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Three-dimensional cone-beam computed tomography-based virtual treatment planning and fabrication of a surgical splint for asymmetric patients: Surgery first approach

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Virtual 3-dimensional planning in orthognathic surgery allows for a detailed visualization and analysis of skeletal and dental deformities, especially in patients with asymmetries. This approach also eliminates conventional stone model surgery through computer-aided fabrication of surgical stents. This article presents a new approach with 3-dimensional cone-beam computed tomography-based treatment planning for the surgical correction of facial asymmetry in conjunction with the surgery first approach. Good esthetic and occlusal outcomes were obtained for 2 patients after orthognathic surgery and orthodontic treatment with a short total treatment time. (Am J Orthod Dentofacial Orthop 2013;144:748-58)

Conventional surgical planning for orthognathic surgery involves collection of data, including a clinical examination, extraoral and intraoral photographs, lateral and posteroanterior cephalograms, and plaster dental models. Dental models are mounted on an articulator, and the interdisciplinary team of the orthodontist and the oral-maxillofacial surgeon evaluates, simulates, and decides on a treatment plan. A surgical splint is fabricated to the newly determined dental occlusion. The main limitation of conventional surgical planning is its 2-dimensional approach, a major handicap especially in patients with facial asymmetries, when often the deformity involves all 3 dimensions.[1,2] Appropriate surgical treatment starts with accurate diagnosis by evaluating all dimensions and determining the nature of the asymmetry because it might be a combination of hard-tissue and soft-tissue components.[3]

To overcome those shortcomings, cone-beam computed tomography (CBCT) for imaging the craniofacial region heralds a true paradigm shift from a 2-dimensional to a 3-dimensional (3D) approach. CBCT allows a 3D display of the craniofacial anatomy with possibilities of image segmentation, thereby expanding the role of imaging from diagnosis to simulation of the surgical procedures and fabrication of the surgical splints in craniofacial surgery. Three-dimensional computer-aided surgical planning techniques for craniofacial deformities introduced by Xia et al[4] and Swennen et al[5,6] allow 3D analysis and a virtual surgical plan and provide the information for fabrication of computer-manufactured surgical splints without conventional model surgery. This virtual planning allows for more thorough analysis and surgical planning, especially in patients with facial asymmetries.

Before the 1960s, most orthognathic surgeries were performed either without orthodontic treatment after removing the orthodontic appliances, or before any orthodontic treatment.[7-9] Later, the 3 stages of conventional surgical orthodontic treatment became popular because of the stability of the results and satisfaction with the posttreatment outcomes. Successful outcomes were due to the development of new surgical techniques and orthodontic materials and the use of rigid internal fixation. However, longer treatment times and transitional detriment to the facial profile have led to a

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Submitted, March 2012; revised and accepted, October 2012.
0889-5406/$36.00

http://dx.doi.org/10.1016/j.ajodo.2012.10.029

Fig 1. Preoperative records of asymmetric patient 1 with vertical maxillary excess, constricted maxilla, occlusal cant, and retrognathic mandible. Dentally, a Class II malocclusion with excessive overjet, unilateral crossbite, anterior openbite tendency, and mild maxillary and mandibular crowding was observed. The patient had the maxillary right first premolar extracted during previous orthodontic treatment.

new approach called "surgery first," which eliminates the presurgical orthodontic phase.[10-14]

The purpose of this article is to document the treatments of 2 patients with facial asymmetry who had orthognathic surgery with the surgery first approach with 3D computer-aided surgical planning based on 1 CBCT scan procedure as described by Xia et al.[15] A virtual composite skull model was created with Simplant OMS software (Materialise, Leuven, Belgium). A computer-aided surgical stent was manufactured for 1 patient based on the occlusion of the projected skeletal outcome.

Patient 1 was a 22-year-old white woman who reported to the orthodontic clinic at the University of Connecticut Health Center with a chief complaint of forwardly placed maxillary incisors (Fig 1). She had a convex profile caused by a retrognathic mandible (Fig 2; Tables I and II), vertical maxillary excess with an occlusal cant, and transverse maxillary constriction. Dentally, she had a Class II molar and canine occlusion, an upper midline shifted to the right side, a unilateral posterior crossbite on the left side, an increased overjet, and an anterior open-bite tendency. Her smile showed excessive gingival display and increased buccal corridors, indicating a narrow maxillary arch. Additionally, she had facial asymmetry with the chin point deviated toward the left. The patient had been previously treated orthodontically for an asymmetric Class II malocclusion with maxillary transverse deficiency, and the maxillary right first premolar was extracted at that time.

