Diagnosis and Management of TMJ Heterotopic Bone and Ankylosis

9

Larry M. Wolford

9.1 Introduction

Temporomandibular joint (TMJ) heterotopic bone refers to calcifications that develop in and around areas of the joint that are normally void of the bone. The development of heterotopic bone within the confines of a joint or in the surrounding area can cause joint dysfunction, pain, as well as progression to ankylosis. Temporomandibular joint ankylosis is a condition where the condyle is fused to the fossa by bony or fibrotic tissues creating a debilitating condition that can interfere with jaw function, mastication, speech, oral hygiene, growth and development, breathing, and normal life activities and cause pain. There are numerous surgical techniques that have been proposed to manage heterotopic bone and TMJ ankylosis with varying outcomes reported. The most common complications following the treatment of ankylosis are limited jaw function, pain, and re-ankylosis.

9.2 Etiology

The formation of TMJ heterotopic bone and ankylosis is most commonly caused from trauma but can also be related to inflammation or bone growth stimulation related to various TMJ pathologies such as infection, reactive arthritis, osteoarthritis, inflammatory conditions, connective tissue/autoimmune diseases (e.g., juvenile idiopathic arthritis, rheumatoid arthritis, psoriatic arthritis, ankylosing spondylitis, scleroderma, etc.), endocrine and metabolic disorders, multiply operated joints,

L.M. Wolford, DMD
Department of Oral and Maxillofacial Surgery, Texas A&M University College of Dentistry, Dallas, TX, USA

Department of Orthodontics, Texas A&M University College of Dentistry, Dallas, TX, USA
e-mail: lwolford@swbell.net

foreign-body giant-cell reaction, repeated injections of medications into the TMJ (i.e., steroids), as well as unsuccessful previous TMJ surgeries including failed TMJ autogenous grafts and alloplastic implants. Heterotopic bone in the initial phase may be asymptomatic, but with further development can create pain, decrease range of motion, and may lead to ankylosis. A variable amount of fibrosis and reactive tissue are normally associated with heterotopic bone, thereby worsening the adverse effects.

Bleeding into a joint by trauma or a surgical procedure as well as the presence of dead space following extensive TMJ debridement or reconstruction with autogenous bone or total joint prosthesis can lead to blood clot formation in the joint area, with subsequent organization. Pluripotential cells can then migrate into the area and differentiate into fibroblasts and osteoblasts, with deposition of collagen and then bone, respectively. This results in the potential for developing heterotopic bone and ankylosis. In excessively fibrotic joints, there is also a decrease in tissue vascularity with a resultant decrease in oxygen tension in the surrounding tissue. This can lead to the transformation of fibrous tissue into cartilage and bone with potential for ankylosis [1]. Temporomandibular joint ankylosis can be even more devastating in growing patients resulting in a profound dentofacial deformity in addition to jaw dysfunction and malocclusion.

9.3   Diagnosis

The diagnosis of TMJ heterotopic bone and ankylosis is usually determined by clinical examination and imaging studies such as CT scans, cone beam CT (CBCT), magnetic resonance imaging (MRI), and the three-dimensional reconstruction of images or stereolithic models. It is important to know the patient's TMJ history relative to age of onset, etiology, previous TMJ treatment, present age, current and past symptoms, medical history and conditions, other joint involvement, allergies, and history of hypersensitivity to metals particularly those used in TMJ total joint prostheses. Guidelines on patient evaluation and treatment for combined TMJ and orthognathic surgery have been previously published [2–8]. Patients with TMJ pathology resulting in heterotopic bone or ankylosis may present with facial symmetry and balance, or they can present with a retruded mandible with the potential for maxillary involvement and facial asymmetry. Patients may have a profound limited opening if the ankylosing bone is predominately cortical in nature or can have moderate opening if the bone is softer with a more cancellous bone composition. In unilateral cases, there may be deviation toward the ipsilateral side with jaw opening as the contralateral side may maintain translation. Patients may have a coexisting dentofacial deformity that was preexisting or developed as a result of the original TMJ injury and pathology or from the ankylosis.

