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Comprehensive virtual orthognathic planning concept in surgery-first patients

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Abstract

The surgery-first concept is becoming increasingly popular in orthognathic surgery since it offers major advantages such as a reduction of treatment duration and an increase in patient satisfaction by eliminating phases of presurgical orthodontic decompensation. Here, we present a novel interdisciplinary pathway of a fully virtual orthodontic-surgical planning concept in a surgery-first setting using a 3D-printed cutting guide and a customised maxillary implant for the Le Fort I osteotomy as well as a CAD/CAM-based stereolithographic final splint. Patient data from cone-beam computed tomography of the skull and a full arch dental scan were processed using the OnyxCeph[3TM] software (Image Instruments). A mutual computer-aided surgical simulation was conducted by the orthodontist and the oral and maxillofacial surgeon to determine the three-dimensional maxillary and mandibular movements. In a separate virtual planning session, the surgeon designed a customised maxillary guide and implant for precise intraoperative transfer (Geomagic Freeform Plus software, 3DSystems). A 3D-printed CAD/CAM-based final splint was fabricated by the orthodontist and used for accurate mandibular repositioning. We established a comprehensive virtual interdisciplinary orthognathic workflow and successfully applied this concept with a high level of accuracy in a series of surgery-first patients with different types of dentofacial anomalies. This novel fully computer-based pathway offers a high potential to improve the outcomes of orthognathic surgery and reduce total treatment time in the management of the orthognathic patient.

Keywords: Orthognathic surgery; Surgery-first approach; CAD/CAM; Customised implant; Computer-aided surgical simulation

Introduction

The surgery-first approach (SFA) in orthognathic surgery is applied with increasing frequency since it offers significant advantages in respect to aesthetics, occlusion, and treatment duration compared to the conventional orthodontic-first approach (OFA). In the SFA, the orthognathic surgical procedure precedes the orthodontic treatment, thus putting the benefits of instant aesthetic facial changes at the very beginning of therapy, rather than worsening facial aesthetics during decompensation as in the OFA.[1,2] This can lead to enhanced patient satisfaction by eliminating the presurgical phase of orthodontic decompensation, which is often accompanied by gradual deterioration of facial aesthetics and malocclusion.[3] In a surgery-first sequence, soft tissue imbalances that result from dental decompensation can be prevented.[4] Orthognathic surgery leads to a proper skeletal relationship in combination with a 'transitional' malocclusion, which is transferred into a solid final occlusion by postoperative orthodontics.[1] Maxillary and mandibular segmental osteotomies can promote the transition from malocclusion towards a stable final occlusion.[4] Postoperative orthodontic movements are facilitated based on the 'regional acceleratory phenomenon' (RAP).[5] Additionally, interdental osteotomies can lead to an increased turnover of bone, which has been postulated to propagate dental movements and reduce total treatment time.[6]

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Computer-aided surgical simulation and surgical transfer by customised guides and implants has been shown to provide accurate planning and transfer tools.[7]

Here, we present a novel interdisciplinary, fully virtual surgical orthodontic treatment pathway in a surgery-first approach using a CAD/CAM-based guide, implant, and splint.

Material and methods

Virtual surgical planning

In a surgery-first approach, the orthognathic surgery was performed by the same two surgeons in the Department of Oral and Maxillofacial Surgery and the orthodontic treatment was delivered in a private orthodontic clinic.

To prepare for computer-aided surgical simulation, the cone-beam computed tomography (CBCT) (ProMax® 3D Mid, Planmeca) data set of the facial skeleton in DICOM file format and the STL data of an intraoral scan of the upper and lower dental arch (TRIOS Color Pod, 3Shape) were fused in the planning software (OnyxCeph^{3TM}, Image Instruments) to create an augmented virtual model. A detailed individual clinical examination and cephalometric assessment was performed for each patient.

