Protocol for Concomitant Temporomandibular Joint Custom-fitted Total Joint Reconstruction and Orthognathic Surgery Using Computer-assisted Surgical Simulation

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KEYWORDS

• Temporomandibular joint • Total joint reconstruction • Orthognathic surgery • Computer-assisted surgical simulation

KEY POINTS

- Combined orthognathic and total joint reconstruction cases can be predictably performed in 1 stage.
- Use of virtual surgical planning can eliminate a significant time requirement in preparation of concomitant orthognathic and temporomandibular joint (TMJ) prostheses cases.
- The concomitant TMJ and orthognathic surgery–computer-assisted surgical simulation technique increases the accuracy of combined cases.
- In order to have flexibility in positioning of the total joint prosthesis, recontouring of the lateral aspect of the rami is advantageous.

INTRODUCTION

Clinicians who address temporomandibular joint (TMJ) disorders and dentofacial deformities surgically can perform the surgery in 1 stage or 2 separate stages. The 2-stage approach requires the patient to undergo 2 separate operations and anesthesia, significantly prolonging the overall treatment. However, performing concomitant TMJ and orthognathic surgery (CTOS) in these cases requires careful treatment planning and surgical proficiency in the two surgical areas. This article presents a new treatment protocol for the application of computer-assisted surgical simulation (CASS) in CTOS cases requiring reconstruction with patient-fitted total joint prostheses. The traditional and new CTOS protocols are described and compared. The new CTOS protocol helps decrease the preoperative work-up time and increase the accuracy of model surgery.

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INDICATIONS

TMJ disorders and dentofacial deformities commonly coexist. The TMJ disorders may be the causative factor of the jaw deformity, or develop as a result of the jaw deformity, or the two entities may develop independently of each other. The most common TMJ disorders that can adversely affect jaw position, occlusion, and orthognathic surgical outcomes include (1) articular disc dislocation, (2) adolescent internal condylar resorption, (3) reactive arthritis, (4) condylar hyperplasia, (5) ankylosis, (6) congenital deformation or absence of the TMJ, (7) connective tissue and autoimmune diseases, (8) trauma, and (9) other end-stage TMJ disorders.[1] These TMJ conditions are often associated with dentofacial deformities, malocclusion, TMJ pain, headaches, myofascial pain, TMJ and jaw functional impairment, ear symptoms, and sleep apnea. Patients with these conditions may benefit from corrective surgical intervention, including TMJ and orthognathic surgery. Some of the aforementioned TMJ disorders may have the best outcome prognosis using custom-fitted total joint prostheses for TMJ reconstruction.

Many clinicians choose to ignore the TMJ disorders and perform only orthognathic surgery for these types of cases. Clinicians who address the TMJ disorders and dentofacial deformities surgically can perform the surgery in 1 stage or 2 separate stages. The 2-stage approach requires the patient to undergo 2 separate operations and anesthesia, significantly prolonging the overall treatment. However, performing CTOS in these cases requires careful treatment planning and surgical proficiency in the two surgical areas. Using traditional model surgery and treatment planning techniques exposes the outcome to its own subset of error margin. As a result, CTOS requires experience and expertise.

Over the past decade, CASS technology has been integrated into many maxillofacial surgical applications,[2,3] including dentofacial deformities, congenital deformities, defects after tumor ablation, posttraumatic defects, reconstruction of cranial defects,[4] and reconstruction of the TMJ.[5] CASS technology can improve surgical accuracy, provide intermediate and final surgical splints, and decrease surgeons' time input for presurgical preparation compared with traditional methods of case preparation.[6]

PROTOCOL FOR TRADITIONAL CONCOMITANT TEMPOROMANDIBULAR JOINT AND ORTHOGNATHIC SURGERY

Treatment planning for CTOS cases is based on prediction tracing, clinical evaluation, and dental models, which provide the template for movements of the upper and lower jaws to establish optimal treatment outcome in relation to function, facial harmony, occlusion, and oropharyngeal airway dimensions. For patients who require total joint prostheses, a computed tomography (CT) scan is acquired of the maxillofacial region that includes the TMJs, maxilla, and mandible with 1-mm overlapping cuts. Using these CT scan data, a stereolithic model is fabricated, with the mandible as a separate piece.