Radiographic imaging may show heterotopic bone in and around the joint area and is best seen on CBCT imaging (Fig. 9.1a, b). The ability of CBCT scans to identify newly developing heterotopic bone may be difficult with the presence of total joint prostheses due to scatter. A medical-grade CT scan is better than CBCT for identifying heterotopic bone around a TJP because of the higher resolution and
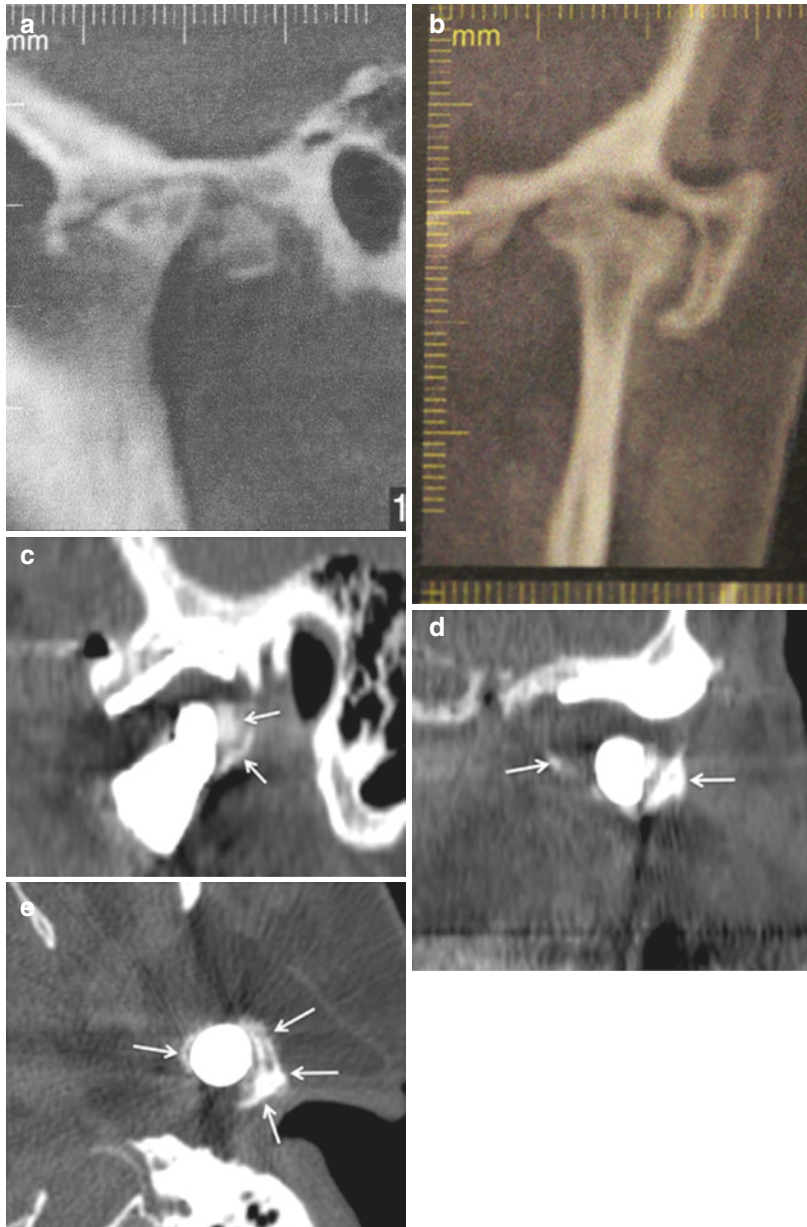
Fig. 9.1 (**a, b**) 22-year-old female with history of adolescent internal condylar resorption (AICR). She had multiple steroid injections into the TMJ resulting in heterotopic bone formation. (**a**) CBCT left TMJ sagittal view and (**b**) coronal view. (**c–e**) 53-year-old female patient with multiple previous surgeries including failed Proplast-Teflon material. Patient was reconstructed with a custom total joint prostheses, but developed heterotopic bone around the prosthesis in reaction to the residual Proplast-Teflon materials, at 10 years postsurgery, creating severe pain and limited jaw function. (**c**) CT scan left sagittal view with *white arrows* pointing to the heterotopic bone, (**d**) coronal view, (**e**) axial view
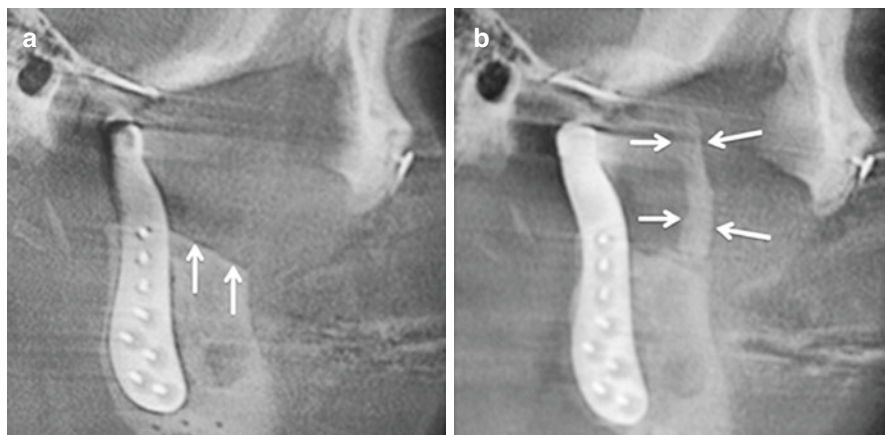
Fig. 9.2 (a, b) Coronoid area heterotopic bone formation; 15-year-old female with history of juvenile idiopathic arthritis treated in a single surgery with bilateral TMJ Concepts prostheses, maxillary osteotomies, TMJ fat grafts, and coronoidectomies. (a) Right TMJ immediate postsurgery showing level of coronoidectomy (*white arrows*). (b) 4 months postsurgery; patient developed heterotopic bone in the original coronoid process area (*white arrows*)

