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CLINICAL ARTICLE

Interdisciplinary full-mouth rehabilitation for redefining esthetics, function, and orofacial harmony

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Abstract

Objective: In severe congenital or acquired orofacial anomalies, both dental esthetics and function are usually compromised. In particular, the esthetic ideas of the final desired appearance may differ from patient to patient, as the human esthetic sensibility differs significantly. Especially in complex cases, digital technology today offers outstanding improvements and simplifications in craniomaxillofacial surgical and prosthetic treatments, leading to a wide range of planning and pretreatment options.

Clinical Considerations: This case report describes a patient-oriented interdisciplinary craniomaxillofacial surgical and prosthetic treatment with noninvasive tooth-colored splints, a Le Fort I osteotomy, and a full-mouth rehabilitation to meet the patient's demand for better function as well as orofacial esthetics and harmony.

Conclusions: By means of the digitally planned Le Fort I intervention and completion of the prosthetic rehabilitation, it was possible to optimize esthetics and facial harmony.

Clinical Significance

In complex cases, digital technology today offers outstanding improvements and simplifications in craniomaxillofacial surgery and prosthetic treatments, leading to a wide range of planning and pretreatment options. Computer-aided design/computer-aided manufacturing technology enables the fabrication of tooth-colored flexible polycarbonate splints that offer a noninvasive, removable, functional, and esthetic solution. In intricate cases involving craniomaxillofacial anomalies, often together with necessary orofacial surgeries or prosthetic treatments due to moderate to severe tooth wear, such digital preprosthetic treatment and planning options represent an important enhancement with more predictable results.

KEYWORDS

full-mouth-rehabilitation, Le Fort I osteotomy, maxillofacial surgery, patient-oriented interdisciplinary treatment, tooth-colored splint

1 | INTRODUCTION

Orofacial congenital anomalies such as cleft lip and palate generally occur in about 1 in 700 births and show a relatively high incidence accordingly. During childhood and adolescence, most patients require multiple surgical procedures, accompanied by orthodontic, prosthetic, further dental interventions, and speech therapy. The characteristic forms and clinical variations differ significantly and involve structures such as the lips, alveolar bone, and the palate. The cleft lip, and the cleft lip and palate represent the most common types within those orofacial anomalies.[1–4] In severe congenital or acquired anomalies, both orofacial esthetics and function are usually compromised. In particular, the esthetic ideas of the final desired appearance may differ depending on the patient, as the human esthetic sensibility differs significantly. Thus, one patient may think a rather natural-looking dentition with special individualizations as esthetically beautiful and another insists on a nearly perfect esthetic. Here, the treating team can serve as a consultant and a close communication with the patient is an essential part of the pretreatment phase.[5]

Especially in complex cases, digital technology today offer outstanding improvements and simplifications in craniomaxillofacial surgery and prosthetic treatments, leading to a wide range of planning and pretreatment options. This is of considerable interest, especially in cases representing a great challenge for the whole interdisciplinary treatment team. Close communication between the specialized disciplines must be carried out to precontrive the desired final result and to conduct a "test run" to calibrate with the patient's needs. During the preprosthetic phase, various dental "test run" options are available. Computer-aided design/computer-aided manufacturing (CAD/CAM) technology enables the fabrication of tooth-colored flexible polycarbonate splints that offer a noninvasive, removable, functional, and esthetic solution in contrast to conventional transparent splints or fixed long-term temporaries; with the latter being very invasiveness. In addition, these bimaxillary full-anatomic splints can be fabricated with a minimum thickness layer of 0.3 mm in both jaws separately, enabling clinicians to verify the final functional result with any possible fine adjustments needed, allowing for good patient compliance.[6–11] In intricate cases involving craniomaxillofacial anomalies, often together with necessary orofacial surgeries or prosthetic treatments due to moderate to severe tooth wear, such digital preprosthetic treatment and planning options represent an important enhancement.[12–14]

Due to diminished maxillary growth, a substantial number of patients with cleft lip and palate require a Le Fort maxillary advancement. To normalize the anterio-posterior position, translational and rotational movements can be carried out, to facilitate symmetric alignment and midline correction. The virtual preoperative planning of osteotomies, such as the Le Fort I osteotomy, is a reproducible, less time-consuming and accurate method by which digital planning via CAD/CAM-fabricated surgical splints for intraoperative transfer can be reliably implemented in patients, which is more user-friendly to the clinicians. Presurgical planning is crucial for optimal functional and esthetic results.[12–16]

The present case report describes the patient-oriented interdisciplinary treatment of a female patient with noninvasive tooth-colored splints, a Le Fort I osteotomy and full-mouth rehabilitation with Lithium disilicate (LS2) restorations to meet the patient's demands for better function as well as dental and orofacial harmony.

2 | CASE REPORT

A female patient with a high dental IQ presented at the Department of Prosthetic Dentistry of the LMU München complaining about the appearance of her smile and facial asymmetries. She had a long medical history with multiple craniomaxillofacial surgeries, including rhinoplasty 1 year ago, due to a cleft lip and palate on the right side.

The following sequential systematic was used for the detailed planning of the different treatment steps: a complete anamnesis, a detailed oral examination, radiographic CT evaluation, a functional analysis of the temporomandibular joints, and a three-dimensional (3D) facial scan (Figures 1–5). Study models, an arbitrary face bow record, registration in centric relation, intra and extra oral photographs and a video recording were also obtained to complete the patient's documentation. The maxillary and mandibular study models were mounted in centric relation using a semiadjustable articulator (Artex CR articulator, Amann Girrbach GmbH, Pforzheim, Germany).

