13.12 Rehabilitating an Edentulous Maxilla with a Fixed Dental Prosthesis Using a DSD-Guided Approach

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A 60-year-old man was referred to the Center of Excellence for Prosthodontics and Implant Dentistry (CEPI) of the School of Dentistry of the University of São Paulo, Brazil for implant therapy. Anamnesis, clinical examination, and radiographs revealed esthetic and functional problems, the absence or structural compromise of various teeth (16 – 11, 21, 22, 24, 25, 37, 45, and 48), periodontal and endodontic problems (17 and 27), implant fracture (46), and occlusal disorders (Figs 1 and 2a). The patient reported that he was undergoing treatment for cardiovascular diseases. Periodontal probing depth, bleeding score, and plaque score were recorded on the periodontal chart available at *www.periodontalchart-online.com* (Department of Periodontology, University of Bern, Switzerland) during the initial examination (Fig 2b).

Conventional impressions, occlusal registration, panoramic radiographs, photographs, videos, intraoral and model scans, and cone-beam computed tomography (CBCT) scans were acquired to provide data for treatment planning. After consultation with specialists in other disciplines, different treatment options were presented to the patient and the following treatment plan was agreed:

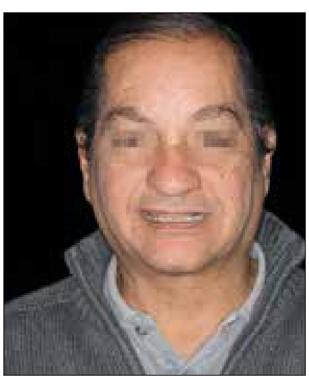
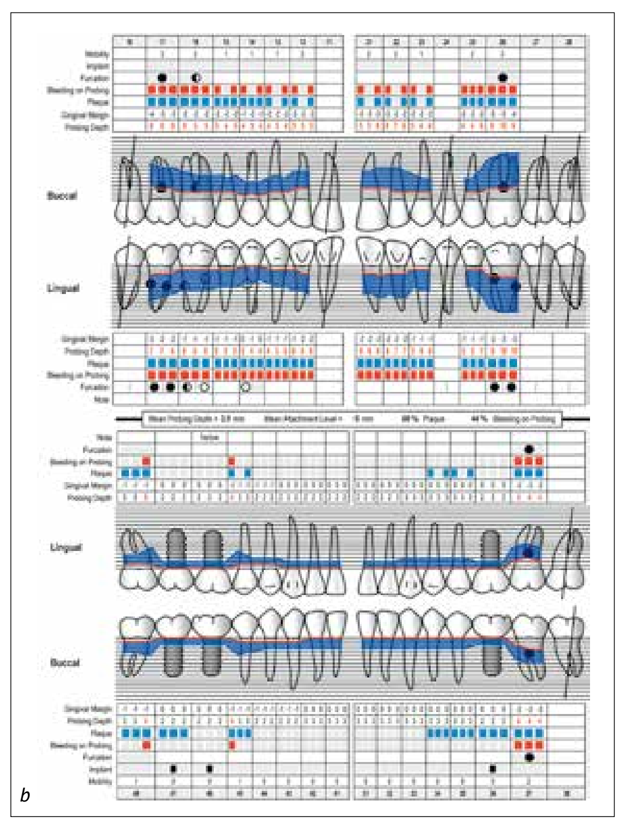


Fig 1 Pre-treatment, facial view.



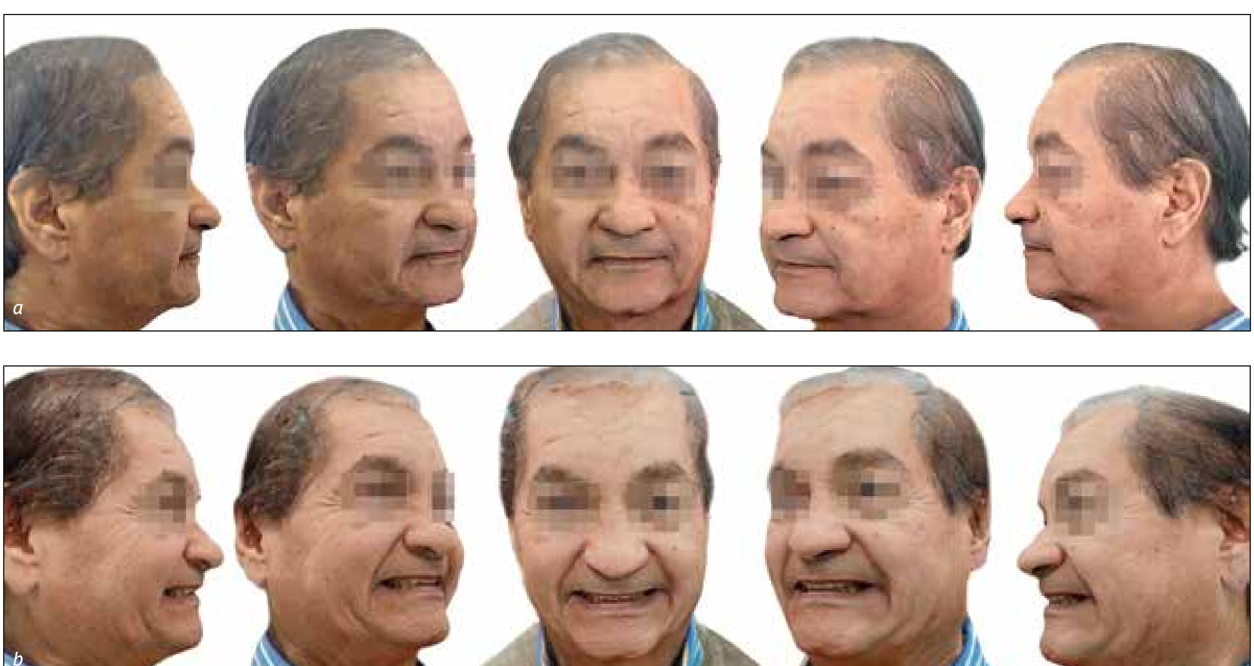
Figs 2a-b Pre-treatment panoramic radiograph (a). Periodontal and peri-implant chart of the baseline clinical examination (b).

