

In-house protocol for fully guided zygomatic implant surgery and prosthesis repositioning

A technical note

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Abstract

Aim: The present study aims to describe an in-house protocol for fully guided zygomatic implant surgery and prosthesis repositioning.

Materials and methods: Four extramaxillary zygomatic dental implants (ZIs) were placed in one patient. The preoperative phase included digital planning, through which a surgical guide was designed and created. The analysis of the accuracy of guided surgery and the guided prosthesis repositioning was carried out by superimposing the digital planning with the final postsurgical implant positioning through CBCT. The radiologic evaluation included implant angular deviation, entrance and exit deviation, platform deviation, and apex apicocoronal and mesiodistal deviation. The prosthetic evaluation was performed in three directions: buccopalatal, apicocoronal, and mesiodistal.

Results: All the ZIs successfully osseointegrated after 3 months of healing, with no complications. The mean

axial angular implant deviation was 0.52 ± 0.36 degrees, and the mean implant depth deviation was 0.47 ± 0.28 mm. The entrance and exit deviation of the implants was 0.74 ± 0.42 mm and 0.7 ± 0.43 mm, respectively. The virtual prosthesis was superimposed and compared with the standard tessellation language file of the provisional polymethyl methacrylate prosthesis at the level of the first molars and central incisors; the mean buccopalatal deviation was 0.6 ± 0.035 mm, the mean apicocoronal deviation was 0.65 ± 0.11 mm, and the mean mesiodistal deviation was 0.3 ± 0.07 mm.

Conclusions: According to the results obtained in this first case of the present case series, careful and meticulous digital planning based on the correct prosthetic parameters can safely guide the performance of surgery.

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Keywords

implantology, prosthodontics

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Introduction

Zygomatic dental implants (ZIs) were first introduced by Bränemark for cases characterized by large maxillary defects due to trauma, tumors, or congenital atrophies.^{1,2} Nowadays, ZIs are considered to be a successful option, affording high implant and prosthesis survival rates in patients where maxillary rehabilitation with conventional implants is complicated due to significant atrophy of the premaxilla and a pneumatized sinus of the posterior maxilla.^{1,3,4} Alternatively, such cases would require invasive regenerative procedures prior to conventional implant placement such as sinus floor elevation and horizontal and vertical guided bone regeneration techniques.²

When comparing the conventional with the ZI option, the reported advantages of the latter include less treatment morbidity since more invasive regenerative procedures are avoided, treatment time is reduced, and fewer implants are needed for a full-arch fixed rehabilitation.³⁻⁵ However, due to the remote position of the zygomatic buttress and the consequent lack of intraoperative visibility, the placement of ZIs is performed almost blindly and requires significant operator experience. Furthermore, the technique poses a risk of complications such as infraorbital nerve paresthesia, periorbital trauma, and sinus infections, which increase the demand for surgical precision.^{3,6-8}

The digitally guided concept has been introduced in implant dentistry and, more specifically, in ZI treatment, increasing the precision of implant placement and reducing surgery time and morbidity.^{9,10} CBCT, in combination with intraoral scanning, provides the data for planning virtual prosthetically guided 3D implant placement prior to surgery.^{11,12} Such digital guidance has been described based on two different concepts: static guidance and computer-

aided surgical navigation.¹¹⁻¹³ Although the latter guidance method may afford high intraoperative accuracy, it requires specific equipment that increases the costs and requires a high level of operator knowledge. Furthermore, the existing software applications are not error-free tools and may malfunction.^{13,14}

The static guidance concept has been studied in cadavers and in cast models and evidences a high level of operative accuracy.¹⁵⁻¹⁷ The present study describes a novel technique involving fully guided digital placement of ZIs based on an in-house protocol using static guides that fully guide the drilling sequence, implant placement, and repositioning of the immediate provisional prosthesis over the multi-units of the ZIs.

Materials and methods

A 69-year-old female with arterial hypertension (controlled with Micardis Plus) and no allergies or toxic habits was seen at the UIC Barcelona International University of Catalonia in the Department of Oral and Maxillofacial surgery. The patient complained of chewing problems with her dentures and needed an esthetic and functional fixed prosthesis that would allow her to smile, eat, and interact again.

