Outcome and Quality of Life after Individual Computer-Assisted Reconstruction of the Midface

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ABSTRACT

Often, midfacial defects are not only relevant regarding functional aspects but also esthetics of such congenital or acquired deformities impair significantly the patients' quality of life. Reconstructions of the midface do not only include replacing lost or non-developed tissue but moreover to achieve predictable results with regard to esthetics as well as function for the individual patient. Digital planning modalities including different surface and volume data in combination with modern additive manufacturing techniques for biomodel and implant production and intraoperative support by using real and virtual 3D volume data for navigation and intraoperative imaging, but also securing the outcome based on postoperative analysis have been implemented in modern midface reconstruction and represent new standards for medical care. The objective of this paper is to describe modern options of patient-specific midfacial reconstruction with integration of computer-assisted planning and production techniques.

Contents

1. Outcome and quality of life after individual computer-assisted reconstruction of the midface

The midface is not only the anatomical center of the face but it is the framework structure and basic precondition for exercising the identity of an individual. Here, important senses like vision and smelling are localized as well as functions like chewing and air passage. It represents a multifunctionality for an anatomical region with regard to structure and design. If the anatomical integrity of the midface is impaired due to congenital or acquired deformities, not only the function is disturbed for the individual but also massively the quality of life [1]. This is an important statement that obliges to perform particular quality management prior to every surgical intervention in the area of the midface. In this context, computer assistance may be suitable to make reconstructive interventions of the midface more predictable, more transparent, and more verifiable and thus associated with lower risk [2, 3]. Digital planning possibilities integrating different surface and volume data including modern additive production techniques for biomodel and implant manufacturing and intraoperative support of real and virtual 3D volume data application by means of navigation as well as intraoperative outcome securing due to 3D volume dataset assessment with 3D C-arm cone beam tomography have been implemented in modern midfacial reconstruction and represent new standards for medical care [4–9].

However, an implementation of new technology must always be considered with the background of clinical significance: the limitations for treatment success are rarely defined by the technology itself but moreover by clinical reasons like for example motor impairment, scars, lack of tissue. Thus, the clinician has the immense responsibility to assess and define the balance of what is theoretically feasible and what can in fact be achieved. The generation of young surgeons as well as the more experienced ones have nowadays the unprecedented chance to see and understand complex reconstructions from the individual three-dimensionality – in all treatment phases, i. e. the pre-, intra-, and postoperative course [10]. Thus, also the term of quality control has a completely new dimension and finally allows to create evidence of every individual case. This means that the term of evidence-based medicine may get a new, real-surgery, and patient-related perspective [3, 11].

In the following chapters, the modern options of patient-specific reconstructions of the midface including patient-specific implants that have been planned and produced by means of computer assistance (CAD/CAM) for reconstruction will be described. In this context, also paradigm shifts will become apparent like for example the aspect that reconstructions of the orbit must be dimensionally stable leading to the fact that bioresorbable materials need particular justification [12, 13]; or that the unimpaired chewing function of the centrally and/or laterally ablated midface may be restored by means of a single-time surgery with a primarily functionally stable, multivector screw retained patient-specific implant [14].

2. Posttraumatic reconstruction of the midface

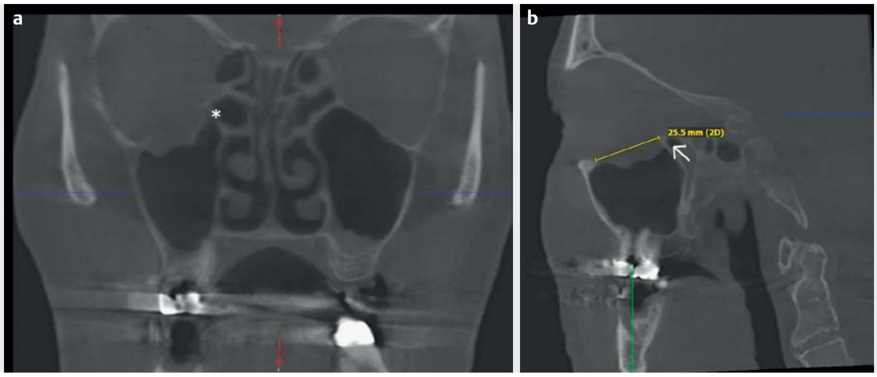
In the context of reconstruction of posttraumatic defects, the difference must be made between primary and secondary reconstruction. Furthermore, there is the difference between isolated orbital defects and combined orbital and midfacial defects [8, 10]. Generally, the following statement is true: Reconstruction is the more difficult the later it is performed and the more complex the individual trauma pattern is. Quality and methods of three-dimensional imaging have led to an enormous step forward so that generally no limitations exist in our healthcare system. In particular spiral CT technology (CT) and cone beam tomography (CBCT) must be mentioned in the context of midfacial trauma. Modern CBCT is often superior to CT scan with regard to diagnostics for hard tissue because metallic artifacts are less negatively overlying compared to CT diagnostics [14, 15]. If soft tissue has to be evaluated like for example with regard to intraorbital bleeding, contrast-enhanced CT scan must certainly be preferred [16, 17]. The clinically more important problem in traumatology that has to be resolved imperatively is that 3D datasets should basically have the quality allowing a digital planning process as integral element [18]. Therefore, traumatology is mentioned as field of indication because it has the highest requirements with regard to the factor of time in the chronological treatment course. Hereby, radiologists should know abou what a 3D dataset may be able to contribute to the treatment beyond diagnostics; and the surgeons are responsible to explain to the diagnosticians that and which therapeutic consequences are developed from the 3D datasets. In short, computer-assisted planning with virtual models and additive manufacturing of 3D biomodels, navigation, robotics are only possible when the volume data are exported in the DICOM format and meet the requirements regarding slice thickness and the scanned volume for possible subsequent applications of technologies. Fortunately, nearly every CT and CBCT device is nowadays able to perform this. Moreover, the specifications for scanning with regard to the midface are rather simple, i. e. the alignment of the object to be scanned in the neutral zero position, axial scan direction, layer thickness of less than 1 mm. However, in reality these scan and/or DICOM exportation requirements are not met in about 50 % of external dataset transmission. Thus new 3D volume datasets have to be created – which could be avoided. In this context, still a lot of information has to be passed on [19].

Based on different areas of indication, modern computer-assisted procedures for reconstructions of the midface will be presented in the following chapters.

2.1 Primary posttraumatic reconstruction of the midface

Due to a fall, an older female patient suffered from right-sided posttraumatic orbital defect that comprised the sagittal as well as the transversal dimension of the entire orbital floor. ▶ **Fig. 1** shows the extended defect that involved the transition zone between medial orbital wall and orbital floor. The justification for the application of patient-specific implants could be focused over the years on the following indications:

There is a necessity of dimensionally stable reconstruction in cases of loss of the so-called key areas of the orbit, those are the anterior 10 mm of the orbital floor ("postentry zone", measured from the infraorbital rim in posterior direction in the paramedian oblique-sagittal plane), the posterior medial bulge, the region between the posterior wall of the maxillary sinus and the posterior



▶ **Fig. 1** Posttraumatic defect of the orbital floor on the right side in coronal sequence **a** as well as oblique-sagittal sequence **b** with subtotal extension of the defect of 25.5 mm seen in CBT. *transition zone; arrow: posterior ledge.