The virtual model was segmented to prepare for virtual treatment planning. The orthodontist and the surgeon conducted a mutual computer-aided surgical planning to determine the three-dimensional maxillary and mandibular movements. In this web-based planning session the orthodontist shared his screen using a videoconference software and conducted the agreed movements. An individual surgical simulation was carried out for each patient based on the cephalometric analysis to reach a class I skeletal relationship, taking the future orthodontic movements into account, and establishing desirable facial aesthetics (Fig. 1). Subsequently, the conversion of the surgical 'transitional' occlusion into the final postorthodontic occlusion by dental decompensation and arch coordination was virtually simulated and assessed for feasibility (Fig. 2). The postoperative skeletal maxillary position was exported as an STL file and transferred to Geomagic Freeform Plus (3DSystems) for further digital processing as follows.

Surgical transfer

In the Freeform software, the tooth roots were segmented on the augmented model of the midfacial skeleton in preparation for the subsequent virtual design process. A CAD/CAM surgical guide and a titanium customised implant (Fig. 3) were then virtually designed in Freeform and manufactured for each patient for accurate intraoperative transfer of the surgical plan (KLS Martin). For mandibular positioning, a 3D-printed final splint was generated in a CAD/CAM-based fashion. A case report illustrating the bony movements and simulating the soft tissue changes was generated and discussed with the patients. Amendments of the surgical movements were made if necessary.

Preoperative orthodontic preparation

After acquisition of the CBCT and dental arch scan, all patients wore a passive upper and lower splint to prevent any tooth movements after registration. All the postoperative dental movements were virtually planned and checked for feasibility (OnyxCeph^{3TM}, Image Instruments). All orthodontic bracket positions were allocated in a computer-aided simulation. On the day before surgery, the brackets were attached to the teeth using a CAD/CAM bonding guide, the 3D-printed final splint for positioning of the mandibular tooth-bearing fragment was checked for fitting, and adjustments were made if necessary.

Orthognathic surgery

Orthognathic surgery was performed under general anaesthesia. The surgical plan was transferred into the operating theatre in a maxilla-first sequence. Initially, the maxilla was exposed, and the customised guide was passively positioned by anatomical fitting and fixed to the bone with four 2.0 mm screws. The holes for the customised titanium implant were pre-drilled, and the lines of the Le Fort I osteotomy were marked with a piezoelectric saw. After removal of the guide, the osteotomies were completed, the downfracture was performed, and the maxilla was mobilised. After elimination of bony interferences, the customised plate was fixed with 1.5 mm screws according to the pre-drilled holes in a passive fashion. Following wound closure, a standard bilateral sagittal split osteotomy (BSSO) was conducted, and the 3D-printed final splint was ligated with wires to the upper braces. The tooth-bearing fragment of the mandible was now positioned in the final splint, and osteosynthesis was performed with one or two conventional four-hole miniplates (KLS Martin).

Postoperative treatment

The day after surgery, light guiding elastics were applied to support postoperative neuromuscular adaptation. Patients were put on a soft diet for 4 weeks. The surgical wafer was worn for 2–3 weeks to provide mandibular guidance in this phase of unstable postoperative occlusion. It was temporarily removed and meticulously cleaned on a weekly basis. After 2–3 weeks, the wafer was removed, and in cases of segmented Le Fort I osteotomy, it was replaced by a transpalatal arch (TPA). The orthodontic treatment for arch coordination and dental decompensation was initiated 2–3 weeks postoperatively.

Results

The presented full virtual concept in surgery-first patients was successfully established as a routine workflow.

