Digital Planning and Guided Surgery for Immediate Implants in Anterior Esthetic Area: Case Report

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ABSTRACT

Background: Despite the high rates of guided-surgery success in the aesthetic region, only few studies describe both the planning protocol and the clinical-tomographic-surgical performance to reach short-term satisfactory outcomes. Aim: The aim of the presents study was to describe the planning applied to a guided surgery in the aesthetic region, and its clinical outcomes, by taking into consideration the peri-implant tissue profile and the implant-supported prosthesis. Method: This report describes the case of a female patient, herein at the age of 48 years, presented herself to seeking rehabilitation treatment based on osseointegratable implant and prosthesis, and to replenish the upper lateral incisor region. Result: The success of treatments based on implant in the aesthetic region depends on several factors, with emphasis on diagnostics and planning. The aforementioned stages are entangled to many benefits from guided surgery planning to conduction, such as surgery duration and acts ʼreduction, lower discomfort, and iatrogenic injuries to soft and hard tissues. Conclusion: The outcome in the rehabilitated aesthetic region was predictable, as well as functionally and aesthetically stable.

Keywords

Dental Implants. Bone regeneration. Prosthesis Implantation. Computer-Guided Surgery. Guided bone regeneration.

1. INTRODUCTION

Mouth rehabilitation has been following technological innovations aimed at improvements and decision-making in dental procedures. Panoramic X-ray has limitations to implants' surgical planning; moreover, freehand surgery also has limitations that lead to different outcomes due to professional skills and decisions made during surgery, without real previous planning [1]. Cone-beam computed tomography is recommended to start the surgical planning applied to osseointegratable implants. Since 2002, implant dentistry assesses and innovates with special software for guided surgeries and prosthesis installation on implants. Guided surgeries are recommended for a whole range of implant rehabilitation cases, including partial or total edentulous, as well as aesthetical nature areas [2]. These concepts have led to changes in surgical perspectives given the possibility to plan implant installations along with temporary or permanent prostheses. Computed tomography and the development of new software enable almost realistic-like virtual planning aimed at accurately guiding to a specific target in rehabilitating plans [3].

Accurate pre-operative planning applied to aesthetic regions, either for implant installation or for the manufacture of prosthetic restorations, as well as for gingival contour predictability, is a fundamental requirement for a successful rehabilitation, based on osseointegratable implants [4]. Cone-beam computed tomography, intraoral scanning and the availability of 3D printers made the practice of virtually planning implants and of using a surgical guide to point out the accurate and correct locations for milling and implant installation accessible, and it leads to aesthetic and biomechanical predictability [5].

The virtual planning of surgery in aesthetic regions became an excellent tool to treatments based on osseointegratable implants, because peri-implant tissue stability, absorption of loads along the long axis, easy cleaning and satisfactory outcomes are the elements accounting for proper tridimensional implant positioning [6-8]. Aspects, such as ideal distance between implants, between implant and dental elements, and implant depth, can also be controlled through this technique. There is close association between high success rate and shorter surgery duration due to previous virtual surgical planning [9].

The development and outspread of different software for planning and prosthetic design allowed combining waxing purposes, which can now be virtually performed based on surgical planning [6-8]. These software types are diagnostic tools to previously analyze implant installation areas and to propose different alternatives to each case, a fact that helps reducing iatrogenic cases [10, 11].

Nowadays, guides' manufacturing is based on CT image overlay (DICOM) of data resulting from digital images of dental arches by using standard tessellation language (STL) intraoral scanning. Stereolithographic guides are made through *Computer-Aided Design /Computer-Aided Manufacturing* (CAD/CAM) by printing or milling devices [6-8].

Despite the high rates of guided-surgery success in the aesthetic region, only few studies describe both the planning protocol and the clinical-tomographic-surgical performance to reach short-term satisfactory outcomes. The aim of the presents study was to describe the planning applied to a guided surgery in the aesthetic region, and its clinical outcomes, by taking into consideration the peri-implant tissue profile and the implant-supported prosthesis.

2. CLINICAL CASE REPORT

Female patient, herein identified as FFF, at the age of 48 years, presented herself to the dentistry clinic of the Brazilian Navy seeking rehabilitation treatment based on osseointegratable implant and prosthesis, and to replenish the upper lateral incisor region (Figures 1 and 2). The patient presented full dentition in the lower dental arch.

Fig. 1. Initial aspect showing root fracture of element 12 with gingival tissue invasion and aesthetic contour loss.