Using the original cephalometric tracing and prediction tracing (Fig. 1A), the mandible on the stereolithic model is placed into its future predetermined position using the planned measurements for correction of mandibular anteroposterior and vertical positions, pitch, yaw, and roll (see Fig. 1). The mandible is stabilized to the maxilla with quick-cure acrylic. Many patients

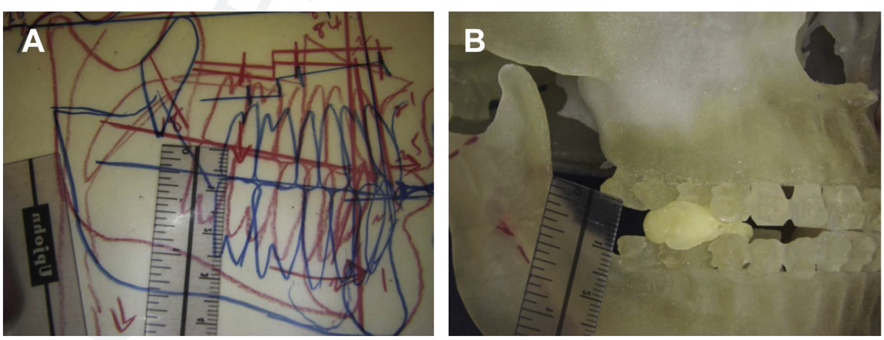

Fig. 1. (*A*) Measurement of the cephalometric prediction tracing for the amount of open bite produced at the second molar after counterclockwise rotation of the mandible into its final position. (*B*) Duplication of the measurement obtained from the prediction tracing to the final mandibular position on the stereolithic model and fixating the mandible to the maxilla with methylmethacrylate. (*From* Movahed R, Teschke M, Wolford LM. Protocol for concomitant temporomandibular joint custom-fitted total joint reconstruction and orthognathic surgery utilizing computer-assisted surgical simulation. J Oral Maxillofac Surg 2013;71(12):2123–9; with permission.)

with temporomandibular disorders requiring concomitant orthognathic surgery benefit from counterclockwise rotation of the maxillomandibular complex, which requires the development of posterior open bites on the model (see Fig. 1B). Because the mandibular position on the stereolithic models is established using hands-on measurements, the operator's manual dexterity and three-dimensional perspective play critical roles in setting the mandible in its proper and final position. This step can predispose the planning process to a certain margin of error.

The next step requires the preparation of the lateral aspect of the rami and fossae (Fig 2A, B) for fabrication of the patient-fitted total joint prostheses. The goal of this step is to recontour the lateral ramus to a flat surface in the area where the mandibular component will be placed. The fossa requires recontouring only if heterotopic bone or unusual anatomy is present. The recontouring areas are marked in red for duplication of bone removal at surgery. Because most patients with TMJ problems requiring CTOS can benefit from counterclockwise rotation of the maxillomandibular complex, the stereolithic model is likely to be set with posterior open bites, because the maxilla is maintained in its original position.

Once the stereolithic model is finalized, the model is sent to TMJ Concepts (Ventura, CA) to perform the design, blueprint, and wax-up of the custom-fitted total joint prostheses (see Fig. 2C), with the design and wax-up sent to the surgeon for approval before manufacture of the prostheses. The period from CT acquisition to the manufacturer's completion of the custom-fitted prostheses is approximately 8 weeks. The surgical procedures are then performed on articulator-mounted dental models. The mandible is repositioned on the articulator, duplicating the movements performed on the stereolithic model, and the intermediate splint is constructed. The maxillary model is repositioned, segmented if indicated, and placed into the maximal occlusal fit. Then, the palatal splint is constructed.

PROTOCOL FOR TRADITIONAL CONCOMITANT TEMPOROMANDIBULAR JOINT AND ORTHOGNATHIC SURGERY

1. CT scan including the entire mandible, maxilla, and TMJs
2. Fabrication of stereolithic model with the mandible separated
3. Surgeon positions the mandible in its final position and fixates it
4. Removal of condyles and recontouring the lateral aspect of the rami and fossae if indicated
5. Model sent to TMJ Concepts for prostheses design, blueprint, and wax-up