- ***Phase 1 — Preparatory therapy.*** Basic periodontal treatment, extraction of all maxillary teeth except 13, 23 and provision of an provisional removable upper partial denture. Extraction of teeth 37, 45, 48 and removal of the fractured implant 46.
- ***Phase 2 — Planning and implant surgery.*** Six months after the extractions: Implant planning, extraction of teeth 13 and 23, flapless implant placement supported by digital technologies, and delivery of an immediately loaded provisional full-arch screw-retained prosthesis.
- ***Phase 3 — Final rehabilitation.*** 10 months after loading with a provisional prosthesis: Definitive computer-aided designed and manufactured (CAD/CAM) maxillary hybrid full-arch fixed prosthesis.

Fig 3 Provisional removable partial denture, occlusal view.

Phase 1 — Preparatory therapy

The vertical dimension of occlusion (VDO) and the centric relation (CR) were recorded clinically and the stone casts were accordingly in a semi-adjustable articulator. Teeth 13 and 23 were retained for strategic reasons to support the surgical template, their extraction planned for the day of implant surgery. A maxillary provisional removable partial denture was fitted immediately after the extraction of teeth 16–12, 21, 22, 25, and 26 to reestablish the VDO, anterior guidance, and occlusal plane (Fig 3). Teeth 37, 45, and 48 were extracted; the fractured implant 46 was removed. We decided to keep the implants and crowns at sites 36 and 47 because they were osseointegrated and clinically acceptable despite the marginal bone loss.



Figs 4a-b 3D digital files of the face at rest (a). Forced smile (b).

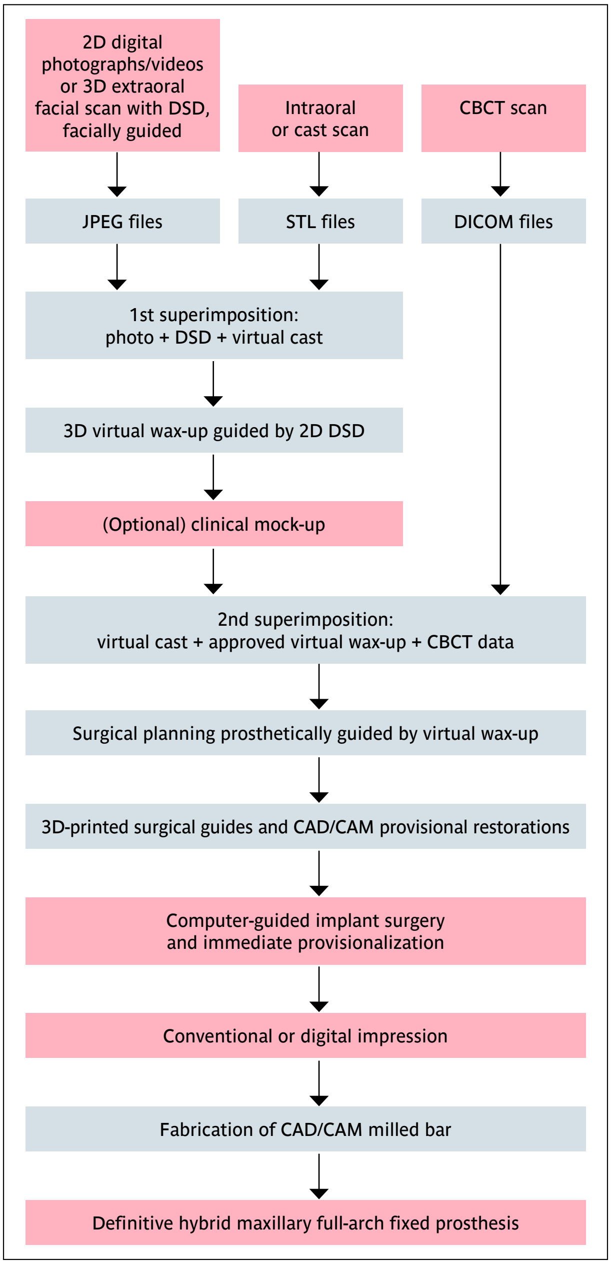
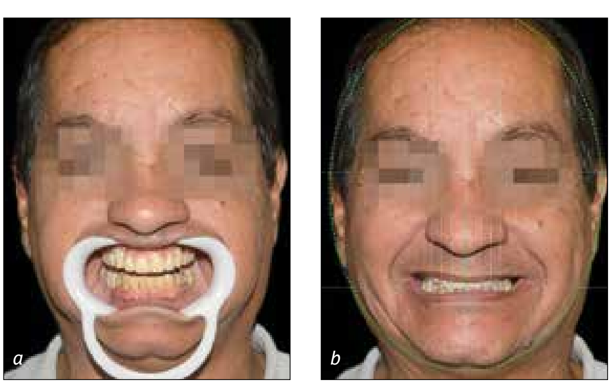


Fig 5 Digital workflow guided by facial references (adapted from Coachman and coworkers 2017). Clinical appointments are shown in pink.