Compiled information was used to create an initial diagnostic wax-up to determine the proper occlusal plane combined with an increase in the vertical dimension of occlusion to meet the face center for orofacial harmony as optimally as possible. The dental and facial harmony turned out to be a special challenge. Due to the cleft lip and palate, an asymmetry of the facial halves, a midline shift of about 3 mm to the right, a smaller facial side and a maxillary shift were present (Figure 4). As an additional secondary diagnosis, the patient presented with the clinical signs of a combination of bioerosion, abrasion, and attrition leading to dentin exposure and sensitivities to thermal and chemical irritations, without any signs of bruxism.

The planned esthetic outcome, through the performed diagnostic wax-up, was intraorally transferred through a direct mock-up with the help of an auto-polymerized resin (Protemp 5, 3 M, Seefeld, Germany). The posterior mock-ups were used to refine the occlusal plane and the vertical dimension of occlusion was defined using the speech method (concentrating on the length of the incisal edges of the upper centrals, speaking distance for f-, s-, and m-sounds). This consisted of any occlusal contacts detected during speech was carefully removed, the incisal edge position of the maxillary centrals was an important phonetic and esthetic parameter. The vertical dimension of occlusion was lifted by 7 mm in total at the incisal pin of the articulator as a loss of vertical occlusion dimension occurred through additional bioerosive effects. The occlusal plane was set closer to the mandible to balance the growth deficiency predominantly on the right maxilla, the maxilla was lifted 64.3% and the mandible 35.7%. This final mock-up also served as a guide for the following treatment steps and the final rehabilitation.

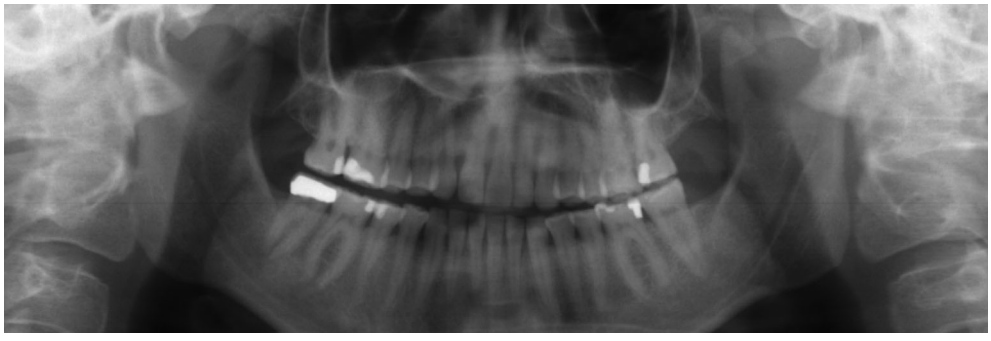

FIGURE 1 Preoperative/preprosthetic panoramic radiograph

FIGURE 2 Preoperative profile pictures in frontal and lateral view

FIGURE 3 Preoperative/preprosthetic smile appearance

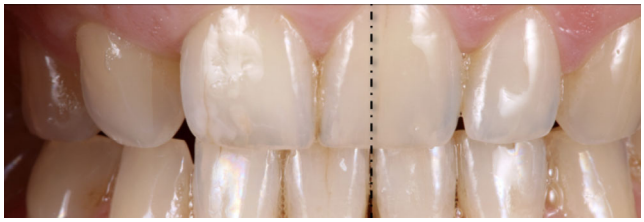

FIGURE 4 Preprosthetic frontal view with midline shift of 3 mm to right side. Alignment of upper canines as indicator for smaller and larger facial half: (A) on the larger facial side is the distal part of the canine slightly outward aligned and (B) on the smaller facial side is the mesial part of the canine slightly outward aligned

2.1 | Tooth-colored splints as an essential pretreatment and communication tool

For the functional and esthetic evaluation in the pretreatment phase, the dental team and the patient selected the option of a tooth-colored polycarbonate splint. This meant the team was able to test the therapeutic wax-up information noninvasively and while being able to remove it from the upper and lower jaw (Figures 6 and 7). The tooth-colored splint also served as a long-term communication tool for functional, phonetical, and esthetical evaluation. In this phase, minor adjustments in static and dynamic occlusion and esthetics can be performed. It is important to emphasize, that the first treatment objective of the restorative and surgical team can be evaluated through using prototype, allowing for a better calibration with the patient without any risks (reset option), accomplishing a higher predictability of the final result. Changes according to the patient´s demands can be easily integrated and can have a decisive contribution to the further treatment planning, as explained in more detail below.

For the fabrication of the tooth-colored polycarbonate splint, both the final therapeutic wax-up and the preprosthetic situation casts of the upper and lower jaw were scanned with the S600 ARTI scanner (Zirkonzahn, Gais, Italy) to create STL- surface data, which are matched.[10] The CAD software was used to design the tooth-colored splint by individually adjusting certain parameters such as the tooth morphology, the insertion angle and the fit, in correspondence to the final wax-up. After successful planning, the tooth-colored splint was milled out of a polycarbonate block (Temp Premium Flexible, Zirkonzahn) using a CNC milling machine (M1, Zirkonzahn), it was then polished and partially individualized in the dental laboratory using Optiglaze (GC Europe, Leuven, Belgium; Figures 8–11).