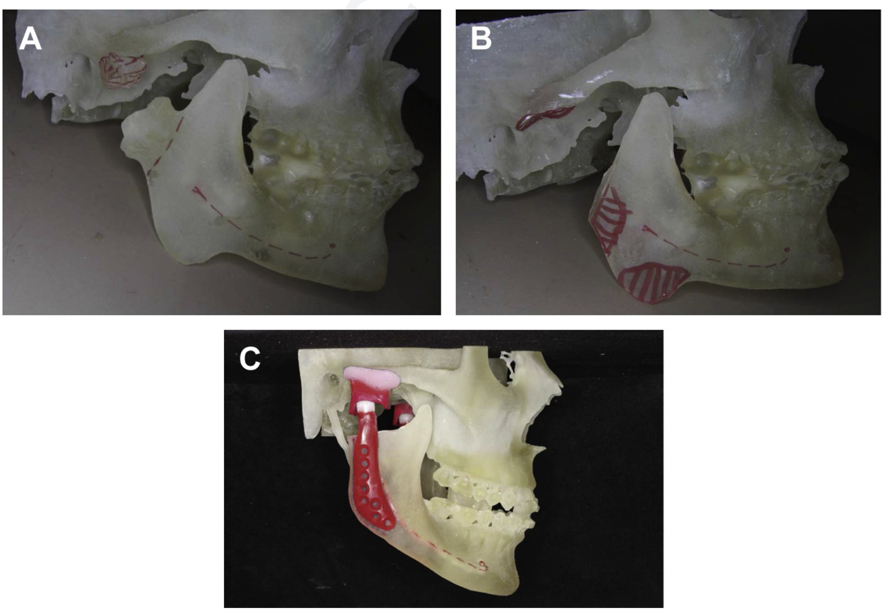

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Fig. 2. (*A*) Marking the condylectomy osteotomy and the irregularities of the fossa. (*B*) The stereolithic model after condylectomy and recontouring of the fossae and rami (marked in *red*). (*C*) Stereolithic model with prostheses wax-up for approval by the surgeon. (*From* Movahed R, Teschke M, Wolford LM. Protocol for concomitant temporomandibular joint custom-fitted total joint reconstruction and orthognathic surgery utilizing computer-assisted surgical simulation. J Oral Maxillofac Surg 2013;71(12):2123–9; with permission.)

6. Approval of total joint prostheses blueprint and wax-up by the surgeon
7. Manufacture of custom-fitted total joint prostheses
8. Prostheses sent to hospital for surgical implantation

STEPS IN TRADITION ORTHOGNATHIC SURGERY, AND INTERMEDIATE AND PALATAL SPLINT FABRICATION FOR CONCOMITANT TEMPOROMANDIBULAR JOINT AND ORTHOGNATHIC SURGERY

1. Acquisition of dental models
2. Mounting maxillary and mandibular dental models on an articulator
3. Repositioning the mandibular dental model, duplicating the positional changes acquired on the stereolithic model
4. Fabrication of intermediate splint
5. Repositioning maxillary dental models with segmentation if indicated
6. Construction of palatal splint
7. Ready for surgery

PROTOCOL FOR CONCOMITANT TEMPOROMANDIBULAR JOINT AND ORTHOGNATHIC SURGERY USING COMPUTER-ASSISTED SURGICAL SIMULATION

For CTOS cases, the orthognathic surgery is planned using Medical Modeling (Golden, CO) CASS technology and moving the maxilla and mandible into their final position in a computer-simulated environment (Fig. 3A, B). Using the computer simulation, the anteroposterior and vertical positions, pitch, yaw, and roll are accurately finalized for the maxilla and mandible based on clinical evaluation, dental models, prediction tracing, and computer-simulation analysis.

Using Digital Imaging and Communications in Medicine (DICOM) data, the stereolithic model is produced with the maxilla and mandible in the final position and provided to the surgeon for removal of the condyle and recontouring of the lateral rami and fossae if indicated (Fig. 4A). The stereolithic model is sent to TMJ Concepts for the design, blueprint, and wax-up of the prostheses. Using the Internet, the design is sent to the surgeon for approval. The custom-fitted total joint prostheses are then manufactured (see Fig. 4B). It takes approximately 8 weeks to manufacture the total joint custom-fitted prostheses.