Phase 2 — Implant planning and implant surgery

Six months after the preparatory phase, digital clinical information was transferred to a software program (Nemo Smile Design; Nemotec, Madrid, Spain). These included digital photographs and screenshots exported from smartphone videos, IOS (STL) files of scanned casts, extraoral photographs of the face converted into three-dimensional (3D) STL files (Remake; Autodesk, San Rafael, USA) (Figs 4a-b), and CBCT scan (DICOM) files.

The starting point for the proposed digital workflow was the Digital Smile Design (DSD) guided by facial references such as the facial midline, bipupillary line, smile curve, and smile height (Fig 5). Frontal photographs of the face were taken with and without lip retractors, keeping the camera and the patient's head still to create photographs with similar distances, angles, and distortions. Using Nemo Smile Design software (Nemotec), the photographs were adjusted and merged. Facial reference lines were drawn over the smiling photograph and transferred to the photographs using lip retractors. These facial references guided the 2D smile design and the 3D virtual wax-up (Figs 6 and 7). Superimposition of the scanned casts on the DSD facilitated a virtual wax-up, correcting the occlusal plane and harmonizing the position of the teeth with the face and smile (Figs 8 to 10). Although the DSD is subject to limitations inherent in the photographic process and in the superimposition of 2D to 3D files, it is a useful planning tool that assists decision-making, improves diagnostic vision, and facilitates education and communication between professionals and patients



Figs 6a-b View of the face with lips retracted (a). Facial reference lines drawn over the 2D photograph of the face to create a smile frame (b).

Fig 7 Generated 2D digital smile design according to the facial reference lines transferred from smile photograph to retracted photograph.

Fig 8 Scanned cast data superimposed on 2D digital smile design using the teeth of the provisional denture as reference points.

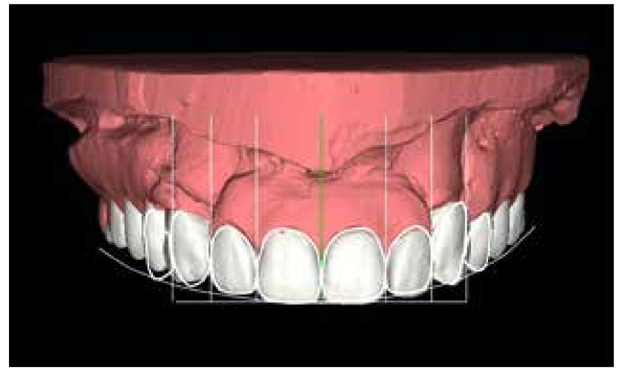


Fig 9 Scanned cast with 3D virtual waxing guided by 2D digital smile design.

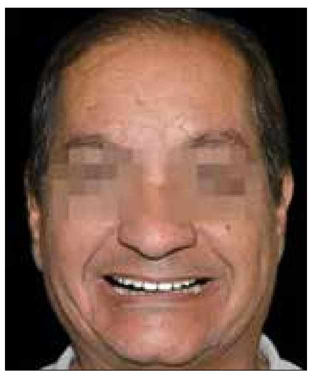


Fig 10 Overlapping digital wax-up and facial photographs for a digital esthetic evaluation before inserting the implants.

Fig 11 3D-printed cast.