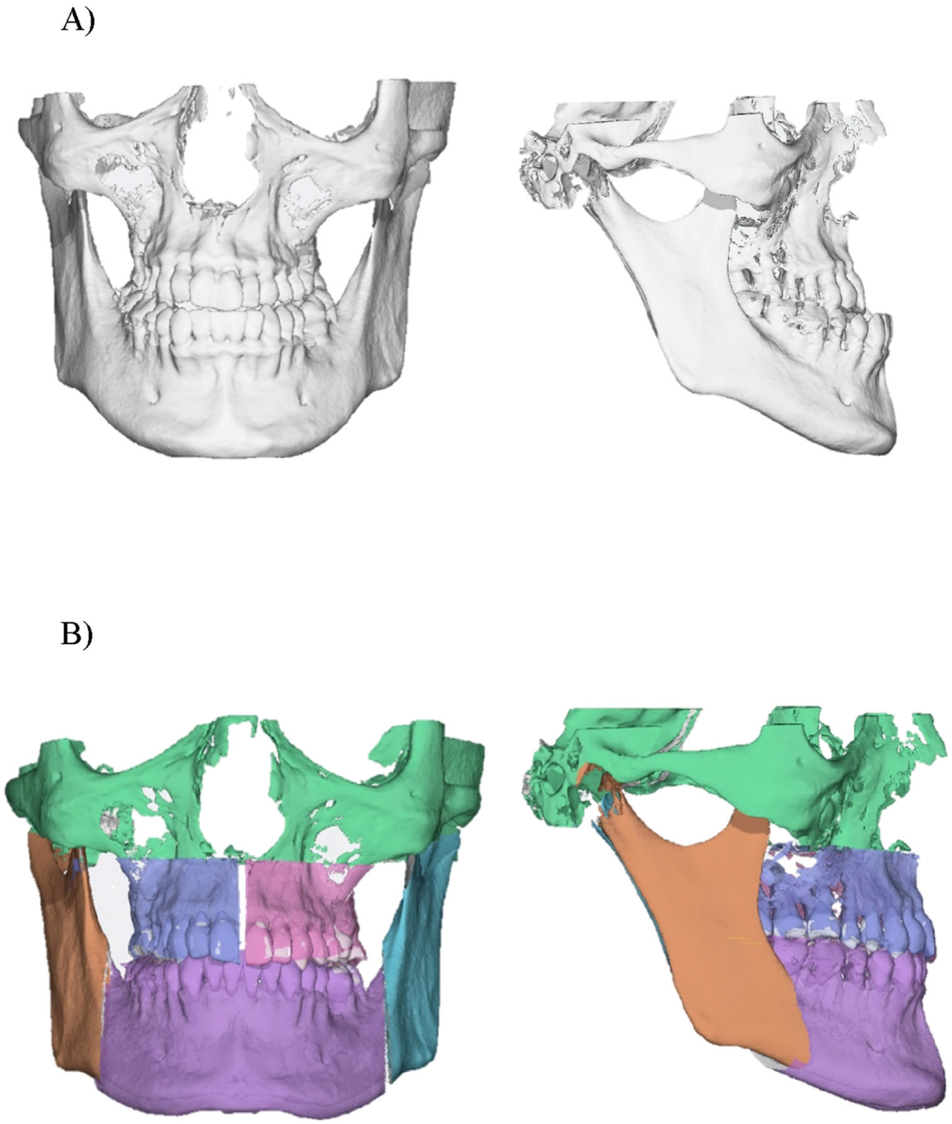

Fig. 1. Computer-aided surgical simulation. Frontal (left side) and profile view (right side) of the virtual model in the preoperative (A) and final (B) situation in a maxilla-first sequence of a class III patient. First, Le Fort I osteotomy was planned for maxillary advancement, segmentation, and midline correction. Second, bilateral sagittal split osteotomy was planned for mandibular setback (B).