In this case report, the patient was additionally treated with a 6-month course of speech therapy. During this period of time, minor adjustments in static and dynamic occlusion were performed. The patient was treated with the polycarbonate tooth-colored splints as part of the pretreatment phase from June 2016 for a total of 12 months. During the 12-month pretreatment, the treatment goal changed fundamentally according to the growing esthetic demand of the patient for facial and dental symmetry or harmony (Figure 11).

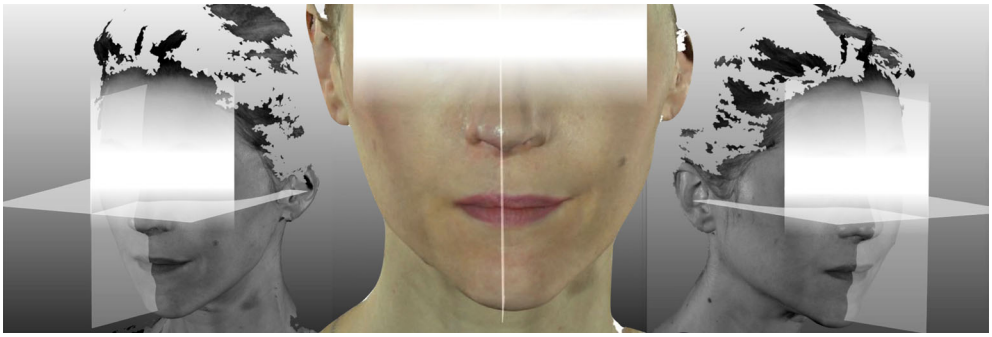

FIGURE 5 Digital face scan of patient´s profile

FIGURE 6 Tooth-colored splint made of flexible polycarbonate for the maxilla

FIGURE 7 Tooth-colored splint made of flexible polycarbonate for the mandible

FIGURE 8 Removable individualized mandibular tooth-colored splint while positioning

FIGURE 9 Removable individualized mandibular tooth-colored splint in final position

For a better predictable final esthetic and surgical outcome using digital or virtual planning, a 3D facial scan (priti mirror, pritidenta GmbH, Leinfelden-Echterdingen, Germany) was conducted as mentioned above, facilitating visualization by matching the 3D facial scan STL-data with the STL-data of both the casts and the wax-up (Figure 5).

2.2 | Maxillary Le Fort I osteotomy with preoperative virtual planning

The patient had a strong esthetic dislike due to a midline shift of about 3 mm to the right side and the significantly reduced right buccal corridor as already mentioned above. After intensive interdisciplinary consultation, the patient decided, in accordance with the Department of Prosthetic Dentistry and the Department for Oral and Maxillofacial Surgery, for a maxillary Le Fort I osteotomy to redefine these deficits. These esthetic corrections would not have been possible by only prosthetic rehabilitation as the upper jaw had to be pivoted to the right side as a whole (July 2017).

Surgical procedure was facilitated with 3D computer-assisted surgical simulation in combination with CAD/CAM-manufactured splints and an osteotomy guide. First, the prosthetic team predefined the final occlusal relationship by modifying the existing wax-up and turning the whole maxillary cast in the dental laboratory with respect to functional and esthetic aspects (midline, buccal corridor, etc.). Both the separated maxillary and mandibular arches and the arches positioned in the predefined occlusion were digitalized by laser surface scanning (S600, Zirkonzahn, Gais, Italy) and transformed to STL-files. A high-resolution CT scan of the craniofacial skeleton (slice thickness 0.6 mm, DICOM-data) was imported into the planning software ProPlan CMF (Materialise, Leuven, Belgium). After segmentation of soft and hard tissues, a reference frame was set using the midsagittal plane and the Frankfurt horizontal plane. To create a virtual composite 3D-model, craniofacial CT data were matched with the STL-files of the maxillary and mandibular arches by a semiautomatic fusion algorithm. After the Le Fort I osteotomy was virtually performed, the STL-file with the maxillary and mandibular arches, registered in the final occlusal relation, was matched to the mandible first. Then, the virtually osteotomized maxillary segment was aligned to the implemented STL-file of the occlusal relationship indicating the new position of the maxillary segment (Figures 12–17). As a result, the main movements of the maxillary segment corresponded to a combined yaw and roll

FIGURE 10 Preoperative profile pictures in frontal and lateral view with inserted tooth-colored full-anatomic splints

FIGURE 11 Preoperative smile appearance with inserted tooth-colored full-anatomic splints. The visible midline shift could be reduced to 2 mm

rotation, therefore correcting the dental midline and occlusal canting as well as harmonizing the buccal corridor. The results of the virtual surgical planning based on the predefined final occlusion were double-checked, discussed between the prosthetic and surgical team and then finally approved. As a last step, to correctly transfer the virtual planning to surgery, an occlusal splint and an osteotomy guide were CAD/CAM-manufactured by rapid prototyping (selective laser sintering [SLS], Materialise, Leuven, Belgium). With respect to surgery, the maxilla was exposed and the prefabricated osteotomy guide was applied and temporarily fixed by four screws. After the Le Fort I osteotomy and complete mobilization of the maxillary segment by down fracture, the new position of the maxilla was guided with the help of the occlusal splint and intermaxillary fixation via archbars. Finally, the maxillary segment was fixed in the new position with four titanium osteosynthesis plates (DePuy Synthes Maxillofacial, Paoli) in the typical manner (Figures 18–22).

2.3 | Preparation and final rehabilitation

After a healing period of 3 months, the final prosthetic treatment could be performed, after minor adjustments of the therapeutic wax-up in the semiadjustable articulator, using bonded glass-ceramic restorations.

