 Periodontal indexes

The probing depth (PD) for each implant is the average of 6 registered sites (M/V, V, D/V, M/P, P, D/P). Plaque index (PI) and bleeding on probing (BOP) is the mean of 4 registered sites (M, V, D, P) and are dichotomous values (0=no plaque/bleeding, 1= plaque/bleeding). (Tab.3).

Parameter	*Control Mean (SD)*	*Test Mean (SD)*	*Statistical significance*
PD T3	-	*2.37 (0.96)*	-
PD T6	*2.45 (0.85)*	*2.34 (1.00)*	*p=0.1100*
PD T12	*2.7 (0.85)*	*2.69 (0.89)*	*p=0.9727*
PI T3	-	*0.42 (0.96)*	-
PI T6	*0.89 (1.10)*	*0.79 (1.08)*	*p=0.7790*
PI T12	*1.06 (1.14)*	*0.94 (1.09)*	*p=0.7558*
BOP T3	-	*0.53 (0.9)*	-
BOP T6	*0.47 (0.7)*	*0.42 (0.69)*	*p=0.8258*
BOP T12	*1.06 (1.34)*	*0.71 (1.10)*	*p=0.4114*

Tab. 3 Periodontal indexes: Control group (two stage) vs Test group (one stage).

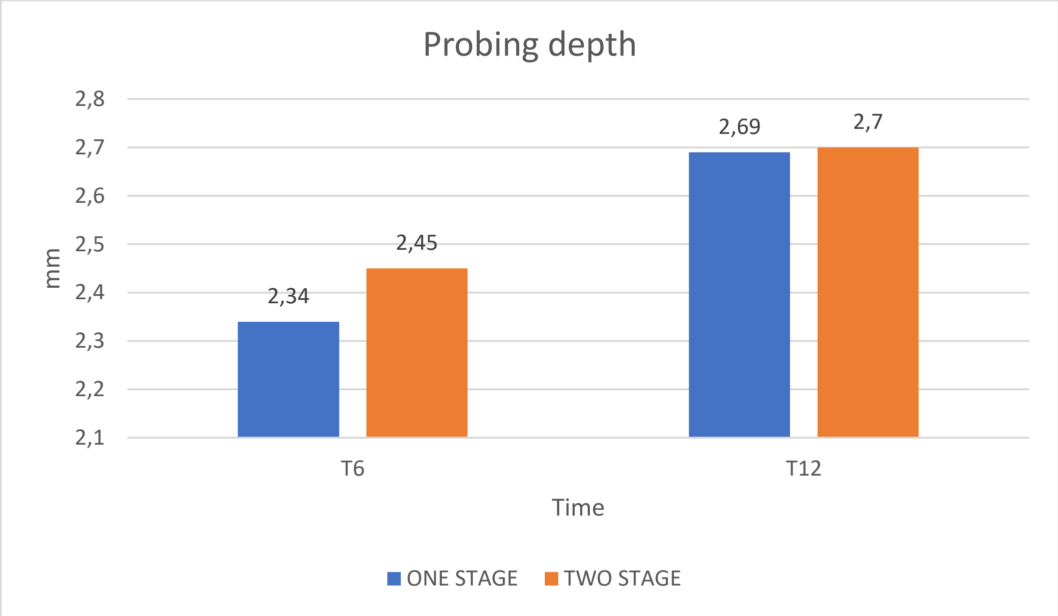

Figura 14 Histogram of PD values in two groups in comparison.

The values show healthy and stable gum in all the times of follow-up, without statistically differences between the two groups.

Discussion and conclusions

In the present study, no statistically differences between one-stage and two-stage technique in extra-short implant are evidenced. The split-mouth methodology adopted in this study allowed to limit the risk of bias: in fact the two techniques analyzed were applied in the same arch in adjacent sites, thus reducing the clinical variables that may have influenced the result.

One of the limitations of this research was, however, the impossibility of carrying out a double-blind study (an element that would have further reduced the risk of bias), as the clinical operator inevitably knew the type of technique applied, despite the 'one or the other have been randomly assigned to each site (without taking into account, for example, bone quality).

Peri-implant bone resorption was minimal and limited to the physiological remodeling values typical of the healing phase.

The ISQ increased, demonstrating that correct osseointegration is essential for implant stability, regardless of the lenght of the implant.

Periodontal indexes show healthy gum, fundamental for maintenance of implant health. The concept of BioBlock introcuced, using che Multi-Im screwed to the implant platform, create a hermetic seal that avoid bacterial proliferation and gum inflammation.

In conclusion, as reported by previous studies[27-28-29] extra-short implants have been shown to achieve comparable results to long implants placed in reconstructed or regenerated bone, in terms of cumulative survival, failure and peri-implant bone resorption. However, short implants guarantee fewer surgical complications (also thanks to the greater respect for anatomical structures), shorter rehabilitation times, with a consequent greater patient satisfaction.

The one stage technique is preferable to the two stage technique because, with the same results, it is more comfortable for the patient who is not undergoing a second surgery. In the author's opinion, it is still preferable to adopt a two stage technique

[27] Esposito, M., Pistilli, R., Barausse, C., Felice, P., (2014). Three-year results from a randomised controlled trial comparing prostheses supported by 5-mm long implants or by longer implants in augmented bone in posterior atrophic edentulous jaws. European Journal of Oral Implantology.

[28] Felice, P., Pistilli, R., Barausse, C., Bruno, V., Trullenque-Eriksson, A., Esposito, M. (2015). Short implants as an alternative to crestal sinus lift: A 1-year multicentre randomised controlled trial. European Journal of Oral Implantology.

[29] Pistilli, R., Felice, P., Cannizzaro, G., Piattelli, M., Corvino, V., Barausse, C., Buti, J., Soardi, E., Esposito, M., (2013). Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long 4 mm wide implants or by longer implants in augmented bone. One-year post-loading results from a pilot randomised controlled trial. European Journal of Oral Implantology.

in cases of an adequate primary stability cannot be obtained at the moment of implant insertion.

Finally, the use of modern technologies for virtual planning (tridimensional visualization of anatomical structures for correct measurements of bone in presurgical phase) is essential to clinician to plan surgical and prosthetic steps.

In future, the goal will be to obtain a completely digital flow chart from the planning, through the surgery, to the prothesis, to minimaze the morbility and disconfort for the patient and semplify the procedures for the clinician.

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