Fig 2. Pretreatment lateral and posteroanterior cephalometric radiographs of patient 1.

Table I. Lateral cephalometric analysis of patient 1

Variable	*Norm*	*Pretreatment*	*Posttreatment*	*Change*
SNA (°)	82	78	79	1
SNB (°)	80	72	76	4
ANB (°)	2	6	3	−3
FMA (°)	32	31	28	−3
IMPA (°)	90	91	96	5
U1-NA (mm)	4	4.5	5	0.5
L1-NB (mm)	4	4.5	6	1.5
Interincisal angle (°)	131	128	125	−3
Upper lip to E-line (mm)	−4	−4.5	−4	0.5
Lower lip to E-line (mm)	−2	−2.5	−4	−1.5

Table II. Posterior cephalometric analysis of patient 1

Variable	*Norm*	*Pretreatment*	*Posttreatment*	*Change*
Occlusal plane tilt (°)	0	2	0	−2
AG right-MSR (mm)	34	34	34	0
AG left-MSR (mm)	34	34	37	3
J-MSR, right (mm)	29	23	25	2
J-MSR, left (mm)	29	25	28	3
A-Me-MSR (°)	0	5.5	0	−5.5
Z-MSR, right (mm)	41	36	36	0
Z-MSR, left (mm)	41	37	37	0
AG right-Me (mm)	40	48	42	−6
AG left-Me (mm)	40	45	44	−1

AG, Antegonial notch; *MSR*, midsagittal reference line; *J*, jugal process; *Me*, menton; *Z*, zygomaticofrontal suture, medial aspect.

Patient 2 was a 26-year-old white man requesting correction of his underbite and crooked smile at the Oral and Maxillofacial Surgery clinic of the University of Connecticut Health Center. The clinical examination (Fig 3) showed a mild concave skeletal and soft-tissue profile caused by a retrusive maxilla and a slightly prognathic mandible. The pretreatment CBCT image (Fig 4) also showed an incidental finding of a lesion at the base of the skull. As a follow-up, magnetic resonance imaging was taken by a medical radiologist, who gave clearance for the orthognathic surgical procedure and recommended a 6-month follow-up based on the likely nonaggressive nature of the lesion.

From a frontal view, a maxillary cant with slightly excessive gingival display on the right was evidenced on smiling. Facial asymmetry was appreciable in the lower third of the face, with the chin deviated toward the left in relation to the facial midline. Dentally, the patient had Class III molar and canine relationships, an anterior crossbite, a mandibular midline shifted to the left, and compensated retroclined mandibular incisors. He had also been treated orthodontically during his adolescence.

The treatment objectives for both patients aimed to address their chief complaints and correct their facial asymmetries. Treatment goals consisted of correlating the maxillary midline to the facial midline, and the frontal occlusal plane parallel to the horizontal plane in natural head position and the chin point in line with the facial midline. Both patients required asymmetric maxillary impaction. From a profile perspective, patient 1 required a significant mandibular advancement to achieve ideal facial convexity. On the other hand, patient 2 required maxillary advancement and unilateral mandibular setback to achieve a balanced profile. Patient 1 required expansion of the maxilla, especially

Fig 3. Pretreatment records of asymmetric patient 2 with an occlusal cant and slightly concave profile due to maxillary retrognathism and slight mandibular prognathism. Dentally, a Class III malocclusion with reverse overjet and mandibular midline deviation was observed.

on the left side. Alignment was good, and a nonextraction approach was chosen for both patients. Since they already had previous orthodontic treatment, they were concerned about having to undergo it again. The surgery first approach was offered as a treatment option, and both patients accepted because it addressed their chief complaints while minimizing the time required with fixed orthodontic appliances.

In patient 1, 4 weeks before surgery, the maxillary and mandibular teeth were bonded with 0.022-in slot preadjusted edgewise appliances, and the molars were banded. The canine and premolar brackets had built-in hooks; additionally, surgical hooks were crimped interdentally between the anterior teeth on the 0.016 $\times$ 0.016-in nickel-titanium archwire. The archwire was removed and ready to be used in the operating room before the start of surgery. A CBCT scan (exposure time, 14 seconds; field of view, 12 in; voxel size, 1.25 mm) based on the Simplant OMS guidelines was taken for the construction of a composite skull model. The virtual surgical plan consisted of a LeFort I maxillary osteotomy with expansion, advancement, impaction, and bilateral sagittal split osteotomy for mandibular advancement with lateral sliding genioplasty (Fig 5). Analysis of the surgical simulation shows the differential movements of the maxilla and the mandible to correct the facial asymmetry. The planned virtual surgery was replicated by stone model surgery, and acrylic splints were fabricated.

