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Atlas of Immediate Dental Implant Loading

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Part I

Biological Principles of Immediate Loading

Introduction to Immediate Loading in Implantology

Enrica Giammarinaro, David Soto-Peñaloza, Javier Aizcorbe-Vicente, Miguel Peñarrocha-Diago, Ugo Covani, and David Peñarrocha-Oltra

Abbreviations

CL	Conventional loading
DL	Delayed loading
EL	Early loading
IL	Immediate loading
INFL & IR	Immediate nonfunctional loading and immediate restoration
IR	Immediate restoration
ISQ	Implant stability quotient
IT	Insertion torque
OL/NOL	Occlusal loading or non-occlusal loading

Take-Home Message
In the last decades, a deeper understanding of bone biology and advance in implant technology allowed a significant evolution of surgical and prosthetic protocols. Early loading and immediate loading protocols have been introduced to reduce the total treatment time and to accommodate new patient needs.

The Evolution of Loading Protocols: Delayed, Early, and Immediate Loading

Brånemark traditional recommendation was to perform implant rehabilitation in two stages: the first entry was only for implant placement; after 3–6 months of undisturbed submerged healing for mandible and maxilla respectively (Adell et al. 1981; Albrektsson et al. 1986), a second surgical entry would have allowed loading of the implants (Randow et al. 1999; Gapski et al. 2003). The rationale behind this approach was that implant micro-movements as consequence by an inadequate primary stability, caused by functional forces at the bone-implant interface in the early wound healing stages, could have induced fibrous tissue formation rather than new bone (Brunski et al. 1979; Lioubavina-Hack et al. 2006), eventually causing clinical failure.

However, the discomfort, inconvenience, and anxiety associated with the waiting period remained a challenge to the patients. The main request was to reduce the overall rehabilitation time from surgery to final restoration delivery: installation of implants in fresh extraction sockets and immediate restored implants have been adopted.

First reports on immediate loading of dental implants can be traced back to the early 1960s thanks to the contribution of Dr. Leonard Linkow. He described immediate loading protocols for root-form and blade implants (Linkow and Mahler 1977). In 1979, Philippe D. Ledermann advised the placement of four non-submerged intra-foramina mandibular implants, in areas where the bone was at least 11 mm in height, and suggested to immediately load them with a splinting bar-retained restoration (Ledermann 1979). This protocol showed favorable long-term clinical results for totally edentulous mandibles, and the reported success rate after a functional phase of 1–72 months was 92.34% for 415 implants on 122 patients. In a later publication, the author summarized 20 years of experience reporting data for 523 implants on 411 patients with an average permanence time of 7.23 years. The survival rate was fair, standing at 92% (Ledermann 1996).

Schnitman and colleagues discussed the possibility of using an immediate fixed partial prosthesis without compromising long-term implant survival in the edentulous mandible (Schnitman et al. 1990).

The authors placed five to six implants in the anterior mandible and two implants distal to the foramina. Abutments

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were connected immediately after surgery to the two distal fixtures and to one fixture in the anterior region. A provisional immediate fixed restoration was loaded on the three exposed implants, whereas the remnant submerged implants served as control. The authors showed that the overall implant success was not affected by the loading procedure.

Nevertheless, at that time, the variation of reported implant survival rates and time of actual loading was high among different clinical studies. Brånemark suggested that the possible reason for high discordance regarding immediate loading was amenable to the lack of consensus on the optimal way to do it. He presented the "same-day-teeth" concept for treatment time reduction in the edentulous mandible, using a standardized methodology involving a rigid connection of the implants at the time of implant surgery with prefabricated prosthetic components. The author reported a success rate of 98% following a functional phase of 6–36 months (Brånemark et al. 1999). In general, the early beginning of immediate loading was a cautious and exploratory period in which authors tended to limit this procedure to areas characterized by dense, high-quality bone.

Since the former reports of immediate loading (Linkow and Mahler 1977; Ledermann 1979), further improvements and innovations in terminology were described to enhance the understanding of this topic. The first immediate loading consensus statement from the Spanish Society of Implantology (SEI) reported by Aparicio et al. (2003) marks a milestone, as attempt to standardize immediate loading definition, and it would become a start point for the evolution of immediate loading terminology across different task forces of international societies of oral implantology and research teams, through clinical studies, reviews, and consensus statements (Degidi and Piatelli 2003; Cochran et al. 2004; Nkenke and Fenner 2006; Esposito et al. 2007; Weber et al. 2009; Gallucci et al. 2014). A timeline for immediate loading concepts evolution is depicted in Fig. 1.

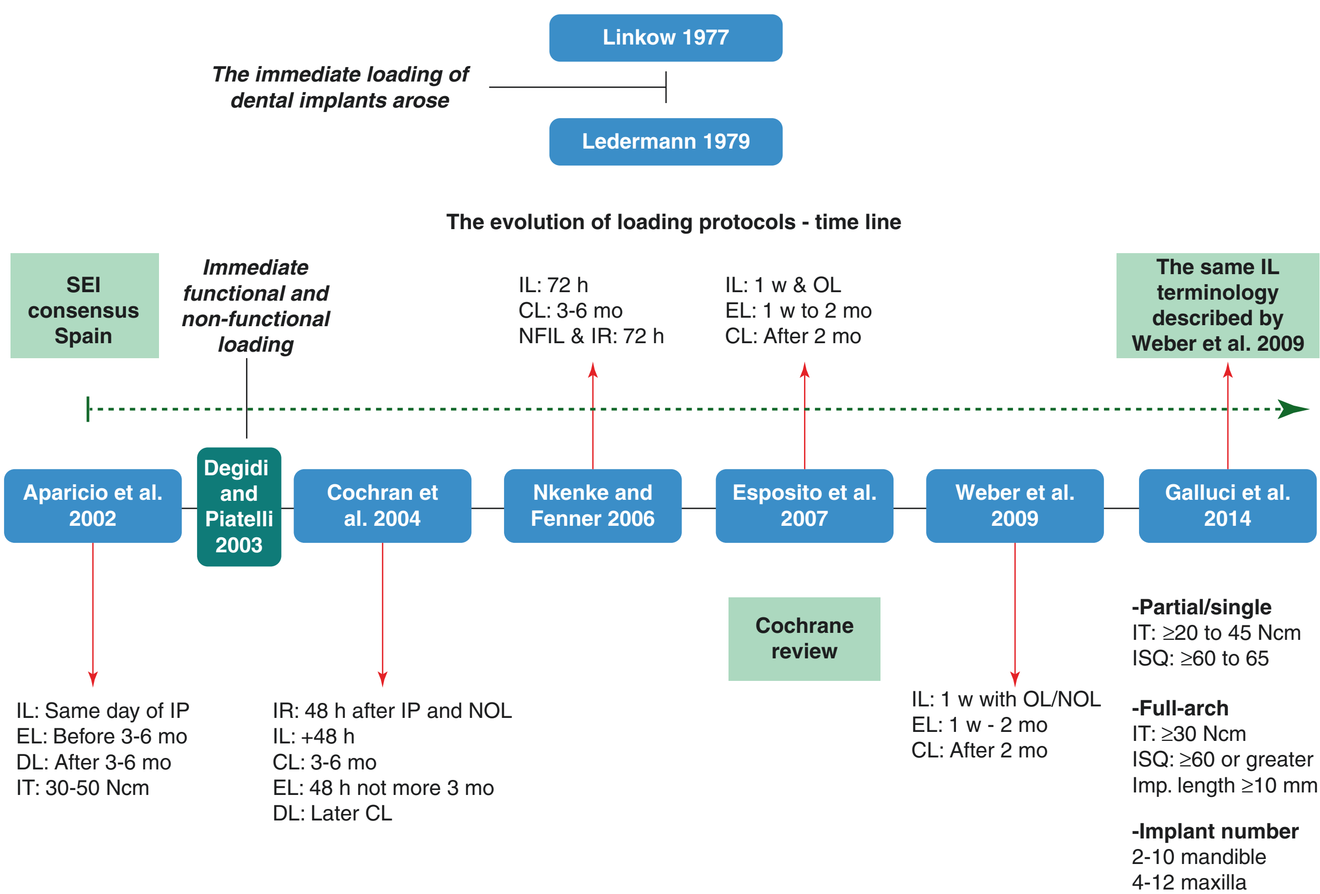


Fig. 1 Evolution of the terminology of immediate loading. Abbreviatures: Immediate restoration (IR): not in occlusion with opposite dentition. Immediate loading (IL): a restoration placed in occlusion with opposite dentition. Early loading (EL): a restoration placed in occlusion with opposite dentition, in a time period range. Conventional loading (CL): prosthesis is attached in a second procedure after a healing period. Delayed loading (DL): takes place some time later than the conventional healing. Immediate nonfunctional loading and immediate restoration (INFL and IR): provisional prostheses are not in occlusion, serve only for esthetic and soft tissue purposes. Occlusal loading or non-occlusal loading (OL/NOL): insertion torque (IT), implant stability quotient (ISQ), implant placement (IP), months (mo), week (w)

Implants with Immediate Loading

Immediate loaded implants (occlusal or non-occlusal loading) are those subjected to prosthetic functionalization within a week of implant placement; updated implant loading terminology is depicted in Table 1. Immediate loading implies that implants would be exposed to the oral environment and subjected to functional loads; therefore some biologic assumptions should be considered:

- Osseointegration would not be affected because of oral exposure of the implant surface.
- Osseointegration would not be affected because of immediate loading.
- Ideal healing time would be very sacrificed.

Even further, we might say that functional forces are key triggers to a series of biological reactions that not only accelerate the initial healing process but also the structural changes of peri-implant bone.

Those assumptions have been supported by several preclinical and clinical studies. The idea is that well-planned loading forces transmitted to the implant might even enhance bone healing in the early stages with more favorable long-term bone and soft tissue outcomes (Romanos 2015). The pioneering experiments by Schroeder and colleagues showed that the physicochemical bone-implant bond is strengthened by functional loading (Schroeder et al. 1978). The fresh bone accumulates on the rough surface and probably propagates as a result of the forces transferred directly to the bone. Further clinical examinations were carried out to transfer this concept to daily clinical practice. Clinical examinations using immediate loading protocol in the posterior mandible showed similar clinical and radiological results for the implants when compared to delayed loading. That means that implants can be immediately loaded also in areas with a relatively weak quality of bone if some important requirements are taken into account. Optimum initial implant stability in low-density bone is a prerequisite for long-term success. Adequate initial splinting improves the prognosis, especially where the bone is of inadequate quality. Critical evaluation of the literature shows that a non-loaded healing period is no longer essential.

Table 1 Actual ITI accepted immediate loading terminology

Terminology of loading protocols	
Immediate loading	Prosthesis connected to the dental implant within 1 week subsequent to implant placement with occlusal loading or non-occlusal loading
Early loading	Prosthesis connected to the dental implant between 1 week and 2 months subsequent to implant placement
Conventional loading	Prosthesis connected to the dental implant more than 2 months subsequent to implant placement

Justification for Immediate Loading

According to standard protocols of implantology, implants should be load-free during the osseointegration period (3–4 months in the jaw and 6–8 months in the maxilla) to prevent formation of a fibrous scar tissue between bone and implant and to achieve a predictable high success (Albrektsson et al. 1981). This standard protocol for restoration of the completely edentulous jaw with implant-supported full-arch prosthesis has been seen to produce favorable results (Peñarrocha-Oltra et al. 2014b).

When only posterior teeth are involved, patients do not usually complain about this time-lengthy approach; however they are unwilling to wait so much time when they are missing all the teeth in one of the arch or when they have lost teeth in the esthetic zone (Crespi et al. 2007; Peñarrocha-Oltra et al. 2014b; Tarazona et al. 2014; Barone et al. 2016). In the case of total edentulism, the dental clinician should respond effectively to the social and psychological needs of patients, providing them with provisional prosthesis during the osseointegration period. However, many patients complain about the discomfort of these temporary prostheses which are barely functional to their perspective (Testori et al. 2003). If only one tooth or a few teeth are missing, they can be replaced with a removable prosthesis stabilized by clasps. Sometimes patients cannot tolerate a removable partial denture so the clinician can make provisional fixed partial dentures bonded to the adjacent teeth, but these prostheses have to be removed during crown preparation and then rebounded again. These provisional restorations also have poor esthetic and are barely functional; furthermore the management of the cervical portion should be trimmed carefully around the mucosa to prevent the impairment of soft tissue healing.

The growing esthetic and functional demands from patients have favored the development of alternative surgical techniques to shorten the period from the placement of implants to the prosthetic loading. Immediate loading protocol allows patients to wear their implant-supported prostheses before the first week after implant surgery, avoiding a secondary surgery (Testori et al. 2003; Sanz-Sanchez et al. 2015; Esposito et al. 2013; Yan et al. 2016).