First, the tooth-colored splint of the maxilla was divided in half and the preparation of the first quadrant for Lithium disilicate (LS2) restorations was conducted according to the outer contour of the final restorations (Figure 23). Second, after preparation of the first quadrant, a bite registration was taken against the mandibular splint in reference to the unprepared teeth and a half splint was inserted into the second quadrant (Figure 23). Then, the second quadrant was prepared and the first part of the bite registration was extended into the second quadrant. After an arbitrary facebow transfer, full-arch polyether impressions (Permadyne blue/Impregum, double mix technique, Penta, 3 M) were taken from the prepared teeth of the maxilla and the mandibular splint. Finally, chairside temporary restorations were manufactured for the maxilla. The LS2 restorations for the maxilla (IPS e.max Multi, Ivoclar Vivadent, Schaan, Liechtenstein) were fabricated in the dental laboratory.

After delivery, the LS2 restorations were tried in with try-in paste (Variolink Esthetic, Ivoclar Vivadent; Figure 24), ultrasonically cleaned in alcohol for 3 minutes and prepared for bonding according to the following steps:

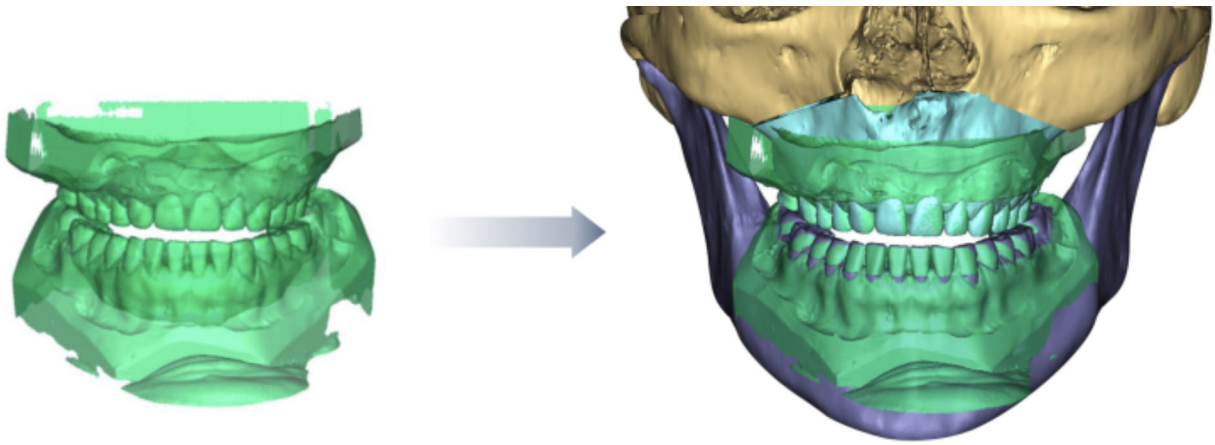

FIGURE 12 Matching of the final occlusal relationship (STL-file, colored green) with virtually segmented CT scan resulting in a combined virtual 3D-model

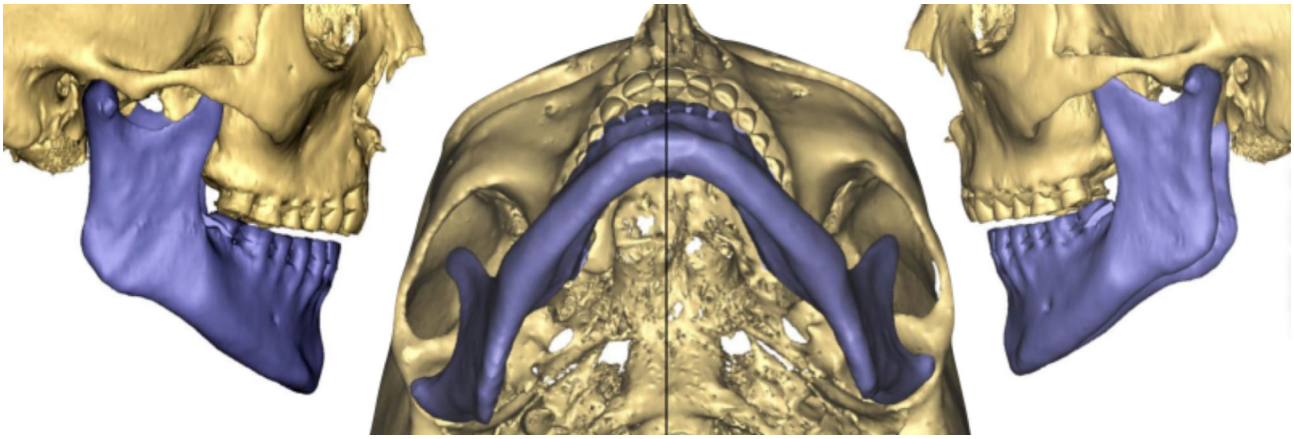

FIGURE 13 Digitized preoperative position of maxilla and mandibula with midline shift using virtual computer software ProPlan CMF (materialise) in lateral and basal position