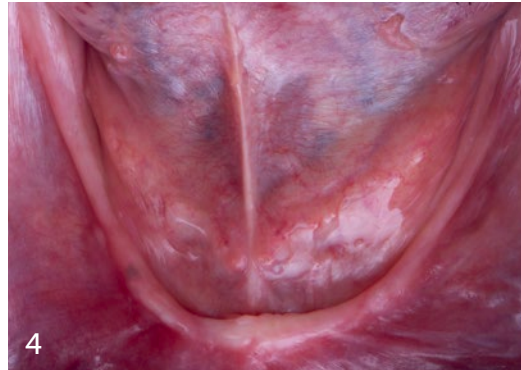
Presurgical procedure

A comprehensive clinical (extraoral, intraoral, functional, and esthetic) and radiologic examination was performed. Standardized extra- and intraoral photographs were taken of the initial situation with the old dentures. The dentures were rebased with additional light body silicone (Zhermack, Lemförde, Germany), and a digital impression (Medit i500; Medit, Seoul, South Korea) of the rebased dentures was taken extraorally.



Figs 1 and 2

Initial condition of the patient with an unesthetic, unstable, and dysfunctional removable prosthesis.



Figs 3 and 4

Initial intraoral photographs showing the fully edentulous situation.

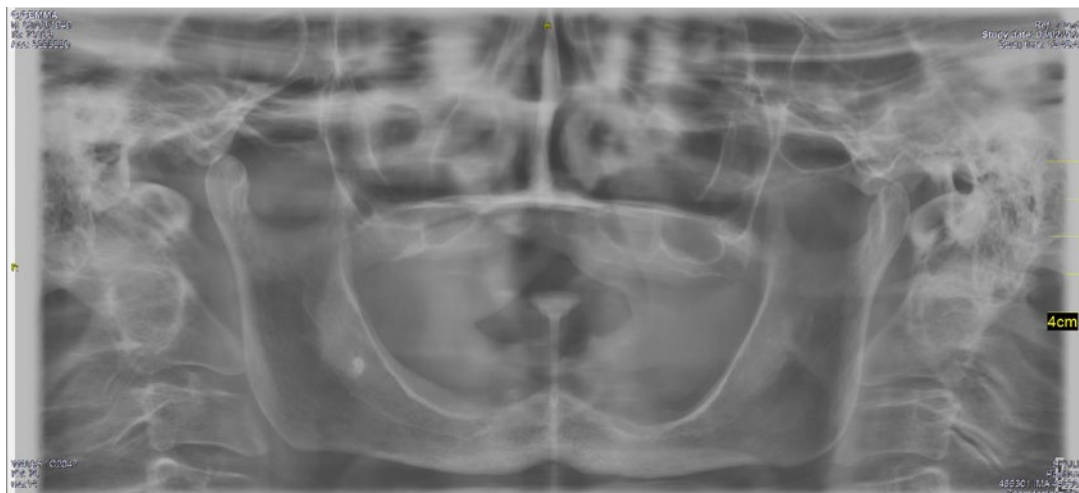


Fig 5 Radiologic examination: Both the upper and lower maxillary ridge present extended bone atrophy.

The clinical examination evidenced an unesthetic smile, with unstable and dysfunctional dentures presenting an edge-to-edge relationship, and complete edentulism (see Figs 1 to 4). Radiologically, the upper maxillary bone presented type VI bone atrophy according to the Cawood and Howell classification¹⁸ (see Fig 5).

Treatment plan

In the upper maxilla, a four ZI-supported fixed prosthetic rehabilitation adopting a fully digital approach was decided upon based on the advanced degree of bone atrophy and the patient's requirements. In the lower mandible, it was decided to perform a