Immediate Loading in Different Scenarios

In the following section, an overview of immediate implants survival rates in different scenarios is presented (Table 2).

Post-extractive and Immediately Loaded Dental Implants

The idea of immediate and early loading on post-extractive implants has been introduced to further improve patients'

Table 2 Summary of literature-reported survival rates for immediate loading in different clinical situations

Immediate loading protocols	Implant survival (%)	Reference
Post-extractive implants	96	Del Fabbro et al. (2015)
Full-arch rehabilitations		Peñarrocha-Oltra (2013)
– Maxilla	96	
– Mandible	98.2	
Zygomatic implants	95.8–100	Wang et al. (2015)
All-on-four	97.6–100	Soto-Penaloza et al. (2017)
Single implants		Yan et al. (2016)
– Anterior	98.25	
– Posterior	91.7–100	

quality of life and to accomplish a simplified therapeutic protocol (Barone et al. 2006). Immediate post-extractive implant placement and loading shorten the healing period, reduce the number of surgical sessions, minimize patient's morbidity and discomfort, limit post-extraction socket remodeling, and allow the clinician to shape and condition the peri-implant soft tissue level. Nevertheless, this procedure is advanced and might be tricky when the residual bone is thin and the gap between the implant and the residual bone is wide.

The implant osteotomy bed and the extraction sites differ in their geometry; therefore, the healing processes of delayed implants and post-extractive ones are not superimposable. In particular, the early phase of repair takes less time in a fresh extractions socket (Wang et al. 2017; Li et al. 2017; Pei et al. 2017), and this peculiarity is probably related to two factors: (1) the peri-implant environment of the post-extractive site contains periodontal ligament remnants which promotes faster healing, and (2) the presence of an irregular bone-to-implant contact decreases the strain stress along the post-extractive implant (Yuan et al. 2018). Those histological findings support the idea of a more favorable environment for wound healing in post-extractive sites undergoing immediate loading than in healed sites undergoing implant bed preparation through drilling.

The 7-year clinical study by Barone and colleagues reported an overall success rate of 94.6% for implants placed in extraction sockets and immediately restored (Barone et al. 2016). The authors suggested that implants placed immediately after tooth extraction and immediately restored had favorable clinical outcomes and stable tissues conditions at a long-term evaluation.

The 2015 meta-analysis by Del Fabbro and co-workers showed better survival rates for implants placed in healed ridge (IS = 99.4%) as compared with post-extraction implants (IS = 95.6%). Yet, immediate restoration of implants placed in fresh extraction sites displayed an excellent implant prognosis. Therefore, such clinical approach can be safely adopted, minimizing the total treatment time and increasing patient's satisfaction (Del Fabbro et al. 2015). In 2017 Zhang published the results of a meta-analysis investigating the non-inferiority of immediate loading in clinical and radiographic outcomes compared with non-immediate loadings (Zhang et al. 2017). They found no differences in implant survival rates nor in marginal bone loss. The non-inferiority of immediate loading was demonstrated both at implant and patient levels.

A post-extractive immediate loading sequential case is depicted in Fig. 2a–s.

Immediate Loading with Full-Arch Prosthesis

The 2007 systematic review by Thomason and co-workers pointed out that the rehabilitation of total edentulism leads to significant improvements in patient quality of life (Thomason et al. 2007). Furthermore, patients restored with implant-retained prosthesis reported greater satisfaction than that of patients restored with conventional removable dentures. Loading protocols for implant-retained prosthesis in the edentulous jaws have been discussed in terms of clinical efficacy. Immediate loading has been introduced to reduce treatment time and to increase patient quality of life with a faster return to oral function. Immediate loading in the fully edentulous jaw by means of a fixed prosthesis is a well-documented treatment concept.

The 2014 systematic review by Papaspyridakos and colleagues revealed that the loading protocol had no influence on the prosthodontic survival rates of implant-retained full-arches in the mandible (Papaspyridakos et al. 2014). Niedermaier followed a cohort of 380 patients treated with implant-supported immediately loaded fixed full-arch dentures for 7 years, and the implant survival rate was 96% in the maxilla and 98.2% in the mandible (Niedermaier et al. 2017). Osteoporotic and smoking patients at a significant level recorded lower scores.

Immediate loading protocols for the maxilla are often regarded with extreme caution due to different bone quality, which is more trabecular, compared to the mandible. However, survival rates between mandible and maxillae did not yield significant differences. The reported survival rate for immediately loaded implants with fixed full-arch prosthesis in the maxilla ranges from 87.5% to 99.2%, with great heterogeneity among different studies (Peñarrocha-Oltra et al. 2014a). No differences could be observed in terms of marginal bone resorption between immediate and conventional loading. In general, immediate loading with full-arch

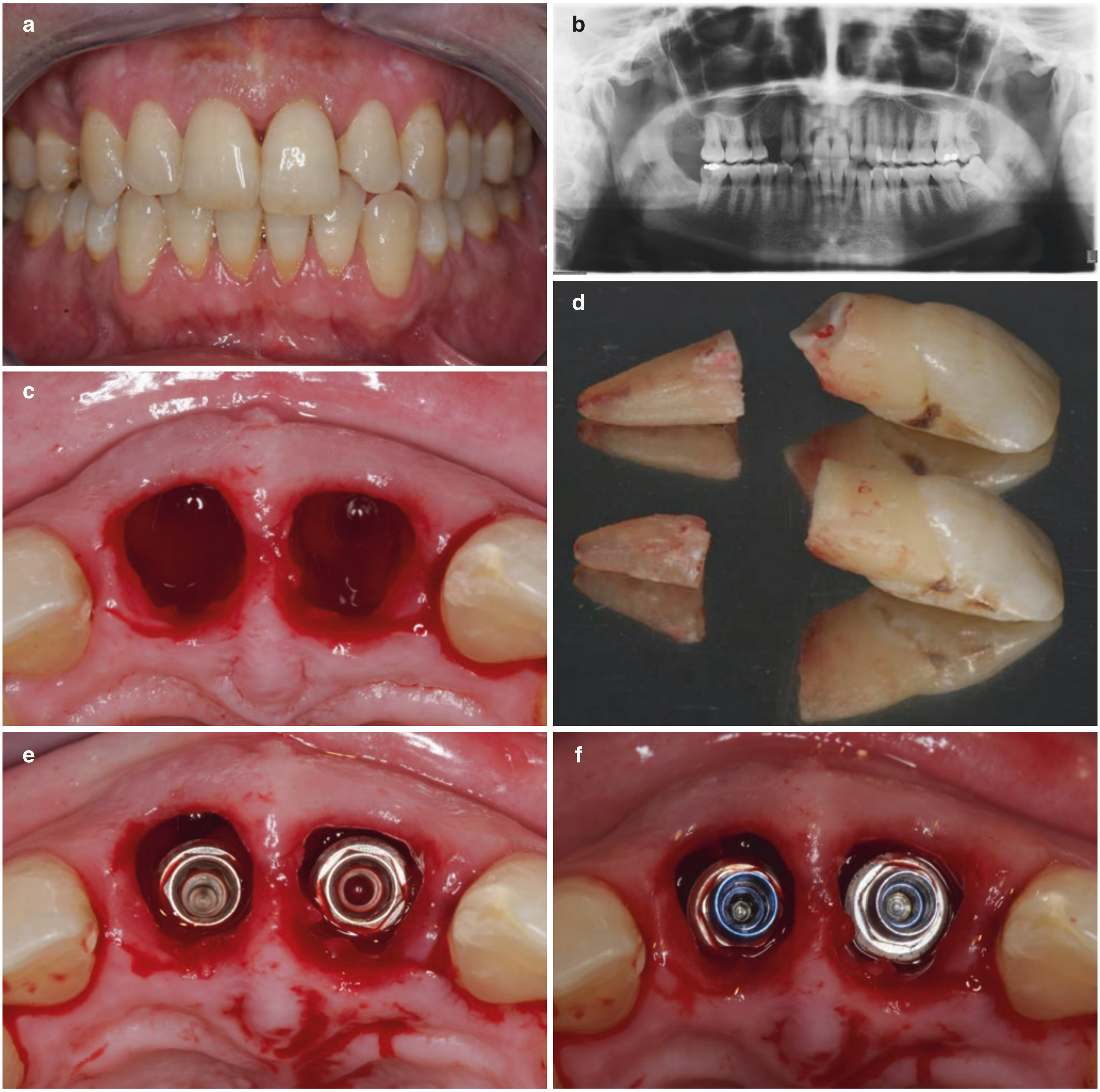
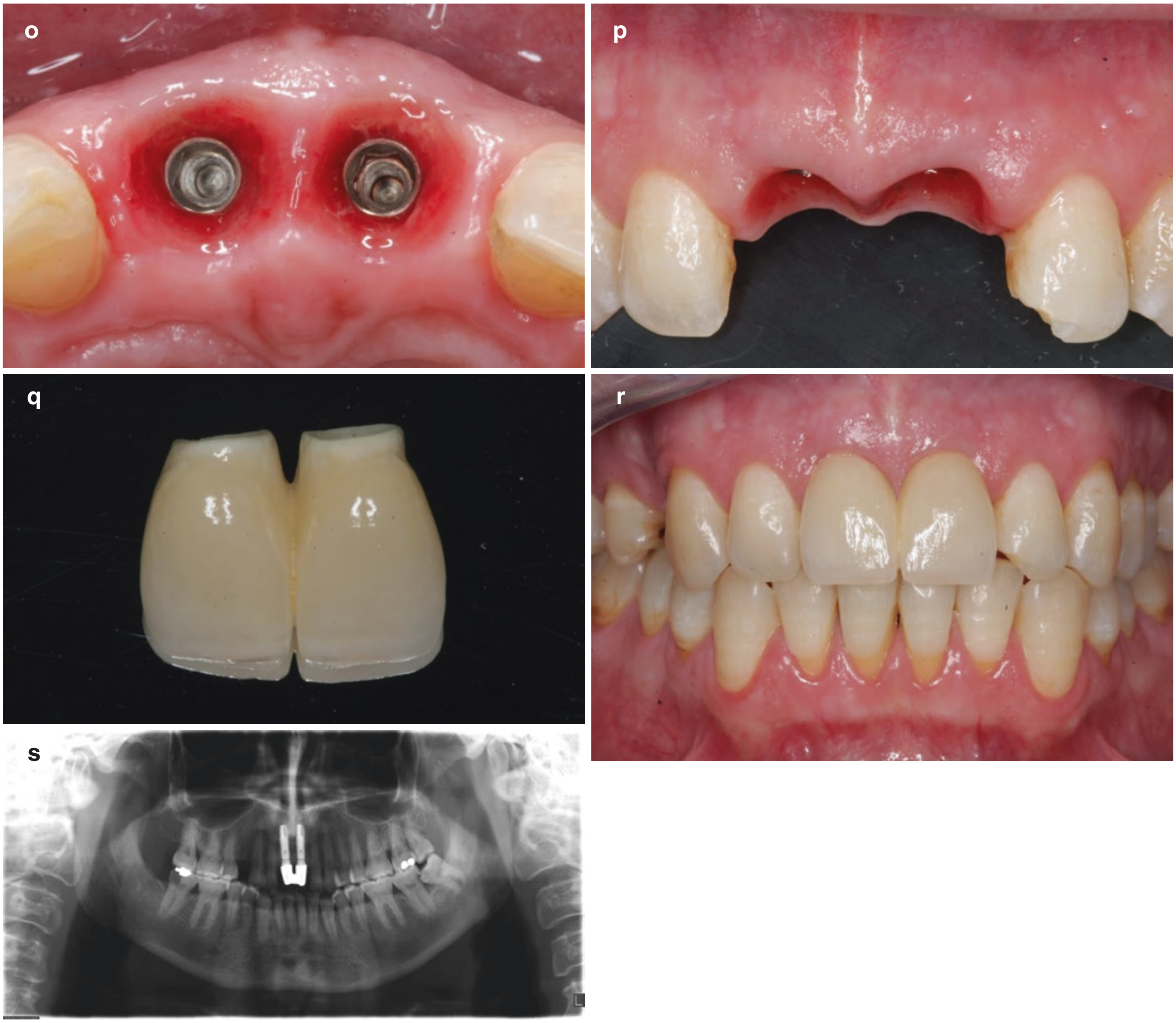


Fig. 2 (**a**) Coronal portion mobility at central incisors is appreciated at clinical exploration. (**b**) A horizontal radicular fracture of 1.1 and 2.1 is observed in the panoramic X-ray. (**c**) Atraumatic teeth extraction. (**d**) View of fractured teeth after extraction. (**e**) Occlusal view of implants within extraction socket (Phibo TSA®, Phibo Dental Solutions, Sentmenat, Barcelona, Spain). (**f**) Prosthetic abutments positioned and screwed on implant connection. (**g**) Insertion of temporary abutments. (**h**) Lab work screw placement. (**i**) After perforation of the temporary prosthesis, it was tried to check any interferences during insertion. (**j**) Auto-polymerizable resin was placed within temporary prosthesis for stabilize. (**k**) Contouring and polishing of the provisional restoration. (**l**) Prosthesis screwing and placement of temporary obturation material. (**m**) Frontal view after immediate repositioning of provisional restoration and surgical suture. (**n**) Suture removing after a postoperative week. (**o**) After osseointegration process, a definitive prosthesis was confectioned; it was observed that a good soft tissue contouring is appreciated. (**p**) Frontal view of soft tissue architecture. An adequate keratinized tissue band is appreciated. (**q**) To attain a good esthetic in anterior zone, a zirconium material prosthesis was done. (**r**) Clinical view of final restoration. (**s**) Final panoramic radiograph

Fig. 2 (continued)



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prostheses in the maxilla is a successful and predictable procedure if adequate criteria are met during patient selection, surgery, and prosthetic delivery with benefits on patient-reported outcomes than conventional loading (Peñarrocha-Oltra et al. 2014b). The most reported complication is limited to the fracture of the provisional prosthesis, and this outcome is often related to preexistent bruxism (Cercadillo-Ibarguren et al. 2017).