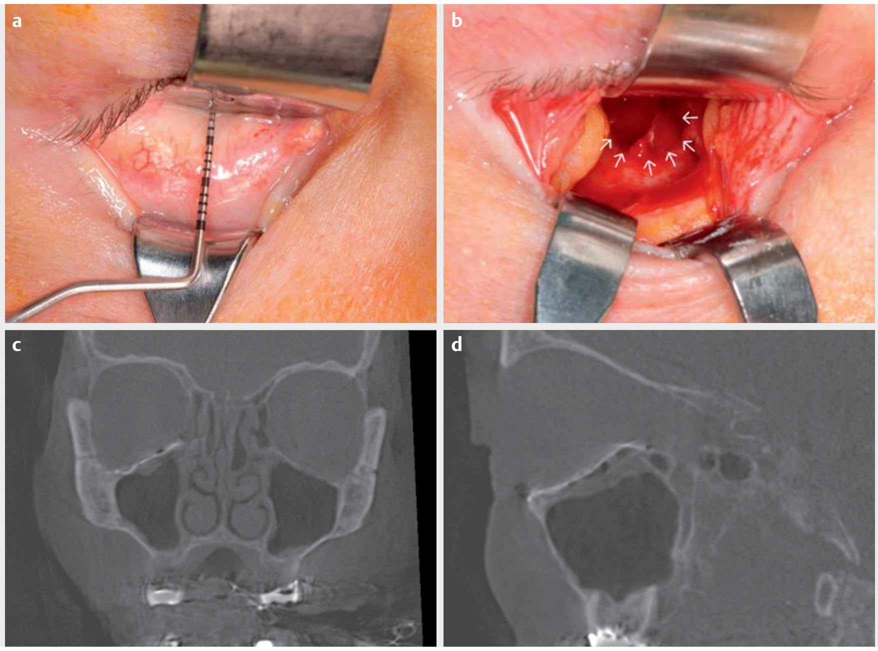
ledge, the posterior third of the orbital floor, the transition zone between the medial orbital wall and the orbital floor, or a change of the lentil-shape-contour of the inferior rectus muscle in the coronal layer to a round formation as indication for an opening of the periorbita as well as enophthalmos or hypoglobus. In all mentioned defect constellations of the internal orbit, patient-specific implants are favored that have the perfect shape and include elements of functionalization and preventive design. These implants have been developed by the author's research group and aim at providing clinically relevant for intraoperative use as well as allowing the automated alignment of the STL files of the patient-specific implants in the volume dataset for intraoperative navigation so that the navigation control may be performed in a pointer-based and trajectory-based way. This workflow is ensured for IPS Implants® (KLS Martin Group, Tuttlingen, Germany) in combination with the iPlan® software (Brainlab, Munich, Germany). In addition, anatomical extensions may be added to these implants in order to provide further stabilization. A round, circular edging (thickness of 0.5 mm) allows the atraumatic interaction of the implant with neighboring tissue of the implant that has only 0.3 mm in its center in the adequately dissected orbit. In the posterior third of the orbit, a clear curvature of the implant geometry is found diverging from the area near the optic canal, shaped like an inverted snow shovel. Multiple slit openings lead to a reduction of the biomaterial and further for drainage in cases of retrobulbar hematoma. This kind of implant includes the experience of 30 years of reconstructive orbital surgery and turned out to avoid the classic mistakes of orbital reconstruction. Fixation at or behind the infraorbital rim is possible by means of one or two mini-screws measuring 1.2, 1.3, or 1.5 mm in diameter. If needed, fixation may also be performed at the anterior or latero-orbital side (▶ **Fig. 2**).

▶ **Fig. 2** Patient-specific implant for reconstruction of the right orbita (KLS Martin Group, Tuttlingen, Germany) with several functionalizations. Arrows: trajectories for intraoperative navigation; ǂpreventive design with caudally angulated dorsal support (inverted snow shovel); *reconstruction of the posterior medial bulge.

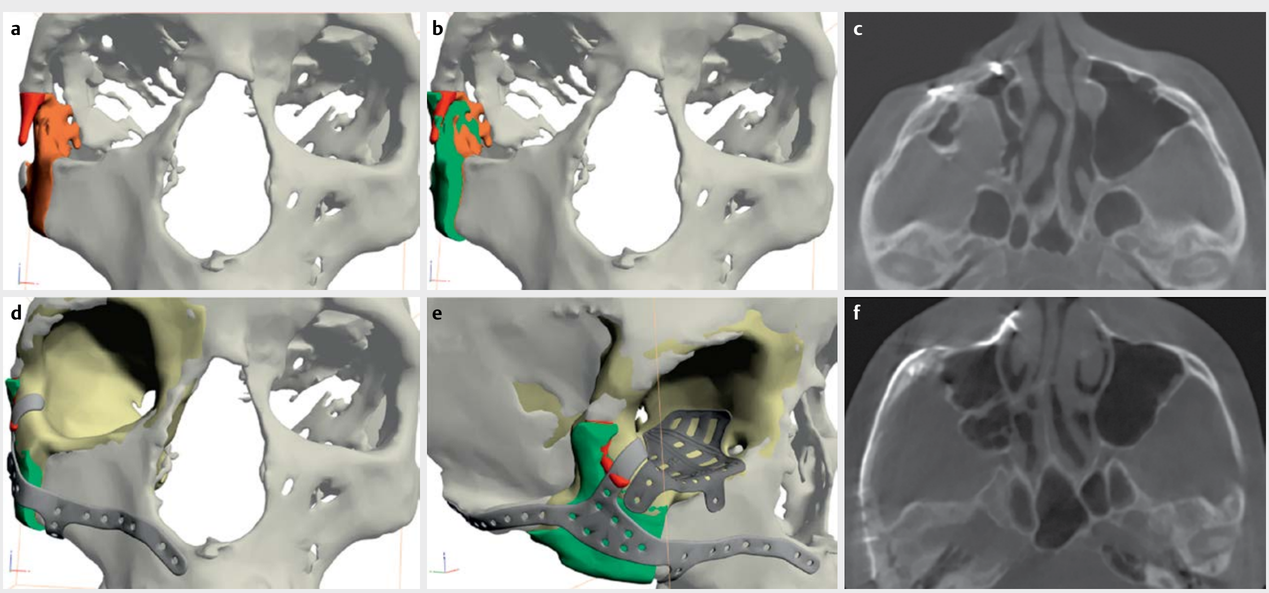
Approaches for orbital reconstruction may generally be smaller, however, they have to meet the requirements of sufficient dissection. The authors have acquired excellent results mainly with the inferior transconjunctival retroseptal approach for the reconstruction of the orbital floor and the caudal parts of the lateral and medial orbital wall (▶ **Fig 3**) – in exceptional cases, canthotomy may be performed for a better overview. If the median orbital wall has to be reconstructed until the inferior part of the anterior skull base, additionally the median transconjunctival approach is recommended from trans- or retrocaruncular direction. Superior parts of the lateral orbital wall and the lateral area of the orbital roof may be safely treated via the superior lateral blepharoplasty approach. Eyebrow incision should no longer be applied.