Approximately 2 weeks before surgery, the final dental models are produced, including 2 maxillary models if the maxilla is to be segmented or dental equilibration is required. One of the maxillary models is segmented if indicated, dental equilibration is performed, and the segments are placed in the best occlusion fit with the mandibular dentition and maxillary segments fixed to each other. The dental models do not require mounting on an articulator. The 3 or 4 models (2 maxillary and 1 mandibular, or 2 mandibular models if equilibrations are done) are sent to Medical Modeling for scanning and simulation into the computer model. Because the authors routinely perform the TMJ reconstruction and mandibular advancement with the TMJ Concepts total joint prosthesis first, the unsegmented maxillary model is simulated into the original maxillary position and the mandible is maintained in the final position. The intermediate splint is constructed (see Fig. 3B), and then the segmented maxillary model is simulated into the computer model in its final position, with the maxilla and mandible placed into the best occlusal fit, and the palatal splint is fabricated. The dental models, splints, and images of the computer-simulated surgery are sent to the surgeon for implementation during surgery.

PROTOCOL OF CONCOMITANT TEMPOROMANDIBULAR JOINT AND ORTHOGNATHIC SURGERY USING COMPUTER-ASSISTED SURGICAL SIMULATION

1. CT scan of entire mandible, maxilla, and TMJs (1-mm overlapping cuts)
2. Processing of DICOM data to create a computer model in the CASS environment
3. Correction of dentofacial deformity, including final positioning of the maxilla and mandible, with computer-simulated surgery
4. Stereolithic model constructed with jaws in final position and sent to surgeon for condylectomy and rami and fossae recontouring if indicated
5. Model sent to TMJ Concepts for prostheses design, blueprint, and wax-up
6. Surgeon evaluation and approval using the Internet
7. TMJ prostheses manufactured and sent to hospital for surgical implantation
8. Two weeks before surgery, acquisition of final dental models (2 maxillary, 1 or 2 mandibular models if dental equilibrations are required); 1 maxillary model is segmented and models equilibrated if indicated to maximize the occlusal fit; models sent to Medical Modeling
9. Models incorporated into computer-simulated surgery for construction of intermediate and final palatal splints