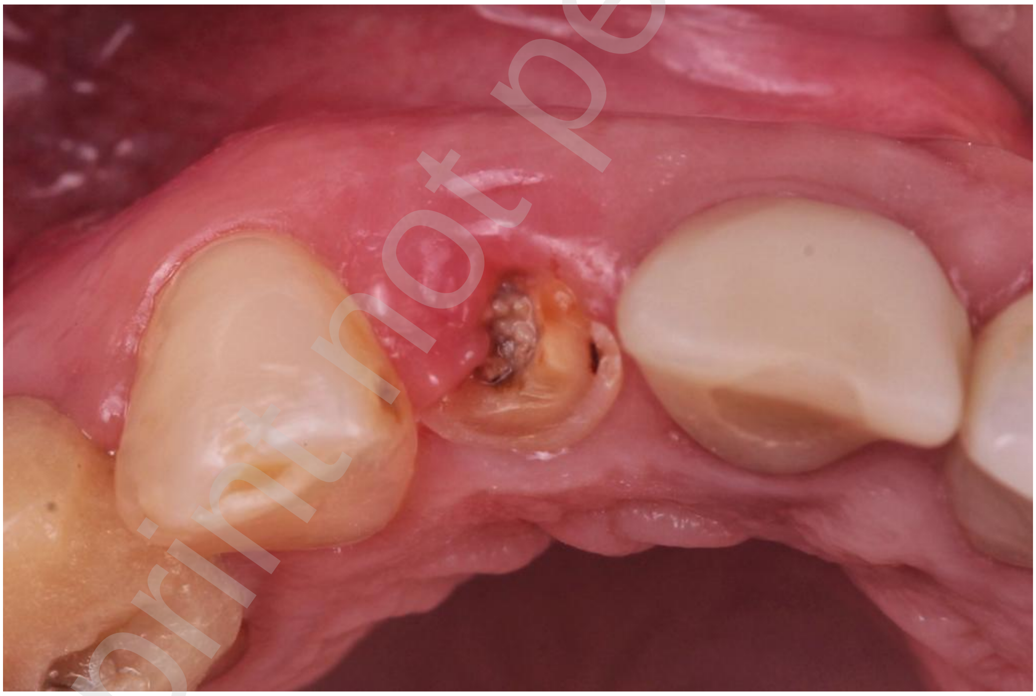

Fig. 2. Initial aspect clinically showing root fracture of element 12, gingival tissue invasion and aesthetic contour loss (Occlusal View).

Guided surgery was the therapy of choice to operate the upper dental arch due to recommendation for tridimensional implant accuracy in this region. It was done to favor aesthetic aspects and bone availability to implant performance based on the remaining root of dental element 12, as spatial reference for guided surgical planning (Figure 3).

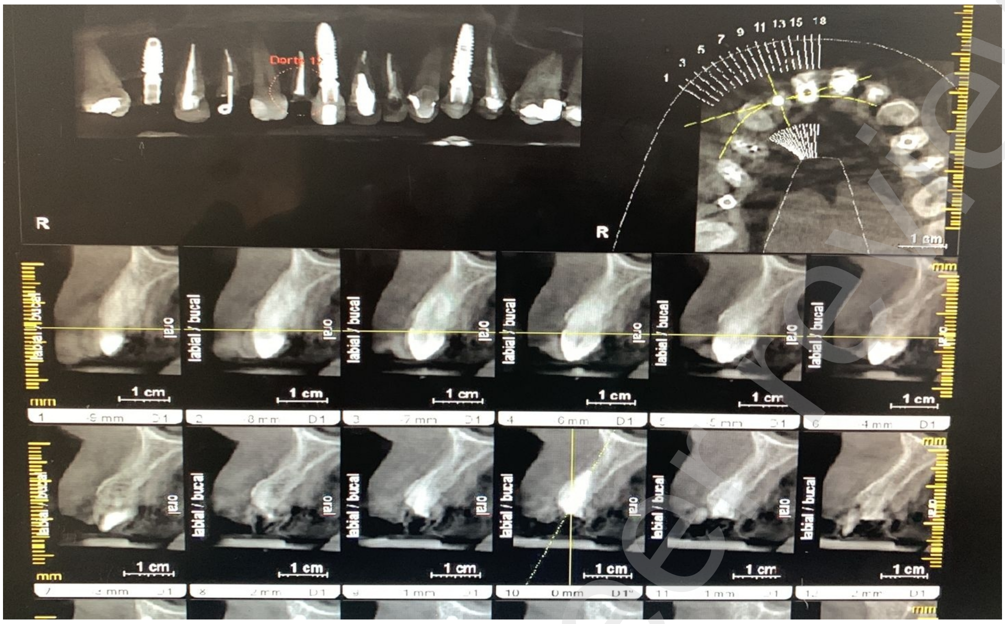

Fig. 3. Tomographic aspect showing bone availability at dental element 12 region: 16mm in height and 5mm in thickness.

2.1 <u>Guided Planning</u>

Surgical planning was sent to the laboratory in video format along with DICOM images and their printed pictures (Figure 3). *Epikut* (by SIN Implantes – São Paulo, Brazil) was the guided surgery system of choice and *Cone Morse* (CM) 3.5x13 mm was the selected implant type. Virtual planning was carried out in Exoplan software (Smart Dent-Germany), which was used to manufacture the surgical guide based on imported STL files resulting from digital scanning (Cerec AC Omnicam 4.6, Dentisply Sirona, SP, Brazil) by using H6.5 washers (Figure 4). The guide was printed in Anycubic Photon S device and Smartdent Clear resin (Smart Dent-Germany) was the base material of choice.

Fig. 4. Surgical guide planned in Exoplan software (Smart Dent-Germany) and manufactured with STL exports

Fig. 5. Surgical guide manufactured in Smartdent Clear resin (Smart Dent-Germany), in 3D type Anycubic Photon S printer.

2.2 Minimally traumatic tooth extraction

Initially, based on diagnostic examinations, the patient was subjected to local anesthesia for anterior superior alveolar plexus block because the prognostic for immediate installation of post-extraction implant was classified as good. Minimally traumatic tooth extraction was carried out starting from periotomy of the palatal, distal and mesial surfaces to make the extraction of the dental element easier and to make this procedure the least traumatic possible, as well as to preserve the vestibular bone plate and to support the soft tissue around element 12 (Figure 6).