2.2 Secondary posttraumatic reconstruction of the orbit and the midface

Secondary reconstructions have the advantage of a longer time for planning and preparation. The orbit and the midface are the most challenging regions for secondary reconstructions because the interaction only of the orbit is associated with 50 % of the 12 cranial nerves. The complexity is defined by the anatomical and functional deficit and becomes even more difficult because of often high expectations in the sense of *restitutio ad integrum* which in cases of secondary corrections is nearly impossible. Only the best possible improvement of the condition can be aimed at that has to be balanced between realistic outcomes and the patient's expectations.



▶ **Fig. 3** Clinical pictures of an inferior, transconjunctival, retroseptal approach. Incision at least 10 mm dorsally to the eyelid **a**; exposition of the orbital floor **b** with fracture zone (arrows). Intraoperative imaging by means of CBCT after insertion of the implant in coronal **c** and diagonal-sagittal paramedian **d** sequence.



▶ **Fig. 4** Planning of a secondary correction of the malar bone with segmentation of the bone healed in malposition **a**, which is repositioned **b**, as well as a patient-specific implant (PSI) for definition of the ideal position **d** and another PSI for orbital reconstruction based on the now volume-enhanced new situation **e**. Preoperative CBCT **c** with malposition of the malar bone and postoperative **f** after correction.

After primary treatment of severe injury with midfacial and orbital fractures several months ago, ▶ **Fig. 4** shows the radiological analogue findings of the clinically apparent deformity of the female patient. In the context of primary treatment, reposition of the midfacial structures had been performed with insertion of bioresorbable material and also the reconstruction of the internal orbita, however, all these structures are now in the fixed stage of apparent malposition and thus inadequately treated. Clinically, a hypoglobus with massive enophthalmos on the right imposes as well as massive retrusion of the right prominence of the right side. Together with the patient the decision was made to correct the outer frame for adequate reconstruction of the midface and the orbit in the same session. This included the recontouring of the right orbit. With the clinical information and the assessment of the tissue situation, the planning requirements are transmitted to the industrial partner so that preoperatively ideal patient-specific implants can be digitally planned and manufactured computer assistance. Exemplarily, some screenshots from the planning view are displayed that show the implant for the external frame as well as the planned functionalized multi-wall implant for the right orbit with aforementioned preventive design ▶ **Fig. 4**. Both implants define separately and in combination the correct position of the malar bone that has to be corrected. The infrared-based navigation was performed intraoperatively for control of the drilling direction and anchoring in the area of the lateral skull base. Pointer-based navigation and trajectory-based navigation were applied in order to verify the correct dissection as well as the implant position in relation to the neighboring structures.

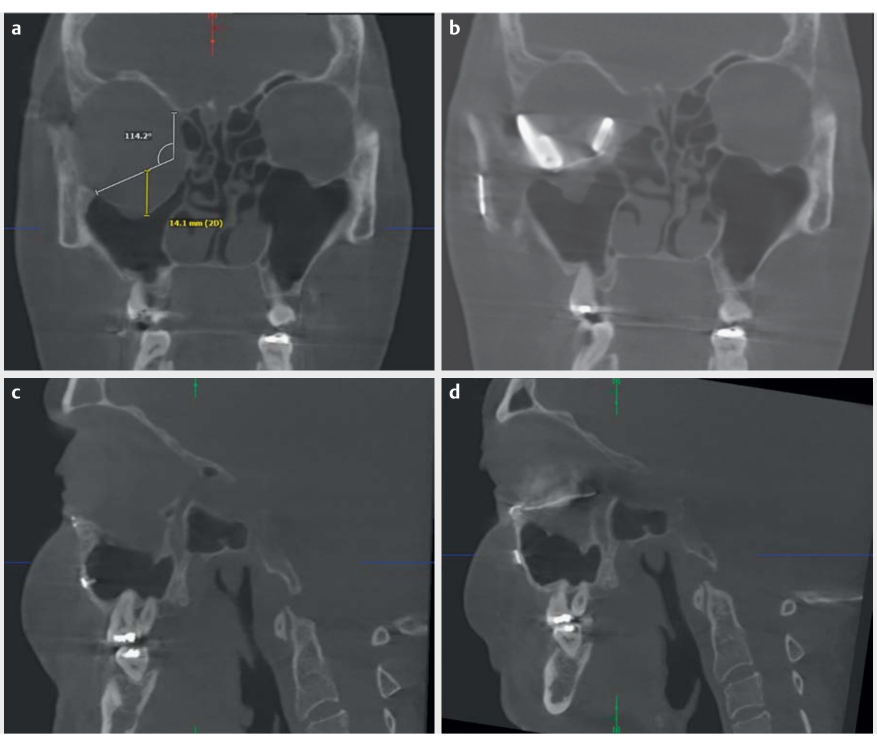
The surgical access was performed for the orbit via the transconjunctival retroseptal approach, for the lateral frame the transoral and pre-auricular approach on the right side was chosen.
The major need of the patient, namely the correction of the facial deformity including the malposition of the globe with diplopia was met. The orbital volume enlargement was additionally corrected by means of titanium spacers (▶ **Fig. 5**). Furthermore, ENT surgeons performed opening and stenting of the right nasofrontal duct.

This case report reveals the enormous contribution to quality management due to computer-assistance at three different stages of treatment: preoperative, intraoperative, and postoperative.

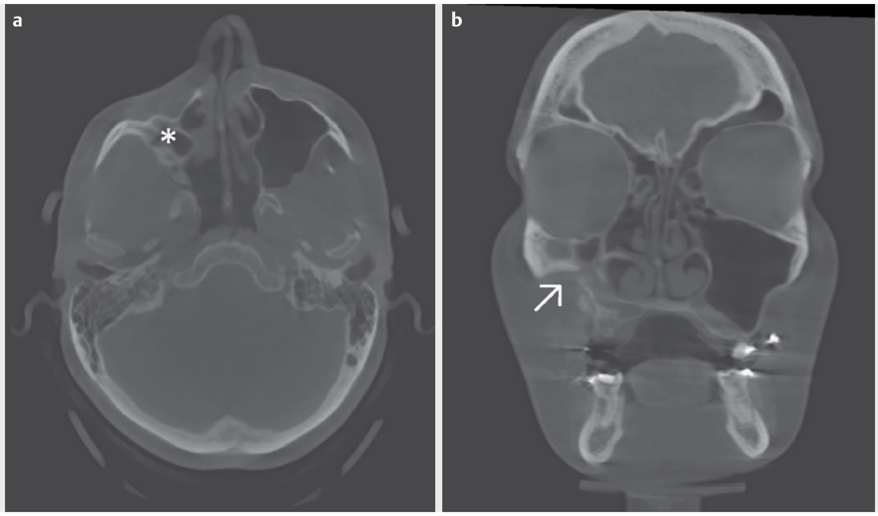
3. Growth-related acquired deformity of the orbit and the midface

Due to an inflammatory disease of the right maxillary sinus with surgical treatment in early childhood, the adult patient showed the clinical picture of a complex facial asymmetry induced by growth disorder of the midface with retrusion of the right malar bone, an orbital asymmetry with hypoglobus and right-sided enophthalmos as well as an occlusal cant (▶ **Fig. 6**). Radiologically, the bony walls of the maxillary sinus were thickened. Primarily, the assessment and association of the asymmetry to the anatomical structures had to be performed. The transition zone between the medial wall and the right orbital floor was shifted in caudal direction, the orbital volume was enlarged on the right side in comparison to the non-affected contralateral side.