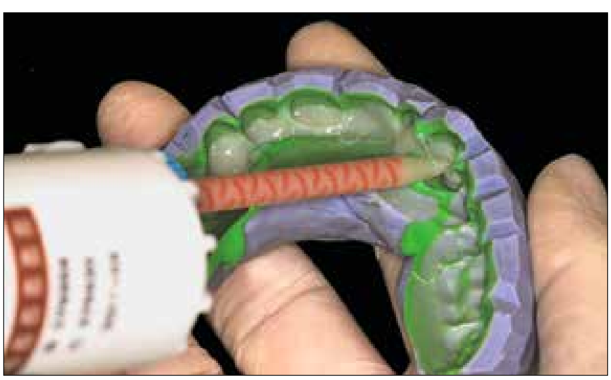
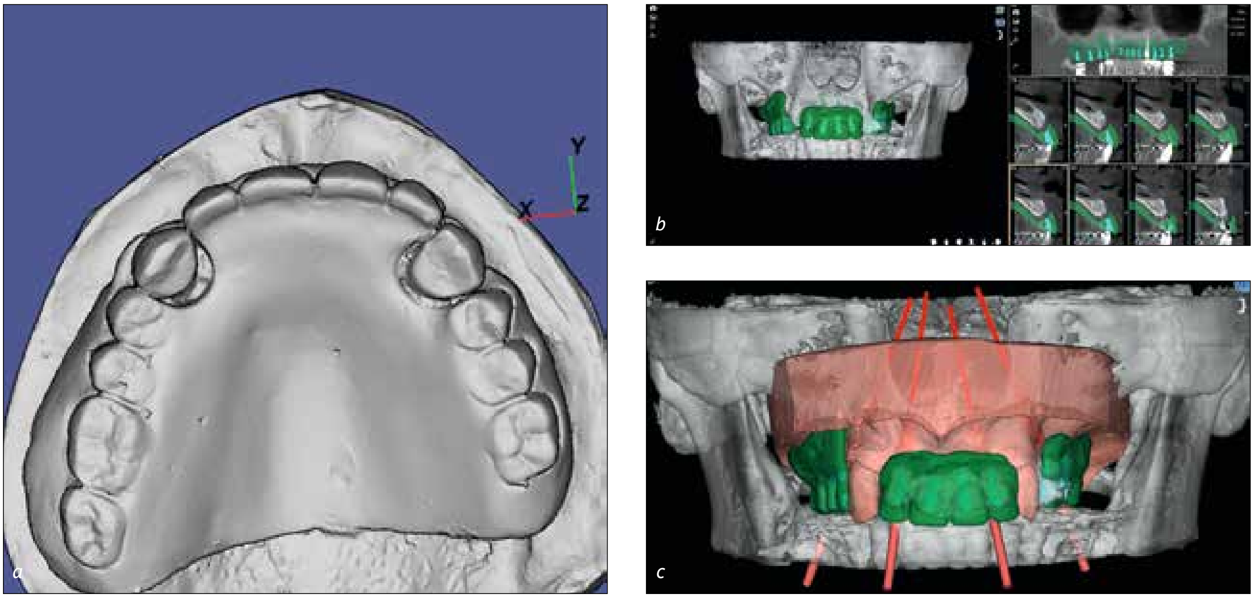


Fig 12 Silicone index and Protemp 4 bisacryl composite resin (3M Espe, Maplewood, MN, USA) for a diagnostic preview.

Fig 13 Trial restoration in harmony with the face.

The maxillary digital wax-up was exported as an STL file to be 3D-printed. A silicone index was prepared for the fabrication of trial restorations (Figs 11 to 13). This clinical step was very useful for the esthetic evaluation; however, this step will not always be possible (especially not in patients with excessive hypereruption or abnormal tooth angulations) as the silicone index will not fit properly over the remaining teeth in such situations.



Figs 14a-c STL of the scanned cast (a). Merged anatomical (CBCT) and prosthetic data (radiographic template) (b). Superimposition of CBCT and virtual-cast data (c).

Fig 15 Prosthetically driven surgical planning.

Once the trial restorations were approved by the patient, the surgical steps were planned.

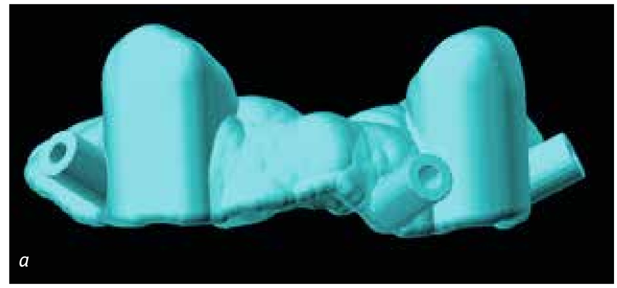
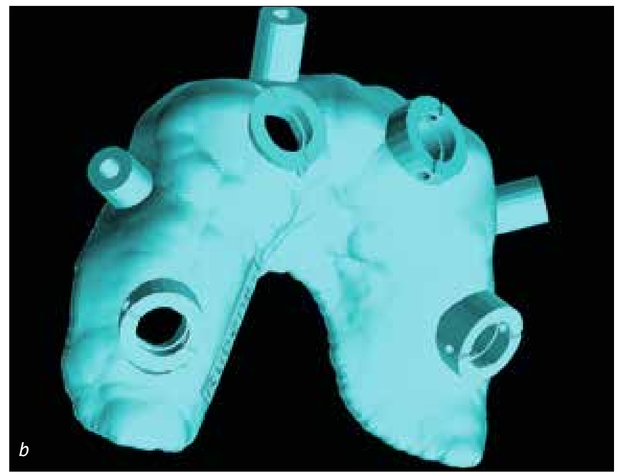
Impressions were taken with the provisional denture in place and the resulting cast was scanned in a lab scanner (7-series; Dental Wings, Montreal, Canada) (Fig 14a). The provisional denture was also used as a radiographic template, using denture teeth filled with radiopaque composite resin. A CBCT scan was obtained using the double-scan technique: The patient was scanned with the radiographic template in the first scan and the radiographic template was scanned separately, extraorally, in the second scan (Fig 14b). The radiopaque fiducial marks were the references for data matching. Using the Nemo Smile Design-DSD software (Nemo Smile Design; Nemotec), the data were superimposed, merging the cast with the virtual wax-up and CBCT data with the denture teeth as reference points, thus allowing prosthetically driven planning of the position of implants (Figs 14c and 15). Implant planning provided was for the placement of four implants (Bone Level; Institut Straumann AG, Basel, Switzerland), two placed axially in the anterior region and two distally tilted implants in the posterior region (Straumann Pro-Arch protocol), using computer-guided flapless implant surgery.