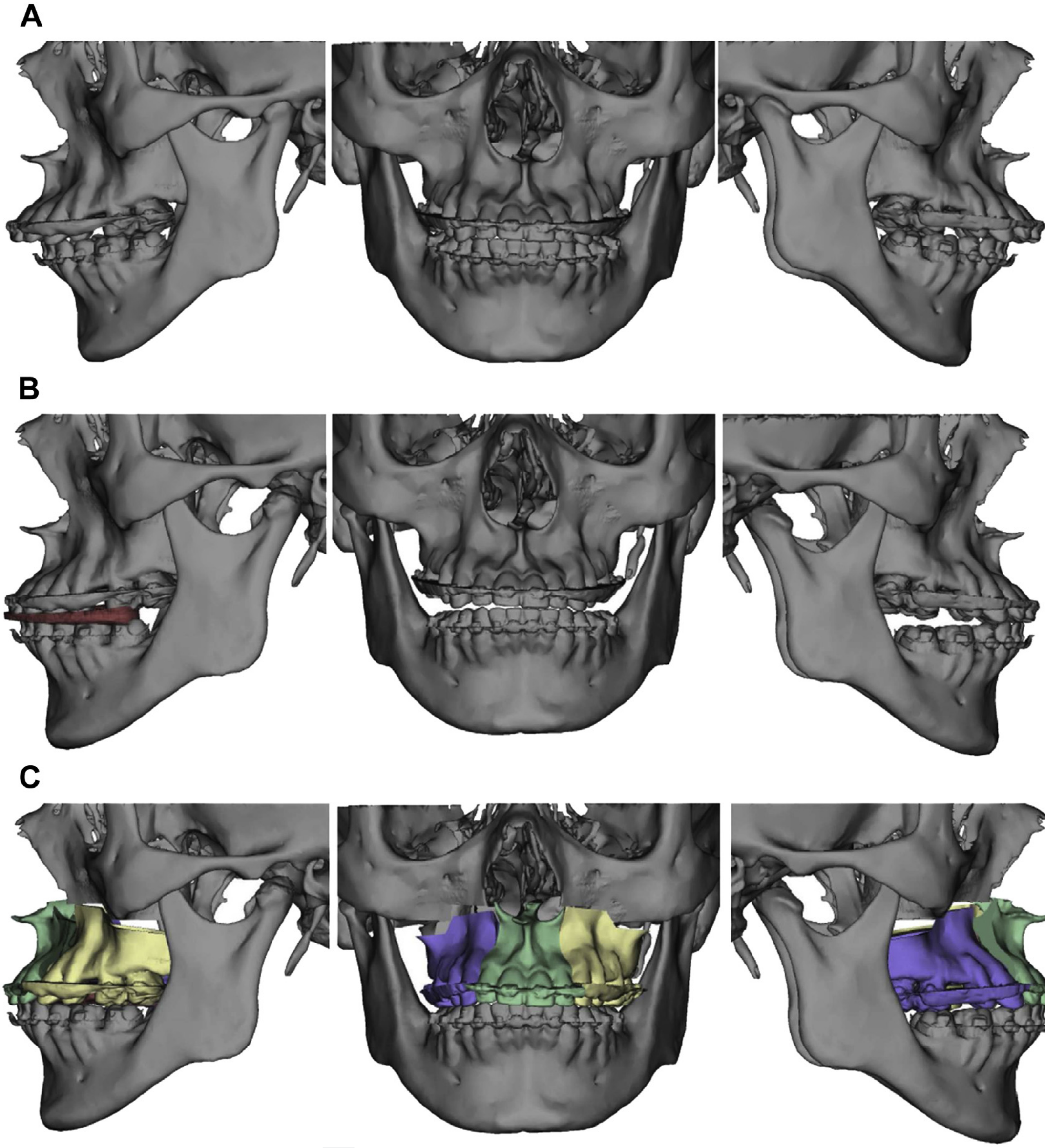

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Fig. 3. Staged computer-aided surgical simulation surgical report. (*A*) Simulated preoperative position of the maxilla and mandible. (*B*) The maxilla and mandible in the simulated intermediate position, with the maxilla in its original position, but the mandible in its final position with the mandibular surgery performed first for fabrication of the intermediate splint. (*C*) The final position of maxilla and mandible, after advancement of mandible and segmental osteotomy of the maxilla, for the production of a palatal splint. (*From* Movahed R, Teschke M, Wolford LM. Protocol for concomitant temporomandibular joint custom-fitted total joint reconstruction and orthognathic surgery utilizing computer-assisted surgical simulation. J Oral Maxillofac Surg 2013;71(12):2123–9; with permission.)

10. Models, splints, and printouts of computer-simulated surgery sent to surgeon

Using CASS technology for CTOS cases eliminates the 'traditional' steps requiring the surgeon to manually set the mandible into its new final position on the stereolithic model, thus saving time and improving surgical accuracy. Although dental model surgery is necessary only if the maxilla requires segmentation, the models do not require

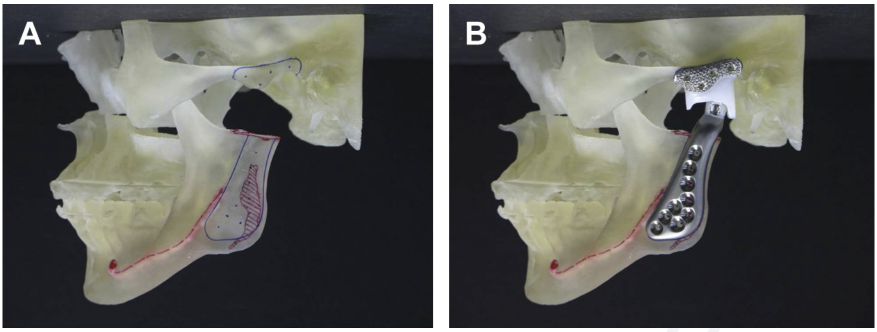

Fig. 4. (*A*) Stereolithic model fabricated after simulated maxillary and mandibular advancement to the final position. Condylectomy and recontouring of the lateral rami and fossae were performed (*red*) and sent to TMJ Concepts for construction of the prostheses. (*B*) Constructed patient-fitted TMJ prosthesis using the computer-aided surgical simulation fabricated stereolithic model. (*From* Movahed R, Teschke M, Wolford LM. Protocol for concomitant temporomandibular joint custom-fitted total joint reconstruction and orthognathic surgery utilizing computer-assisted surgical simulation. J Oral Maxillofac Surg 2013;71(12):2123–9; with permission.)

mounting on an articulator, which saves considerable time by eliminating the time required to mount the models, prepare the model bases for model surgery, reposition the mandible, construct the intermediate occlusal splint, and make the final palatal splint. With CASS technology, the splints are manufactured by Medical Modeling.