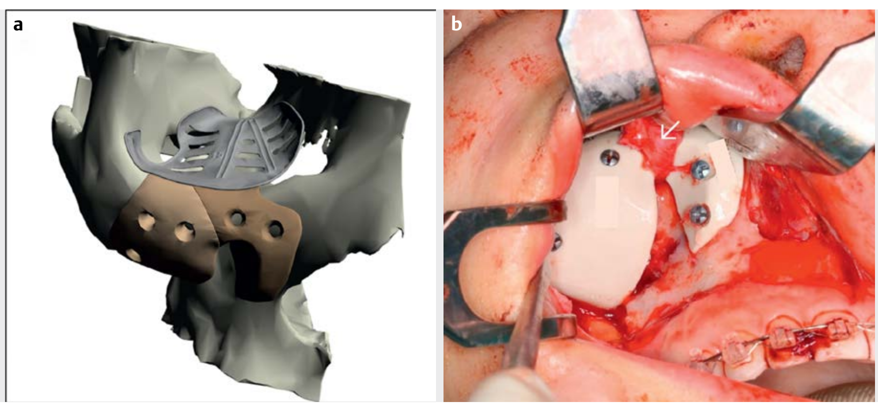
The result of the interactive imaging analysis between surface and volume data and the correlation to the clinically assessable asymmetry led to the following treatment plan. In two sessions, first the lateral midface and the right orbit should be reconstructed and symmetrized. In a second intervention, bimaxillary orthognatic surgery was planned in order to correct the central midface and the mandible. While the midfacial deformity caused the patient's major suffering, the jaws were not the leading problem so that corrective osteotomy was finally not performed. However, in order not to spoil this option for the future, the orbital and midfacial reconstruction had to be planned in that way that later Le Fort I osteotomy was possible without jeopardizing the outcome of the first intervention.



▶ **Fig. 5** CBCT of the patient from fig. 4 before orbital reconstruction **a + c** with an extended orbital defect and after reconstruction **b + d** by means of patient-specific orbital implant as well as titanium spacers for volume augmentation.



▶ **Fig. 6** Preoperative CBCT of a female patient with midfacial deformity in axial **a** and coronal plane **b** with hypoplastic right maxillary sinus (star) as well as reactive increase of density of the surrounding bone (arrow) and clearly backshifted prominence of right malar bone.



▶ **Fig. 7** Planning **a** of a reconstruction for the patient from fig. 6 by means of patient-specific orbital implant as well as two-part PEEK implant. Intraoperative situation **b** with preservation of the infraorbital nerve (arrow).

For the orbit and also for the external midfacial skeleton, two independent patient-specific implants were planned that could be inserted independently from each other in case of complications. Furthermore, a two-part PEEK (polyetheretherketon) implant for the near-nerve augmentation in the area of the malar bone was chosen in order to surgically realize the contour and volume effect around the area near the infraorbital nerve with low risk and to achieve less heat conduction of the material. For correction of the globe position, however, an IPS implant® (KLS Martin Group, Tuttlingen, Germany) was manufactured for the orbit in a laser melting process that was fixed independently from the PEEK implant (▶ **Fig. 7**). Both implant types could be inserted in the planned target position only via the transoral approach and the retroseptal transconjunctial approach. Postoperatively, diplopia was observed for some weeks that disappeared in the visual field as well as in direct vision.

4. Defects of the maxilla and midface

Dental implantology is one of the major achievements of modern maxillofacial and dental surgery that is mainly based on the implantation of an alloplastic foreign body into the existing bone. If the conditions are unfavorable regarding bone situation and quality combined with negatively enhancing biomechanical stress with regard to an increased atrophy, all conventional procedures of pre-implantological bone transplantation with subsequent application of conventional dental implants are limited. This situation becomes worse when additional general diseases and medication as well as irradiation or impaired immune system, tissue defects and replacement complicate the basic condition.

Conventional therapy strategies also include the classic external sinus lift by means of an osteoplasty in the alveolar recess, which already may lead to a complex disease and that usually heals without complication if autogenous bone is used in cases of maxillary sinusitis. The widespread application of so-called bone replacement materials of self-proclaimed implantologists in often uncontrolled ways may lead to serious inflammations and thus additional loss of bone and tissue.

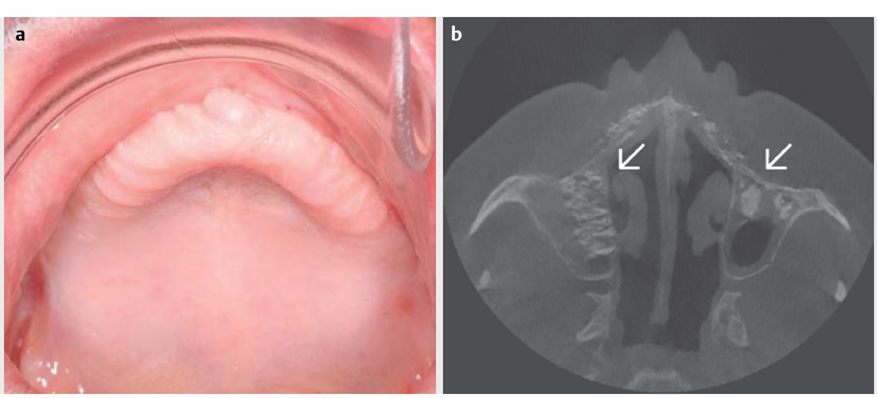
The problem of unfavorable biomechanical stress in cases of severe atrophy in form of a Angle class III relation is one of the biggest challenges for the weak and atrophic maxilla and was the origin of a new treatment strategy where computer-assisted planning with innovations in biomedical technology achieved a new approach in form of the patient-specific implants (individual patient-specific solution [IPS] implants® Preprosthetic, KLS Martin Group, Tuttlingen, Germany). Furthermore, it is a preventive treatment response because conventional procedures were often characterized by an enormous invasiveness or represented a biologically inadequate approach for already incurable or hardly treatable patients because they were too old, too sick, or already pre-injured. In this context, "preventive" means that this procedure that has been newly developed by the authors leaves out for example the maxillary sinus and internal midfacial structures and merely rests on the remaining bone-structures in combination with a rigidly multivector screw retention. This procedure is not competitive to dental implantology but it may be a crucial line-extension for those cases where the invasiveness of classic pre-implantological interventions is considered as inadequate. Apart from this, the conventional strategies are associated with a treatment protocol that takes about one year. So all conventional strategies have to be considered critically and even more at risk with regard to the target, the more unfavorable the above-mentioned skeletal relationship is in direction of an Angle class III. Here, only the zygomatic-implant must be mentioned as possible alternative for the atrophic maxilla, however, it has basic design weaknesses because the anchoring is off-site in the zygoma – which is generally positive – but the implant axis is in direct neighborhood or even in the passage through the maxillary sinus. If anterior teeth remain in the mandible, the treatment of the extremely atrophic maxilla requires particularly stable conditions. This consideration is not at all limited to old patients but already e. g., in young patients suffering from syndromic diseases associated with teeth loss or also compromise-afflicted singularly conservative orthodontic compensation attempts in cases of e. g., patients with severe cleft palate and limited maxillary growth, complex biomechanically lip and induced teeth and subsequent bone loss may be observed early. In these cases, at least the intact mandibular situation must be considered as causal for a decompensation mechanism due to an unequal or overload of the anterior maxillary region that may lead to extremely atrophic maxillae already in middle-aged patients. A particular challenge is the combination of maxillary weakness due to severe atrophy with additional ablation of maxillary parts and surrounding soft tissue as a consequence of radical surgery after malignant diseases, sometimes combined with adjuvant radio- and/or chemotherapy with at the same time fully dentated mandible. Regarding the planning process for computer-assisted production of an IPS implant® Preprosthetic, there is generally no difference to the otherwise typical planning of dental implant treatment. This means that the planning may be performed in an analogue, digital, or even combined analogue/digital way. Mainly in cases of non-defined maxillary relation and occlusal height, a radiopaque wax setup should be performed and be an integral part of the pretherapeutic scan volume either in CBCT or CT scan. If preoperative situations are present as 3D datasets based on plaster models, these data may be integrated in the planning dataset. The number of pillars and their alignment have to be defined in order to design their digital connection to the basic framework.