quality (Fig. 9.1c–e). However, when the previous TMJ reconstruction is autogenous, either imaging technique will usually be diagnostic. Heterotopic bone most commonly develops around the TMJ on the medial side, followed by posterior, anterior, and lateral aspects. Heterotopic bone and ankylosis can also develop in the coronoid area (Fig. 9.2a, b). This may require a different approach for management as compared with heterotopic bone associated directly with the TMJ.

When TMJ bony ankylosis occurs during the growing years, it can adversely affect jaw growth and development. The common clinical and radiographic characteristics of TMJ ankylosis include decreased jaw mobility and function, decreased growth on the involved side(s), facial asymmetry if unilateral involvement with the mandible shifted toward the ipsilateral side, retruded mandible, a Class II occlusion, high occlusal plane angle facial morphology, and imaging evidence of bony ankylosis at the condyle/fossa area.

9.4 Treatment Options

The ultimate goal in treatment of TMJ heterotopic bone formation and ankylosis is to return the patient to normal function with stable skeletal and occlusal results, correct associated facial and occlusal deformity, decrease pain, and prevent redevelopment of heterotopic bone and re-ankylosis.

Multiple surgical options have been proposed to treat TMJ ankylosis including gap arthroplasty, interpositional arthroplasty, and autogenous or alloplastic total joint reconstruction. Autogenous tissues that have been used after gap arthroplasty include ear cartilage, temporalis muscle flap, dermis, and fat. Some alloplastic

materials such as Proplast Teflon®[1], Silastic®[2], and metal fossa liners have also been used, but with higher failure rates [9, 10].