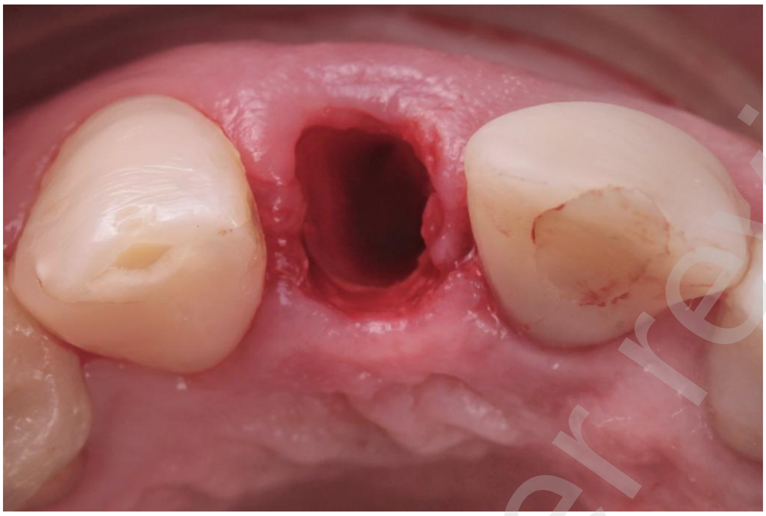

Fig. 6. Clinical aspect right after tooth extraction showing the favorable mucosa contour and papillae and bone plates preservation.

The surgical guide received the windows to assess their stabilization, because it provides greater procedural safety. It is projected in areas presenting good-quality and sufficient bone tissue selected during digital planning (Figure 7).

Fig. 7. Positioned surgical guide

The implant was installed based on following the sequence of Epikut Guided Surgery System Surgical Kit Drills by SIN Implants (São Paulo - Brazil), according to manufacturer's recommendations.

Implant positioning followed the tridimensional positioning principles by keeping the minimum distance of 12mm from implant platform and from adjacent teeth, and 3-4mm distance between gingival margin and implant platform. The installed implant recorded 45N torque (Figures 8 and 9).

Fig. 8. Installation of CM Epikut 3.5x13 mm type implant (SIN – São Paulo, Brazil).

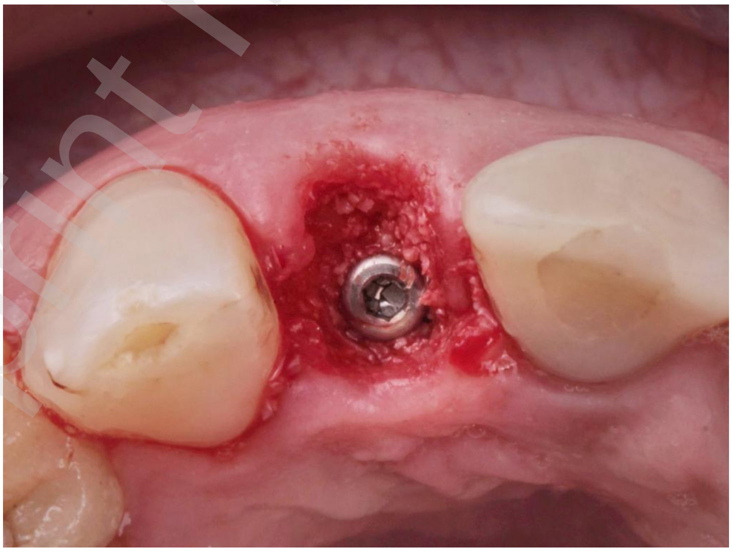

Fig. 9. Placement of CM Epikut 3.5x13 mm type implant (SIN – São Paulo, Brazil) (occlusal view).

The surgical guide was removed and bone replenishing was carried out with biomaterial in the space between the installed implant and the vestibular bone plate, after implant installation. Replenishing was performed through Alobone® allograft (Osseocon, Rio de Janeiro, RJ, Brazil) (Figure 10).

Fig. 10. Immediate clinical aspect showing the favorable position of the installed implant and the integrity of the remaining soft vestibular tissues (Occlusal view).

2.3 PROVISIONAL TOOTH CREATION

The provisional tooth was created in B1 resin and made up by El Lab Externo, with emergency profile captured in A1 flow resin, based on using the connection in titanium provisional cylinder (CPTMU 3502-H, SIN – São Paulo, Brazil), right after implant installation (Figures 11 and 12).

Fig. 11. Immediate provisional tooth over the CM Epikut 3.5x13 mm implant (SIN - São Paulo, Brazil) printed in B1 resin and made up by El Lab Externo.

Fig. 12. Immediate provisional tooth over the CM Epikut 3.5x13 mm implant (SIN - São Paulo, Brazil) made up by El Lab Externo with emergency profile captured in A1 flow resin, based on using titanium provisional cylinder connection (Occlusal view).

The concavity in the sub-gingival portion of the prosthetic pillar was stressed with the aid of diamond drills under refrigeration. It was done to get thicker peri-implant tissue, which accounts for long-term stability in gingival margin positioning. It was possible observing immediate aesthetics outcomes due to the use of provisional tooth, based on the virtual planning and on rehabilitating procedure accuracy (Figure 13).