▶ **Fig. 8** shows the clinical condition of a 84-year-old female patient after multiple surgical interventions with scarring and tissue reaction on the uncontrolled insertion of inadequate quantities of bone substitutes in the massively atrophic maxilla as well as the maxillary sinus on both sides. Diagnostic CBCT allowed the analysis of the bone and displayed the massively dislocated radiodense bone substitute in both maxillary sinuses so that first this material had to be comprehensively removed.

Preexisting oroantral fistulas in the bilateral dental areas healed consequently. The patient did not want new attempts of pre-implantological augmentations. Also, for the mandible, the disturbing concept of the previous treatment became obvious in form of very rigid anchoring of the dental prosthesis with completely malpositioned dental implant axes with regard to the already weakened maxilla, i. e., by lifting the implant shoulders in labial direction, the biomechanical stress was additionally negatively enhanced for the extremely atrophic maxilla (▶ **Fig. 9**).

The decision was made for the treatment alternative by means of an IPS-Implants® Preprosthetic for the extremely atrophic maxilla that was maximally disadvantaged due to the foreign material. ▶ **Fig. 10** shows the situation after removal of the infected bone substitute with ventilated maxillary sinuses as well as a splint for backwards planning worn in the context of 3D scan.

Treatment was performed in one single session by means of an IPS-Implants® Preprosthetic which is possible as an outpatient procedure due to the less invasive approach. In contrast to conventional augmentative procedures, this implant can be loaded immedi-



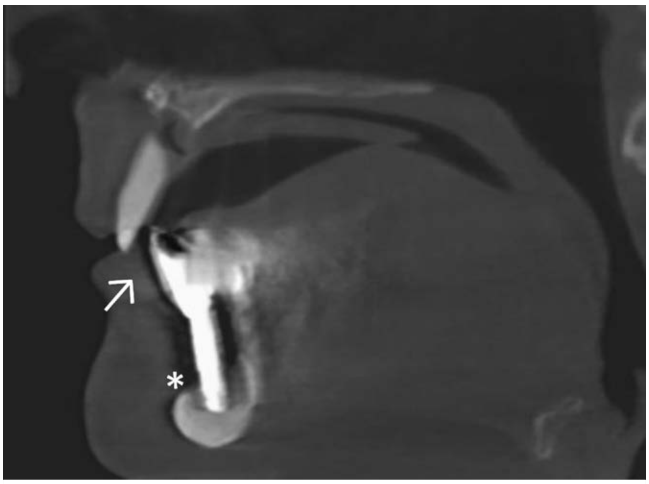
▶ **Fig. 8** Patient with insufficient intraoral situation for prosthesis placement after augmentation elsewhere with bone substitutes. Intraoral situation **a** and CBT **b** with depiction of the bone replacement material (arrows).

ately which is a great advantage in particular for older patients who shun complex multistage treatment concepts.

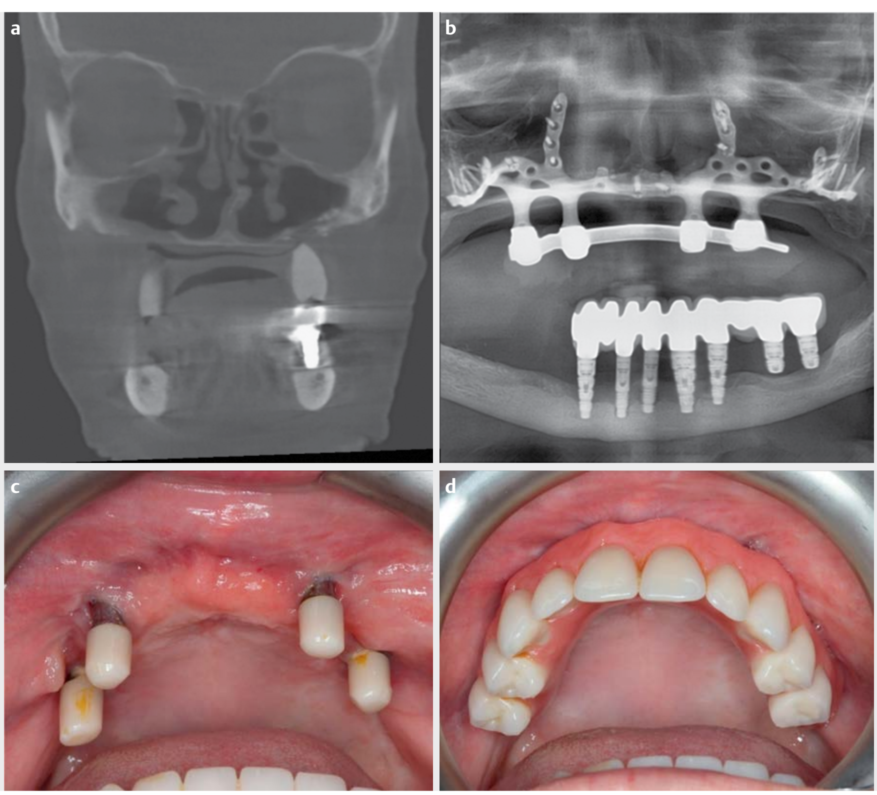
4.1 Cleft lip and palate related midfacial defects

▶ **Fig. 11** shows a large anterior oronasal fistula after loss of the premaxilla in the context of primary intervention performed elsewhere. In ▶ **Fig. 11b**, the computer-assisted planning for reconstruction by means of an IPS-Implants® Preprosthetic shows the new unfavorable skeletal Angle class III relation. In the interactive viewer of the case designer, different planning stages are displayed from different views by including soft tissue information based on the scanned edentulous maxilla model, the scanned prosthetic wax setup for the planned maxillary denture, the planned occlusion level, and the framework implant with necessary bone resection. The design of the IPS-Implants® Preprosthetic allows an important protrusion of the pillars in order to compensate the position of the clearly backwards located maxilla compared to the skeletal mandible. The surgery itself is performed on an outpatient basis and allows the rehabilitation of complex maxillary defects within one day which would be impossible for conventional protocols that take at least one year – with associated severe morbidity.