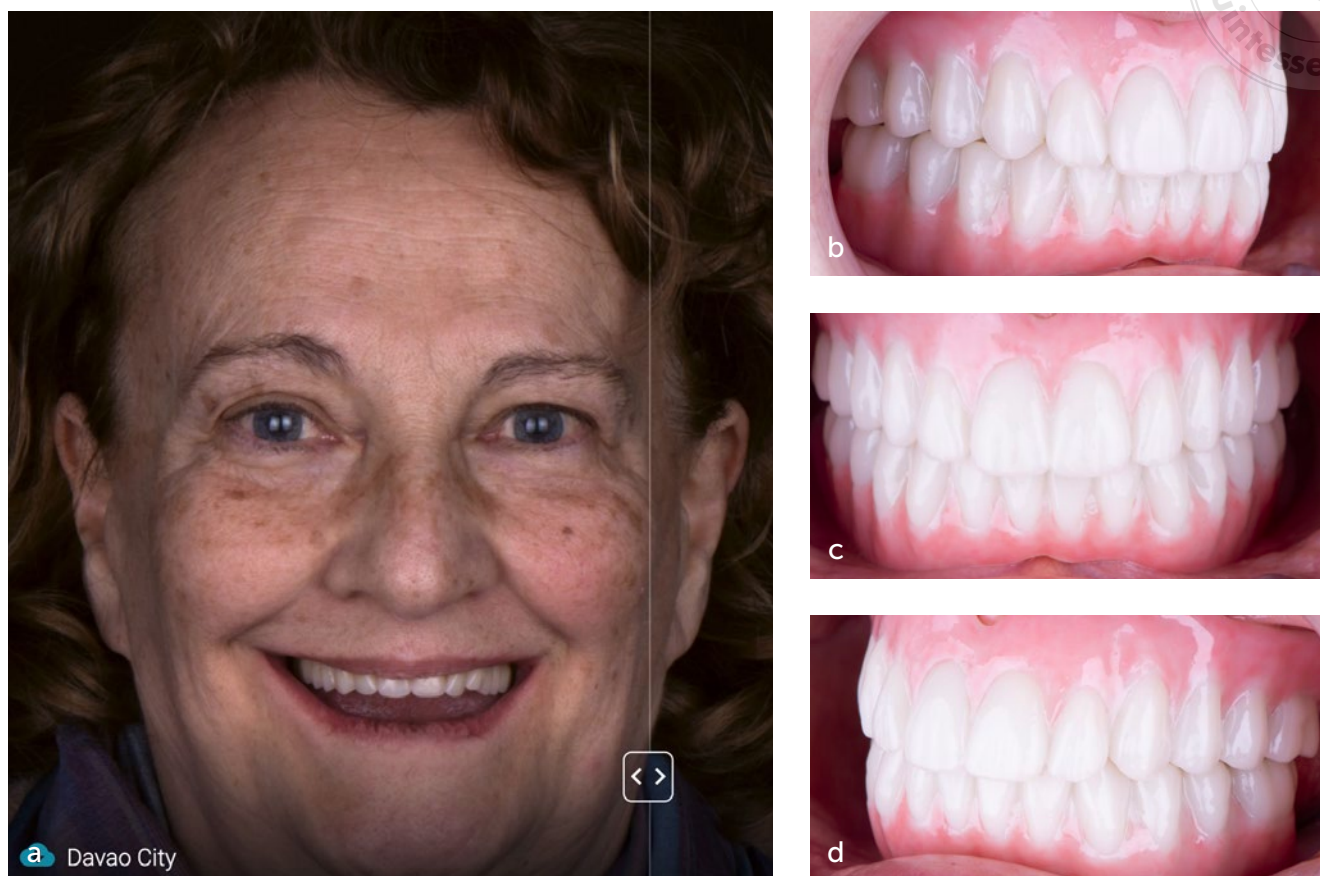


Fig 6a to d A new pair of dentures were fabricated according to the new smile design.

removable prosthetic rehabilitation over four conventional implants.

The initial extraoral photographs with the old dentures were used as a reference to provide an initial smile design with individual tooth shapes (Smilecloud, Timișoara, Romania). The photographs were calibrated, and indications were sent to the dental laboratory for the fabrication of new provisional dentures with a new intermaxillary relationship, function, and esthetic parameters (Figs 6 to 8).

Fully digital approach

A CBCT scan was performed with a 3D Imaging device (i-CAT Imaging Science Inter-

national, Hatfield, PA, USA) with the following settings: 120 kVp, 8 mA, voxel size 0.4 mm. The CBCT data were imported into implant planning software (Blue Sky Bio, Libertyville, IL, USA), along with the scan data of the new dentures. To facilitate the superimposition of the CBCT with the standard tessellation language (STL) files of the new dentures, composite pellets were added at the buccal and palatal/lingual surfaces of the dentures. All data were matched in the implant planning software (Blue Sky Bio) and used to virtually plan the four ZIs (Neo-dent zygomatic GM implants; Straumann, Basel, Switzerland; Fig 9). The positioning of the implants was planned according to the guidelines described by Rigolizzo¹⁹ and



Fig 7 Extraoral photograph of the patient with the new complete dentures in the rest position.



Fig 8 Extraoral photograph of the patient with the new complete dentures in the maximum smile position.