For patient 2, a composite skull model was constructed as described for patient 1. The surgical plan (Fig 6) included a LeFort I maxillary osteotomy with advancement, asymmetric posterior impaction for correction of the occlusal cant, reduction of the gingival display on smile, bilateral split sagittal osteotomy with asymmetric mandibular setback, and lateral sliding genioplasty addressing his facial asymmetry. Based on the virtual surgical plan, the company engineers designed

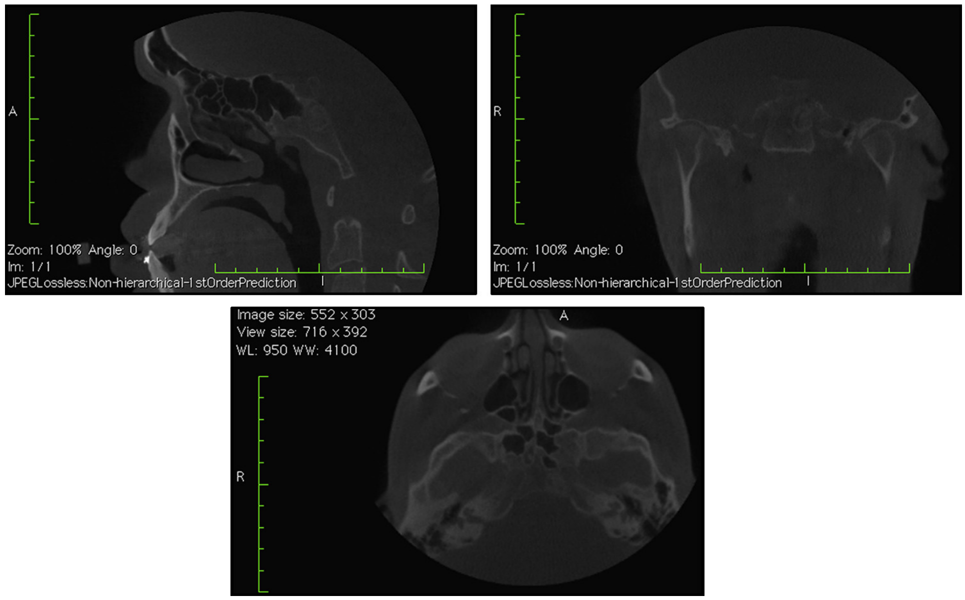

Fig 4. Incidental finding of a lesion in the clivus area of the cranial base on the CBCT image in the sagittal, coronal, and axial planes in patient 2.

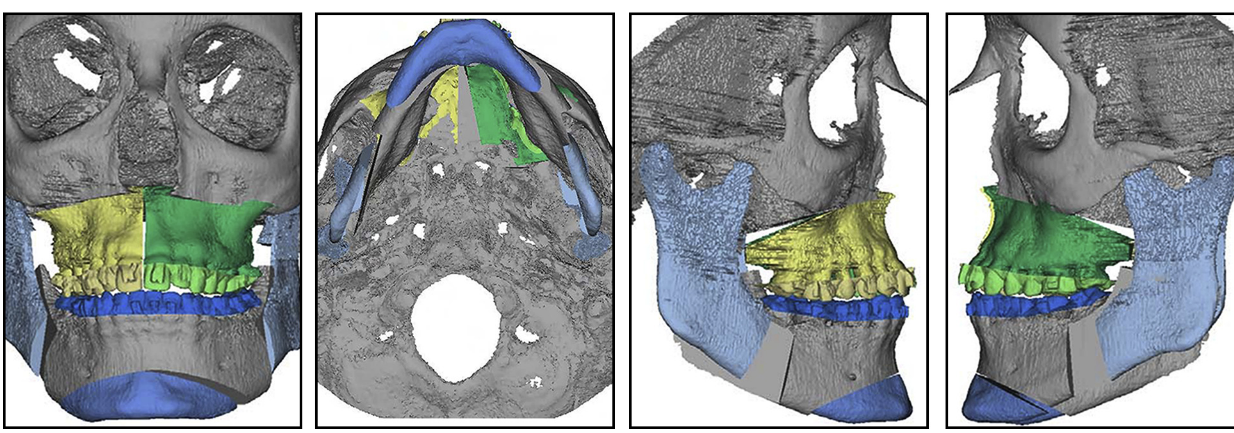

Fig 5. Three-dimensional virtual surgical plan for patient 1: segmented LeFort I osteotomy with maxillary expansion, advancement, and anterior impaction. The mandible was planned for a bilateral split sagittal osteotomy with advancement and lateral sliding genioplasty (yaw movement). A counterclockwise rotation of the maxillomandibular complex was the result of the planned movements. The interim malocclusion after surgery reflects a slight anterior open bite, Class I canine relationships, and adequate overjet.