In 2014, De Bruyn summarized the evidence regarding immediate loading in completely edentulous jaws (De Bruyn et al. 2014). When four or more implants are placed, the implant failure is 0–3.3% in the mandible. In the maxilla, four to six implants yield a failure rate of up to 7.2%, but this is reduced to 3.3% when the number of implants is increased. An immediate loading full-arch reconstruction is depicted in Fig. 3a–y.

Immediate Loading and Zygomatic Implants

Available bone volume for implant placement is frequently limited in the atrophic maxilla because of post-extraction alveolar bone resorption and pneumatization of the maxillary sinus. Several bone grafting techniques, such as sinus lifting and bone grafting procedures, have been described as methods to restore the volume of the atrophic maxillae, allowing implant placement in reabsorbed sites (Esposito et al. 2014). However, those procedures require additional surgery and increased morbidity for the patient, demanding considerable time until final prostheses can be delivered.

A less invasive alternative to major reconstruction procedures for the severe atrophic maxilla is the zygomatic implant. Prostheses supported by four zygomatic implants or two zygomatic implants combined with two standard anterior implants were successfully introduced and successfully approached in restoring function in the severely atrophic maxilla.

A review of the literature on 1541 zygoma implants reported a survival rate of 97.8% (Goiato et al. 2014). The authors also reported that most studies that have investigated zygomatic implants with immediate loading have used modified implant surfaces to achieve the primary stability.

Wang and colleagues performed a systematic review on the reliability of four zygomatic implant-supported prostheses reporting high survival rates for immediate loading protocols ranging from 95.8% to 100% (Wang et al. 2015).

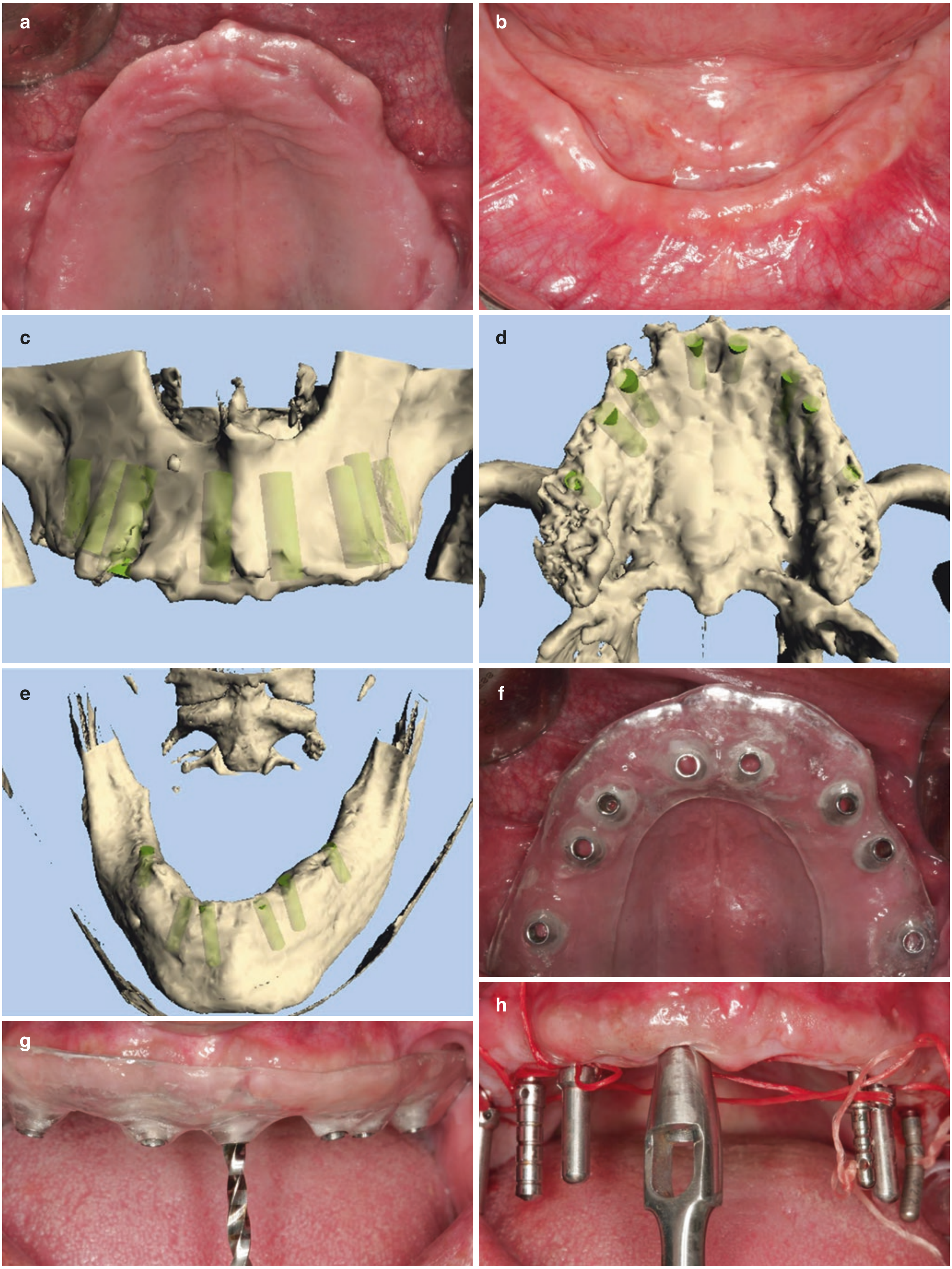
In 2017, Agliardi reported the 6-year outcome of full-arch maxillary prostheses retained by four zygomatic implants or two zygomatic implants in conjunction with two conventional fixtures. Implant survival was 100% with high level of patient satisfaction for function, esthetics, and phonetics (Agliardi et al. 2017). An important drawback of this approach is its advanced technical requirements; to ensure treatment success, a careful pre-operatory diagnosis should be performed on computed tomography scans.

Immediate Loading and the All-on-Four Treatment Concept

Long-term edentulous jaws often prevent implant placement. A noninvasive option to rehabilitate the atrophic jaws is the use of fewer implants placed with a polygon disposition. The all-on-four concept was introduced in 2003 and basically refers to the placement of two axially loaded anterior implants and two tilted implants in the posterior zone (Maló et al. 2003). The tilting of distal implants should allow for a reduction in the prosthetic cantilever length, resulting in decreased peri-implant bone stress (Horita et al. 2017).

Long-term data on fixed prostheses retained by four implants in the edentulous mandible showed similar outcomes of those retained by more implants (Gallucci et al. 2009). The recent systematic review by Soto-Penaloza and co-workers shed light upon the therapeutic indications, surgical procedures, prosthetic protocols, patient satisfaction, and main complications associated with the all-on-four treatment concept (Soto-Penaloza et al. 2017). The authors reported a success rate ranging between 94.8% and 100% at implant level; the survival rate ranged between 97.6% and 100%. Achieving adequate primary stability seems to be the most important factor in determining implant survival during the first year of loading. Implant primary stability has been often related to insertion torque, which is defined as the rotational resistance at the time of implant placement (Anitua

Fig. 3 (**a**) Intraoral clinical picture, maxillary occlusal view. (**b**) Intraoral clinical picture, mandible occlusal view. (**c**) 3D surgical planification software Implametric®. Frontal view of implant positioning in upper jaw. Data was send to dental lab for surgical splint confection with metallic guides, considering planed positions. (**d**) 3D surgical planification software Implametric®. Implant positioning was planned at the level of incisives, canines, first premolars, and molars. (**e**) 3D surgical planification software Implametric®. Aimed by computed tomography and dental software, six implants placement was planned in the lower jaw. (**f**) Maxillary surgical split was placed and its stability was checked. (**g**) Through the metallic guides in surgical splint, implant position was marked. (**h**) A soft tissue rib was removed with a surgical punch, then the implant bed was prepared, and implant parallelism was verified using surgical pins for this purpose. (**i**) Intraoperative occlusal view after implant placement (Phibo TSA®, Phibo Dental Solutions, Sentmenat, Barcelona, Spain). (**j**) Intraoperative occlusal view after implant placement. Transmucosal prosthetic abutments were placed to perform an immediate loading. (**k**) Intraoperative occlusal view after implant placement. Provisional caps were adapted; only the six anterior implants were used for the immediate loading. (**l**) Intraoperative occlusal view after implant placement. A duplicate provisional prosthesis of white resin was perforated to make holes at each implant position. It is obtained from the complete denture of patient. (**m**) Intraoperative frontal view of lower jaw. The surgical splint is placed to check its stability as in the upper jaw, and the implantation sites were marked. (**n**) Intraoperative view of lower jaw. A total thickness flap with distal discharges is raised. (**o**) Intraoperative view of lower jaw. Preparation of implant beds and parallelism verification using surgical pins for this purpose. (**p**) Intraoperative view of lower jaw. Placement of four implants of standard diameter in inter-foramina position and two distal implants of wide diameter (Phibo TSA®, Phibo Dental Solutions, Sentmenat, Barcelona, Spain). (**q**) Intraoperative view of lower jaw. After implant placement the implant transporters were removed. (**r**) Intraoperative view of lower jaw after implant placement. Transmucosal prosthetic abutments were placed to perform an immediate loading. (**s**) Intraoperative view of lower jaw after implant placement. After plastic cap placement, the flap was sutured. (**t**) Intraoperative view of lower jaw after implant placement. A gum dam is placed to avoid resin invagination during provisional restoration fixation. (**u**) Provisional restoration with four holes drilled. The prosthesis fitting was checked intraorally to avoid interferences with plastic caps. (**v**) Provisional prosthesis before final polishing and before the relining of retentive spaces to avoid biofilm accumulation. (**w**) Provisional prosthesis installation. After polishing of retentive borders and resin emergence contouring, the prostheses were adjusted using clinical short screws, according to manufacturer recommendations based on the screws metric. (**x**) Frontal view of installed prostheses in both maxillae. (**y**) Panoramic radiograph after implants placement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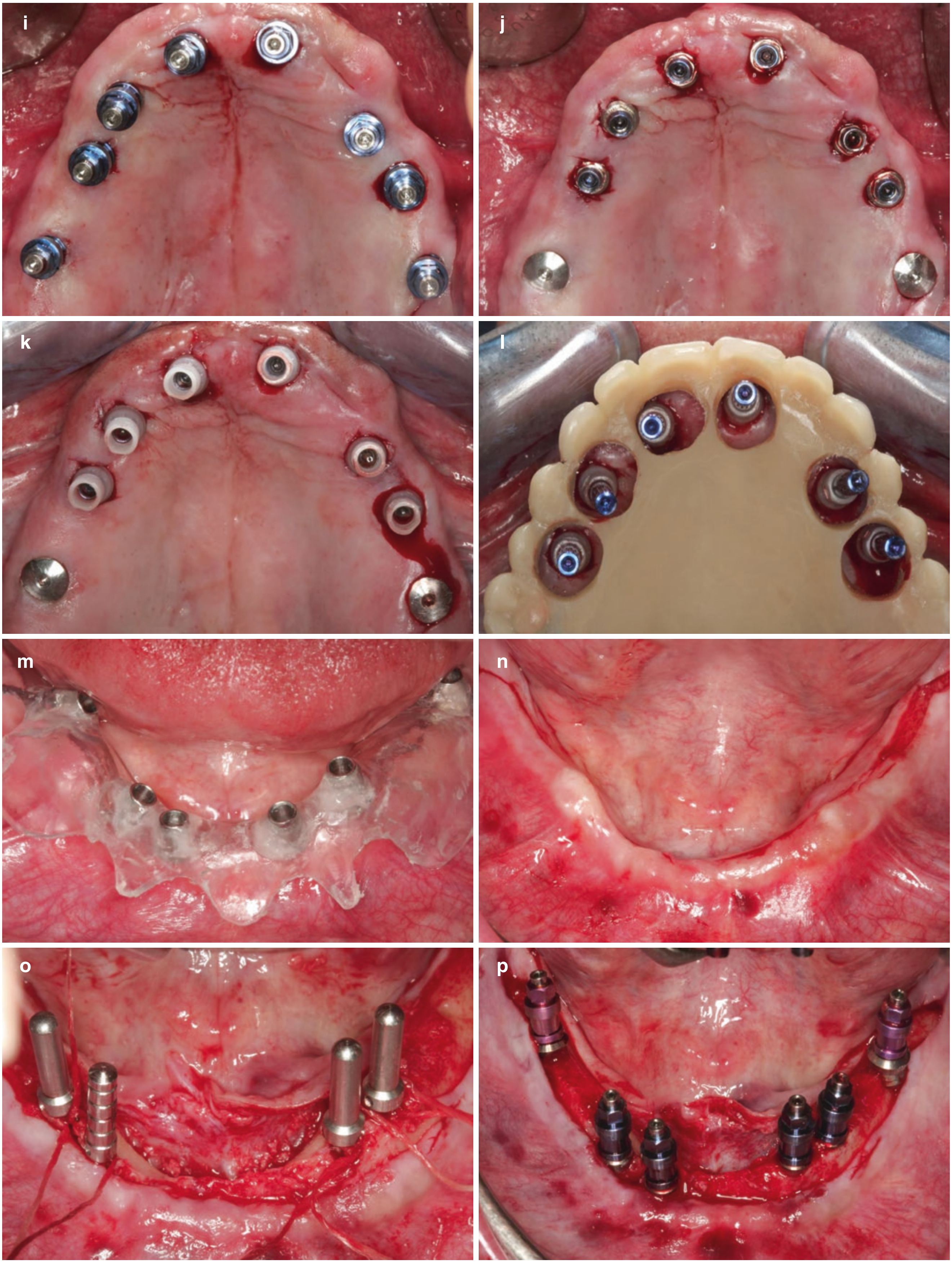