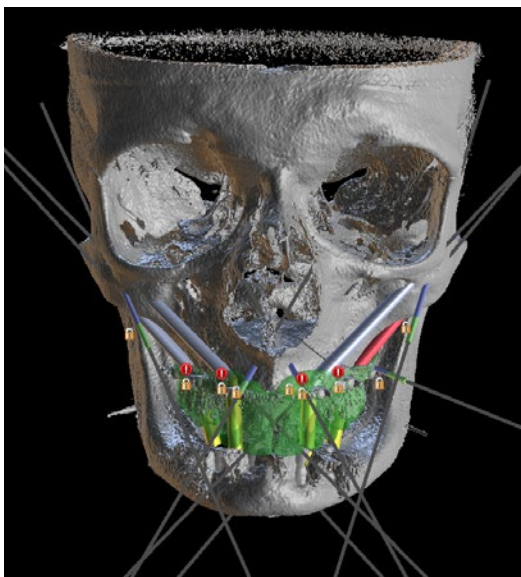


Fig 9 The STL file of the copy of the new maxillary provisional complete denture is superimposed onto the CBCT with the use of the composite pellets as points of reference.



Fig 10a to d The provisional denture is 3D printed and the composite pellets are placed over it (a and b). This copy is then scanned (c and d). After the superimposition of the STL data of the maxillary prosthesis (green) with the CBCT, the ideal position of the ZIs is chosen. The emergence levels of the ZIs are the maxillary lateral incisors and maxillary second premolars.

Rossi,²⁰ and correct prosthetic emergence was planned according to the digitalized maxillary prosthesis; thus, the emergence profiles of the implants' platforms were positioned at the level of the maxillary lateral incisors and second premolars^{19,20} (Fig 10).

Autodesk Meshmixer (Autodesk, San Rafael, CA, USA) and Blue Sky Plan version

4.7.20 (Blue Sky Bio) were used to design the surgical and prosthetic guides once the ZIs were perfectly placed according to the previously mentioned anatomical and prosthetic parameters.

Zygomatic implant surgical guidance (ZiSG) comprises the use of two-unit guides that rest on the malar bone, the lateral wall

of the maxillary bone, the maxillary crest, and the subnasal area of the premaxilla, avoiding extension over the nasopalatine nerve and the palatal area. The first guide was reserved exclusively for pilot drilling and consisted of a customized resin tube that fully guided this first drill from the beginning, from the alveolar crest to the malar bone. The second guide was used to complete the rest of the drilling sequence and implant placement. Both guides have a longitudinal slot along the longitudinal axis of the guide tube, which provides the operator with visual control of the drilling and correct irrigation, and affords a visual reference. Each surgical guide has several anchor pins to secure it to the bone: two subnasal, one sub-malar, and one between implants or distal to the distal implant, depending on the amount of residual bone available for anchoring the pins. The surgical guides share the subnasal anchor pins, which are used as a reference and as a guide to properly place the contralateral guides (Fig 11).

The prosthetic positioning guide (PPG) is a cage-shaped framework that contains the provisional prosthesis for immediate loading. The guide was designed to achieve adequate support of the prosthesis without compromising the resin-bonding process of the immediate loading titanium abutments. The two sub-nasal and two tuberosity anchor pin holes were used to properly place the prosthesis guide.

All the surgical guides were printed (Formlabs 2; Formlabs, Somerville, MA, USA) with biocompatible photopolymer resin (Surgical Guide Resin; Formlabs), washed with 70% isopropyl alcohol for 7 min using a wash and cure machine (Anycubic Technology, Shenzhen, China), light cured, and sterilized at 121°C for 30 min in a gravity displacement autoclave (W&H, Bürmoos, Austria). The provisional prosthesis was milled from a polymethyl methacrylate (PMMA) block (Anaxdent, Stuttgart, Ger-

many) with a milling machine (vhf camfacture, Stuttgart, Germany) and sterilized with the same protocol as for the surgical and prosthetic guides (see Fig 8).

Surgical and prosthetic phase

Implant surgery was performed under conscious sedation and local anesthesia (4% articaine plus epinephrine 1:100,000; Normon, Salamanca, Spain). A full-thickness incision was performed along the maxillary crest from teeth 17 to 27, with two distal vertical releasing incisions. A full-thickness flap was raised extending to the nasal floor in the premaxilla and the two zygomatic maxillary buttresses in the malar areas, and the infraorbital nerves were identified and protected. Reflection of the palatal flap was performed to facilitate insertion of the surgical guides. The patient had previously undergone a bilateral sinus lift without success, as can be seen in the frontal image after the raising of the flap (Fig 12).

The initial pilot surgical drilling guide was placed and secured with two fixation pins in the premaxilla, one fixation pin in the malar bone, and another in the tuberosity of each quadrant. Once pilot drilling was completed, the first surgical drilling guide was replaced by the second one to finish the drilling sequence, and finally the ZIs (Neodent) were placed (Fig 13).