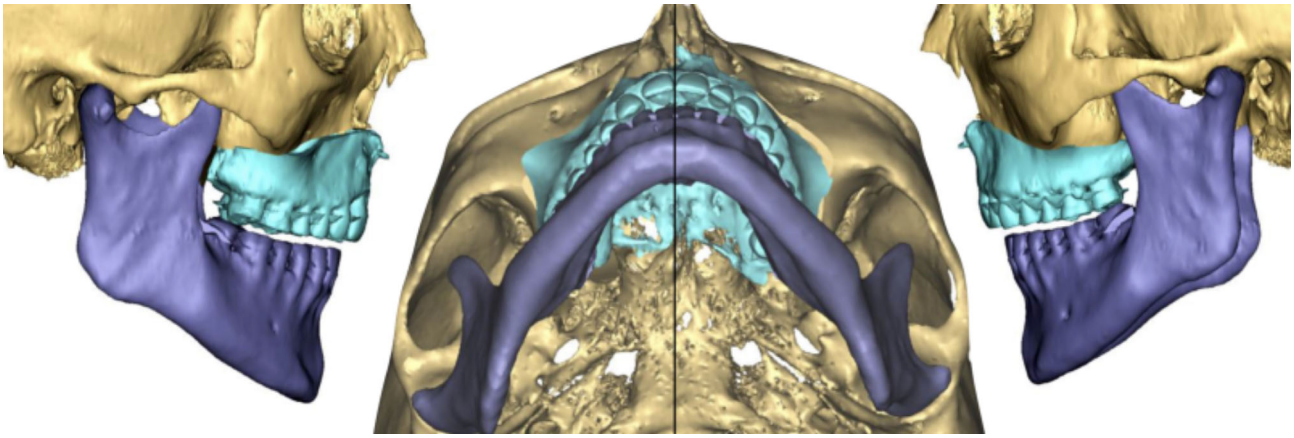

FIGURE 14 Planned postperative position of maxilla and mandibula without midline shift using virtual computer software ProPlan CMF (materialise) in lateral and basal position

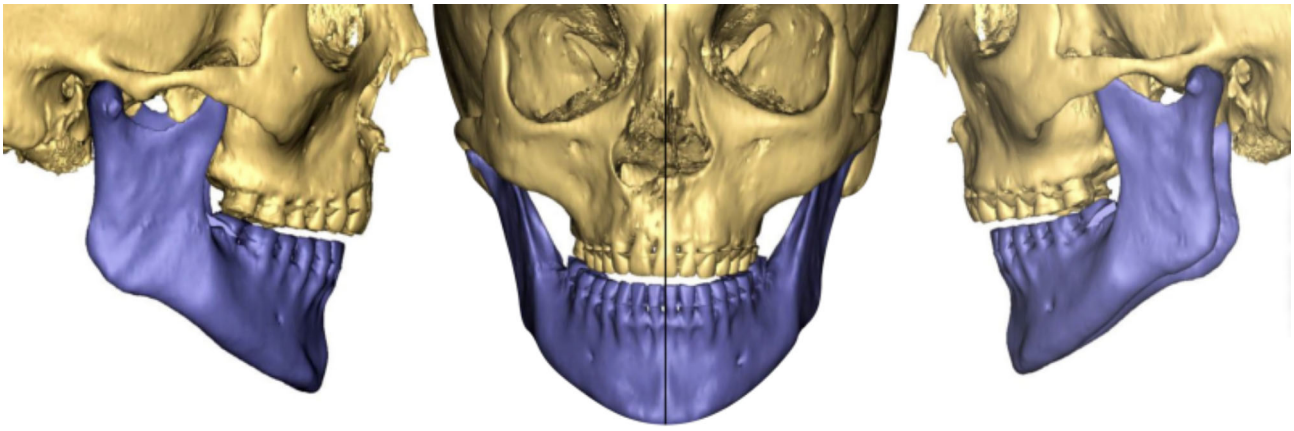

FIGURE 15 Digitized preoperative position of maxilla and mandibula with midline shift using virtual computer software ProPlan CMF (materialise) in lateral and frontal position

1. Etching (20 seconds, IPS Ceramic Etching Gel, Ivoclar Vivadent),
2. Rinsing and drying with oil-free air;
3. Silane application (Monobond Plus, Ivoclar Vivadent);
4. Application of the luting resin cement (Variolink Esthetic DC - light, Ivoclar Vivadent).

All maxillary teeth were prepared for bonding by:

1. Silicoating of the areas with extended composite build-ups (CoJet, 3 M),
2. Selective enamel etching for 30 seconds (37% phosphoric acid, Ivoclar Vivadent),
3. Rinsing and drying with oil-free air,
4. Silane application on silicoated areas (Monobond Plus, Ivoclar Vivadent),

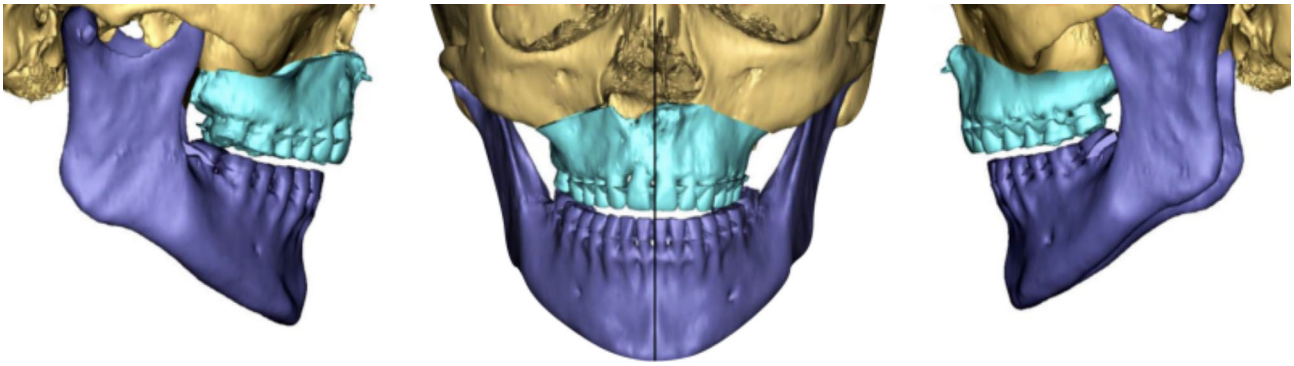

FIGURE 16 Planned postoperative position of maxilla and mandibula without midline shift using virtual computer software ProPlan CMF (materialise) in lateral and frontal position