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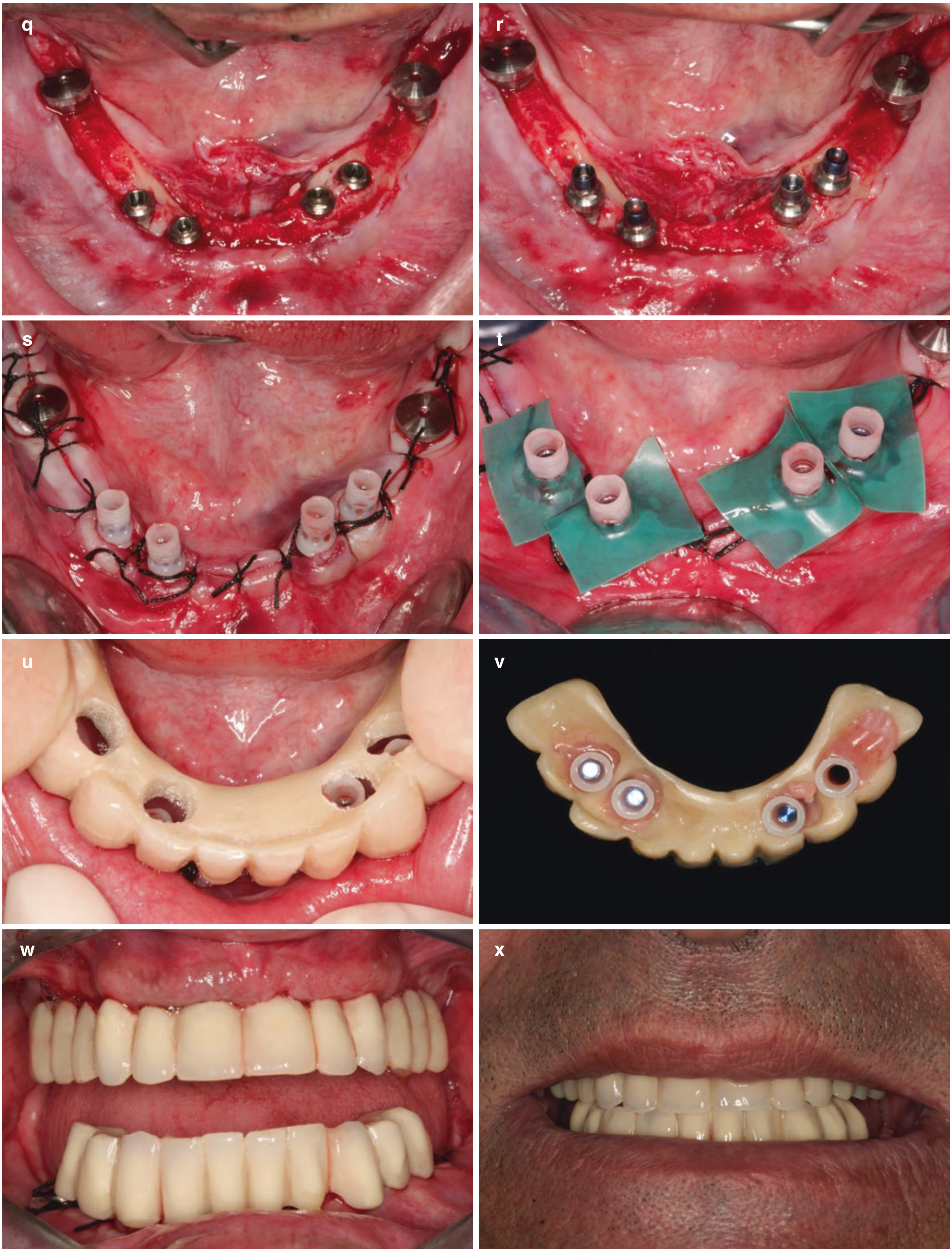

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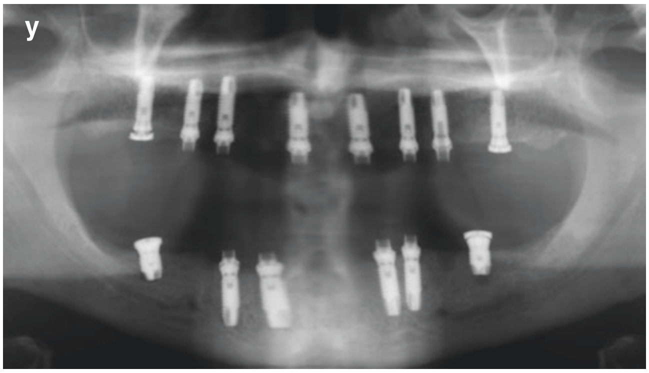

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et al. 2015). Even though it may seem intuitive that high insertion torque leads to better thread engagement to the bone, different preclinical and clinical studies have suggested that IT does not necessarily relate with primary stability (Marconcini et al. 2018). High levels of insertion torque might exceed the elastic limit of the bone causing compression necrosis and increasing the risk for marginal bone remodeling. Therefore, clinicians should pay great attention to insertion torque values when performing implant sites preparation for all-on-four implant-retained prostheses.

Immediately Loaded Single Implants

In 2016, Yan published a systematic review aiming to compare immediate protocols with conventional protocols of single-tooth implants in terms of changes in the surrounding hard and soft tissue in the esthetic area (Yan et al. 2016). The authors failed to prove any significant difference in marginal bone loss and soft tissue appearance—in terms of papillae filling—between immediate and delayed protocols in the anterior maxilla. Similar results have been suggested by Weigl and Strangio in 2016: immediate loading resulted in a high success (97.96%) and survival rate (98.25%) after a mean follow-up period of 31.2 months (Weigl and Strangio 2016).

The mean crestal bone and the mean interproximal mucosa level changes were less than 1 mm compared to the baseline. The midfacial peri-implant mucosal level change was less than 0.95 mm. A few potential risk factors for mucosal recession such as preexisting buccal bone defects, thin buccal bone, thin soft tissue biotype, and implant malposition have been identified. Accordingly, different authors have proposed treatment strategies to counteract the possible tissue changes, including the use of autologous connective tissue graft, xenograft fillers in peri-implant gap, and flapless surgery (Barone et al. 2016).

Moraschini and Barboza performed a meta-analysis to compare midterm implant survival, marginal bone loss, and complications between immediate and conventional loading of single implants installed in the posterior mandible (Moraschini and Porto Barboza 2016). They found no differences in terms of implant survival and marginal bone loss. The survival of the implants in the immediate and conventional loading groups at a mean follow-up of 31.2 months ranged from 91.7%13 to 100% and from 96.6% to 100%, respectively. Immediate loading in single implants could be with or without occlusal contact. A recent systematic review suggested that there are no clear impacts of occlusal contact on implant survival rates, which ranged between 85.7% and 100% (De Bruyn et al. 2014).

Concluding Remarks and Future Trends

The 2018 systematic review by Troiano and co-workers reported data from 11 trials included in the analytic comparison between two-stage and one-stage implants (Troiano et al. 2018). No differences were found in late implant failure nor in marginal bone loss. However, immediate loading was burdened by a higher risk for early failure (within 1 year). It must be said that adherence to scientific indications and guidelines alone is not sufficient to achieve implant success. An expert surgeon, a throughout anamnesis, a proper diagnosis, and an efficient communication with the patient would be crucial in the algorithm for immediate loading success. This consideration is all the more so in the case of early implant failure, which is often related to prosthetic planning mistakes or clinician inexperience.

Current trends in implant dentistry are shifting toward the digital workflow helped by evolving technologies. Reducing the need of grafting procedures and allowing for prosthodontically driven implant placement in the extremely atrophic jaws may be accomplished with the application of digital and CAD-CAM technology. The aim is to reduce the total chair time and the costs of implant therapy for both the patient and the clinician. The digital approach in immediate loading in the anterior area might help in achieving optimal esthetic results and facial integration of the implant-retained prosthesis. It must be remarked that guided surgery and digital planning require a significant learning curve.

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Basic Bone Biology Healing During Osseointegration of Titanium Dental Implants

David Soto-Peñaloza, José Javier Martín-de-Llano, Carmen Carda-Batalla, Miguel Peñarrocha-Diago, and David Peñarrocha-Oltra

Abbreviations

3 integrin	Alpha (v) beta (3) integrin
BIC	Bone-to-implant contact
BMP	Bone morphogenetic protein
BMU	Basic multicellular unit
CaP	Calcium phosphate
DC-Stamp	Dendrocyte-expressed seven transmembrane protein
FGF	Fibroblastic growth factor
GLAST	Glutamate transport by transporters
HA	Hydroxyapatite
HVC	Haversian canal
IGF	Insulin growth factor
LB	Lamellar bone
LL	Lamellae
M-CSF	Macrophage colony-stimulating factor
NFATc1	Nuclear factor of activated T cells 1
OBM	Organic bone matrix
OSCAR	Osteoclast-associated, immunoglobulin-like receptor
PGE2	Prostaglandin-E2
PGI2	Prostacyclin
RANKL	Receptor activator of nuclear factor kappa-B ligand
SLA	Sandblasted/acid etched
Src	Proto-oncogene tyrosine-protein kinase
TGF-B	Transforming growth factor beta
WB	Woven bone

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Take Home Message

- The majority of bones of the skull, including jaws, form directly from mesenchymal cells from the first branchial arch without the prior formation of cartilage; this type of osteogenesis is called intramembranous ossification. It has three major cell types (osteocytes, osteoblasts, and osteoclasts) responsible for mechano-transduction, bone matrix secretion, and bone resorption, respectively.
- Woven bone (WB) is non-lamellar and characterized by the random disposition of type I collagen fibers and is the first type of bone tissue to appear in embryonic development and fracture repair. It is usually temporary and is replaced by lamellar bone.
- Lamellar bone (LB), characterized by multiple layers of calcified matrix containing osteons, which are bone functional units or the "Haversian system", refers to the complex of concentric lamellae, with one osteocyte interconnected by canaliculi containing the cells' dendritic process, connected with the processes of neighboring cells through gap junctions.
- Osteointegration is a dynamic process during the establishment and maintenance of implants, characterized by resorption and apposition events, and the extent and degree of osteointegration is in part affected by implant surface configuration and a number of variables (e.g., implant macro-design, surface treatment design, native bone features, timing of placement, and loading characteristics).
- It was recognized and suggested that the early osseointegration in an animal model was twice as effective as in humans.