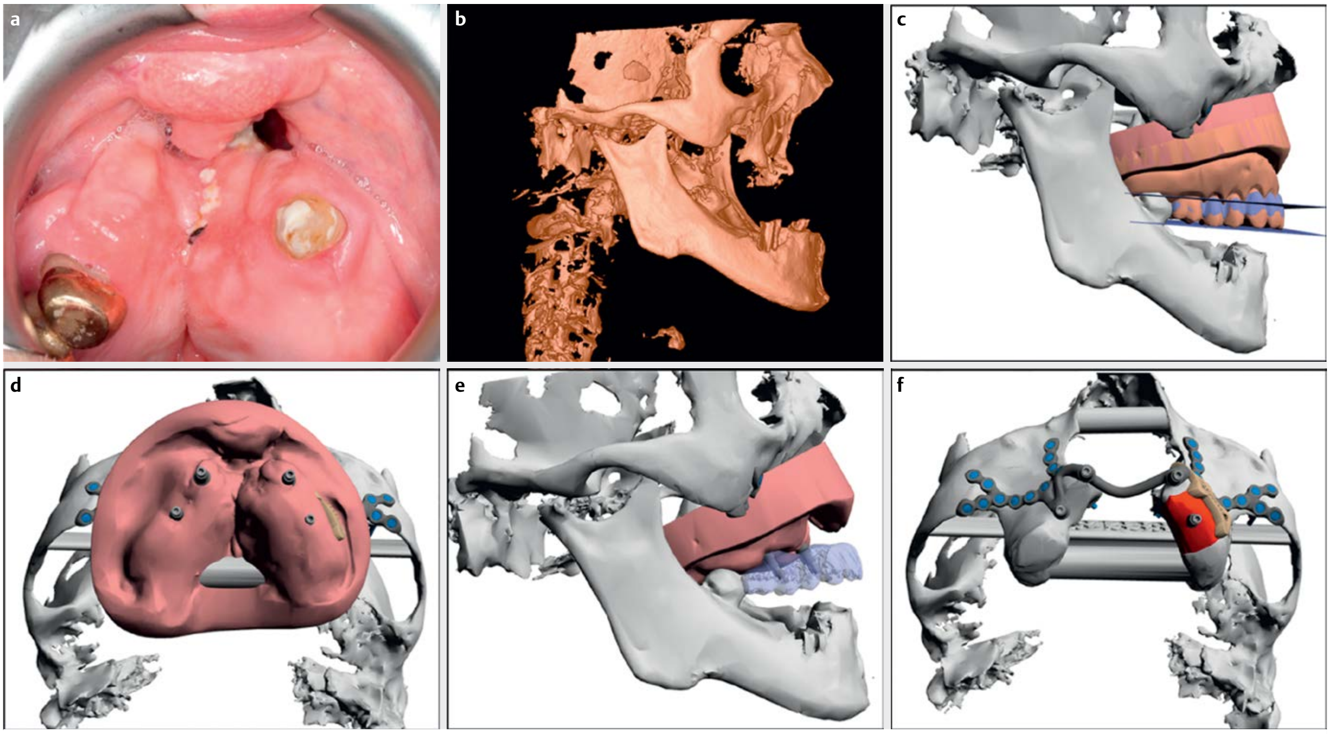
According to the case presentation in ▶ **Fig. 11**, the functionalized and preventive design for the IPS-Implants® Preprosthetic must be particularly mentioned which means that a clear positioning is given that may be supported by additional three-dimensional landmarks that may be designed for the individual implant like small stabilizers, arms, or flunges around anatomical structures. In the maxilla, mainly the middle and lateral midfacial pillars around the piriform aperture or the alveolar zygomatic crest are used. The thickness of the framework basis can be designed in a tapered way to the palpable edge, the use of 1.5 or 2.0 mm non-locking or also locking osteosynthesis screws is possible. The basic principle is the primarily stable osteosynthesis performed remote from the pillar passages.



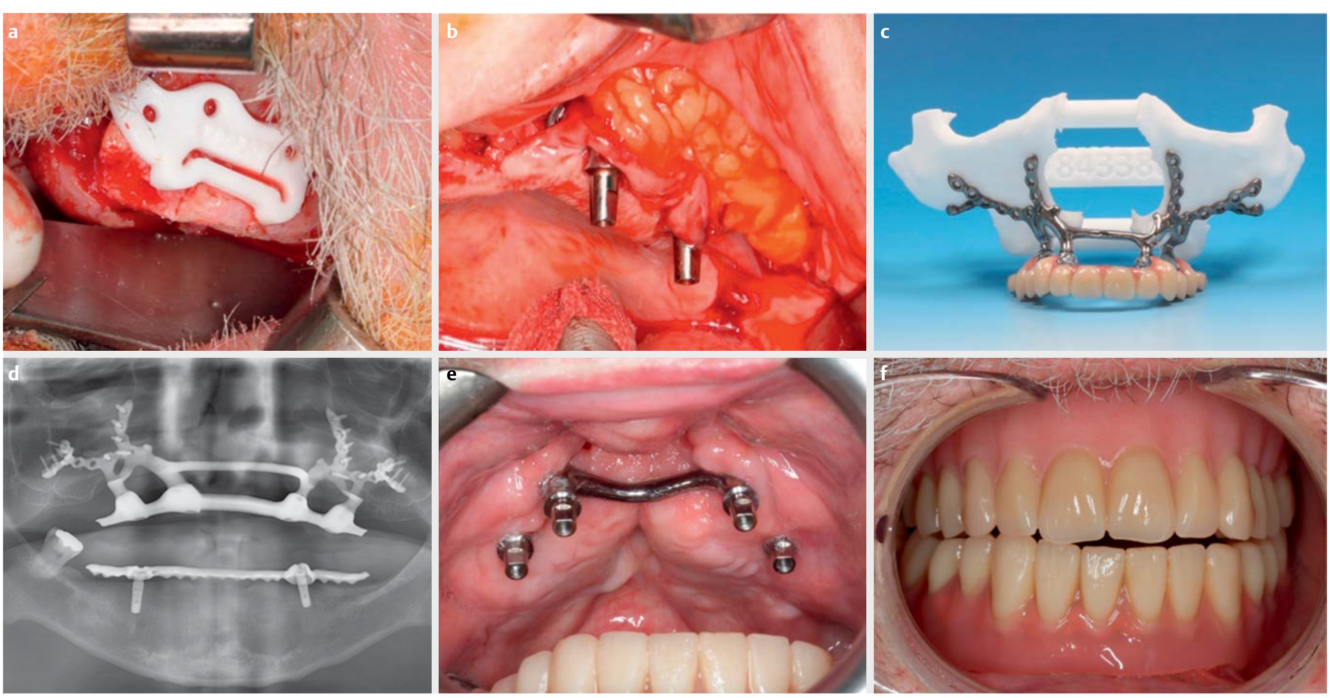
▶ **Fig. 9** CBCT in sagittal layer of the patient from fig. 8 with unfavorable Angle class III relation (arrow) as well as peri-implant bone loss (*).