and manufactured intermediate and final splints with a completely digital method. The 3D digital tooth models from the virtual surgical planning software were exported into a computer-aided design software program for splint creation. The splints were designed based on the intermediate and final tooth positions, essentially by filling the void spaces between the teeth and trimming to the virtually planned specifications. The completed digital splint files were prepared for manufacturing and produced in a stereolithography rapid prototyping machine (Fig 7).

Both patients received 4 skeletal anchorage plates (1 in each quadrant) to control for any relapse tendencies observed postsurgically.

For patient 1, 0.016 $\times$ 0.016-in nickel-titanium archwires with surgical hooks were placed in the operating

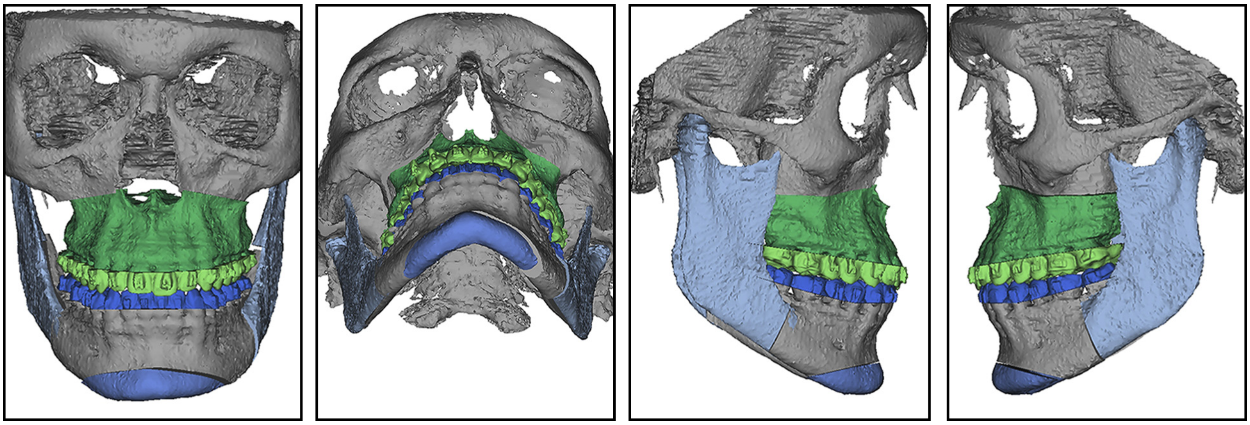

Fig 6. Patient 2's 3D virtual planning LeFort I osteotomy with maxillary advancement, unilateral impaction on the right, bilateral split sagittal osteotomy with unilateral setback (right side), and lateral sliding genioplasty.

Fig 7. Computer-manufactured intermediate and final splints (2 intermediate and 2 final) for patient 2.

room before the surgery. Intermaxillary fixation was obtained using stainless steel ligature wires connected between the archwires and the brackets. After fixation of the repositioned jaw segments with miniplates and screws, intermaxillary fixation was removed. Six weeks postsurgically, the splint was removed from the maxillary arch, and a transpalatal arch was placed to maintain the transverse dimension. Lighter archwires with short Class II elastics were placed for settling of the occlusion. Progression into stiffer archwires was done until completing the orthodontic treatment. Patient 1 was debonded (Figs 8 and 9) after 12 months of orthodontic treatment. Superimposition of the 3D virtual plan and the outcome shows the differences in the surgical movements, which were within the limits of deviations previously reported in the literature.[16-18] The differences between the planned and postoperative dental outcomes can be attributed to postsurgical orthodontic tooth movement. In the surgery first approach, orthodontic tooth movement occurs only

Fig 8. Postoperative records for patient 1 reflect good facial symmetry, reduced gingival display, and orthognathic profile. A fuller smile was obtained with the maxillary expansion. A good occlusal outcome is observed.

after surgery; thus, the planned surgical outcome should be evaluated primarily at the osseous level (Fig 10). Three-dimensional superimpositions show the initial images compared with the outcome CBCT images reflecting the movements of the maxilla and the mandible for correction of the facial asymmetry (Fig 11).