Introduction

In 1892, Julius Wolff postulated that bone was a dynamic tissue that adapts to meet the physical demands of its external environment (Wolff 1986). Nowadays, bone is considered a

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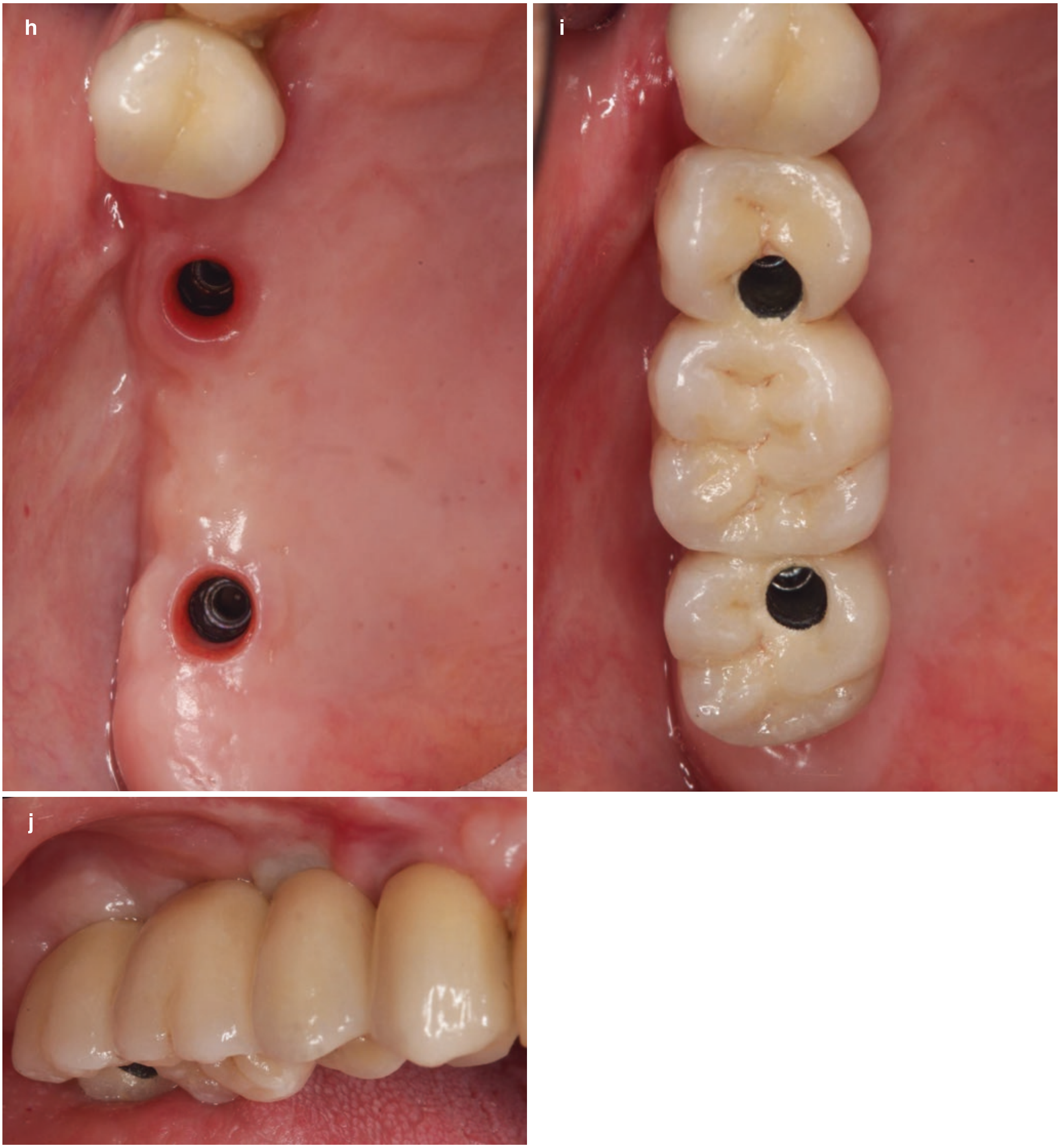

Fig. 12 (continued)

Occlusal Adjustment Procedures

The prerequisite for the prevention of the consequences of occlusal overload is the detection, measurement, and quantification of the latter both in natural teeth and in implant-supported structures.

Conventional methods for controlling and adjusting occlusion include articular papers, fabrics and vinyl, as well as shim stock strips. The thickness of these materials for clinical use varies between 8 and 40 μm, with the use of thicknesses of up to 200 μm in laboratory work.

The problem with these procedures is that the information obtained regarding the occlusal load is conditioned to operator experience and to the subjective perception of the patient, which is imprecise since the sensory receptors are subjected to adaptation. These methods allow the localization of the con-

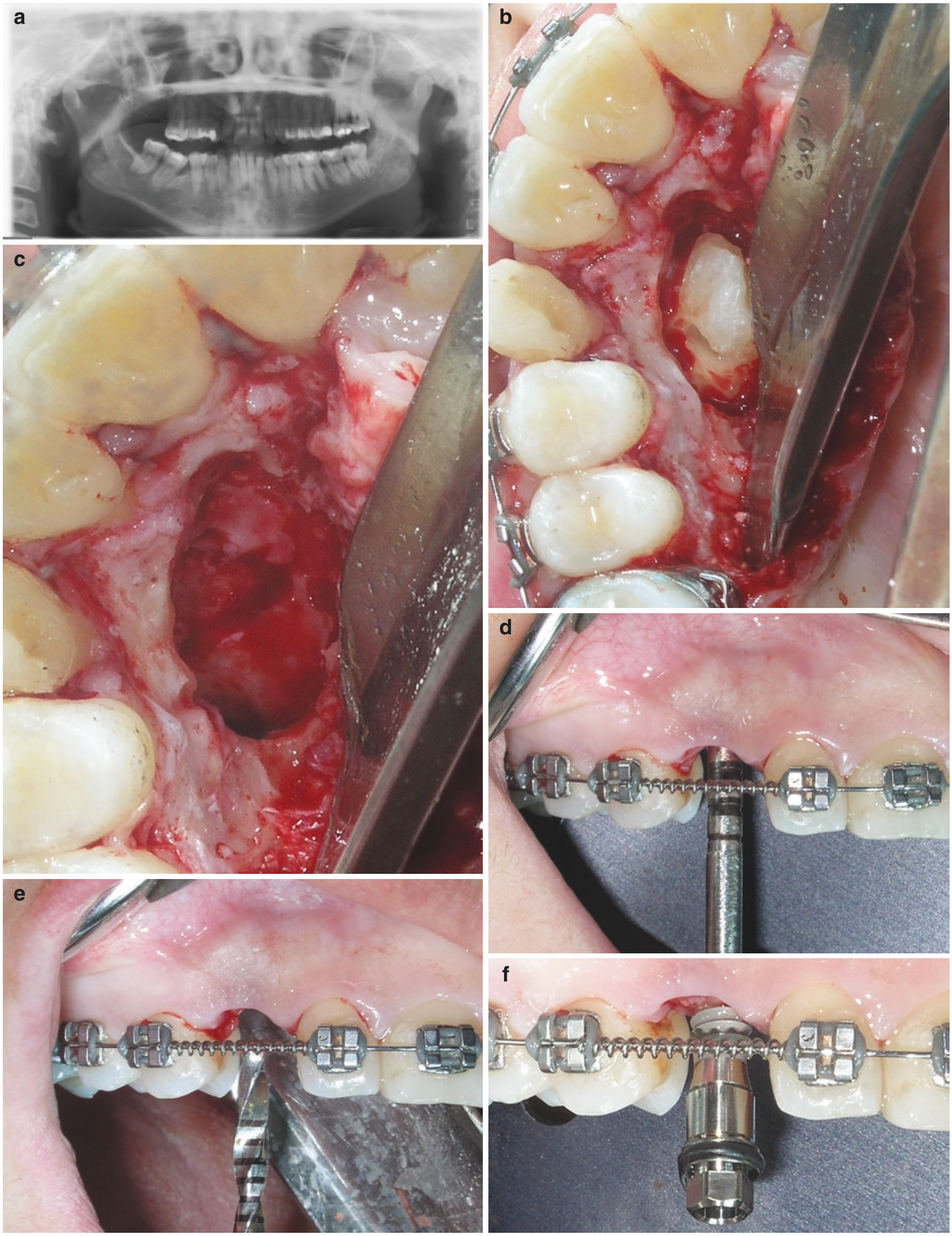

Fig. 2 (**a**) Impacted upper right canine with no possibility of orthodontic extrusion due to its higher position close to the apex of adjacent teeth. (**b**) Patient underwent orthodontic treatment to create enough mesiodistal space to put an implant in the canine position. A full-thickness palatine flap was raised. After ostectomy, the included tooth was exposed. (**c**) After tooth section, the crown and root were extracted separately. (**d**, **e**) Implant bed preparation with a sequence of osteotomes and drills. (**f**) Intraoperative image of Phibo 4.2 × 16 mm implant placement (Phibo TSA®, Phibo Dental Solutions, Sentmenat, Barcelona, Spain). (**g**) Implant installation. (**h**) Palatal view. The implant was anchorage in the alveolar crest and the bottom of bone cavity (nasal cavity floor). (**i**) The bone cavity was filled with autogenous bone particles. (**j**) Extraoral panoramic radiographic after implant placement. (**k**) Clinical view at suture removal 1 week after implant placement. (**l**) Occlusal view at 1 week control. (**m**) After 3 months, orthodontic treatment was removed and definitive impressions were taken. (**n**) Definitive prosthetic abutment in place. (**o**) Definitive prosthesis delivery. (**p**) Occlusal view of the definitive restoration in place. (**q**) Extraoral panoramic radiograph after 1 year of prosthesis delivery

Fig. 7 Smile image after the end of the treatment

Fig. 8 Front view of the patient, where it checked the rehabilitation of the last third of the face

Planning using guided surgery software facilitates the production of surgical splints with perforations that allow a more accurate placement of the implant and the insertion of a prefabricated provisional restoration.

Photographs

The photographic record of the development of the treatment has become practically a necessity in the case of implants and must include at least the initial intraoral and extraoral situation of the patient, with the old prostheses and without them (if it is the case), the treatment concluded, and the details of the surgical, prosthetic, and laboratory phases that may be of interest.

This photographic archive will allow to document each case with images, to record the results of the different techniques used, and to review and analyze the treatments and their execution, and it is a way of communicating with our patients and with the rest of the companions. For this planning phase, both extraoral and intraoral photographs are detailed in the following tables:

Extraoral:

- Front facial (full face) at rest.
- Front facial smiling.
- Profile facial at rest.
- Profile facial smiling.
- Front (only mouth) at rest.
- Front smiling.
- 45° right and left smiling.

Intraoral:

- Front in occlusion with spacers.
- 45° right and left in occlusion with spacers.
- Front to the frontal sextant.
- Overall upper and down with mirrors.

Study Models

The initial clinical situation should be evaluated with the help of the study models. These can be obtained by analog procedures (silicones or alginates) or digitized by the use of intraoral scanners.

Second Planning Phase

It is one of the most important phases of planning since it will guide the clinician to the type of rehabilitation that is indicated for each patient. This second phase includes the assembly of the models in semi-adjustable articulator, analysis of the models, communication with the laboratory technician to make a tooth setup according to individual specifications, and, then, transforming it in a radiological splint.