Correct positioning of the implants according to the alveolar crest was carried out through the surgical guide, which indicates the level of implant insertion and the rotational position of the internal hexagon of the implants in order to facilitate correct placement of the prosthetic abutments. Multi-unit abutments measuring 1.5 mm in height were placed at a 45-degree angle over all the ZIs and torqued to 20 Ncm. Temporary titanium cylinders were screwed over the multi-unit abutments, and polytetrafluoroethylene (PTFE) tape was placed on

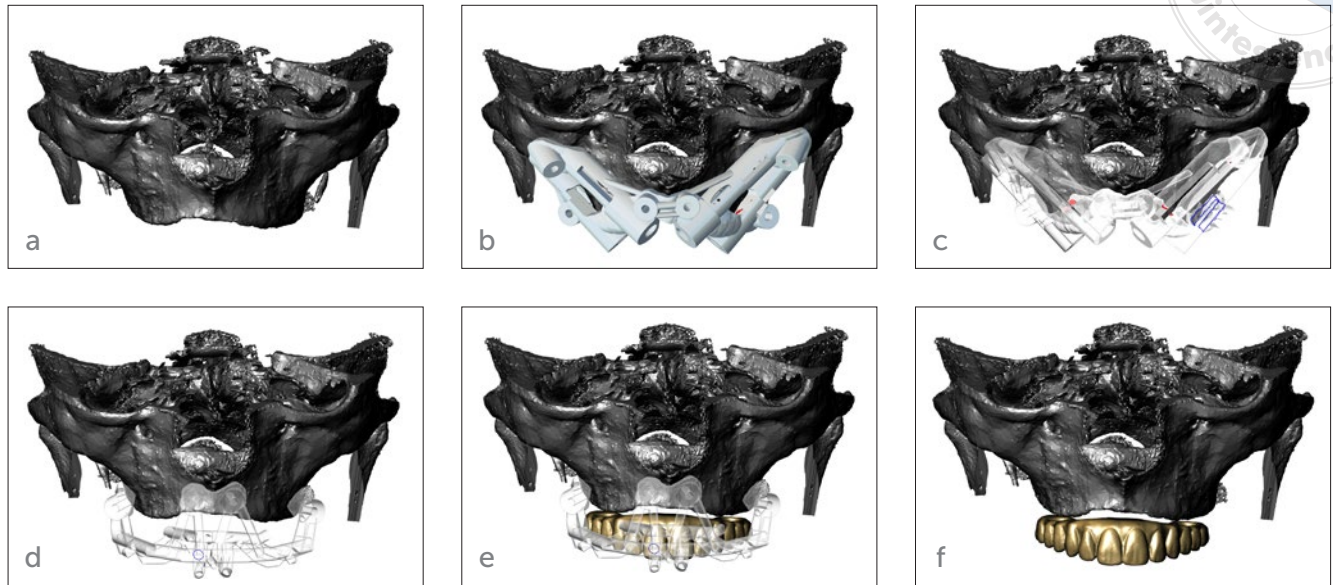


Fig 11a to f The sequence of guides for the drills and implants (a to c) and for the prosthesis for the immediate loading (d to f).

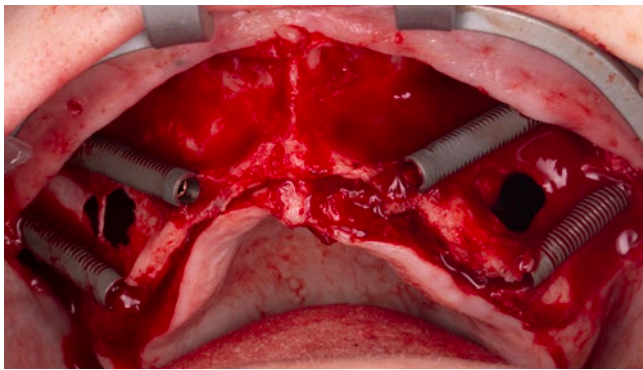


Fig 12 Frontal view after implant placement. The sinus windows are apparent due to a previous failed attempt at bilateral sinus floor elevation.