From this planning, two surgical guides and an provisional denture were designed in a CAD software package (Nemo Smile Design; Nemotec) (Figs 16a-c). The surgical guides were 3D-printed (Digital Wax; DWS Systems, Vicenza, Italy), and the CAD/CAM provisional denture was milled from the 3D virtual wax-up (Ceramill Motion2; Amann Girrbach, Pforzheim, Germany), all with sleeves for anchor guide pins in the predetermined positions (Fig 17).

Following administration of a local anesthetic, the first tooth-supported guide (Fig 18) was positioned on the remaining maxillary teeth. This guide was used to secure the position of the anchoring guide pins so that the second guide for implant placement (used after removing the teeth) and the dental prosthesis itself would use the same positional references as indicated by these pins.

Teeth 13 and 23 were extracted (Fig 19) and the mucosa-supported surgical guide was positioned according to the anchor guide pins. Two bone-level implants (Bone Level RC, diameter 4.1 mm, length 8 mm; Institut Straumann AG, Basel, Switzerland) were placed in the anterior region and two additional bone-level implants (Bone Level RC, diameter 4.1 mm, length 12 mm; Institut Straumann AG) were placed in the posterior maxilla in a flapless approach (Fig 20). All implants displayed a high insertion torque and adequate primary stability, so immediate provisionalization was possible.

Definitive screw-retained abutments (SRA; Institut Straumann AG) were tightened on the implants at a torque of 35 Ncm. The provisional was positioned in the mouth using the anchor guide pins, and provisional titanium cylinders were connected to the prosthesis with autopolymerizing acrylic resin.


Figs 16a-c STL image of the tooth-supported guide (a). STL image of the mucosa-supported guide for implant placement (b). STL image of the provisional prosthesis (c).

Fig 17 Printed guides and milled provisional denture.

Fig 18 Tooth-supported guide used to determine position of anchor guide pins.

Fig 19 Extraction of teeth 13 and 23.

Fig 20 Guided flapless implant placement.

Fig 21 CAD/CAM provisional maxillary fixed dental prosthesis, frontal view.

Fig 22 Postoperative view of the face.

The anchor guide pins were removed together with the corresponding guide sleeves in the denture. The occlusion was checked and adjusted and the prosthesis was polished before being screwed in place at a torque of 15 Ncm (Fig 21). The screw access holes were sealed with PTFE tape and composite resin, and the patient was given postoperative instructions. Clinical and radiographic postoperative evaluations (Figs 22 to 24) were performed during the 10 months until the definitive prosthesis was fabricated.

Fig 23 Postoperative radiograph.

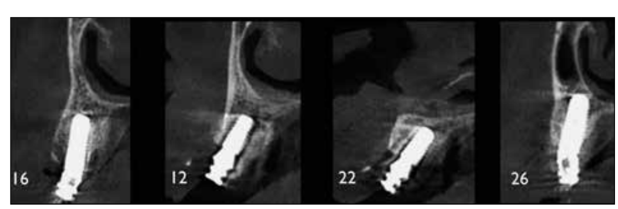


Fig 24 Postoperative CBCT scan.

Phase 3 — Final rehabilitation

In the mandible, two bone-level implants (Bone Level NC, diameter 3.3 mm, length 10 mm; Institut Straumann AG) were placed at sites 45 and 46 in a conventional manner after computer-assisted planning (Fig 25).

Two months after mandibular implant placement, an implant-level digital impression was taken with scanbodies inserted into the implants (Scan Body; Institut Straumann, AG) using an intraoral scanner (Straumann Cares/Dental Wings; Institut Straumann AG). Using the resulting STL file, the single crowns were designed digitally. Monolithic zirconia crowns (Prettau; Zirkonzahn, Gais, Italy) were fabricated by CAM, cemented to the Variobase abutments, and screwed onto the implants (Figs 26a-b).

For the maxillary rehabilitation, a conventional abutment-level impression was taken and a working model made 10 months after implant placement and loading with the provisional prosthesis. A trial wax set-up was tested and adjusted in the mouth. A silicone index was made to evaluate the space available for the bar (Figs 27a-e).

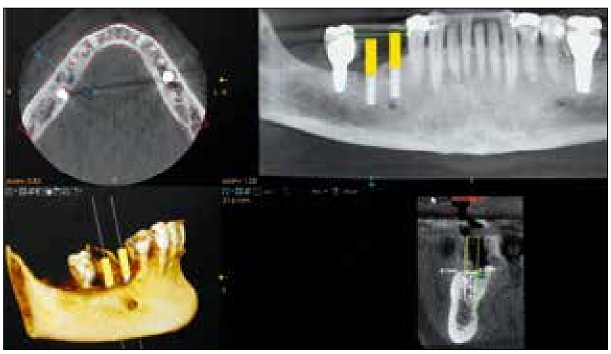
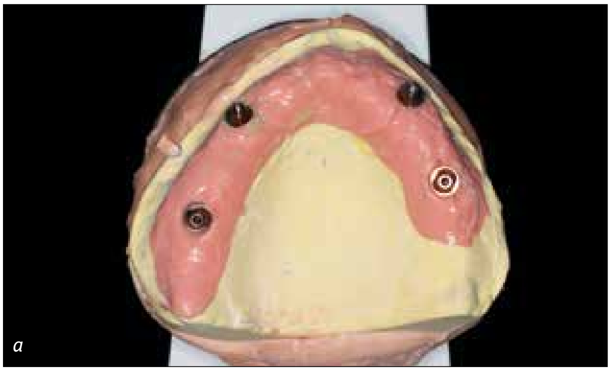
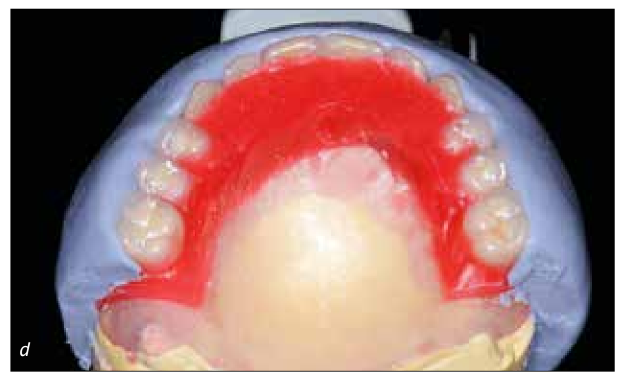