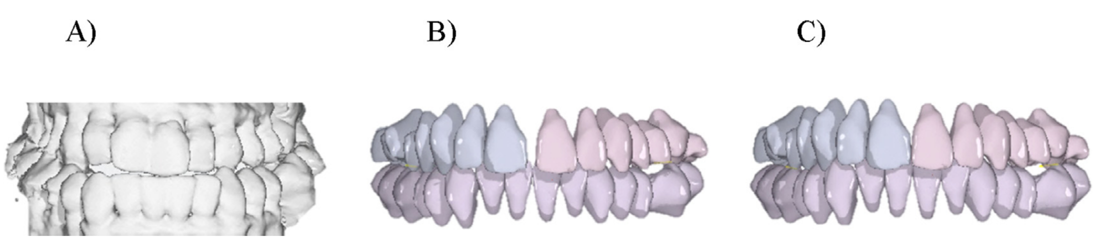

Fig. 2. Computer-aided orthodontic simulation. The preoperative occlusion (A) was transferred to the postoperative occlusion (B) by simulation of the maxillary advancement and midline segmentation as well as mandibular setback. Virtual simulation of the final postorthodontic occlusion (C) after dental decompensation and arch coordination.

Computer-aided surgical and orthodontic treatment simulation allowed virtual planning of the required skeletal movements to convert a dentofacial deformity into a skeletal class I relationship with a postoperative ‘transitional’ malocclusion. This treatable malocclusion was virtually transferred into a class I occlusion by computer-aided simulation of orthodontic movements. These predicted dental movements were assessed by the orthodontist for feasibility, and adjustments to the surgical plan were made if necessary.

The design of the bonding guide for bracket placement, the surgical guide and customised implant for maxillary osteotomy and positioning, as well as the 3D-printed final

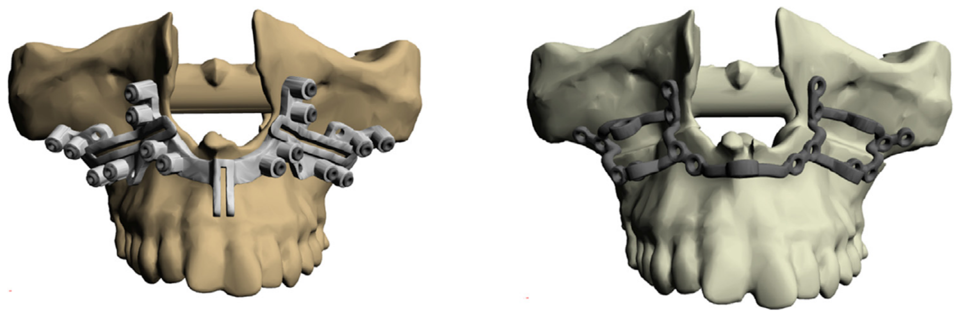

Fig. 3. Surgical transfer. Augmented model of the midfacial skeleton with the virtual design of the CAD/CAM surgical guide (left) for Le-Fort-I osteotomy and the titanium customised implant (right).

splint for mandibular positioning proved to be highly effective. These devices were successfully applied in all cases, and no major complications were experienced.

Discussion

Dentofacial deformities can have major psychosocial implications by influencing the patient's self-esteem and quality of life and affecting the individual's social and professional success.[8,9] A combined surgical orthodontic treatment can significantly improve the function, facial balance, and self-confidence of the patient.[9] Strong interdisciplinary collaboration between experienced orthodontists and surgeons is fundamental, since inadequate planning of the orthodontic or surgical part, or in the coordination of both, can lead to unfavourable results in terms of occlusion, aesthetics, and airway dynamics.[10] Therefore, a precise planning and treatment workflow is the basis of predictable and stable treatment outcomes and patient satisfaction.

Computer-aided surgical simulation (CASS) has become an integral part of orthognathic surgery planning and offers many advantages compared to traditional plaster model surgery.[11] Digital three-dimensional analysis has enhanced the accuracy of individual cephalometric analysis in routine as well as complex cases of dentofacial deformity.[12] Virtual planning of osteotomy lines has improved surgical safety and accuracy by visualising important anatomical structures such as tooth roots and the course of nerves.[13] Patient-specific cutting guides and three-dimensional printing of surgical wafers as well as customised implants have revolutionised the transfer of the surgical planning to the operating theatre with unprecedented predictability and precision. The accuracy of surgical transfer from planning to surgical result has been reported to be around 1 mm.[7] In addition, virtual planning of customised implants enables surgeons to selectively position and angulate screws in the areas with the strongest bone thickness, thus optimising the stability of internal fixation.