In patient 2, the same 0.016 × 0.016-in nickel-titanium maxillary and mandibular archwires with surgical hooks were placed in the operating room before the surgery. Intermaxillary fixation was obtained using stainless steel ligature wires connected between the archwires and brackets (Fig 12). Intermaxillary fixation and surgical splints were removed immediately after fixation of the repositioned jaw segments with miniplates and screws. The patient was seen 2 weeks later for follow-up. At that time, the archwires with surgical hooks were removed, and smaller-dimension archwires with intermaxillary elastics were placed. Orthodontic treatment lasted for 7 months (Fig 13). The postoperative records showed good improvement in the facial profile and no gross asymmetry. Both patients were extremely satisfied with their esthetic results and short treatment times.

DISCUSSION

Peck and Peck[19] defined facial symmetry as the state of equilibrium, the correspondence in size, and the form and arrangement of facial features on the opposite sides of the median sagittal plane. Severt and Proffit[20] reported that the frequencies of facial asymmetry were 4.7%, 36%, and 74% in the upper, middle, and lower thirds of the face, respectively. In spite of the high prevalence, assessment of facial asymmetry, a complex 3D defect, is not accurate with 2-dimensional imaging such as posteroanterior cephalograms, panoramic radiographs, and submentovertex views. Several limitations include magnification, distortion, projection errors, and questionable width measurements.[21] It is possible to overcome these shortcomings and acquire, diagnose, and produce a virtual surgical plan with 3D CBCT imaging.

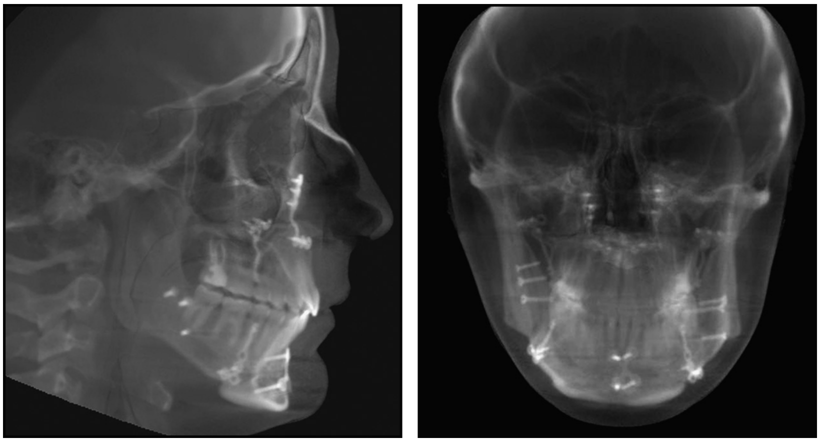

Fig 9. Posttreatment lateral and posteroanterior cephalometric radiographs for patient 1.

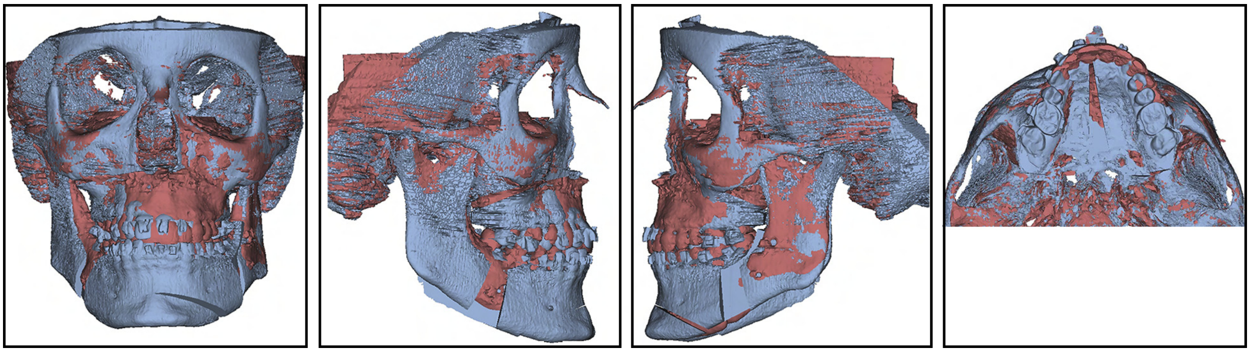

Fig 10. Three-dimensional superimposition of the virtual plan and the outcome for patient 1 (*blue*, plan; *red*, outcome).