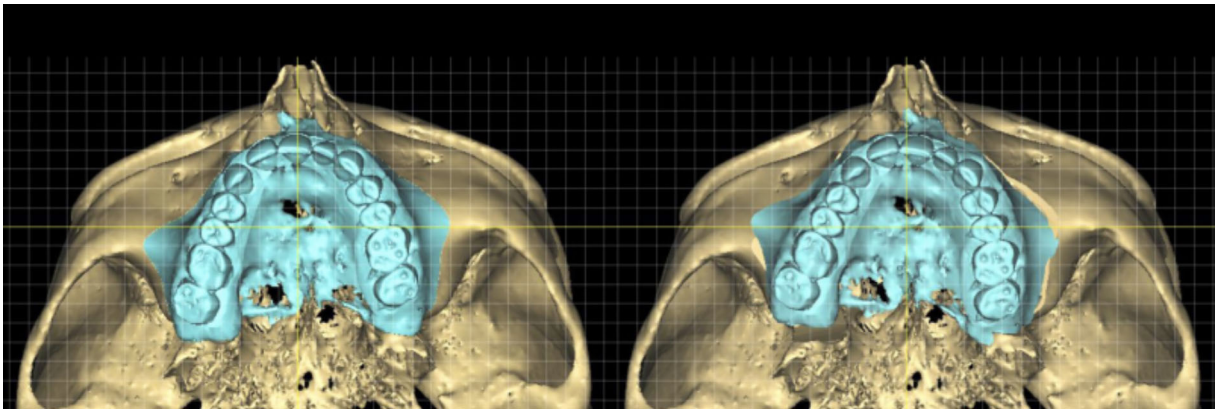

FIGURE 17 Pre and postoperative position of maxilla in basal view showing yaw rotation as the principal movement component for the correction of the dental midline as well as harmonizing the buccal corridor

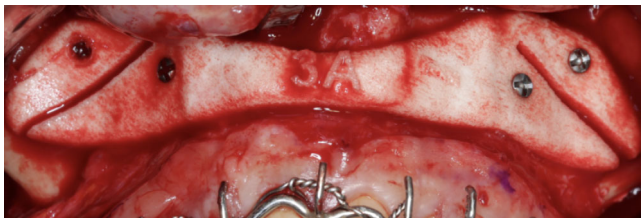

FIGURE 18 Computer-aided design/computer-aided manufacturing-fabricated osteotomy guide, intraorally fixed for optimized and preplanned maxillary surgical intervention

5. Adhesive application (scrubbing for 20 seconds and air-blowing for dispersing; Adhese Universal, Ivoclar Vivadent),
6. Light curing for 10 seconds;
7. Insertion of the LS2 restorations with filled luting resin cement,

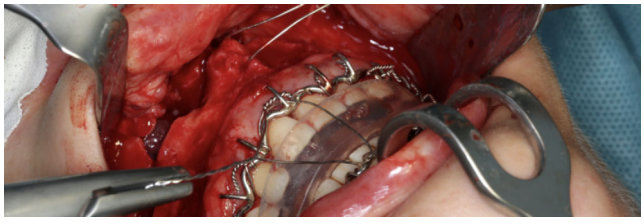

FIGURE 19 Intraoperative view of the mobilized maxillary segment during mandibulomaxillary fixation and repositioning

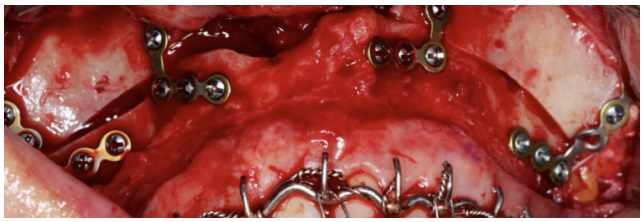

FIGURE 20 Intraoperative view of the fixed maxilla using titanium osteosynthesis plates

8. Initial light-curing for 5 seconds with a Light Probe Pin Point (Bluephase Style 20i, Ivoclar Vivadent) and removal of luting resin cement excess,
9. Glycerine gel application at bonding interfaces (Liquid Strip, Ivoclar Vivadent),

FIGURE 21 Intraoral intermaxillary fixation in new occlusal relation guided by a Computer-aided design/computer-aided manufacturing-fabricated occlusal splint