In the traditional orthodontic-first approach, decompensation precedes corrective jaw surgery. Preoperative orthodontics, surgery, and postoperative orthodontics comprise the three stages of the OFA. Orthodontic decompensation, which might be directed contrary to soft tissue forces, regularly impairs the malocclusion and can be time-consuming and particularly exhausting for patients until a balanced presurgical occlusion is established.[14]

In the surgery-first approach, the skeletal framework is corrected first, which renders the physiology of subsequent orthodontic alignment more favourable.[2] Thus, tedious phases of presurgical orthodontic decompensation against soft tissue forces can be avoided. Additionally, the patient becomes more flexible in choosing the start of treatment.[14]

Postoperative orthodontic movements are expedited based on the theory of the RAP. Orthognathic surgery induces increased turnover of bone for several months after surgery,[13] with enhanced osteoclastic activity leading to accelerated tooth movements and a reduction in total treatment time.[15] The enhanced bone metabolism peaks 1–2 months after surgery.[13] In a meta-analysis of ten comparative studies, Yang et al reported a shorter overall treatment time of 5.25 months with similar functional outcomes in terms of skeletal stability and quality of occlusion in surgery-first patients compared to conventional treatment.[16]

Treating patients in a surgery-first approach requires a high level of experience in orthognathic treatment from both the orthodontist and the surgeon as well as close collaboration and communication.[4] Since a balanced occlusion cannot be used as a reference for surgical movement, the orthodontist and surgeon must have a high degree of expertise in surgical orthodontics in order to project the postsurgical position of the skeletal framework, taking the complex subsequent dental movements into account.[2,13] The magnitude of postsurgical dental decompensation as well as the extent of concomitant mandibular autorotation during arch coordination need to be incorporated in the prediction of the postoperative skeletal position.[2,13] Three-dimensional simulation has become a great asset in this treatment planning pathway and has tremendously enhanced the predictability of treatment results, especially in surgery-first patients.[17] The SFA has been advocated to have a limited spectrum of indications and should only be applied in cases with minimal anterior crowding, a flat-to-mild curve of Spee, and a mild deviation of the interincisal angle.[13] The authors are convinced that virtual orthodontic and surgical treatment planning has the potential to vastly expand the width of indications of the SFA.

In patients with a transverse maxillary deficiency in conjunction with an additional sagittal or vertical deficiency all three-dimensional discrepancies can be potentially treated with a single surgery in a one-stage surgery-first approach with segmental maxillary Le Fort I osteotomy. In contrast, in a two-stage treatment, the transverse maxillary deficiency is treated first by surgically assisted rapid palatal expansion (SARPE), followed by orthodontic treatment and a second surgery to correct any residual sagittal and vertical discrepancies.[18] Thus, a one-stage surgery-first approach with segmental maxillary Le Fort I osteotomy can reduce the number of surgeries.

Conclusion

Surgical orthodontic treatment has benefited tremendously from recent technological developments. Advances in three-dimensional analysis and treatment planning have considerably expanded the range of indications and the predictability of treatment outcomes in the surgery-first approach. A high level of skill in surgical orthodontics is fundamental for successful achievement of treatment goals. Here, we present the concept of a fully virtual treatment pathway in surgery-first cases incorporating orthodontic and surgical simulation in a mutual interdisciplinary planning pathway.

Ethics statement/confirmation of patients' permission

Ethics approval not required. Written informed consent was obtained from each patient or their guardian.

Conflict of interest

We have no conflicts of interest.