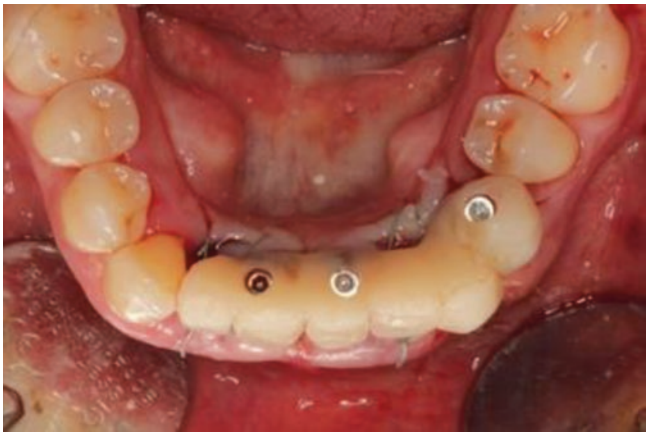

Fig. 55 Immediate fixed screw-retained provisional restoration on the day of surgery

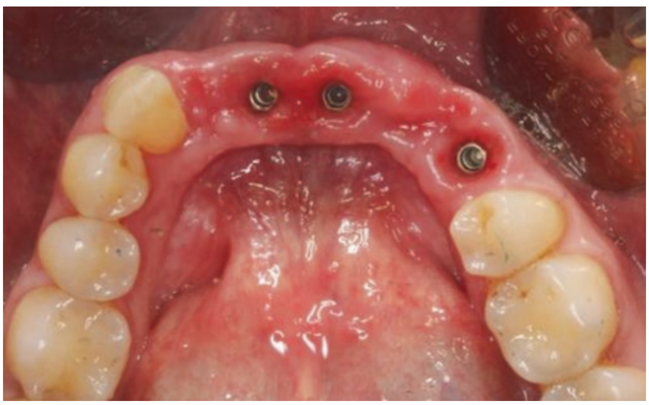

Fig. 56 Immediate fixed screw-retained provisional restoration after healing period

Fig. 57 Healing of the gingival tissue around the implants

Fig. 58 Clinical situation of the final restoration

Fig. 59 Clinical situation after delivery of the final restoration

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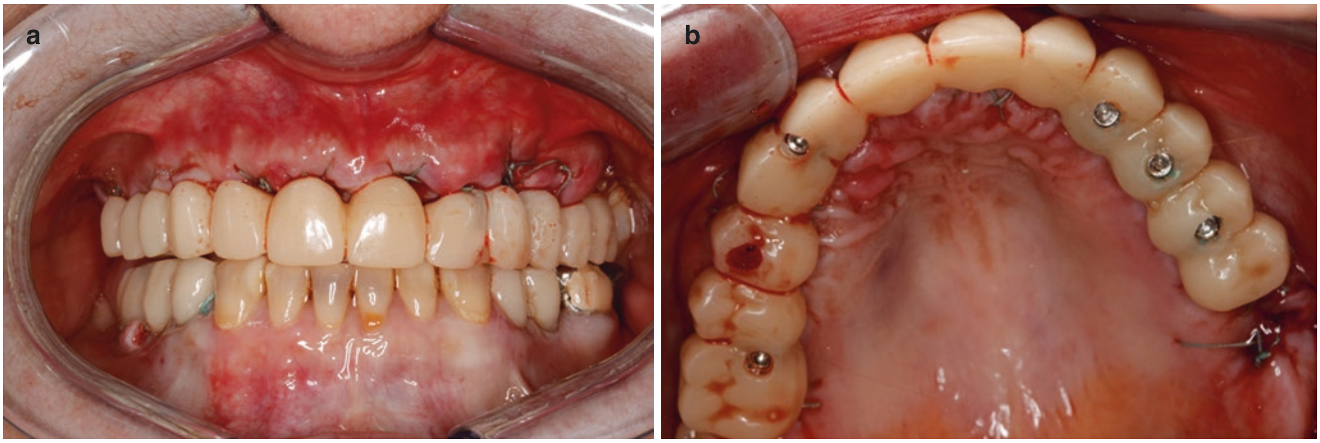

Fig. 67 Fit the provisional prosthesis into the primary abutments. Then screw the prosthesis with the prosthetic fixation screws, applying an insertion torque of 15 Ncm. Frontal (**a**) and occlusal view (**b**)

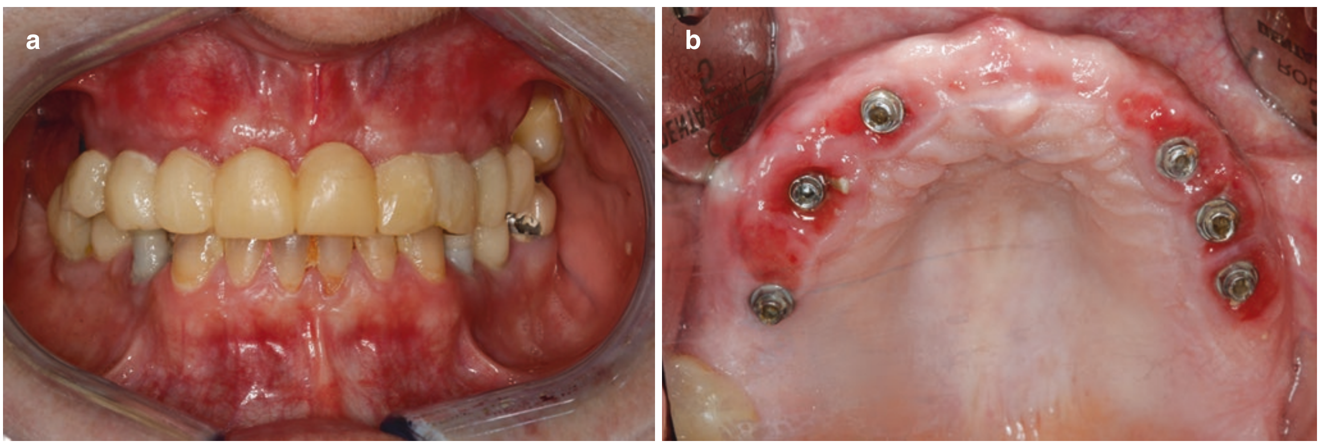

Fig. 68 Review at 2 months with (**a**) and without (**b**) the immediate loading prosthesis

Fig. 69 Initial panoramic radiograph

patient. New digital techniques such as stereophotogrammetry may mitigate this. Patient and dentist satisfaction improves, and the work time is reduced (Agustín-Panadero et al. 2015). A clinical case is exposed to understand the procedure by PIC Camera® (PicDental®, Madrid, Spain) (Figs. 69 and 70a–c) with 3D planning (Fig. 71). This case was operated by a flapless surgery (Fig. 72a–d).

After implant placement, the healing abutments are screwed and their height is recorded. The soft tissues are registered either with a conventional impression that is poured with gypsum and digitalized with a laboratory scanner or directly with an intraoral scanner. Then the scanbodies (PIC abutment; PIC Dental) are screwed into the implants (Fig. 73). The PIC Camera® consists of two infrared charge-coupled device (CCD) cameras that register the distance and angulation between the scanbodies using photogrammetry. The cameras register 50 images for every two abutments. Thus, for an edentulous case, it obtains 600 images in under 60 s.

The file with the position of the implants registered with the PIC Camera® is automatically aligned with the soft tissues file by best fit. In order to establish the vertical dimension and perform a trial tooth arrangement, a virtual articulator or a physical definitive cast is required. A 3D printer (Objet Eden 260VS; Stratasys) can be used for this second option. Once the vertical dimension is established, the metal framework of the prosthesis is designed, filed in open 3D stereo-

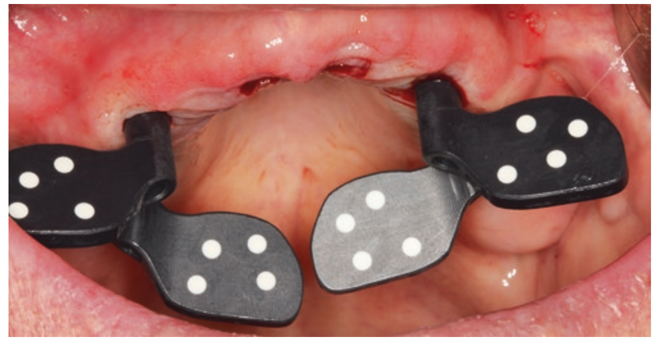

Fig. 73 PIC Abutments® placed to register implant positions. PIC Camera® registers the implant position through these abutment types

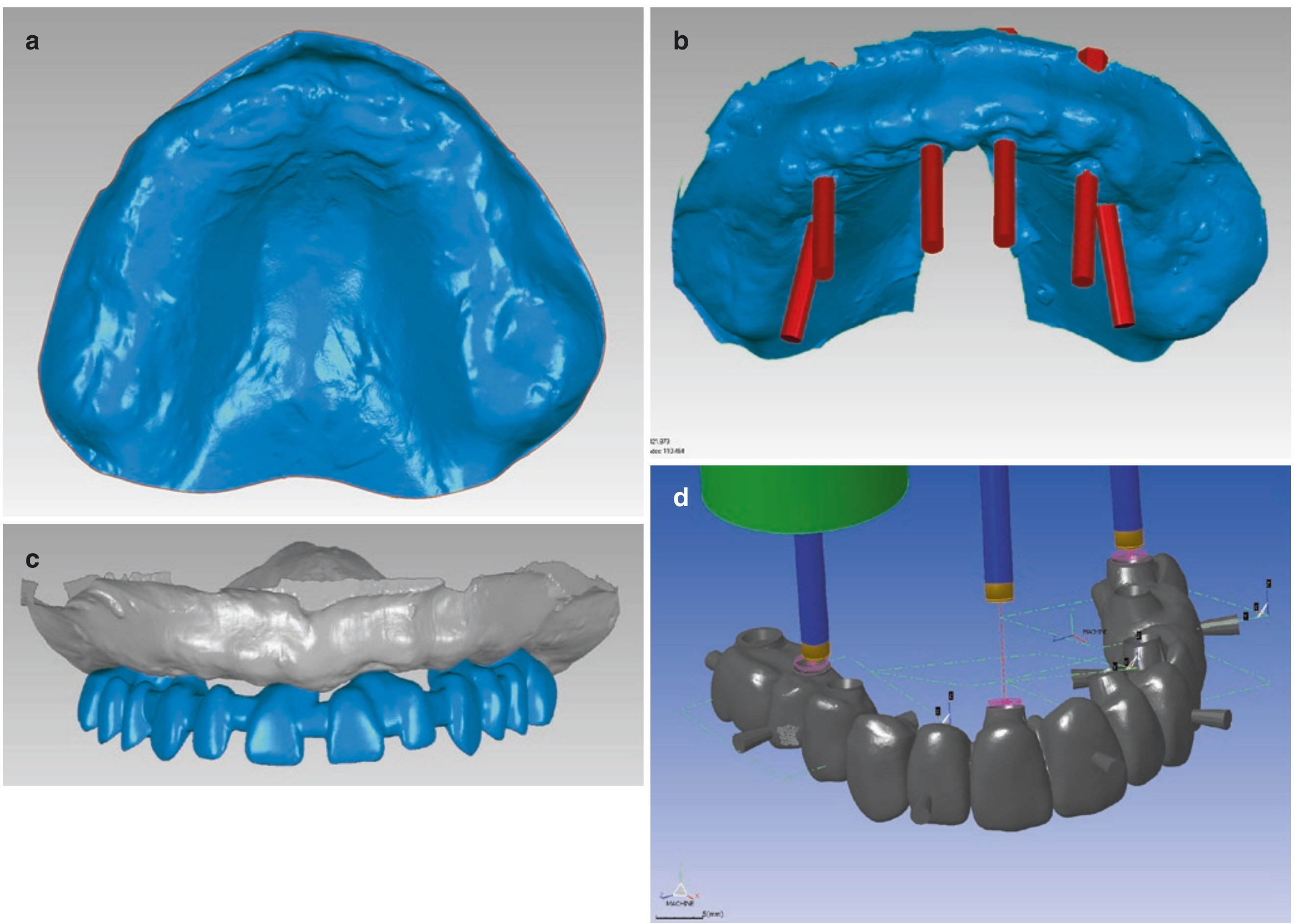

Fig. 74 (**a**) Digitalized impression of the soft tissues. (**b**) STL file containing the soft tissues and the position of the implants obtained with the PIC Camera® after alignment of the two files by best fit. (**c**, **d**) Design of the metal structure of the definitive prosthesis