DISCUSSION

Using CASS technology for CTOS cases, the surgeon superimposes the orthognathic computer-simulated surgery into the production of the stereolithic model, hence decreasing the margin of error that can occur with hands-on positioning of the mandible on the stereolithic model. Furthermore, this technique decreases the time taken by the surgeon in the laboratory, by TMJ Concepts for the fabrication of prostheses, and for setting the stereolithic model with increased accuracy in the process.

The remaining areas in which improvement can be made in CASS technology include performing recontouring of the rami and fossae in the simulated environment in an accurate fashion, eliminating the requirement for the acquisition of dental models by using laser scanning technology, and performing accurate maxillary segmentation and equilibration using CASS technology. Further research is necessary to achieve this goal and to move the workflow directly from the CASS environment to the fabrication of custom-fitted TMJ Concepts prostheses, without requiring the surgeon to have 'hands-on' involvement in the process.

Pearls

1. Combined orthognathic and total joint reconstruction cases can be predictably performed in 1 stage.
2. Use of virtual surgical planning can eliminate a significant time requirement in preparation of concomitant orthognathic and TMJ prostheses cases.
3. The CTOS-CASS technique increases the accuracy of combined cases.
4. In order to have flexibility in positioning of the total joint prosthesis, recontouring of the lateral aspect of the rami is advantageous.

CASE

A 32-year-old woman was diagnosed with juvenile idiopathic arthritis in grade school, had orthodontics from 15 to 17 years of age with maxillary first bicuspids extractions, and developed an open bite at age 28 years (Figs. 5–9). Over the years she was treated conservatively with occlusal splints and arthroscopic surgeries. Her myofascial pain persisted over the years and worsened before her initial consultation. The maximal incisal opening measured with pain was 36 mm and without pain was 14 mm. Excursion movements to the right were 9 mm and to the left were 10 mm. Her surgery was planned using CTOS-CASS technology:

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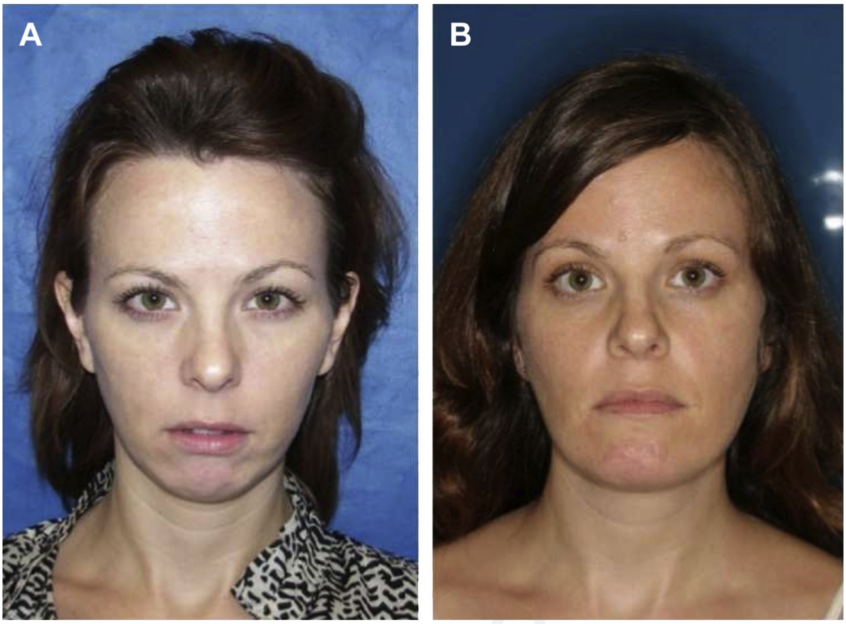

Q17 **Fig. 5.** Frontal view, before surgery (*A*) and 1 year after surgery (*B*).