▶ **Fig. 10** CBCT in coronal layer of the patient from figs. 8 and 9 after removal of the bone replacement material **a** as well as orthopantomography **b** after insertion of a patient-specific framework implant (IPS-Implants® Preprosthetic, KLS Martin Group, Tuttlingen, Germany). Clinical situation after healing with telescopes **c** and definitive dentures in situ **d**.



▶ **Fig. 11** Patient with extended residual cleft **a** and prosthetically unfavorable Angle class III relation **b**. Digital backwards planning of prosthetic rehabilitation **c** including the soft tissue situation **d** with patient-specific framework implant **e + f** (IPS-Implants® Preprosthetic, KLS Martin Group, Tuttlingen, Germany).



▶ **Fig. 12** Intraoperative situation of the patient from fig. 11 with patient-specific template **a** as well as coverage of the framework implant **c** with buccal fat pad **b**. Postoperative situation after insertion of the implant in OPT **d** and clinically **e** as well as after implementation of the dentures **f**.

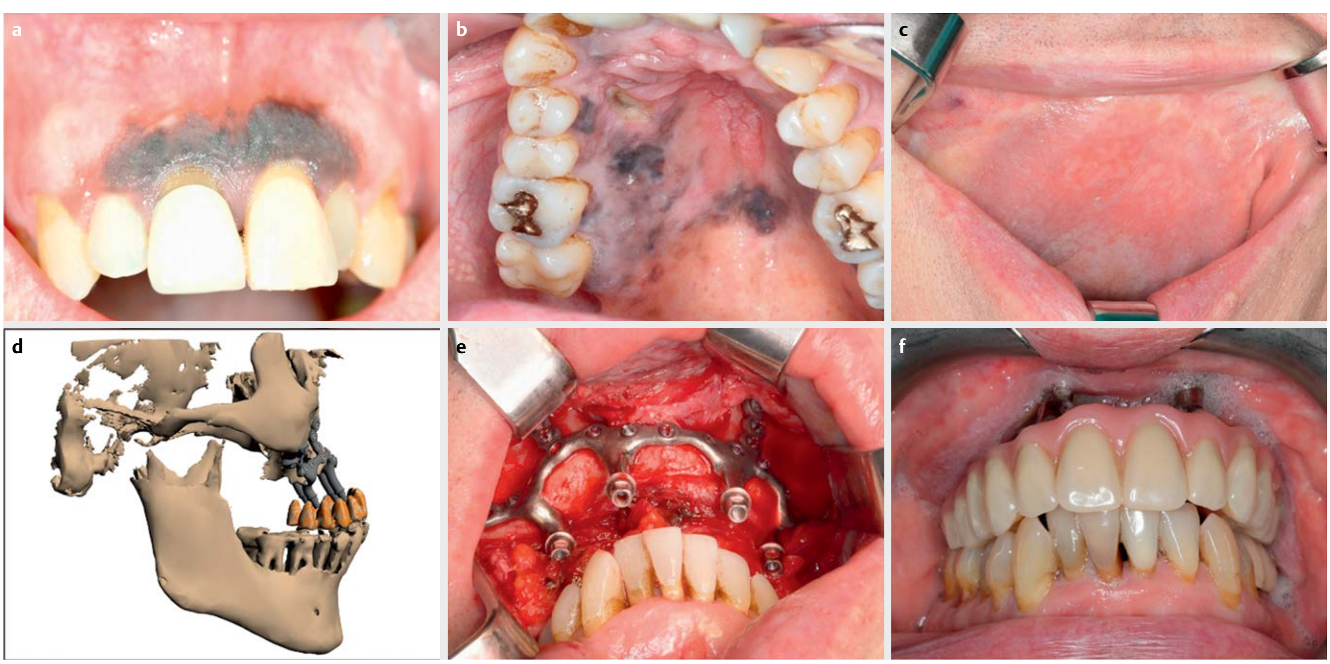
For better protection of the buccal soft tissue against the framework implant posts, sheathing of the pillar passages in the posterior area by means of the buccal fat pad shifted in anterior direction turned out to be beneficial for the atrophic maxilla. Furthermore, in cases of a very irregular alveolar ridge, the limited removal of crestal parts of the alveolar ridge may be justified so that an improved congruence between the bottom of the implant and the receiver region may be achieved (▶ **Fig. 12a**). This resection may be planned digitally in advance and transferred into an individual 3D resection template that is then used immediately prior to insertion of the IPS-Implants® Preprosthetic for modification of the alveolar ridge. Of course, the IPS-Implants® Preprosthetic may be combined with conventional dental implants. The provisional prosthetic treatment for the IPS-Implants® Preprosthetic is performed with application of a simple metal bar that serves as quality management tool for checking the parallelism of the single pillars of the IPS-Implants® Preprosthetics at the time of surgical intervention. In the further course it may be used together with a matrix for anchoring a bar-supported temporary prosthesis.

Despite simultaneous or delayed restoration with e. g. soft and hard tissue transplantation, the maxillary tissue loss is generally a challenge for the treatment strategy of dental rehabilitation, which can only be considered as being successful when finally also a biologically adequate dental rehabilitation can be achieved. Outstanding microsurgical reconstruction that do neither functionally nor anatomically achieve the sufficient separation of the biological units and also the restoration of a bony basis that cannot bear any implant, are biologically inadequate and have to be rated as reconstruction failure since they are measured with the above-mentioned parameters. Regarding treatment in our healthcare system that allows implant-supported dental rehabilitation for tumor-related maxilla ablation, always bone reconstruction in cases of partially, hemi- or completely maxillectomized patients has to be performed based on prosthetic backwards planning in order to find a planning approach for a later successful implant-supported prosthetic rehabilitation. However, there is an enormous gap between clinical reality and quality management that is required for these reconstructive interventions.