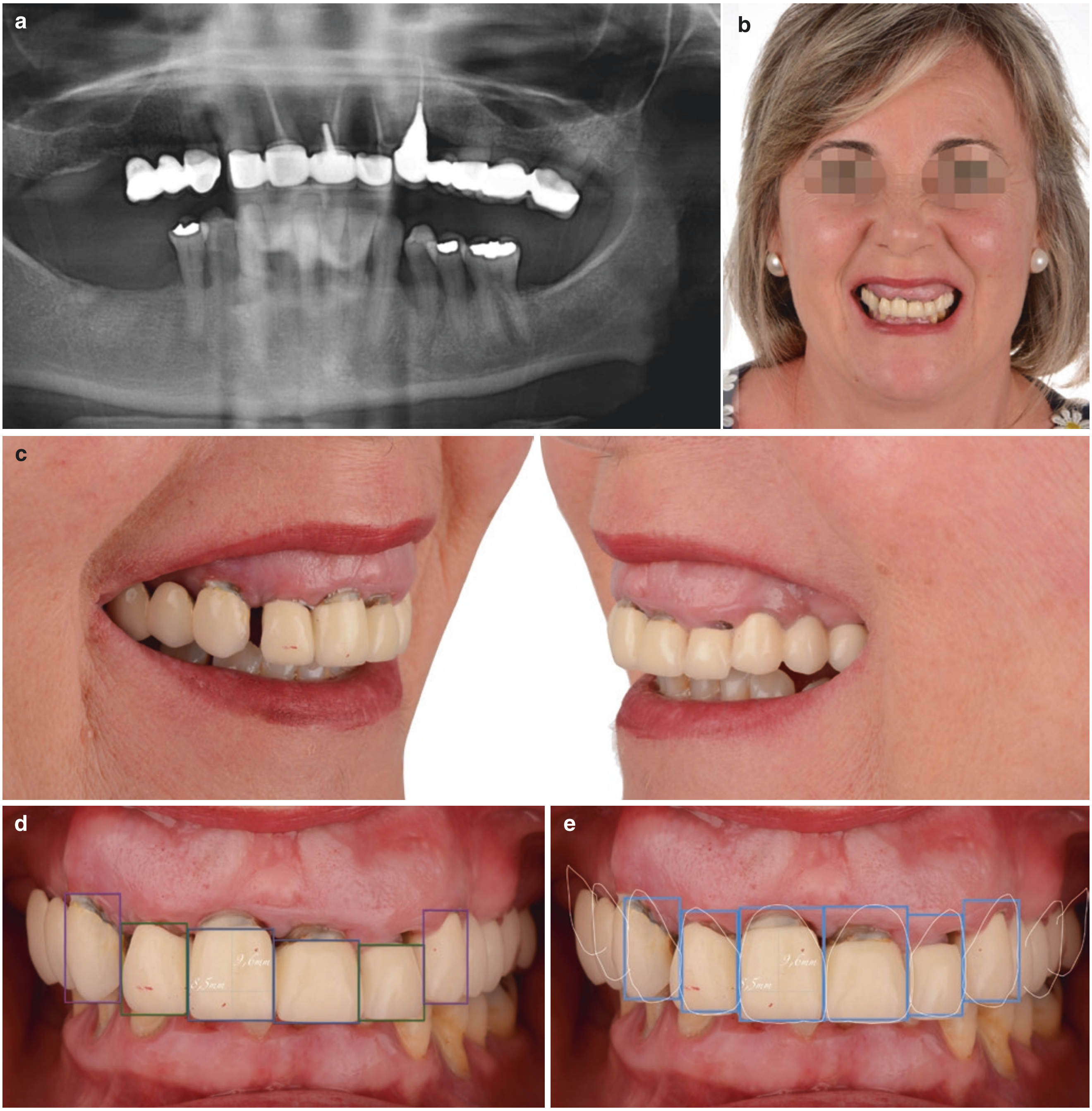

Fig. 7 (**a**) Initial panoramic x-ray of the patient showing multiple restorative procedures, the presence of broken teeth and periodontal disease. (**b**) Extraoral view of the patient. Gummy smile. The patient demands an improvement of her dental esthetics. (**c**) Gummy smile of the patient, right and left views. These cases are very demanding for the surgeon because it is mandatory to hide the transition line above the lip line. (**d**) Incorrect proportions of the anterior teeth. (**e**) Digital smile design to valorate the correct proportion and disposition of the future anterior teeth

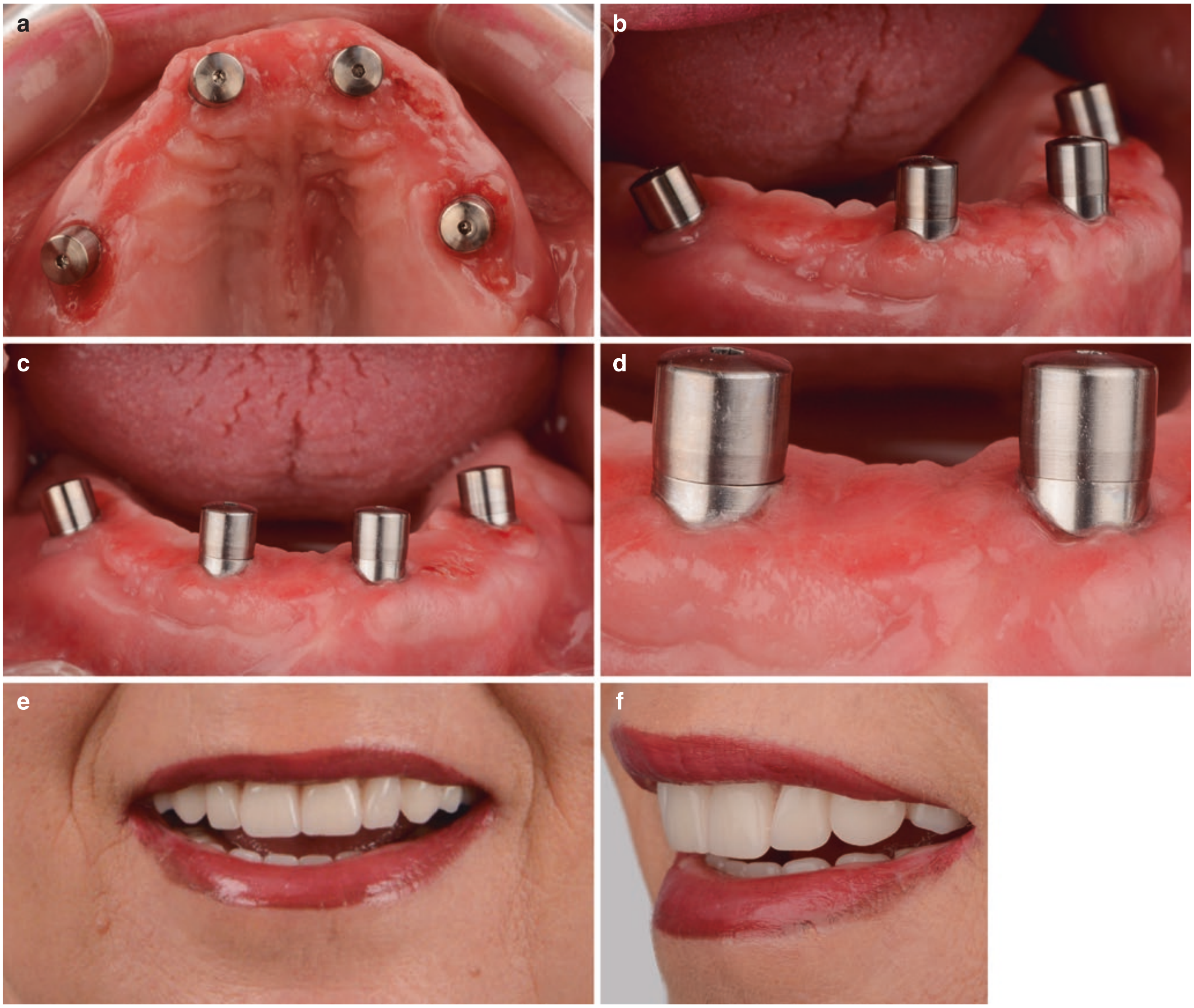

Fig. 11 (**a**) Occlusal aspect of the peri-implant mucosa at 4 months, in the moment of the final impressions. (**b**) Lateral and (**c**) frontal view of the lower peri-implant mucosa at 4 months. (**d**) Detail of the peri-implant mucosa of the axial implants. (**e**) Frontal and (**f**) lateral view of the definitive restoration

Fig. 31 Lateral image after cementation

Fig. 32 One month after the placement of the final prosthesis, the good conditions of the soft tissues is appreciated

Fig. 33 Lateral image, the contour of the soft tissues is appreciated

Fig. 42 A 53-year-old patient who requests treatment with implants. The patient is diagnosed with advanced generalized periodontitis, and the maxillary teeth had to be extracted. Front image of the patient

Fig. 43 Orthopantomography after maxillary extractions

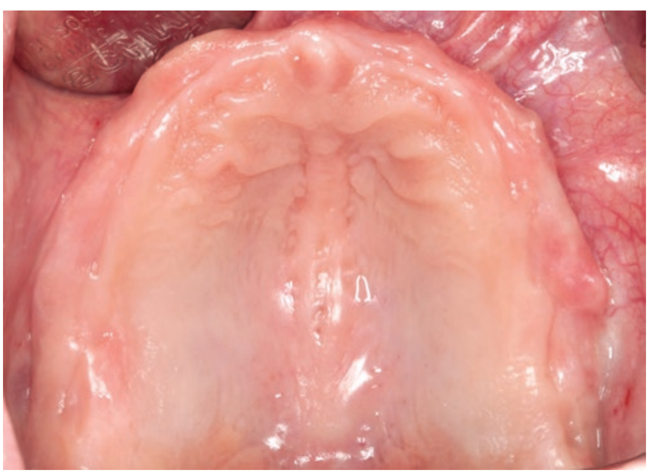

Fig. 44 Occlusal image of the maxilla

Fig. 45 After the diagnostic waxup, a radiographic guide is made

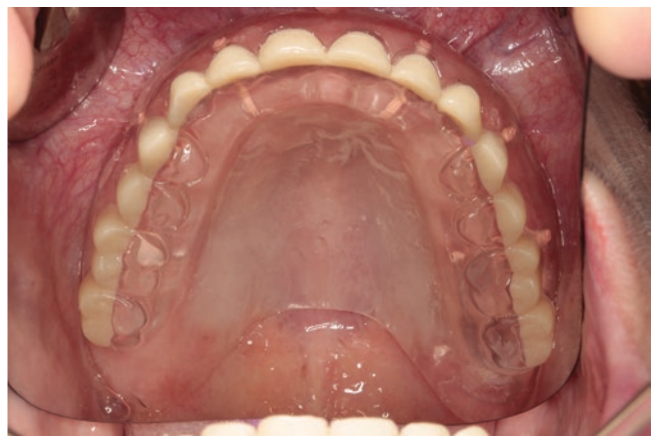

Fig. 46 Occlusal image of the radiographic guide

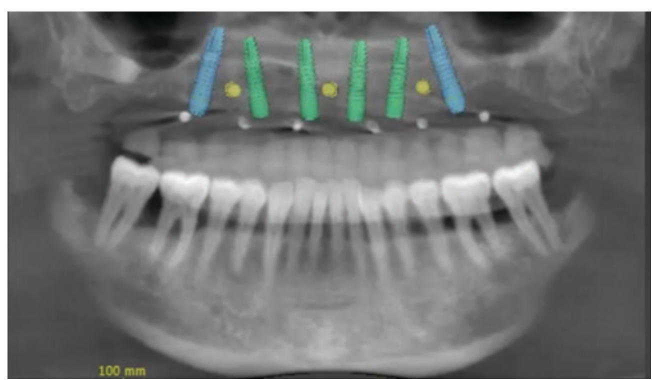

Fig. 47 After introducing all the data in the software, six maxillary PRAMA implants were planned (Sweden & Martina, Padua, Italy) using all-on-six design in order to avoid performing maxillary sinus floor elevation

Fig. 81 Orthopantomography image

Fig. 82 Extraoral picture

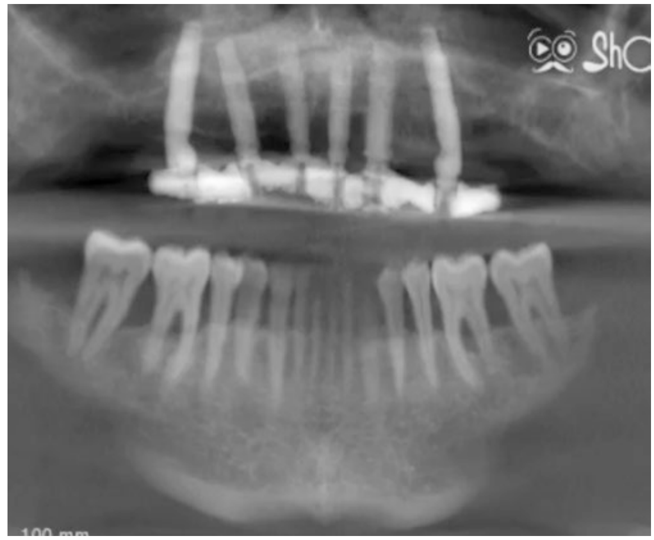

Fig. 83 Image of the postoperative CT

Pre-surgical Preparation

Although more data are now available, it is still difficult to compare reported treatment outcomes due to a number of factors, such as insufficiently defined preoperative parameters or the variety of therapeutic approaches. In addition, the impact of computer-guided software programs available in the market in treatment planning remains insufficiently defined.

Today, there are different systems on the market to guide the surgeon during the planning procedure and the placement of these implants. In the double scanning technique, a scanning is performed to the patient to get the DICOM images; afterward, a second CT scan (dual scan) is taken to the prosthesis only. The two scans are merged and superimposed on each other relating the denture to the patient's jaw. The resulting CT images are converted into a DICOM image and transformed into a three-dimensional virtual model where the surgeon will plan the implant positioning. The completed surgical plan is now sent, and the surgical template is fabricated. With this surgical template, the laboratory technician begins the fabrication of the master cast, the mounting of the newly master cast, the fabrication of the surgical bite registration (in edentulous patients), and in some cases the abutment selection and fabrication of the jig and ends with the fabrication of the provisional prosthesis (Bedrossian 2007).

For fabrication of the surgical template, stereolithography (SLA) and selective laser sintering (SLS) are currently in use. SLA uses an ultraviolet laser to successfully "laser cure" cross sections of a liquid resin. SLS uses a carbon dioxide laser to fuse together layers of a fine polyamide powder, and the models are opaque, whereas SLA models are translucent (Di Giacomo et al. 2012).