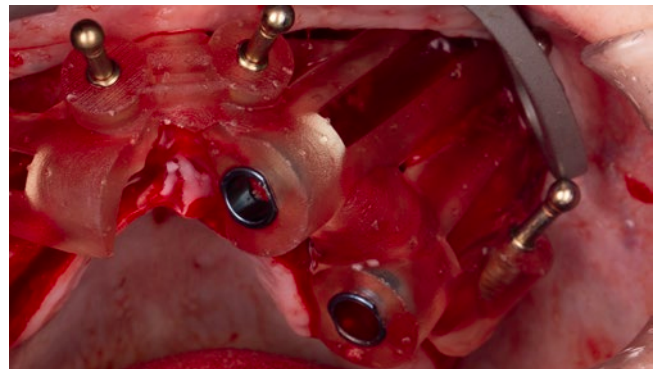


Fig 13 The guide for the final drilling and implant placement, positioned and stabilized with fixation pins on the second quadrant.

the access hole of the cylinders. Then, a temporary PMMA CAD/CAM prosthesis according to the previous digital wax-up was set into the PPG, and the entire assembly was placed and stabilized in the digitally planned position with the anchor pins into the same anchor pin holes used for the ZiSG (Fig 14).

The temporary titanium cylinders were attached to the PMMA CAD/CAM prosthesis with acrylic resin (Ivocron PMMA; Ivoclar

Vivadent, Schaan, Liechtenstein). Then, the anchor pins were removed, followed by the PPG and the prosthesis. A pedicled buccal fat pad flap was subsequently herniated through the vertical releasing incision at the level of the maxillary first molar using a tunnel approach. The flap was placed over the implants to protect them from possible soft tissue dehiscences, as described by Hernández-Alfaro et al,²¹ and the flaps were sutured without tension using interrupted simple su-

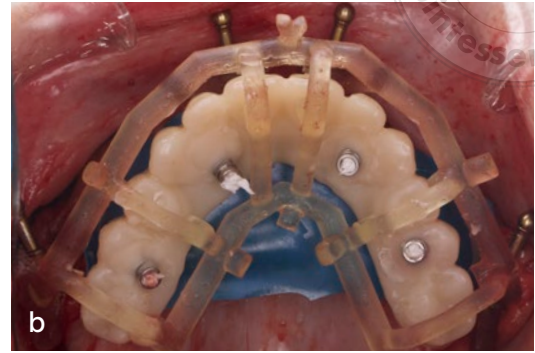
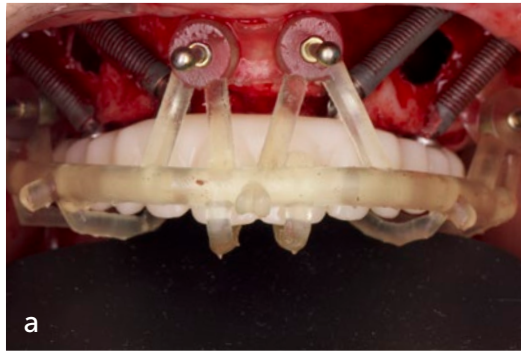


Fig 14a and b Frontal (a) and occlusal (b) views of the provisional prosthesis repositioned over the provisional abutments through the guidance of the corresponding guide. The provisional abutments are connected with the polytetrafluoroethylene (PMMA) prosthesis using acrylic resin.

Fig 15 After performing the pick-up, the remaining gaps between the cylinders and the temporary prosthesis are filled and the prosthesis is polished.

tures (Vicryl 4-0; Ethicon, Somerville, NJ, USA). The remaining gaps between the cylinders and the temporary prosthesis were filled with the same PMMA material, as previously mentioned (Fig 15). All excesses were removed and the temporary prosthesis was polished to ensure soft tissue adaptation. The prosthesis was then screwed into the mouth, the access holes were filled with PTFE tape and Telio CS Inlay (Ivoclar Vivadent), and polymerization was performed. Lastly, the occlusion was adapted to provide homogenous contacts in the posterior and anterior zones in static relation, and group function in lateral movements. Extra- and intraoral photographs and a new CBCT scan were taken to check the position of the implants and the prosthesis in comparison with the original planning (Fig 16). The final prosthetic rehabilitation with monolithic zirconia was performed after 3 months (Figs 17 to 21).

Radiologic measurement

A postoperative CBCT scan was taken and an evaluation performed directly after implant and prosthesis placement (i-CAT Imaging Science International), and an intraoral scan of the maxillary arch was performed (Medit i500). The intraoral scan STL data were imported into the CBCT. The postoperative maxilla was segmented and superimposed with the initial segmented CBCT by using anatomical structures as reference points (infraorbital foramen, nasopalatine foramen, anterior nasal spine, and zygomatic arches). Thus, the virtual implant and prosthesis planning were superimposed with the real postsurgical situation, and the discrepancy measurements of the implants and prosthesis were analyzed.