Fig 25 Surgical planning of the mandibular implants assisted by software.

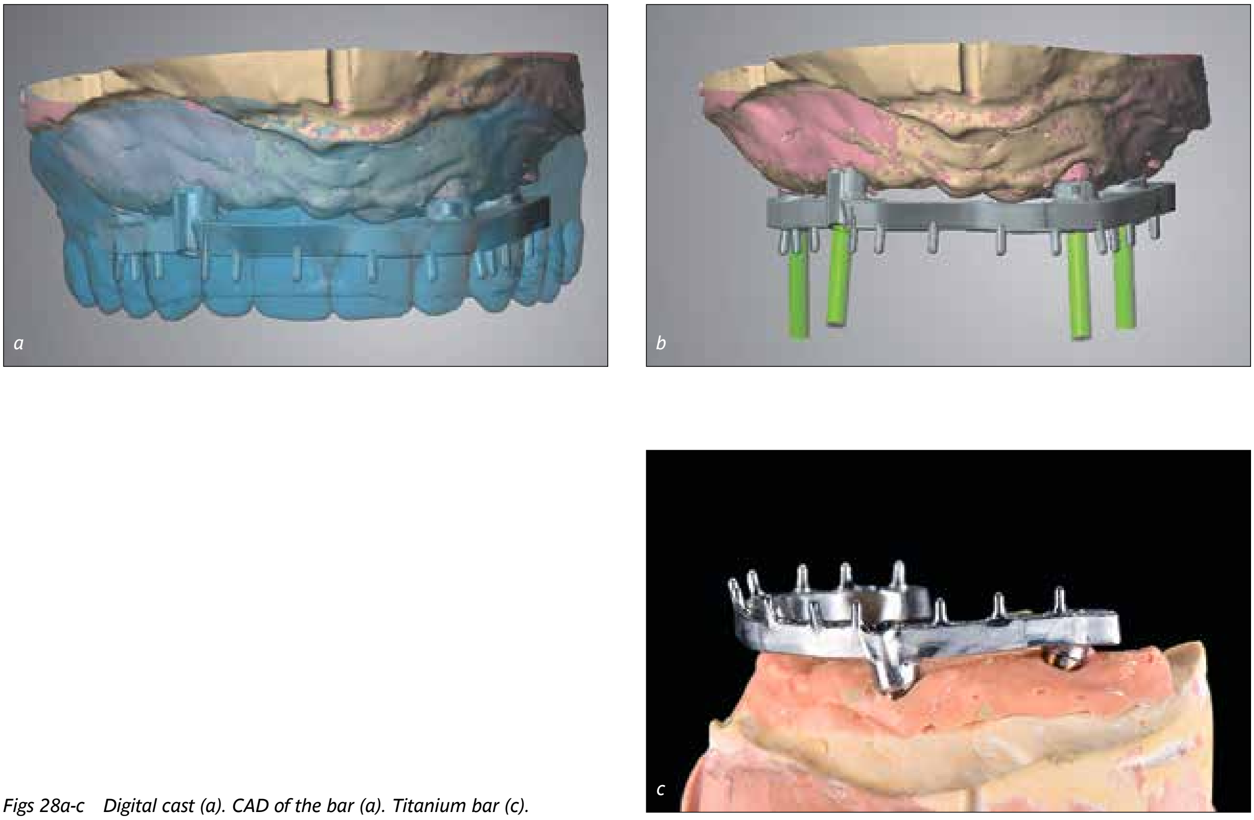
Fig 26a Zirconia crowns cemented onto Variobase abutments and screw-retained on the implants.

Fig 26b Periapical radiograph.





Figs 27a-e Working model (a). Clinical VDO measurement (b). Trial set-up (c). Silicone index (d). Checking the space for the bar (e).



Figs 28a-c Digital cast (a). CAD of the bar (a). Titanium bar (c).

The maxillary working model was scanned in an extraoral lab scanner (7 series, Dental Wings, Montreal, Canada) and a CAD/CAM-milled titanium bar was fabricated (Straumann Milling Center, Curitiba, Brazil) (Figs 28a-c).