Total joint reconstruction can be divided into autogenous tissue replacement such as costochondral (CCG) and sternoclavicular grafts (SCG) [11–14] or alloplastic total joint prosthesis (TJP) reconstruction. The CCG has had mixed results in TMJ reconstruction [15–18]. Costochondral grafts and SCG grafts used for ankylosis in adults or children have common postoperative complications including re-ankylosis (resorption, no growth, overgrowth) [19, 20], fracture, and pain. Sternoclavicular grafts have growth potential for younger patients similar to the mandibular condyle, and a section of the SCG articular disc can be harvested with the SCG providing the potential for better function, but re-ankylosis is still a significant risk [14].

Wolford and colleagues [21–33], Mercuri and colleagues [34–44], and others [45–47] have validated the successful use of TMJ Concepts™[3] patient-fitted TJP for TMJ reconstruction. The TMJ Concepts devices are computer-assisted-designed/computer-assisted-manufactured (CAD/CAM) devices, designed and manufactured to fit the specific anatomical, functional, and esthetic requirements of each specific patient. Temporomandibular joint TJP by themselves may not prevent heterotopic bone development and re-ankylosis, particularly in the presence of significant inflammatory disease and previous ankylosis [27, 48].

9.4.1 Nonsurgical Options

In the orthopedic experience, various pharmacologic agents, most notably indomethacin and etidronate, have been used with varying success in preventing heterotopic bone in hip and knee TJP reconstruction [49, 50]. Pharmacologic therapy has been suggested for use after TMJ TJP reconstruction, but no data exists regarding its effectiveness. Radiation treatment of the operated area within 4 days of prosthetic hip reconstruction is now a common practice and appears to offer an effective means of preventing heterotopic bone formation in orthopedics. However, local radiation of the TMJ raises concerns regarding potential adverse effects on adjacent vital structures. The use of postoperative radiation (10Gy) following CCG, gap arthroplasty, or debridement of heterotopic bone has been shown to still result in heterotopic bone in 33–50% of cases [51, 52].

9.4.2 Gap Arthroplasty and Grafts

Various techniques have been used to treat TMJ ankylosis including gap arthroplasty with or without tissue grafts and flaps. The long-term functional results after gap arthroplasty and interpositional grafting have been shown to be comparable to those obtained through use of other treatments [53]. However, the incidence of

---

[1] ®Vitek Inc., Houston, TX.

[2] ®Dow-Corning, Midland, MO.

[3] ™TMJ Concepts, Ventura, CA.

re-ankylosis with gap arthroplasty does appear to be higher than with CCG [54]. An additional problem with gap arthroplasty either with or without an interposing tissue is the vertical stability of the mandible and the occlusion.

Topazian compared gap arthroplasty with interpositional arthroplasty in TMJ ankylosis surgery and found interpositional arthroplasty to provide more favorable results [55]. The use of temporalis myofascial flaps and dermal grafts also appear to produce satisfactory results [56]. Similar results have been reported with the use of dermis-fat grafts [57–59]. The pedicled vascularized temporalis myofascial flap continues to be a relatively predictable and stable interpositional graft following gap arthroplasty. The ability of this flap to prevent heterotopic bone is less clear in part due to the lack of a critical-sized defect with this flap.

Concomitant use of CCG and the temporalis myofascial flap has also been reported to be successful in maintaining the occlusion with good functional outcomes and decreased pain [60–62]. The disadvantages of CCG are the poor quality of medullary and cortical bone, the possibility of resorption or infection, bone flexibility, elasticity that may cause the graft to be deformed, possible separation of the cartilage from the bone, and occasional fractures. Furthermore, the inherent growth potential of CCG can result in unpredictable growth.