Fig 16a to c Extra- and intraoral photographs of the finished provisional prosthesis made of PMMA.



Figs 17 to 20 Final prosthesis at the 1-year follow-up.

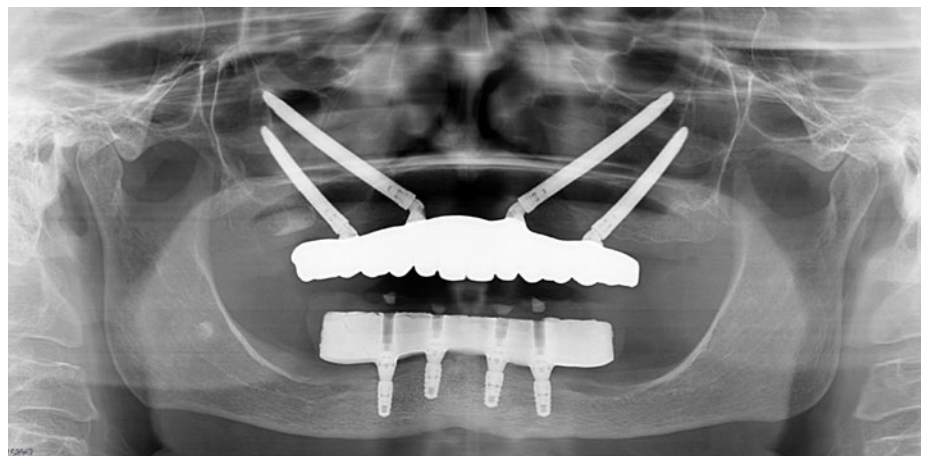


Fig 21 Final orthopantomography.

Data analysis

1. Axial angular implant deviation (AID):
The angle formed by the axis of the virtual implant when crossing the axis of the real implant, in a lateral view.
2. Implant entrance deviation (IEND):
The distance between the centers of the platforms of the virtual and real implants, in an axial view.
3. Implant exit deviation (IEXD):
The distance between the centers of the apexes of the virtual and real implants, in an axial view.
4. Apical mesiodistal deviation (AMDD):
The distance between the most mesial point of the apex of the virtual implant and the most mesial point of the apex of the real implant, in an axial view.
5. Apical buccopalatal deviation (ABPD):
The distance between the most buccal point of the apex of the virtual implant and the most buccal point of the apex of the real implant, in an axial view.
6. Platform buccopalatal deviation (PBPD):
The distance between the most buccal point of the platform of the virtual implant and the most buccal point of the platform of the real implant, in an axial view.
7. Platform mesiodistal deviation (PMDD):
The distance between the most mesial point of the platform of the virtual implant and the most mesial point of the platform of the real implant, in an axial view.
8. Implant depth deviation (IDD):
The distance between virtual and real implant depth at platform level, in a lateral view.
9. Prosthesis deviation:
 - a) Right first molar measurements:
 - i) Buccolingual
 - ii) Mesiodistal
 - iii) Apicocoronal
 - b) Left first molar measurements:

- i) Buccolingual
- ii) Mesiodistal
- iii) Apicocoronal
- c) Right central incisor measurements:
 - i) Buccolingual
 - ii) Mesiodistal
 - iii) Apicocoronal
- d) Left central incisor measurements:
 - i) Buccolingual
 - ii) Mesiodistal
 - iii) Apicocoronal

All measurements were linear and were performed with Blue Sky Bio software.

Results

All ZIs were successfully osseointegrated after 3 months of healing, with no complications and a survival rate of 100%. The results of the radiographic comparison between the virtual implant planning and the real positioning are shown in Tables 1 and 2.

The mean AID was 0.52 ± 0.36 degrees, and the mean IDD was 0.47 ± 0.28 mm. Regarding the entrance and exit deviations of the implants, IEND was 0.74 ± 0.42 mm, and IEXD was 0.7 ± 0.43 mm. The platforms and apexes of the implants were evaluated in the mesiodistal and buccopalatal directions. At platform level, the mean PBPD was 0.55 ± 0.23 mm, and the mean PMDD was 0.73 ± 0.16 mm. Regarding the apical deviation, ABPD was 0.3 ± 0.18 mm and AMDD was 0.63 ± 0.63 mm.