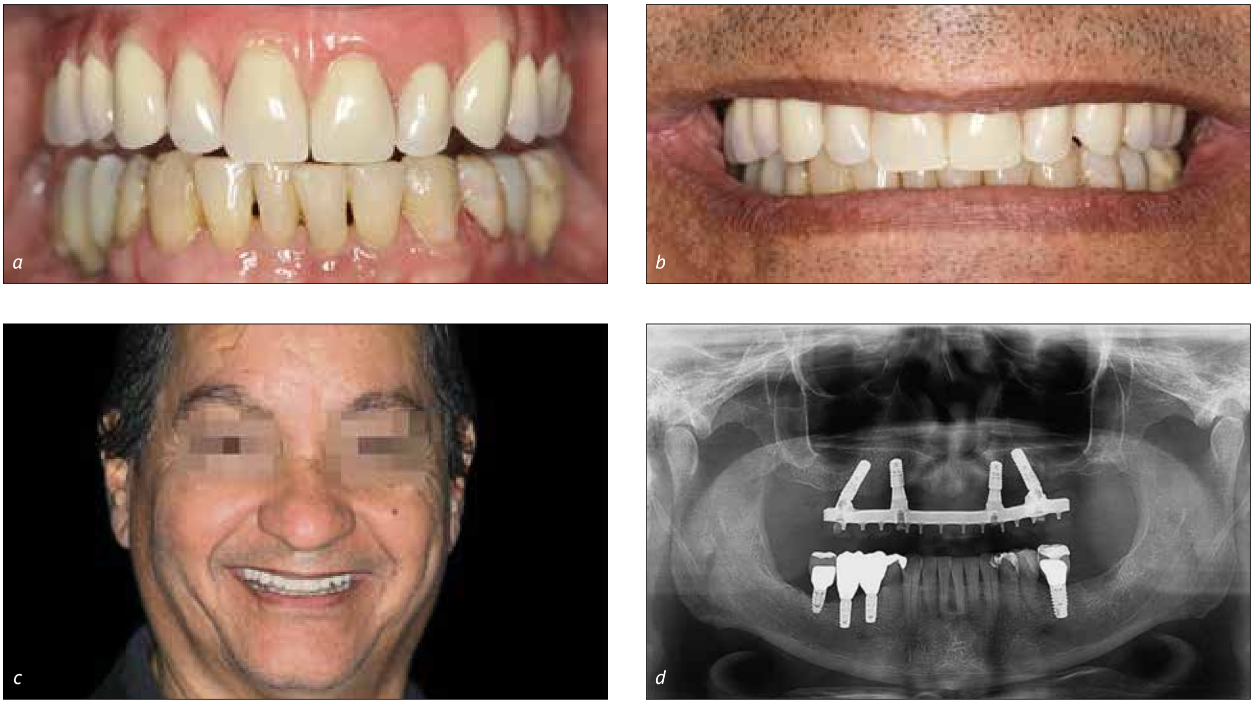
A final wax try-in of the teeth on the titanium bar was performed, and the denture was processed in the lab. A definitive hybrid maxillary full-arch fixed prosthesis was fitted (Figs 29a-d). Centric and lateral contacts were assessed to obtain uniform occlusal contacts distributed over the entire arch. Screw access holes were sealed with PTFE tape and composite resin. A convex mucosal contact surface facilitates the use of dental floss. The extension of the buccal flange was just sufficient to prevent the escape of air and phonetic difficulties, without compromising access for adequate oral hygiene at home (Fig 29e).

At delivery, some peri-implant marginal bone loss was observed, especially on the distal aspect of the tilted implants, which may have been caused by an inadequately balanced distribution of occlusal forces while the patient was using the provisional prosthesis without reinforcement from a metal framework. The patient was instructed in correct oral hygiene procedures and clinically followed every 3 months for 1 year. No significant additional bone loss or clinical complications were observed (Figs 30a-d). Peri-implant and periodontal indices were recorded at the one-year follow-up (Fig 31).