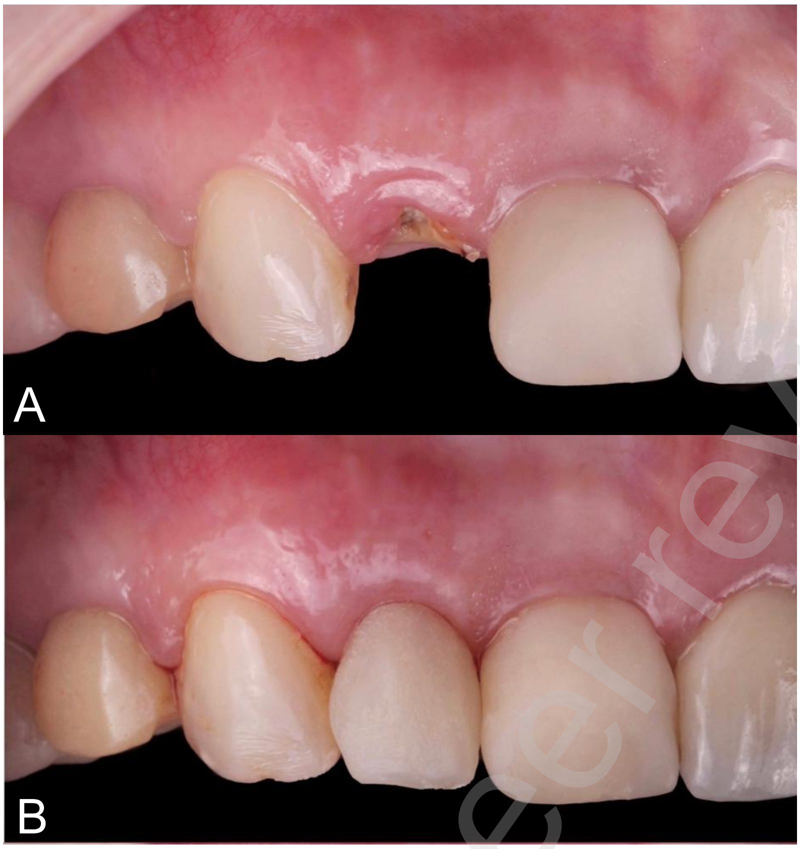

Fig. 13. Initial aspect showing the root remains of dental element 12 (Figure 13A). Immediate provisional tooth over CM Epikut 3.5x13 mm implant (SIN - São Paulo, Brazil), printed in B1 resin and made up by El Lab Externo, with emergency profile captured in A1 flow resin, by using titanium provisional cylinder connection (Figure 13B).

Provisional restoration can be cemented and the hole to access the pin can be closed after 20N torque is applied to the prosthetic pillar. The patient appeared extremely happy with the immediate clinical aspect.

Six months later, the definitive porcelain prosthesis EUCLA type abutment (EUCLAMU 3502-H, SIN - São Paulo, Brazil) was installed (Figure 14).

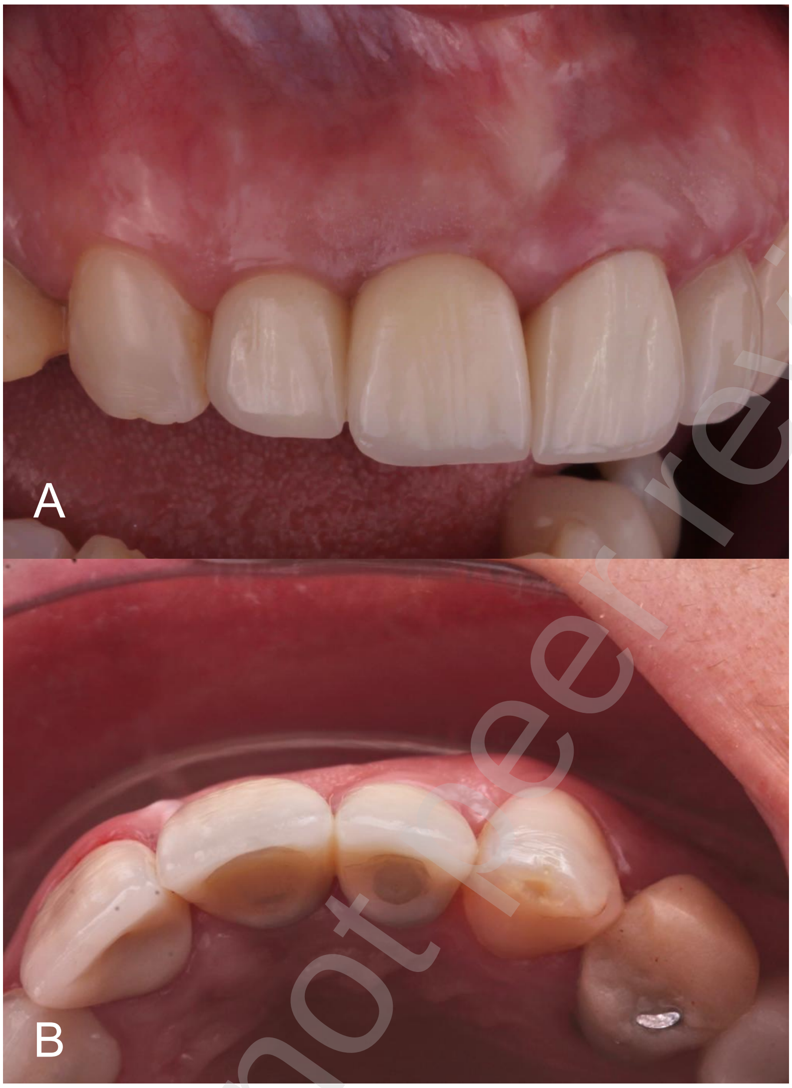

Fig. 14. Final clinical aspect with the definitive porcelain prosthesis in frontal (A) and occlusal view (B). Note the aesthetics, the peri-implant mucosa contour. This case was carried out based on virtual guided surgery planning.