In addition, the virtual prosthesis was superimposed and compared with the STL data of the provisional PMMA prosthesis at the level of the first molars and central incisors. The evaluation was performed in three directions: buccopalatal, apicocoronal, and mesiodistal. The mean buccopalatal deviation was 0.6 ± 0.035 mm, the mean apicocoronal deviation was 0.65 ± 0.11 mm, and the mean mesiodistal deviation was 0.3 ± 0.07 mm.

Table 1 Results of the radiographic comparisons between the virtual implant planning and the real implant positioning

Implant position		15	12	22	25	SD
AID		0.34	0.11	0.9	0.76	0.36
Platform horizontal deviation	PBPD	0.3	0.88	0.63	0.4	0.23
	PMDD	0.78	0.55	0.94	0.67	0.16
Apex horizontal deviation	ABPD	0.23	0.16	0.22	0.57	0.18
	AMDD	0.62	0.18	0.2	1.52	0.63
IDD		0.35	0.36	0.9	0.29	0.28
IEXD		0.72	0.39	0.39	1.31	0.43
IEND		0.38	0.57	1.34	0.69	0.42

AID: axial angular implant deviation; IEND: implant entrance deviation; IEXD: implant exit deviation; AMDD: apical mesiodistal deviation; ABPD: apical buccopalatal deviation; PMDD: platform mesiodistal deviation; IDD: implant depth deviation; SD: standard deviation

Table 2 Results of the evaluation of the deviation between the virtual and the real prostheses

Prosthesis measurements							
		16	26	11	21	SD	Mean
Prosthesis position	Buccopalatal	0.58	0.58	0.65	0.58	0.035	0.6
	Apicocoronal	0.77	0.72	0.57	0.53	0.11	0.65
	Mesiodistal	0.29	0.4	0.27	0.25	0.07	0.3

Discussion

The prosthetic rehabilitation of patients with advanced maxillary bone atrophies using ZIs is becoming increasingly relevant due to the reduction in treatment time and morbidity when compared with bone reconstructive procedures.^{22,23} However, some authors consider it to be a complicated and aggressive treatment that involves serious intra- and postoperative complications.²⁴ For this reason, the need arises to develop a protocol allowing these potential complications to be minimized and to make this technique increasingly predictable and safe, from surgery to prosthesis repositioning.

Digital dental technology is increasingly being used in oral implantology, leading to more precise implant placement with shorter surgical times and less morbidity.²⁵

Computed tomography (CT) as well as CBCT creates 2D image slices of the patient situation that are then displayed individually or filed as stack rendering 3D radiographic imaging data (DICOM).²⁶⁻²⁸ Moreover, digitization of the hard and soft tissue of the oral cavity can be achieved using extra- or intra-oral scanners. Data derived from these two distinct processes are available in the universal stereolithography format as an STL file.^{29,30} The combination of STL and DICOM files allows for the virtual superimposition of the initial intraoral condition with the restorative planning, the bone, and the soft tissue imaging. Thus, prosthetically oriented implant positioning is virtually planned to secure maximal intrabony anchorage and intrasurgical precision.

Schiroli et al used a 3D-printed static guide to place six ZIs flaplessly in cadavers.³¹

Although the ZI implant entrance deviation values were slightly lower, the exit and angular deviation values were much greater: 5.9 ± 4.87 mm in the case of exit deviation versus only 0.7 ± 0.43 in the present study, and 6.11 ± 4.3 degrees in the case of angular deviation versus 0.52 ± 0.36 degrees in the present study. Grecchi et al placed 40 ZIs in cadavers using a different metal static splint design.³² The common parameters investigated were IEND, IDD, IEXD, and AID, with slightly lower results. Finally, it is important to mention that there are no clinical studies on digitally guided ZI placement; moreover, studies are lacking regarding methods for digitally guiding prosthesis repositioning over ZI abutments, and evaluating prosthesis deviation between virtual and planned as well as real and postoperative prosthesis positioning.

In the present study, the values obtained in terms of superimposition of the 3D planning with the final implant positions show

that the extrapolation of the digital planning to the surgical field was extremely precise, according to the deviation observed in terms of angulation and definitive positioning of the implants. In addition, through the prosthetic placement system proposed in the present study, correct 3D positioning of the prosthesis in the mouth is seen to be very simple and precise.

Conclusions

According to the results obtained in this first case of the present case series, careful and meticulous digital planning based on the correct prosthetic parameters can safely guide the performance of surgery. Although possible complications do exist, the results obtained suggest the procedure to be safe and reliable. However, controlled trials are needed to confirm the accuracy and reproducibility of the technique.

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