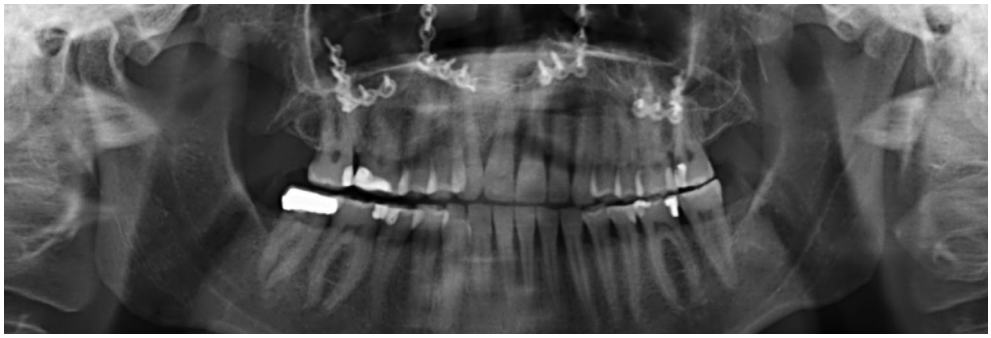

FIGURE 22 Postoperative panoramic radiograph depicting four osteosynthesis plates, which bridge the Le Fort I plane in typical manner

FIGURE 23 After postsurgical adjustment of the tooth-colored splints and a healing period of 3 months the preparation for final glass-ceramic restorations was conducted and bite transfer with the left half of the splint inserted in the still unprepared left quadrant (Luxa Bite; DMG), corrected with Aluwax)

FIGURE 24 Try-in of final maxillary LS2 restorations using glycerine gel

10. Final light-curing (40 seconds on each side).

Luting procedures were executed predominantly under absolute isolation absolute isolation (rubber dam), avoiding any contact with saliva or blood. After a short period of time, final adjustments to the static and dynamic occlusion were made to the mandibular splint. Two weeks later, the mandibular teeth were also prepared for LS2 restorations according to the same procedure as the maxillary restorations and insertion steps as already described above (Figures 25–27).

After the final surgical and prosthetic rehabilitation redefining the orofacial symmetry (Figures 28–32), the patient got a transparent night guard for protection of the LS2 restorations and to aid in muscular relaxation at night time.

FIGURE 25 Preprosthetic frontal view of the lower front teeth

3 | DISCUSSION

Cleft lip and palate are the most common congenital craniofacial anomalies. Affected patients often require multiple craniomaxillofacial surgeries during their childhood and adolescence to restore function and esthetics. In addition, there are often different levels of dental involvement, prosthodontics treatment can be a valuable option for adults. The management of these complex patients presents a great interdisciplinary challenge. Depending on the form and severity of the anomaly as well as the esthetic demands of the patients, the necessary prosthetic treatment plan can vary immensely. It can range from simple restorative therapy to complex full-mouth rehabilitation.[12,13,17,18] This case could only lead to a satisfactory result for the patient through the close cooperation of different disciplines and

FIGURE 26 Minimally invasive veneer preparations of the lower front teeth

FIGURE 27 Try-in of final minimally invasive mandibular LS2 restorations using glycerine gel

FIGURE 28 Postprosthetic frontal view of final LS2 restorations without upper midline shift and dental harmony

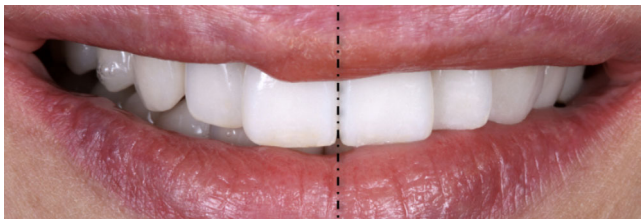

FIGURE 29 Postoperative/postprosthetic smile appearance

further surgical and prosthetic interventions, as high esthetic demands were present.

Through the continuous introduction of digital technologies in all areas of prosthetic dentistry as well as craniomaxillofacial and facial plastic surgery, new procedures can be integrated in daily practice. With regard to this case, this includes the CAD/CAM-generated preprosthetic treatment, using tooth-colored splints together with a conventional wax-up in the dental laboratory and digital planning using 3D-face scanning. Due to the explicit request of the patient for a Le Fort I operation, as explained in detail in a lower section, the optimal final result was planned digitally/virtually with a surgical planning software (ProPlan CMF, Materialise) integrating STL- and DICOM-data together with all specialized disciplines. CAD/CAM technology facilitated the procedure by individualized surgical 3D printed aids like an occlusal splint and an osteotomy guide, which helped in transferring the virtual planning into the operation and leading to an optimal intraoperative positioning of the maxilla. After the conversion of the maxilla, a new tooth-colored splint had to be produced and adjusted for the optimal postoperative situation as repositioning of the maxilla led to changed intermaxillary relations. During the tooth preparation, the separated polycarbonate splint also served as a preparation guide for the necessary minimal reduction of hard tooth tissues of the upper and lower jaw for the LS2 restorations. Through additional esthetic customization in the dental laboratory, there was excellent patient compliance within the preprosthetic phase. The great advantages of tooth-colored polycarbonate splints, with regard to comfort and patient compliance, in contrast to the transparent splints, has already been emphasized several times in the literature.[6,10] The dental team

FIGURE 30 Postoperative/postprosthetic profile pictures in frontal and lateral view