Surgical Procedure and Implant Placement

Most major implant manufacturers have created and marketed instrumentation for the fully guided placement of their implants. In some systems, a unique surgical template is used during all the drilling procedure, while in others for every specific diameter of implant drills required by the manufacturer, a different surgical guide was constructed (Van de Velde et al. 2010).

Fig. 63 Immediate, same-day smile of the patient

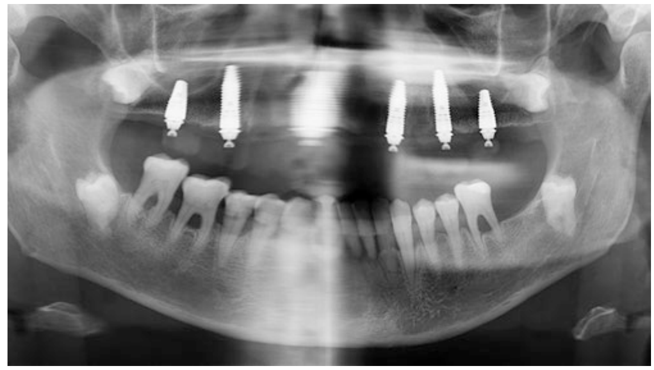

Fig. 64 Post-op X-ray

Fig. 65 Final result with the same-day temporary full arch bridge

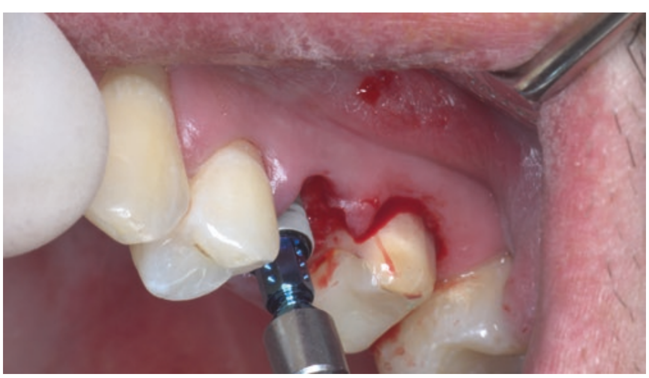

Fig. 66 Single unit case: immediate implant on 25. Implant placement. Also #26 has been prepared and scanned for a final lithium disilicate crown milled chairside. While the crown is being milled, surgery is performed

Fig. 67 Scan body in place (mirror view). Final ceramic crown on #26 seated

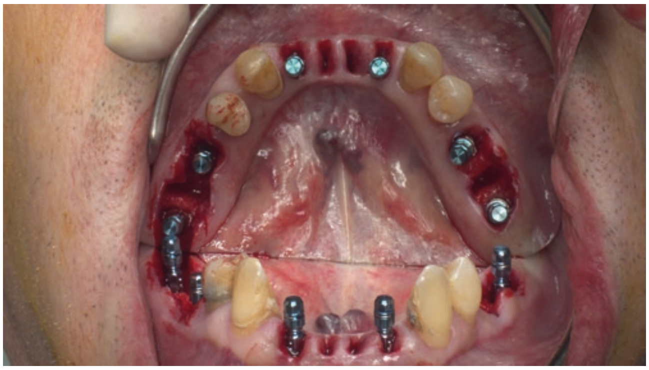

Fig. 6 Lower maxilla: extractions performed, keeping in place key teeth. Implants placed

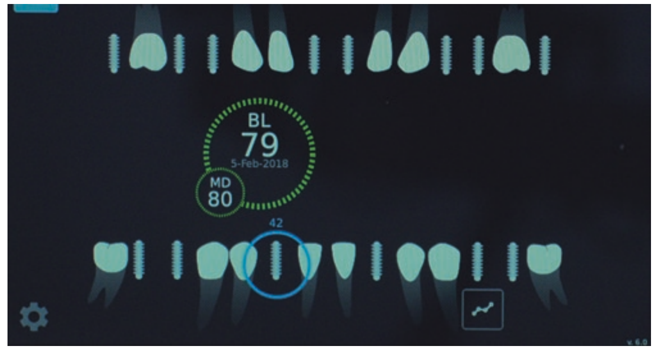

Fig. 10 Taking ISQ values

Fig. 7 Taking ISQ values

Fig. 11 Angled abutment placement in 21 and 11

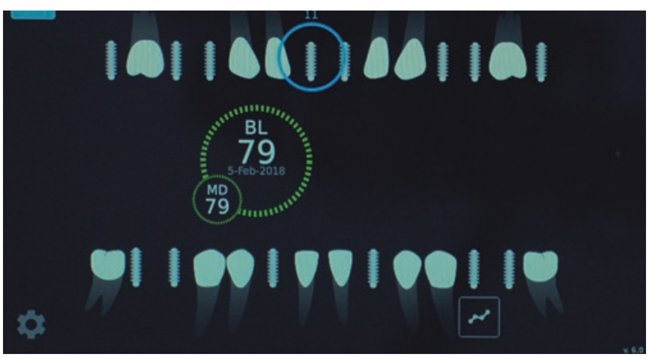

Fig. 8 Taking ISQ values

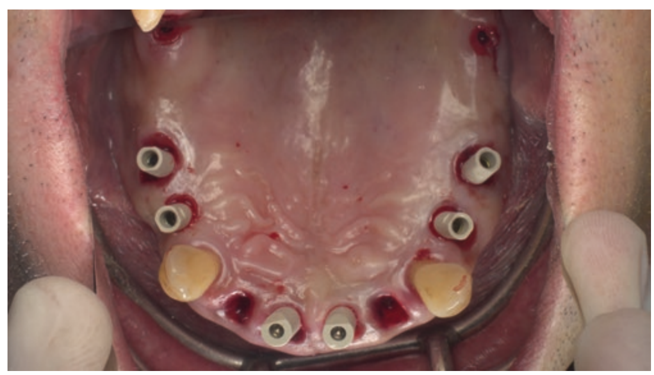

Fig. 12 Scan bodies placed on maxilla

Fig. 9 Taking ISQ values

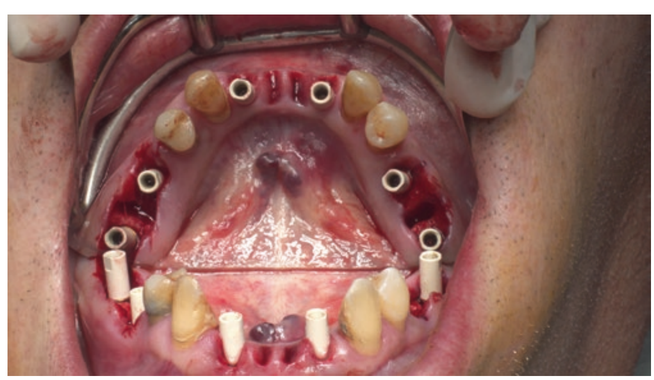

Fig. 13 Scan bodies placed on mandible

Fig. 19 A final characterization is done, adding artificial gingiva for lip support and enhancing esthetics

Fig. 20 Once processed the guided prostheses are ready to deliver to the patient

Fig. 21 Final intraoral appearance with the temp guided prostheses

illa. With the i2 element in position in the edentulous maxilla, we scan the patient (file 1).

Then, we again position the prosthesis in the patient, and without removing the i2 element, we perform another intraoral scan (file 2). This file contains the positioned i2 element (or elements) together with the patient prosthesis, the antagonist, and the bite.

Both files (file 1 and file 2) are sent to the laboratory, where the technician can align them using the i2 elements as reference.

Fig. 22 Final appearance of the patient with the temp guided prostheses

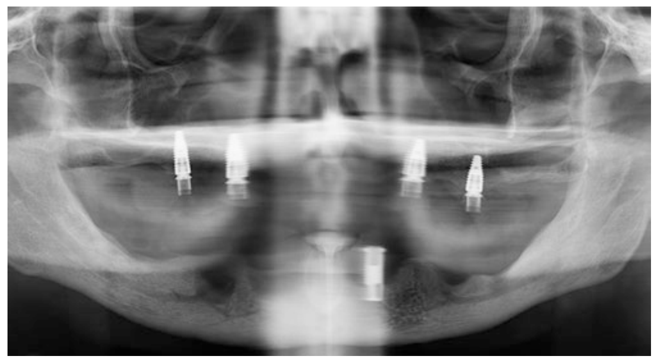

Fig. 23 Post-op immediate OPG showing the passive fit of all the ti-bases

In this way the software of the technician contains the scan of the edentulous maxilla and of the complete prosthesis of the patient, duly aligned. The technician is able to design the GUi2 element selecting and copying, the esthetics and spatial-functional position of the teeth, the technician wants to appear in the new radiopaque splint. These teeth are joined by connectors that should not occupy the gingival position where the implants will be placed in the guided surgical procedure. Ideally, moreover, selection should be made of those teeth not located over possible implant receptor sites.

Production of the GUi2 element is made by milling from a barium resin disc or through three-dimensional printing using barium resin.

In this way we obtain a radiopaque element fitted to the maxilla and transforming the patient into a partially edentulous individual ready both to be scanned with the intraoral scanner and to undergo the exploratory computed tomography scan for guided surgery.

The GUi2 element is affixed to the maxilla with adhesives or an osteosynthesis screw, and we obtain the intraoral scan of the maxilla, the antagonist, and occlusion. Then, without removing the GUi2 element, the computed tomography scan is performed.

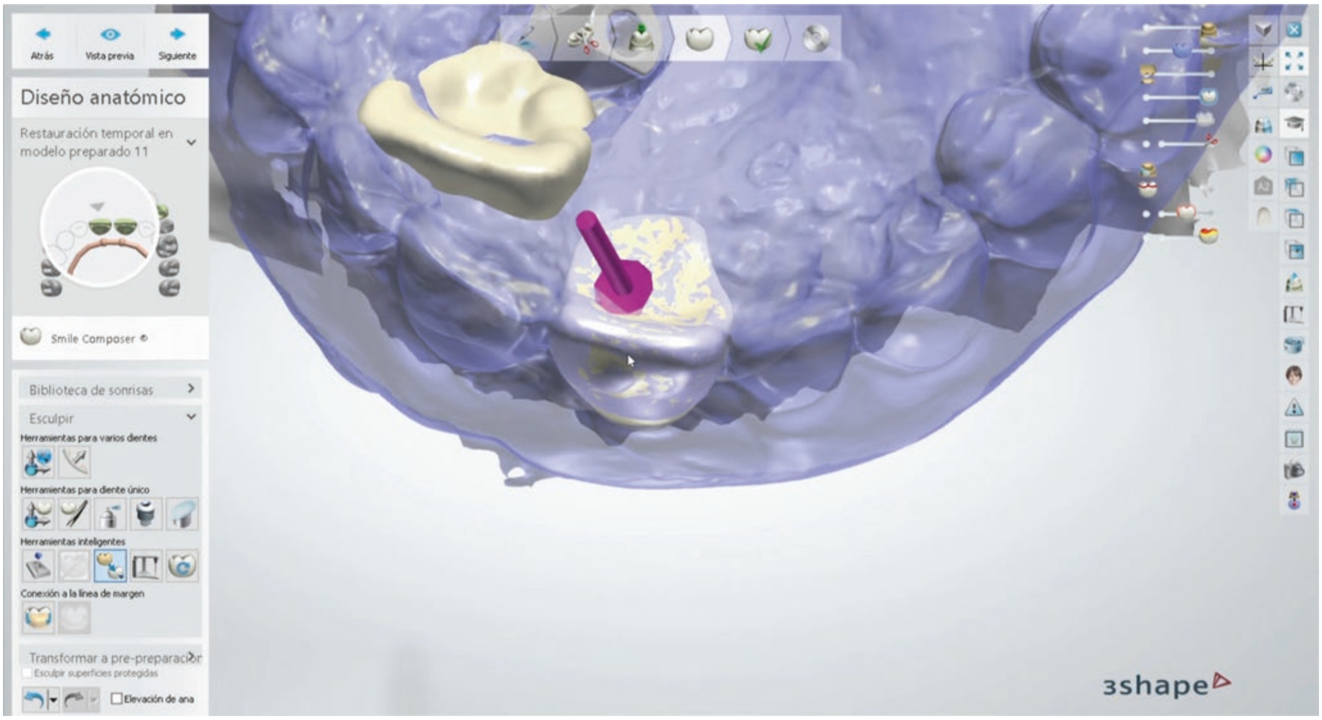

Fig. 34 The DT starts designing the Gui2, using, as a pre-preparation, the complete denture scan. Only three to four teeth are needed for a perfect workflow

Fig. 35 The final Gui2 design onto the complete denture scan