3. DISCUSSION

Implant dentistry has been having great impact on how we deal with edentulism. Rehabilitation based on dental implant has become the standard procedure to replace the lost teeth. Some parameters must be observed in aesthetic rehabilitation in order to reach long-term success. Gingiva biotype, smile line, dental elements' color, peri-implant mucosa contour, papillae preservation, and the thickness and height of the underlying bone ridge, are among the main aspects observed in the maxilla anterior region [12,13,14]. The aim of all these factors does not only lie on reaching the expected aesthetics, but also on having treatment predictability when it comes to dental implants. The present case report opens room for discussions about some relevant points from the surgical and prosthesis aspect viewpoint, as well as about the emergence of digital planning as excellent tool to implant dentistry. Outcomes have clearly pointed out the functionality and aesthetics acquisition within a short period-of-time due to guided surgery employment.

Scientific evidence shows that early digital planning and 3D guided surgery duration were marked by concepts established in 2005, which have outspread guided surgery employment. The technology of choice at digital planning scope is called CAD (Computer Aided Design), which is an integration system substantiated by computer sciences. Digital planning is carried out in DTX software, which can import files in STL format. These files result from intra-oral scanning or from tomographic images. This tool allows previously planning surgery conduction by determining the ideal location for implant installation based on bone amount and quality. It also allows visualizing important accidents and anatomic structures that are often identified in other analogous tools, as well as takes into account the prosthetic needs at high positioning accuracy, reproducibility, color and shape [15].

The guided planning uses tomographic images associated with up-to-date 3D software capable of accurately and faithfully reproducing the anatomic structures of peri-implants, as well as of their intermediate prosthetics and prosthesis, before the surgical procedure. It makes the production of surgical guides in high-accuracy acrylic resin feasible. These guides orient the implant insertion axis and optimize surgery duration, besides benefitting trans-surgical and post-surgical time [16-20].

Al Yafi F. et al (2019) stated that the guided implant surgery is more accurate and reliable than freehanded implant surgeries. It is so, because the digital workflow for guided surgery follows a protocol to generate a tridimensional digital plan to be transferred to the patients' mouth through the surgical guide and protocol in order to reduce deviation and error risks [21]. All herein reported case stages, from tomography performance to tomography coupling to STL scanning, led to surgical accuracy and to high post-operative success predictability.

The guided surgery represents a less invasive, conservative and more accurate surgical modality [22]. According to Balem et al. (2010), the guided surgery and prototyping represent a new wave in dentistry, according to which, procedures become safer, predictable and less complex [23]. In addition, the adopted surgical kits and the implant of choice, based on manufacturers' recommendations, are essential for implants' primary stability and for trans-surgical handling. It is also important highlighting that surgical guide manufacture must follow the manufacturer's requirements, because they lead to accurate surgical conduction based on selected implant size.

The choice made for guided surgeries enables performing implant installations based on flap reflection, or not. The case presented by each patient is what differentiates the choice for a given surgical access, and one must take into account the need of bone and/or conjunctive graft followed by implant installation – a fact that demands opening the flap. Whenever there is no need of graft, one can choose the closed surgery, because it is possible building a tomographic guide after the tomography to virtually plan the best implant anchorage area [24]. The best positioning predictability is observed when the virtual planning is carried out by accurately respecting the 2mm distance between the implant and the vestibular bone plate, and the 3-4mm distance between the gingival margin and the implant platform. It must be done to reach the best tridimensional implant control and, consequently, to allow adjacent tissue recovery [25, 26, 27]. This fact is clearly identified during immediate post-operative outcomes and it is mediated by guided rehabilitation, as shown in the current report.

Studies have evidenced that a surgical approach without flap can have additional advantages when it comes to traditional protocols with mucoperiosteal flap that, in its turn, can be related to higher reabsorption rates for the alveolar bone crest and of bone-implant contact (IOC) loss in implant's cervical region [28]. According to studies of remarkable scientific relevance, one can expect approximately 1mm of vestibular gingival retraction 1 year after implant installation [29]. We believe that adjacent tissues in the present report were preserved due to the adoption of the guided surgery without flap - no peri-implant gingival retraction was identified.

Guided surgery predictability is only possible in specific software available in the market that generate linear and angle coordinates for washers' positioning. All tomographic images were generated in DICOM format and converted by the adopted software into the proper format required by each one of them [30]. Other studies have pointed out the advantages of the guided surgery, such as safe, simple, reliable and accurate technique; positive receptivity by patients; shorter surgical time; minimum post-operative discount; faster prosthesis installation [31]. Reverse planning stands out in the literature, and it is substantiated by several studies that state the proper use of this resource, which significantly reduces fail rates at the initial rehabilitation stage [32]. Reserve planning was an excellent resource for satisfactory clinical outcomes in this study. The 3D diagnostics and digital planning allowed determining the ideal location for dental implant installation with the aid of a guide, since it reduced the chances of having significant anatomic accidents.

This technique presents some limitations, such as higher costs due to the need of having a customized surgical guide and the necessary minimum amount of bones [6, 7, 8]. The main variation in comparison to the conventional technique is linked to milling sizes, which present longer upper length in the guided surgery system. Patient's mouth opening in the implant region must match the use of millings and installation keys of the system of choice. Limited mouth opening can interfere with implant instruments and installation, and cause surgery interruption.