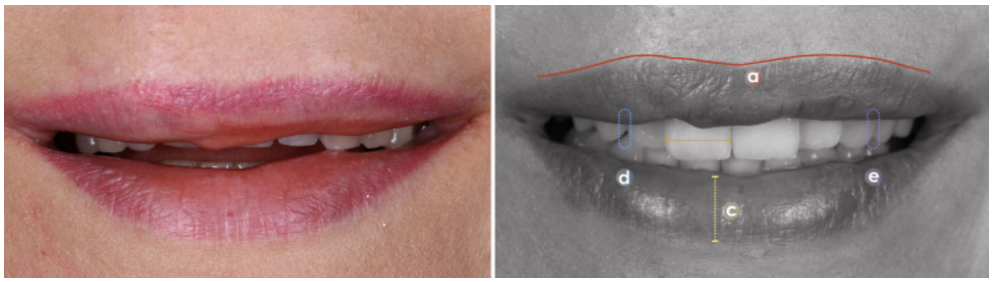

FIGURE 31 Personal facial analyses: a—upper lip contour describes the incisal edge; c—the dimension of the lower lip describes the width of a single central; d, e—canine rotation describing the wider or smaller facial side (wider side—the canine is rotated distally out; smaller side—the canine is mesial rotated)

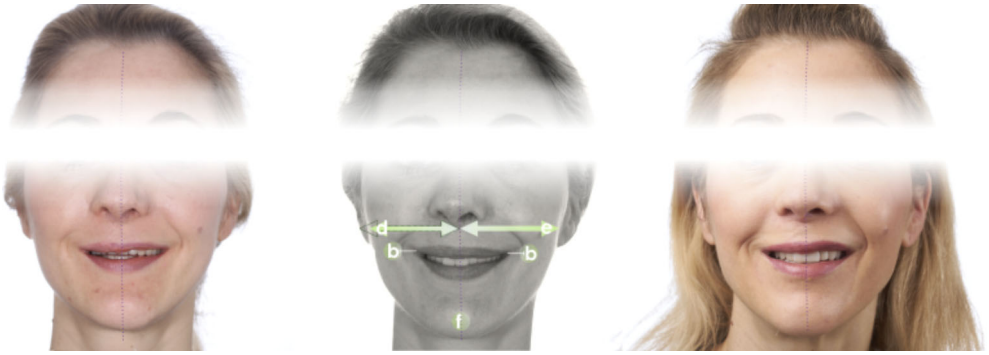

FIGURE 32 Personal facial analyses: b—corner of the mouth shows the longer and shorter face; d, e—canine rotation describing the wider or smaller facial side (wider side—the canine is rotated distally out; smaller side—the canine is mesial rotated); f—the Pogonion (on the lower chin) shows the direction of the central incisor

also decided not to perform a more invasive preprosthetic "test run" with adhesively fixed long-term temporaries, as a noninvasive and removable esthetic bimaxillary splint offered significant benefits in the present case. The benefits included the improvement of safety and predictability by timely and reversible implementation of functional, phonetic, and esthetic changes. Additionally, the simplification of complex rehabilitations with the option of a segment-by-segment transfer to the definitive restorations and the easy reproducibility, in case of loss or fracture of the occlusal splint, based on the existing digital data facilitated the complex treatment.

The entire treatment could also have been carried out conventionally without any digitally planning. Conventional planning was performed in the dental laboratory as a backup, but the digital workflow provided a very reliable and predictable final result and was therefore the preferred treatment way. Digital preoperative planning is widespread and can lead to reliable results with precise planning, especially when performing orthognathic surgery.[12–16] This could also be confirmed in the present case. The advantages of virtual planning lie in the visual presentation of bone deformities and facial asymmetries, which are often not obvious in conventional oral examinations, together with the possibility of testing different surgical procedures and scenarios to visualize the optimal final result preoperatively.[12]

With the virtual planning, it is necessary that the dental team of a dentist and dental technician is involved at an early stage to be able to interdisciplinary plan or discuss in how far the desired final result can be surgically and prosthetically implemented. Sometimes the patient's ideas and the realistic possibilities might be different. However, it must be noted that it is necessary to keep up-to-date with the new virtual 3D possibilities of existing imaging and software to enable the best possible computerized 3D-planning with more and more accurate results and predictability.[13]

In the present case report, the initial treatment plan only provided a minimally invasive nonsurgical prosthetic rehabilitation. As the patient already had a long history of multiple surgeries due to a cleft lip and palate, she initially preferred a treatment option without any additional surgical intervention. The pretreatment time using a removable noninvasive polycarbonate tooth-colored splint proved to be the key communication tool between the patient and the treatment team. Due to the growing esthetic demands of the patient, she was very dissatisfied with the resulting midline shift of about 3 mm and the enlarged right buccal corridor. The pretreatment phase of 1 year appears to be very long, but was indispensable for the decision making of the patient. In addition, the modification of the treatment procedure required additional time for the virtual surgical planning and final surgical treatment.

The existing dental esthetic disadvantages of the patient could have been optimized by sole prosthetic rehabilitation, but could not have been completely corrected, which was made clear by the diagnostic and therapeutic wax-up and the polycarbonate splint during the preprosthetic phase. The basic reason was the already surgically corrected cleft lip and palate as well as the slightly reduced right half of the patient's face and palate during growth; in addition, there was a dental shift to the right side due to the missing lateral upper incisor. Especially the desire for esthetic improvement and optimization of facial harmony and symmetry led to such a physiological strain that an invasive surgical approach was chosen.

The patient further reported that the surgical intervention provided her clear advantages in terms of the airway space during talking, sports, and sleeping. Before surgery, the airway space was strongly deviant to the right. By means of the Le Fort I intervention and consistent speech therapy, after completion of the prosthetic restoration, it was possible, according to the patient, to enlarge the nasal airflow and to simplify speaking.[19]

By using digital information and detailed planning in advance, results can be more predictable and patient satisfaction increases after final treatment.

DISCLOSURE

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

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