In corrective surgeries for facial asymmetry with conventional planning, it is not possible to visualize the condylar positional changes or bony interferences between the proximal and distal segments because of asymmetric surgical movements, which could compromise the stability and temporomandibular joint function.[1,22] With 3D surgical planning, it is possible to evaluate and perform relocation planning of the osteotomy cut to prevent bone interferences and to select the appropriate location and size of the fixation screws and plates.[16] Additionally, quantification of relocated bony segments can be done after simulated surgery, and measurements can be assessed in the x-, y-, and z-axes. According to Xia et al,[15] relocation of osteotomized segments might not be sufficient to obtain facial symmetry not only because patients with asymmetry have asymmetrically displaced skeletal units, but also because the morphologies of the bones and associated soft tissues can be different on the 2 sides. With a mirroring technique, it is possible to evaluate the symmetry during planning, and the differences between the 2 sides can help the surgeon to decide whether to use grafting, ostectomy, or repositioning of the segments.

Once the 3D plan is finalized, it is absolutely important to accurately carry out the plan during the surgery. The surgical splint fabricated by the computer-aided design and manufacturing technique helps in accomplishing this purpose. Gateno et al[23] assessed the precision of digitally generated surgical wafers with conventional splints and found a high degree of accuracy with the computer-generated splints. Furthermore, another pilot study showed that surgical outcomes deviated statistically and clinically insignificantly from the planned surgical procedures using computer-aided manufactured surgical splints.[18] The authors concluded that splints generated by computer-aided design and manufacturing techniques had a high degree of accuracy, and the fit was similar to that of conventional splints.

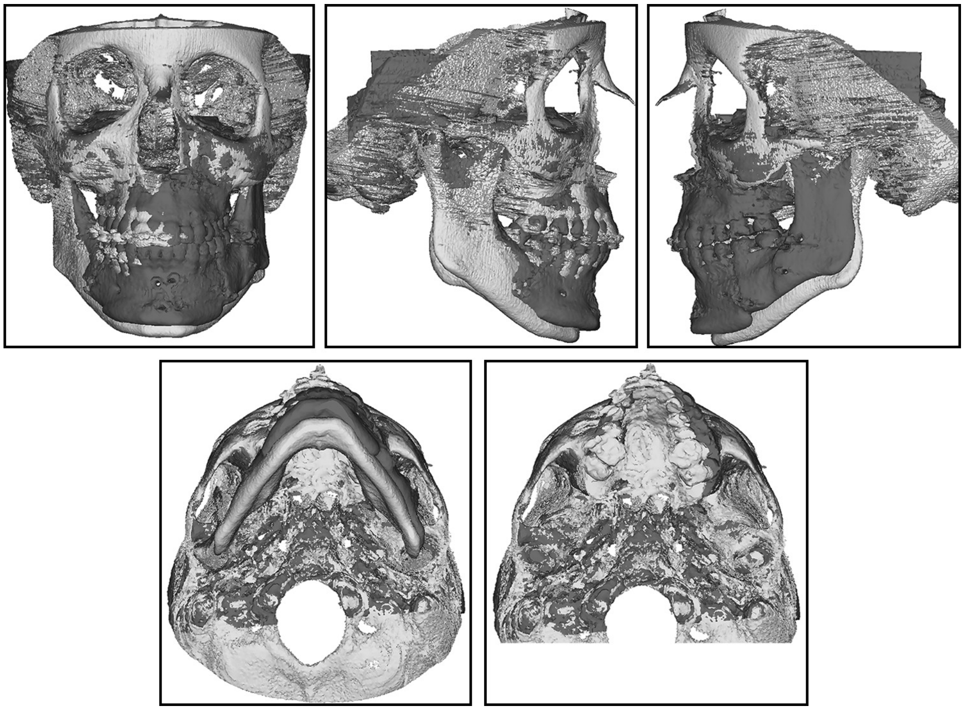

Fig 11. Three-dimensional superimposition of the initial and the outcome scans for patient 1 (*white*, initial; *gray*, final).

Fig 12. Three-dimensional final computer-manufactured surgical splint immediately after orthognathic surgery in patient 2. Notice the good occlusal relationship achieved.

The orthognathic surgery first approach is becoming popular because of several advantages, such as reduced treatment times, efficient tooth decompensations, rapid improvement in facial esthetics, and greater cooperation from the patients after surgery.[11-14] At the Division of Orthodontics, University of Connecticut Health Center, approximately 30 patients have been treated successfully with the surgery first approach during the past 5 years, with an average treatment time of approximately 10 months. Although there are currently no set criteria for patient selection for this approach, recently Liou et al[24] described general and specific guidelines for successful orthodontic and surgical management of these patients.