As for the moment to extract the dental element and to install the dental implant, it is possible taking into consideration some facts evidenced in scientific studies according to which, one can expect horizontal loss close to 30% of the bone volume three months after tooth extraction [33]. Accordingly, immediate implant installation associated with bone graft avoids the need of further regeneration procedures and emerges as excellent option for patients recommended for this technique [34]. Besides, the use of surgical techniques that avoid incision acts, as well as gingival papillae displacement, are associated with lower bone loss standards [35]. We herein opted for preserving the adjacent tissues.

With respect to the immediate prosthetic and rehabilitating scope, it is important highlighting the need of installing the prosthetic pillar at the time to install the implant. It is known that the repetition of prosthetic pillar's connections and disconnections leads to marginal recession and to bone absorption in animal models [36]. Disruption of the junctional epithelium of the peri-implant biological space was removed and the installation of new pillars can lead to new apical biological space at implant level, with consequent bone resorption. Humans show traces that more than two connections affect the peri-implant mucosa sealing. Screwed provisional restoration installation at surgery time can be a quite feasible alternative; it must be disconnected three months later for the modeling stage and for the installation of the pillar associated with the definitive restoration [34]. As for the current case report, definitive prosthesis manufacture happened 6 months after implant installation, and it showed full peri-implant mucosa stabilization and satisfactory aesthetic profile.

Based on relevant scientific studies, when the problem is the vestibular gingival retraction, one can expect approximately 1mm retraction 1 year after implant installation. The use of customized prosthetic pillars minimizes such a loss, since it keeps soft tissue architecture [37, 38, 39]. Data in scientific studies show either vertical increase or lack of tissue recession at casuistic margin higher than 80% after 2-year follow-up. It sets the biological space in the prosthetic pillar structure and, consequently, preserves the bone crest of the peri-implant region [36, 38].

Levine et al. (2017) considered 10 stages to reach a successful surgery to install immediate implants in the aesthetic region, namely: two planning stages, five surgical stages and three prosthetic stages. Altogether, these stages aim at minimizing soft and hard tissue complications to achieve the ideal implant aesthetic restoration [40]. We can consider that the herein introduced clinical case followed these ten stages, because we have employed two planning stages (tomographic and reverse planning), five surgical stages (non-traumatic tooth extraction, tissue manipulation, biomaterial installation, guided surgery and proper implant positioning) and thee prosthetic stages (manufacture of the milled provisional material, porcelain prosthesis design and digital prosthesis planning).

With respect to treatment based on dental implant in the aesthetic region, the multi-factorial dependence to clinical success is known, with emphasis on diagnostics and planning. These stages influence the reduction in intervention numbers, and it also reduces the risk of sequelae in soft and hard tissue structures, without affecting rehabilitation functional and aesthetic profiles. The guided surgery is an excellent alternative when the amount of bone in the patient is enough to receive dental implants without the need of long surgical cut [41]. This technique leads to surgical predictability, which enables much more safety for surgeons and comfort to patients [42-45]. The present case report allows observing that the guided surgery was an excellent alternative, because the patient's clinical response was extremely satisfactory, and it allowed making an aesthetically ideal porcelain prosthesis in the shortest period-of-time.

Virtual diagnostic and planning based on current scientific evidence, careful procedural planning and on using high-quality materials are the essential requirements for a successful procedure. The guided surgery can accurately transfer the virtual planning to the surgical act; besides, it is one more tool to help dental surgeons in the dentistry implant field to reach the best outcomes. As for the herein introduced clinical case, we have combined the following factors: (a) proper dental implant planning; (b) accurate soft tissue handling; (c) effective choice for the biomaterial; and (d) using new technologies associated with planning, and surgical and prosthetic performance. Based on these guidelines, it was possible ensuring a predictable aesthetic and functional outcome.

4. **CONCLUSION**

The success of treatments based on implant in the aesthetic region depends on several factors, with emphasis on diagnostics and planning. The aforementioned stages are entangled to many benefits from guided surgery planning to conduction, such as surgery duration and acts' reduction, lower discomfort, and iatrogenic injuries to soft and hard tissues. The outcome in the rehabilitated aesthetic region was predictable, as well as functionally and aesthetically stable.

Author's contributions

xxx; Conception of the work, Design of the work, Acquisition of data, Analysis of data, Interpretation of data Drafting the work; xxxx, Revising the work critically for important intellectual content and direct supervisor; xxxx Final approval of the version to be published and direct supervisor

Patient consent

Written informed consent was obtained from the patient for publication of this case report and any accompanying images including clinical pictures and investigations. A copy of the written consent and approval by ethics committee from our institution are available for review by the Editor of this journal.

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Authorship

Declaration of competing interest

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Declaration of Generative AI and AI-assisted technologies in the writing process

There was no Applied AI-assisted Technologies.

REFERENCES

[1] Chen P, Nikoyan L. Guided Implant Surgery: A Technique Whose Time Has Come. Dent Clin North Am. 2021 Jan;65(1):67-80. doi: 10.1016/j.cden.2020.09.005. Epub 2020 Nov 2.

[2] Neto MDEH, Magalhães ACP, Carneiro TAPN, André NV, Andrade GC. Planejamento virtual e cirurgia guiada na reabilitação de maxila edêntula. 2012; 6 (04): 180-188.