1. Bilateral TMJ reconstruction and counter-clockwise rotation of the mandible with TMJ Concepts patient-fitted total joint prostheses
2. Bilateral TMJ fat grafts packed around the articulating area of the prostheses, harvested from the abdomen
3. Bilateral coronoidectomies

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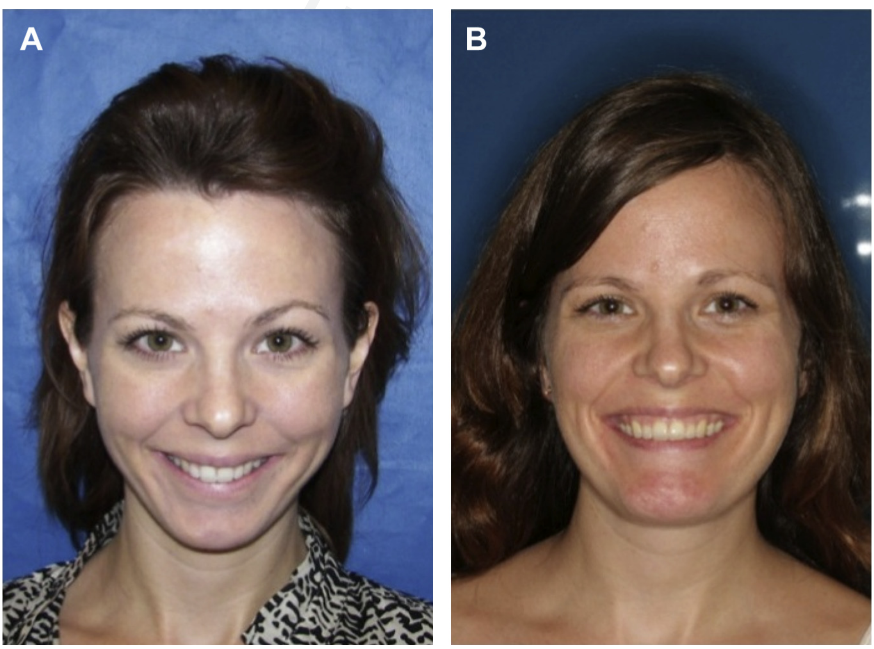

Fig. 6. Frontal view, smiling, before surgery (*A*) and 1 year after surgery (*B*).

Fig. 7. Profile view, before surgery (*A*) and 1 year after surgery(*B*).

4. Multiple maxillary osteotomies for counter-clockwise rotation and advancement
5. Bilateral partial inferior turbinectomies

One-year after surgery she reported no myofascial, TMJ, or headache pain and her incisal opening improved to 50 mm. Excursion movements were 4 mm to the right and 2 mm to the left. A class I occlusion was obtained and better facial harmony was achieved.

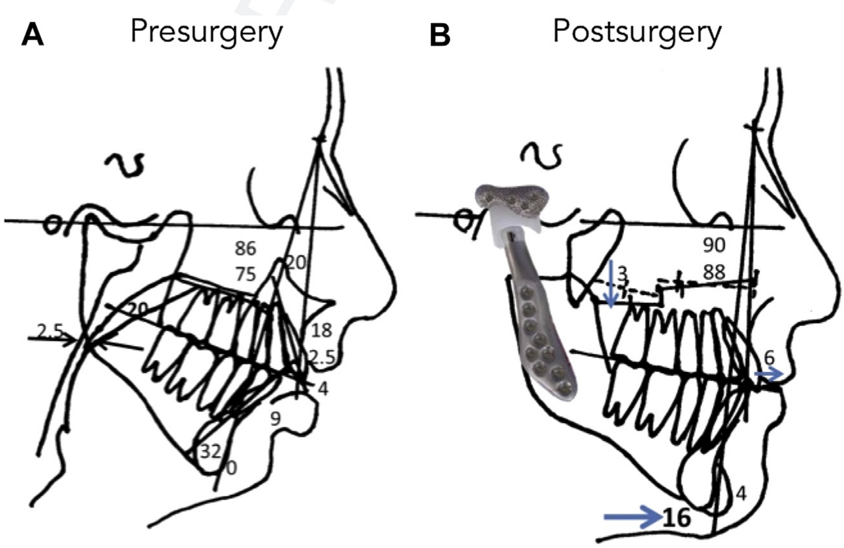

Fig. 8. Prediction analysis before surgery (*A*) and after surgery (*B*).

Fig. 9. Presurgery occlusion (*A–C*) and postsurgery occlusion 1 year after surgery (*D–F*).

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