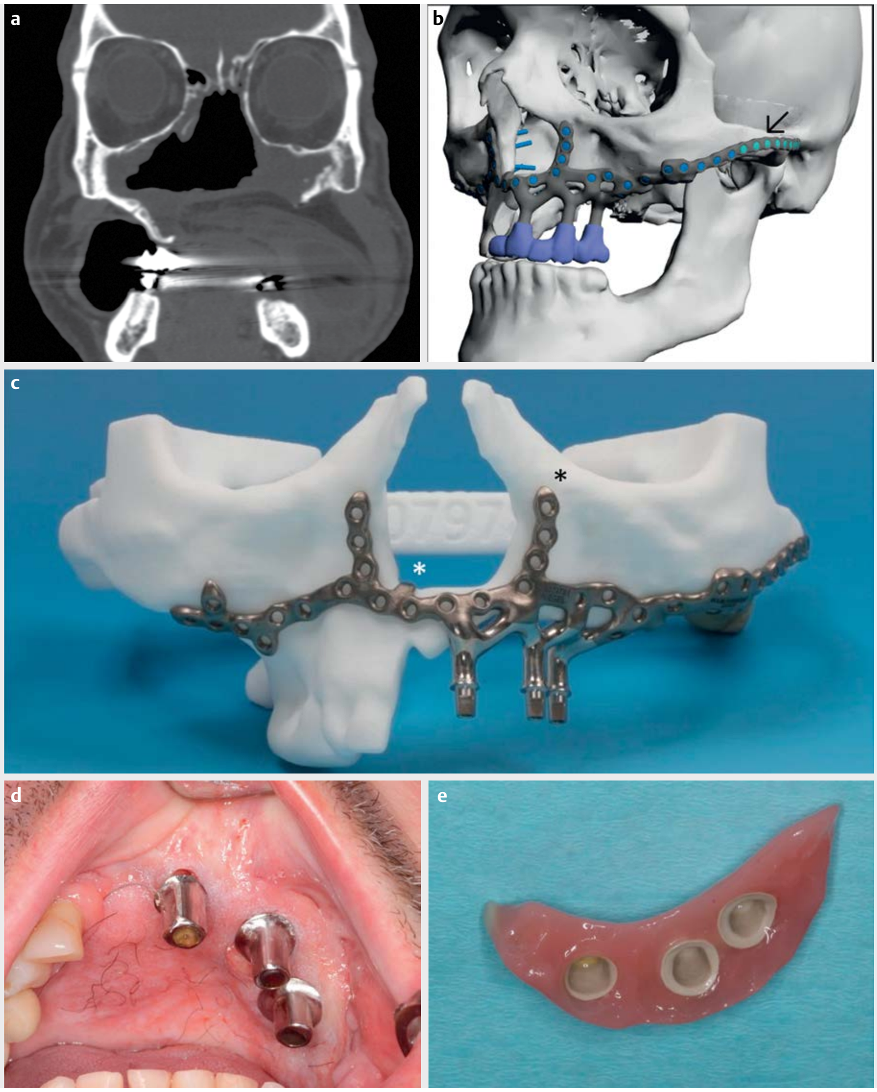
4.2 Postablative maxillary and midfacial defects

▶ **Fig. 13** shows the clinical situation of a multilocular melanoma of the maxilla. According to the recommendations of the interdisciplinary tumor board, immune therapy and irradiation of the patient were performed in addition to radical resection (maxillectomy). After pathohistological confirmation of the R0 resection stage and exclusively for separation of anatomical units and for preservation of the perioral, oral, and oropharyngeal competence, the intraoral microsurgical soft tissue reconstruction by means of a microvascular anastomosed latissimus dorsi flap (▶ **Fig. 13c**) was performed as delayed primary reconstruction. ▶ **Fig. 13d** illustrates the postablatively found class III relation with adequately present mandibular dentition. Without massive bone transplantation, an implant-supported prosthetic treatment would not have been possible. However, for the patient this meant possible donor site morbidities at the bone graft harvesting sites (iliac crest, scapula, or fibula) as well as an overall rehabilitation time of about one year beside an inpatient treatment including intensive care.

Instead, an IPS-Implants® Preprosthetic was early inserted secondarily in the context of an outpatient intervention with first provisional prosthetic treatment and full primary functional stability and thus unlimited biomechanical stress possibilities. In particular the intraoperative view (▶ **Fig. 13e**) reveals the complex anchoring



▶ **Fig. 13** Patient with multilocular melanoma of the maxilla **a + b** as well as after maxillectomy and reconstruction by means of a microvascular anastomosed latissimus dorsi flap **c**. Delayed primary reconstruction by means of a digitally planned **d** patient-specific framework implant **e** and definitive treatment with coverdenture **f**.



▶ **Fig. 14** Computed tomography **a** of a patient after midfacial ablation and adjuvant therapy because of an adenoidcystic carcinoma. Secondary reconstruction by means of a patient-specific framework implant (IPS-Implants Preprosthetic, KLS Martin Group, Tuttlingen, Germany). Digital planning **b** with anchoring in the area of the left-sided zygomatic arch. The arrow shows optional screw holes for anchoring in the lateral midface. Patient-specific implant **c** on a stereolithography model. Intraoral situation after implant insertion and microvascular anastomosed tissue transfer **d** with telescope-supported prosthesis **e**.

in the bony central and lateral midface as well as the one-piece implant with widely protruded posts. ▶ **Fig. 13f** shows the clinical site with the definitive prosthetic treatment supported by the transorally inserted implant with a removable bar-supported palate-free coverdenture.

In case of later secondary treatment of maxilla and midface for oncologic patients, the therapy sequelae of tissue loss, xerostomia, irradiation, scarring have to be considered even more critically. This matter is illustrated in a patient who underwent curative irradiation after ablation without performing primary restoration of the ablated midface and maxilla. Temporarily, the patient was treated with a multi-piece obturator for the missing central midfacial structures. The left maxillary dentition was found in the osteonecrotic bone of the centrolateral maxillary alveolar process and the bony midface. The two-stage reconstruction concept consisted of separating anatomical units, the extraoral soft tissue and the intraoral soft tissue, while especially the lip competence should be preserved and the oral and oropharyngeal competence should be restored. However, due to the complete soft palate loss, *restitutio ad integrum* was not completely possible for the velopharyngeal area.

The necrotic bone was removed from the left midface and it was covered by means of a microvascular latissimus dorsi flap that wasanastomosed on the left side cervically, the central maxillary and midfacial defects were obliterated. By means of an ipsilateral preauricularly anastomosed microvascular radial forearm flap, the pre-reconstructed horizontal unit – with separation of the oral from the nasal cavity and the paranasal sinuses – was separated from the vertical unit consisting of upper lip and cheek. Between the separation borders created in this way, the later pillar passages of the IPS-Implants® Preprosthetic were planned. After healing of at least three months, the one-piece framework implant could be inserted in a functionally stable way and provisionally equipped with dentures. The definitive prosthetic treatment was performed on telescopes with modular coverdenture.

The difficulty of an implant-supported dental rehabilitation of the maxilla is not only defined by the remaining maxillary bone or the bone quality but moreover by the clinically based assessment of the integrity and adequate separation of anatomical units of the bony maxilla including the surrounding and neighboring soft tissue structures in relation to the individual functional and anatomical mandibular circumstances. Only the overall assessment represents the basis for qualified therapy decisions of the individual patient. It is generally true that the more a mandible goes in direction of an Angle class III with regard to biomechanics and skeleton, the more biomechanically stable the overall concept has to be for the affected maxilla and the neighboring midface. In this context, the advantage of primarily functionally stable patient-specific framework implants is seen for the dental rehabilitation of patients with extreme maxillary atrophy or conditions after maxillary ablation because these frameworks – despite higher efforts for the treating physicians – represent the most modern and rapid form of mechanically immediately usable dental rehabilitation for the patient. Even tumor patients consider them as highly positive with regard to their quality of life.

Conclusion

Modern possibilities of interactive imaging analysis based on standardized volume datasets optimally created for diagnostics and exported in DICOM format, have the high potential to support all reconstructive measures in the midface, independently from the indication, in all treatment stages [20]. It is the task of the treating disciplines to know about these treatment options in order to use them for the benefit of the individual patient, depending on the indication. In this way, significant improvements of the quality of life may be achieved for indications in the areas of oncology, traumatology, acquired or congenital malformations, and severe atrophies [21].

Conflict of Interest

The authors declare: lecture fees for KLS Martin Group, Tuttlingen, Germany, and Brainlab, Munich, Germany.

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