[3] Salviano SH, Lopes JCA, da Silva Brum I, Machado K, Pedrazzi MT, de Carvalho JJ. Digital Planning for Immediate Implants in Anterior Esthetic

Area: Immediate Result and Follow-Up after 3 Years of Clinical Outcome-Case Report. Dent J (Basel). 2023 Jan 3;11(1):15. doi: 10.3390/dj11010015.

[4] De Vico G, Spinelli D, Bonino M, Schiavetti R, Pozzi A, Ottria L. Computer-assisted virtual treatment planning combined with flapless surgery and immediate loading in the rehabilitation of partial edentulies. Oral Implantol (Rome). 2012 Jan;5(1):3-10. Epub 2012 Jul 17. PMID: 23285400; PMCID: PMC3533979.

[5] Elsayed A, Farrag G, Chaar MS, Abdelnabi N, Kern M. Influence of Different CAD/CAM Crown Materials on the Fracture of Custom-Made Titanium and Zirconia Implant Abutments After Artificial Aging. Int J Prosthodont. 2019 Jan/Feb;32(1):91-96. doi: 10.11607/ijp.6137.

[6] D'haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A. Current state of the art of computer-guided implant surgery. Periodontol 2000. 2017 Feb;73(1):121-133. doi: 10.1111/prd.12175.

[7] Katsoulis J, Pazera P, Mericske-Stern R. Prosthetically driven, computer-guided implant planning for the edentulous maxilla: a model study. Clin Implant Dent Relat Res. 2009 Sep;11(3):238-45. doi: 10.1111/j.1708-8208.2008.00110.x.s

[8] Jang JY, Lee SJ, Lee JD. Considerations in the replacement of over-retained primary teeth with implant restorations in the esthetic zone: A case report. J Esthet Restor Dent. 2020 Apr;32(3):272-279. doi: 10.1111/jerd.12569.

[9] Nuss KCB, Gomes FV, Mattis F, Mayer L. Grau de confiabilidade na reprodução do planejamento virtual para o posicionamento final de implantes por meio de cirurgia guiada: relato de caso. Revista Da Faculdade De Odontologia - UPF, 21(1). https://doi.org/10.5335/rfo.v21i1.5245

[10] Chackartchi T, Romanos GE, Parkanyi L, Schwarz F, Sculean A. Reducing errors in guided implant surgery to optimize treatment outcomes. Periodontol 2000. 2022 Feb;88(1):64-72. doi: 10.1111/prd.12411.

[11] Colombo M, Mangano C, Mijiritsky E, Krebs M, Hauschild U, Fortin T. Clinical applications and effectiveness of guided implant surgery: a critical review based on randomized controlled trials. BMC Oral Health. 2017 Dec 13;17(1):150. doi: 10.1186/s12903-017-0441-y.

[12] Chiapasco M, Casentini P. Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration. Periodontol 2000. 2018 Jun;77(1):213-240. doi: 10.1111/prd.12219.

[13] Wennerberg A, Albrektsson T. Current challenges in successful rehabilitation with oral implants. J Oral Rehabil. 2011 Apr;38(4):286-94. doi: 10.1111/j.1365-2842.2010.02170.x.

[14] Cehreli M, Sahin S, Akça K. Role of mechanical environment and implant design on bone tissue differentiation: current knowledge and future contexts. J Dent. 2004 Feb;32(2):123-32. doi: 10.1016/j.jdent.2003.09.003. PMID: 14749084.

[15] Ganz SD. Three-dimensional imaging and guided surgery for dental implants. Dent Clin North Am. 2015 Apr;59(2):265-90. doi: 10.1016/j.cden.2014.11.001.

[16] Alauddin MS, Baharuddin AS, Mohd Ghazali MI. The Modern and Digital Transformation of Oral Health Care: A Mini Review. Healthcare (Basel). 2021 Jan 25;9(2):118. doi: 10.3390/healthcare9020118.

[17] Schwendicke F, Samek W, Krois J. Artificial Intelligence in Dentistry: Chances and Challenges. J Dent Res. 2020 Jul;99(7):769-774. doi: 10.1177/0022034520915714.

[18] Hoarau R, Zweifel D, Simon C, Broome M. The use of 3D planning in facial surgery: preliminary observations. Rev Stomatol Chir Maxillofac Chir Orale. 2014 Dec;115(6):353-60. doi: 10.1016/j.revsto.2014.07.006.

[19] Weijs WL, Coppen C, Schreurs R, Vreeken RD, Verhulst AC, Merkx MA, Bergé SJ, Maal TJ. Accuracy of virtually 3D planned resection templates in mandibular reconstruction. J Craniomaxillofac Surg. 2016 Nov;44(11):1828-1832. doi: 10.1016/j.jcms.2016.08.024.

[20] Witjes MJH, Schepers RH, Kraeima J. Impact of 3D virtual planning on reconstruction of mandibular and maxillary surgical defects in head and neck oncology. Curr Opin Otolaryngol Head Neck Surg. 2018 Apr;26(2):108-114. doi: 10.1097/MOO.0000000000000437. PMID: 29470184.

[21] Al Yafi F, Camenisch B, Al-Sabbagh M. Is Digital Guided Implant

Surgery Accurate and Reliable? Dent Clin North Am. 2019 Jul;63(3):381-397. doi: 10.1016/j.cden.2019.02.006.

[22] Pegorini VS et al. VIRTUAL PLANNING AND SURGERY IN GUIDED IMPLANTOLOGY. REVISTA SAÚDE INTEGRADA. 2013; 6 (11-12): 243-261.

[23] Balem, Francisco Pessotto (2010) The use of rapid prototyping in dentistry. Monograph, Federal University of Rio Grande do Sul.