In general, most patients with dentofacial deformities undergoing orthognathic surgery can be treated with surgery first, including patients with severe crowding and rotations.[13,14] With the aid of a skeletal anchorage system, arch length can be increased by postsurgical distalization of the posterior teeth to accommodate the crowded teeth and still achieve proper axial incisor inclinations, obviating the need for extractions.[13] The primary indication, reflected in most publications on the surgery first approach, is the treatment of Class III malocclusions.[10,13,14] Patients with proper maxillary anteroposterior incisal inclination and mild to moderate mandibular crowding with retroclined mandibular incisors could be considered ideal for this approach. The major contraindication would be any patient whose postsurgical posterior occlusal contacts would be prevented by the incisor inclination, resulting in a negative overjet after surgery. Such would be the case with excessive lingual inclination of the maxillary incisors in a Class II patient or excessive labial inclination of the mandibular incisors in a Class III patient.

Combining the surgery first approach with 3D CBCT virtual planning enables us to obtain symmetry in the

Fig 13. Postoperative records for patient 2 reflect good facial symmetry, leveled maxillary occlusal plane, and good occlusal outcome.

facial structures with great accuracy while significantly increasing treatment efficiency. The most complicated step with this approach is the determination of the transitional occlusion immediately after surgery. In essence, the surgery is planned to achieve skeletal symmetry in all planes of space, adequate facial proportions, and harmony. The occlusion resulting from the process is then evaluated, and an orthodontic setup is constructed.

The orthodontic setup serves to visualize the movements necessary to achieve an ideal occlusion after surgery. This is similar to the process that the orthodontist performs to correct any malocclusion. Based on the complexity of the movements, the orthodontist plans with the surgeon the addition of orthodontic miniplates to be used as skeletal anchorage after surgery to aid with specific tooth movements.[14] Once the surgical movement and the transitional occlusion are planned virtually, they are replicated in hard stone models and sent to the company (Medical Modeling, Golden, Colo), which will use them as the reference for fabrication of the final surgical splint.

Recently, Hernandez-Alfaro et al[11] presented 2 patients treated by the surgery first approach using 3D CBCT and similar software for virtual orthodontic and surgical planning in bimaxillary surgery. They used an intermediate splint fabricated by a computer-aided design and manufacturing technique; the final surgical splint was fabricated from poured stone models in both patients. In our report, the software was used for treatment planning purposes in patient 1. The intermediate and final surgical splints were fabricated from stone models according to the virtual plan. On the other hand, patient 2 had virtual 3D planning and computer-aided manufacturing of the intermediate and final occlusal splints. The final surgical wafer was removed immediately after surgery as stable occlusion was obtained.

Accurate surgical planning and a true team approach between the surgeon and the orthodontist are crucial when using the surgery first approach and virtual 3D planning. Probably, a greater level of planning is required when this approach is applied to patients with significant asymmetries. Although both patients were asymmetric, they represented opposite ends in the spectrum of sagittal discrepancy (Class II vs Class III). Nonetheless, both treatment outcomes showed good occlusal and facial relationships in all 3 planes of space.

CONCLUSIONS

Fusion of relatively new technologies and techniques such as 3D CBCT-based surgical planning, computer-aided splint fabrication, and the surgery first approach can make orthognathic surgery more efficient and effective for patients and the surgical-orthodontic team. Patients with significant facial asymmetries seem to benefit from the combination of these technologies and techniques. Accurate, predictable, and efficient treatment outcomes can be achieved, as demonstrated by these 2 patients.

ACKNOWLEDGMENTS

We thank Katie Weimer and Andrew Battan at Medical Modeling for all the help in the 3D planning of the cases reported in this manuscript.