References

1.. Liou EJ, Chen PH, Wang YC, et al. Surgery-first accelerated orthognathic surgery: orthodontic guidelines and setup for model surgery. *J Oral Maxillofac Surg* 2011;**69**:771–780.
2.. Hwang HS, Oh MH, Oh HK, et al. Surgery-first approach in correcting skeletal Class III malocclusion with mandibular asymmetry. *Am J Orthod Dentofacial Orthop* 2017;**152**:255–267.
3.. Hernández-Alfaro F, Guijarro-Martinez R, Molina-Coral A, et al. “Surgery first” in bimaxillary orthognathic surgery. *J Oral Maxillofac Surg* 2011;**69**:e201–e207.
4.. Hernández-Alfaro F, Guijarro-Martinez R, Peiro-Guijarro MA. Surgery first in orthognathic surgery: what have we learned? A comprehensive workflow based on 45 consecutive cases. *J Oral Maxillofac Surg* 2014;**72**:376–390.
5.. Uribe F, Agarwal S, Shafer D, et al. Increasing orthodontic and orthognathic surgery treatment efficiency with a modified surgery-first approach. *Am J Orthod Dentofacial Orthop* 2015;**148**:838–848.
6.. Huang CS, Chen YR. Orthodontic principles and guidelines for the surgery-first approach to orthognathic surgery. *Int J Oral Maxillofac Surg* 2015;**44**:1457–1462.
7.. Kim JW, Kim JC, Jeong CG, et al. The accuracy and stability of the maxillary position after orthognathic surgery using a novel computer-aided surgical simulation system. *BMC Oral Health* 2019;**19**:18.
8.. Dos Santos PR, Meneghim MC, Ambrosano GM, et al. Influence of quality of life, self-perception, and self-esteem on orthodontic treatment need. *Am J Orthod Dentofacial Orthop* 2017;**151**:143–147.
9.. Grewal H, Sapawat P, Modi P, et al. Psychological impact of orthodontic treatment on quality of life – a longitudinal study. *Int Orthod* 2019;**17**:269–276.
10.. Klein KP, Kaban LB, Masoud MI. Orthognathic surgery and orthodontics: Inadequate planning leading to complications or unfavorable results. *Oral Maxillofac Surg Clin North Am* 2020;**32**:71–82.
11.. Alkhayer A, Piffkó J, Lippold C, et al. Accuracy of virtual planning in orthognathic surgery: a systematic review. *Head Face Med* 2020;**16**:34.
12.. Schneider D, Kämmerer PW, Hennig M, et al. Customized virtual surgical planning in bimaxillary orthognathic surgery: a prospective randomized trial. *Clin Oral Investig* 2019;**23**:3115–3122.
13.. Choi DS, Garagiola U, Kim SG. Current status of the surgery-first approach (part I): Concepts and orthodontic protocols. *Maxillofac Plast Reconstr Surg* 2019;**41**:10.
14.. Naran S, Steinbacher DM, Taylor JA. Current concepts in orthognathic surgery. *Plast Reconstr Surg* 2018;**141**:925–936.
15.. Liou EJ, Chen PH, Wang YC, et al. Surgery-first accelerated orthognathic surgery: postoperative rapid orthodontic tooth movement. *J Oral Maxillofac Surg* 2011;**69**:781–785.
16.. Yang L, Xiao YD, Liang YJ, et al. Does the surgery-first approach produce better outcomes in orthognathic surgery? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2017;**75**:2422–2429.
17.. Hernández-Alfaro F, Guijarro-Martínez R. On a definition of the appropriate timing for surgical intervention in orthognathic surgery. *Int J Oral Maxillofac Surg* 2014;**43**:846–855.
18.. da Costa SO, Smeets M, Willaert R, et al. Complications following one-stage versus two-stage surgical treatment of transverse maxillary hypoplasia. *J Oral Maxillofac Surg* 2021;**79**:1531–1539.