[24] Vercruyssen M, Fortin T, Widmann G, Jacobs R, Quirynen M. Different techniques of static/dynamic guided implant surgery: modalities and indications. Periodontol 2000. 2014 Oct;66(1):214-27. doi: 10.1111/prd.12056.

[25] Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent. 2005 Apr;25(2):113-9. PMID: 15839587.

[26] Paolantonio M, Dolci M, Scarano A, d'Archivio D, di Placido G, Tumini V, Piattelli A. Immediate implantation in fresh extraction sockets. A controlled clinical and histological study in man. J Periodontol. 2001 Nov;72(11):1560-71. doi: 10.1902/jop.2001.72.11.1560.

[27] Saadoun AP, Le Gall MG, Touati B. Current trends in implantology: part II--treatment planning, aesthetic considerations, and tissue regeneration. Pract Proced Aesthet Dent. 2004 Nov-Dec;16(10):707-14; quiz 716. PMID: 15739910.

[28] Lacerda, EJR de et al. (2018) Guided Surgery With and Without Flap in the Same Patient. The International Journal Of Oral & Maxillofacial Implants. Ubá, MG, pp 56-62.

[29] Small PN, Tarnow DP. Gingival recession around implants: a 1-year longitudinal prospective study. Int J Oral Maxillofac Implants. 2000 Jul-Aug;15(4):527-32. PMID: 10960986.

[30] D'haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A. Current state of the art of computer-guided implant surgery. Periodontol 2000. 2017 Feb;73(1):121-133. doi: 10.1111/prd.12175.

[31] GUIMARÃES CM (2016) SIMPLIFICATION AND PRECISION IN GUIDED SURGERY FOR OSSOINTEGRATED IMPLANTS.Dissertation, University of Uberaba.

[32] Sierra-Rebolledo A, Tariba-Forero D, Rios-Calvo MD, Gay-Escoda C. Effect of undersized drilling on the stability of immediate tapered implants in the anterior maxillary sector. A randomized clinical trial. Med Oral Patol Oral Cir Bucal. 2021 Mar 1;26(2):e187-e194. doi: 10.4317/medoral.24107.

[33] Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003 Aug;23(4):313-23. PMID: 12956475.

[34] Funato A, Salama MA, Ishikawa T, Garber DA, Salama H. Timing, positioning, and sequential staging in esthetic implant therapy: a four-dimensional perspective. Int J Periodontics Restorative Dent. 2007 Aug;27(4):313-23. PMID: 17726987.

[35] Gomez-Roman G. Influence of flap design on peri-implant interproximal crestal bone loss around single-tooth implants. Int J Oral Maxillofac Implants. 2001 Jan-Feb;16(1):61-7. PMID: 11280363.

[36] Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. J Clin Periodontol. 1997 Aug;24(8):568-72. doi: 10.1111/j.1600-051x.1997.tb00230.x.

[37] Small PN, Tarnow DP. Gingival recession around implants: a 1-year longitudinal prospective study. Int J Oral Maxillofac Implants. 2000 Jul-Aug;15(4):527-32. PMID: 10960986.

[38] Rompen E, Raepsaet N, Domken O, Touati B, Van Dooren E. Soft tissue stability at the facial aspect of gingivally converging abutments in the esthetic zone: a pilot clinical study. J Prosthet Dent. 2007 Jun;97(6 Suppl):S119-25. doi: 10.1016/S0022-3913(07)60015-8.

[39] Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. Int J Oral Maxillofac Implants. 2004;19 Suppl:43-61. PMID: 15635945.

[40] Levine RA, Ganeles J, Gonzaga L, Kan JK, Randel H, Evans CD, Chen ST. 10 Keys for Successful Esthetic-Zone Single Immediate Implants. Compend Contin Educ Dent. 2017 Apr;38(4):248-260. PMID: 28368133.

[41] Chen P, Nikoyan L. Guided Implant Surgery: A Technique Whose Time Has Come. Dent Clin North Am. 2021 Jan;65(1):67-80. doi: 10.1016/j.cden.2020.09.005.

[42] Kernen F, Kramer J, Wanner L, Wismeijer D, Nelson K, Flügge T. A review of virtual planning software for guided implant surgery - data import and visualization, drill guide design and manufacturing. BMC Oral Health. 2020 Sep 10;20(1):251. doi: 10.1186/s12903-020-01208-1.

[43] Báez-Marrero N, Rafel JL, Rodríguez-Cárdenas YA, Aliaga-Del Castillo A, Dias-Da Silveira HL, Arriola-Guillén LE. Accuracy of computer-assisted surgery in immediate implant placement: An experimental study. J Indian Soc Periodontol. 2022 May-Jun;26(3):219-223. doi: 10.4103/jisp.jisp_763_20.

[44] Pessoa R, Siqueira R, Li J, Saleh I, Meneghetti P, Bezerra F, Wang HL, Mendonça G. The Impact of Surgical Guide Fixation and Implant Location on Accuracy of Static Computer-Assisted Implant Surgery. J Prosthodont. 2022 Feb;31(2):155-164. doi: 10.1111/jopr.13371.

[45] Henprasert P, Dawson DV, El-Kerdani T, Song X, Couso-Queiruga E, Holloway JA. Comparison of the Accuracy of Implant Position Using Surgical Guides Fabricated by Additive and Subtractive Techniques. J Prosthodont. 2020 Jul;29(6):534-541. doi: 10.1111/jopr.13161.