REFERENCES

1. Schwartz HC. Efficient surgical management of mandibular asymmetry. J Oral Maxillofac Surg 2011;69:645-54.
2. Baek SH, Cho IS, Chang YI, Kim MJ. Skeletodental factors affecting chin point deviation in female patients with Class III malocclusion and facial asymmetry: a three-dimensional analysis using computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:628-39.
3. Cheong YW, Lo LJ. Facial asymmetry: etiology, evaluation, and management. Chang Gung Med J 2011;34:341-51.
4. Xia J, Ip HH, Samman N, Wang D, Kot CS, Yeung RW, et al. Computer-assisted three-dimensional surgical planning and simulation: 3D virtual osteotomy. Int J Oral Maxillofac Surg 2000;29:11-7.
5. Swennen GR, Mollemans W, De Clercq C, Abeloos J, Lamoral P, Lippens F, et al. A cone-beam computed tomography triple scan procedure to obtain a three-dimensional augmented virtual skull model appropriate for orthognathic surgery planning. J Craniofac Surg 2009;20:297-307.
6. Swennen GR, Mommaerts MY, Abeloos J, De Clercq C, Lamoral P, Neyt N, et al. A cone-beam CT based technique to augment the 3D virtual skull model with a detailed dental surface. Int J Oral Maxillofac Surg 2009;38:48-57.
7. Dingman RO. Surgical correction of mandibular prognathism, and improved method. Am J Orthod Oral Surg 1944;30:683-92.
8. Pettit JA, Walrath CH. The bow-back operation for the relief of prognathism. Am J Orthod 1947;33:773-9.
9. Proffit W, White RP. Dentofacial problems: prevalence and treatment need. In: Proffit W, White RP, Sarver DM, editors. Contemporary treatment of dentofacial deformity. St Louis: Mosby; 2003. p. 25.
10. Baek SH, Ahn HW, Kwon YH, Choi JY. Surgery-first approach in skeletal class III malocclusion treated with 2-jaw surgery: evaluation of surgical movement and postoperative orthodontic treatment. J Craniofac Surg 2010;21:332-8.
11. Hernandez-Alfaro F, Guijarro-Martinez R, Molina-Coral A, Badia-Escriche C. "Surgery first" in bimaxillary orthognathic surgery. J Oral Maxillofac Surg 2011;69:e201-7.
12. Liou EJ, Chen PH, Wang YC, Yu CC, Huang CS, Chen YR. Surgery-first accelerated orthognathic surgery: postoperative rapid orthodontic tooth movement. J Oral Maxillofac Surg 2011;69:781-5.
13. Nagasaka H, Sugawara J, Kawamura H, Nanda R. "Surgery first" skeletal Class III correction using the skeletal anchorage system. J Clin Orthod 2009;43:97-105.
14. Villegas C, Uribe F, Sugawara J, Nanda R. Expedited correction of significant dentofacial asymmetry using a "surgery first" approach. J Clin Orthod 2010;44:97-103.
15. Xia JJ, Gateno J, Teichgraeber JF. New clinical protocol to evaluate craniomaxillofacial deformity and plan surgical correction. J Oral Maxillofac Surg 2009;67:2093-106.
16. Hsu SS, Gateno J, Bell RB, Hirsch DL, Markiewicz MR, Teichgraeber JF, et al. Accuracy of a computer-aided surgical simulation protocol for orthognathic surgery: a prospective multicenter study. J Oral Maxillofac Surg 2013;71:128-42.
17. Tucker S, Cevidanes LH, Styner M, Kim H, Reyes M, Proffit W, et al. Comparison of actual surgical outcomes and 3-dimensional surgical simulations. J Oral Maxillofac Surg 2010;68:2412-21.
18. Xia JJ, Gateno J, Teichgraeber JF, Christensen AM, Lasky RE, Lemoine JJ, et al. Accuracy of the computer-aided surgical simulation (CASS) system in the treatment of patients with complex craniomaxillofacial deformity: a pilot study. J Oral Maxillofac Surg 2007;65:248-54.
19. Peck H, Peck S. A concept of facial esthetics. Angle Orthod 1970;40:284-318.
20. Severt TR, Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population at the University of North Carolina. Int J Adult Orthod Orthognath Surg 1997;12:171-6.
21. You KH, Lee KJ, Lee SH, Baik HS. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular prognathism. Am J Orthod Dentofacial Orthop 2010;138:540.e1-8; discussion, 540-1.
22. Yang HJ, Lee WJ, Yi WJ, Hwang SJ. Interferences between mandibular proximal and distal segments in orthognathic surgery for patients with asymmetric mandibular prognathism depending on different osteotomy techniques. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:18-24.
23. Gateno J, Xia J, Teichgraeber JF, Rosen A, Hultgren B, Vadnais T. The precision of computer-generated surgical splints. J Oral Maxillofac Surg 2003;61:814-7.
24. Liou EJ, Chen PH, Wang YC, Yu CC, Huang CS, Chen YR. Surgery-first accelerated orthognathic surgery: orthodontic guidelines and setup for model surgery. J Oral Maxillofac Surg 2011;69:771-80.