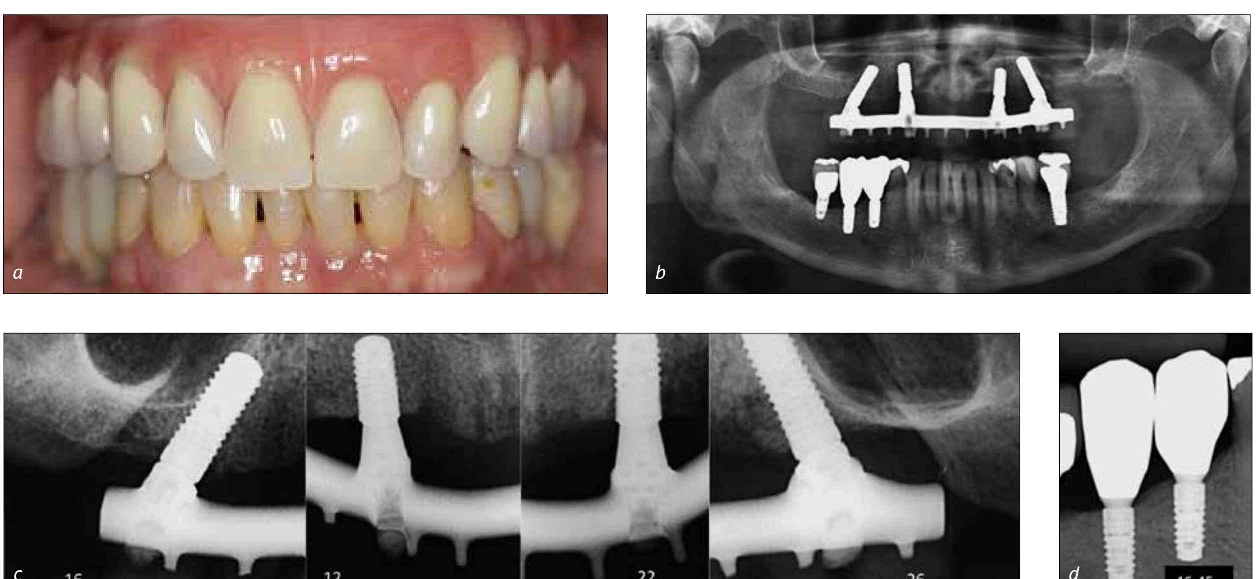
Discussion

Perfect harmony between the teeth, lips, and facial components is the goal of every prosthodontic treatment, whether performed in a conventional or digital workflow. In anterior restorations and extensive rehabilitations of complete arches, treatment planning must be guided by the face to obtain adequate esthetic and functional results (Spear and Kokich 2007; Calamia and coworkers 2011; Giannuzzi and Motlagh 2015).

A great challenge when rehabilitating patients with complete or anterior partial edentulism has been to relate the face to a definitive cast and fabricate wax patterns in harmony with the face. In the digital workflow, the challenge remains the same, but now these facial references need to be transferred to the virtual cast in the planning software. Complex rehabilitations are commonly associated with out-of-balance esthetics and occlusal conditions that present unreliable occlusal references and require correction.



Figs 29a-e Final restorations. Intraoral view (a). Smile (b). Facial view (c). Radiograph (d). Access for home oral hygiene (e).



Figs 30a-d 1-year follow-up. Clinical view (a). Panoramic radiograph (a). Periapical radiographs of teeth 16, 12, 22, and 26 (c). Periapical radiograph of teeth 45 and 46 (d).

Examples of such situations may include patients with partial edentulism where the extraction of all remaining teeth is indicated. This is a challenging situation, because as long as the compromised teeth have not been extracted, the clinical evaluation of the teeth for the new dental prostheses may be difficult or even impossible. The use of digital resources may be the only way to visualize the future dental set-up before the extractions are performed. This virtual waxing must be guided by facial references and must be in harmony with the smile, making a facial approach to planning essential (Coachman and coworkers 2017).

Various authors have reported on different clinical surgical and prosthodontic solutions assisted by digital technology (Stapleton and coworkers 2014; Lanis and coworkers 2015a, Lewis and coworkers 2015; Arunyanak and coworkers 2016; Charette and coworkers 2016). The 3D facial scan has been successfully integrated into the CAD/CAM workflow for partial and full-arch rehabilitations (Joda and Gallucci 2015; Harris and coworkers 2017; Hassan and coworkers 2017) and for esthetic restorations (Lin and coworkers 2017). A recent consensus statement (Hämmerle and coworkers 2015) recommends:

- As guided surgery may add precision to flapless surgery, it can have its implications in geriatric patients and individuals with compromised medical conditions.
- Digital technology can provide technical, clinical, and procedural benefits.
- Where available, multiple patient-related data sets (e.g., CBCT, intraoral and laboratory scans, virtual planning for implants and restorations) should ideally be integrated to maximize their synergistic diagnostic value.

Further scientific validation and large-scale clinical studies on digital treatment modalities are still needed to understand the impact of this promising technology for modifying well-established conventional protocols (Joda and coworkers 2017a).

The treatment planning of the presented case included both digital and conventional workflows at different clinical stages, seeking to leverage the benefits of each.

Recording a comprehensive case history, clinical examinations, respect for biological principles, and a thorough knowledge of the relevant esthetic and functional parameters remain the keys to the success of the digital workflow, just as with conventional workflows.

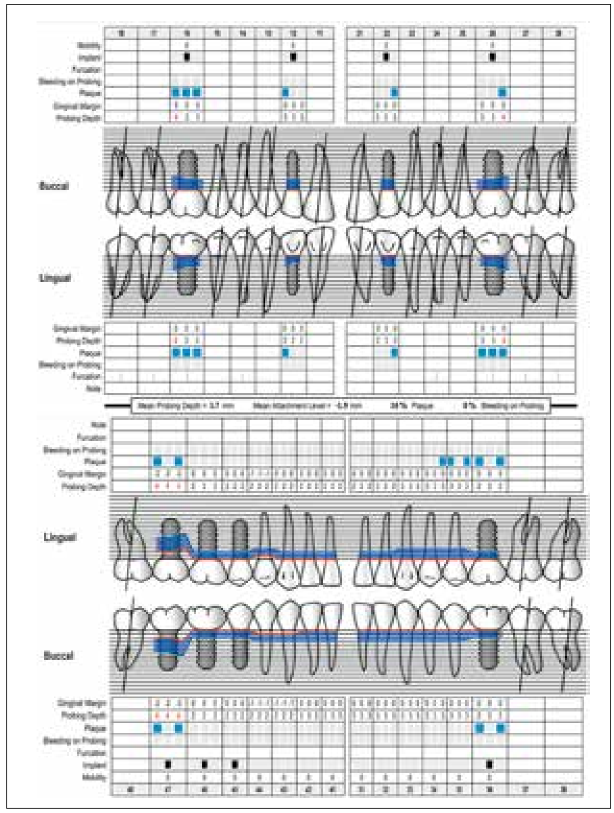


Fig 31 Peri-implant and periodontal indices at the one-year follow-up.

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