9.4.3 Fat Grafts

The first reported use of autologous fat graft placement into the TMJ for the treatment of ankylosis is more than 100 years old [63, 64]. Wolford reported a technique of placing autogenous fat grafts around TJP to prevent postsurgical heterotopic bone and fibrosis development in 1992 [48]. The rationale for placing autologous fat grafts around the TMJ TJP was to obliterate the dead space surrounding the prosthesis, thus preventing the formation and subsequent organization of a blood clot. Creating this physical barrier, the fat grafts serve to reduce the differentiation of pluripotential cells and prevent the formation of extensive fibrosis and heterotopic calcification. Fat grafts have been shown to inhibit osteogenesis in other bone defects [65]. The fate of fat grafts has also been described with the graft going through a period of initial breakdown of fat cells, followed by revascularization, resulting in normal appearing fat, although a smaller volume than originally grafted [66]. The early and adequate revascularization of autogenous fat grafts for maintenance of graft volume and for the production of adipocyte-derived angiogenic peptides such as vascular endothelial growth factor (VEGF) and leptin which are important for graft survival and volume maintenance has been reported [67, 68]. However, following free fat grafting, the fat shows features of ischemia with adipocytes releasing lipid and dedifferentiating to pre-adipocytes. After revascularization, the pre-adipocytes begin to absorb lipid and develop into mature adipocytes with the fat grafts almost normal at 6 months [69].

The use of fat grafts around TMJ TJP has been shown to be superior to no fat grafting when evaluating both maximum incisal opening, the development of heterotopic bone, and re-ankylosis [31, 48, 70–72]. The importance of using fat grafts to prevent heterotopic bone may be even more important in those patients who have had Proplast-Teflon and Silastic implants given the increase inflammatory response
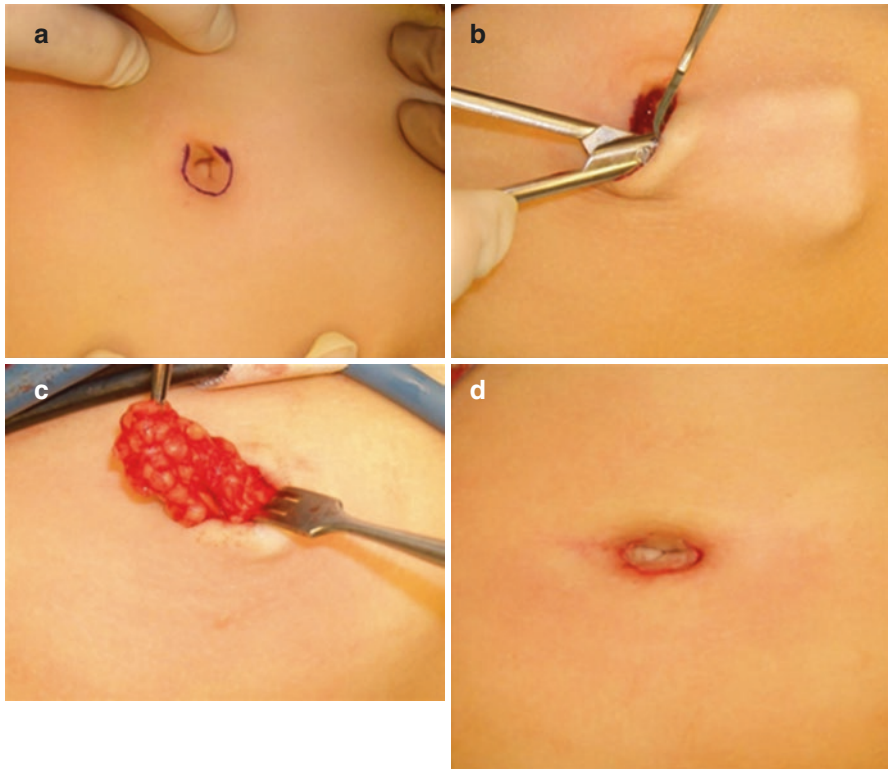
Fig. 9.3 (**a**) Umbilical incision outlined. (**b**) Following incision, a superficial and deeper dissection is completed. (**c**) Fat being delivered. (**d**) Incision closed

within the TMJ tissues and the likelihood of heterotopic bone formation [26, 27]. Despite the apparent benefit to the use of fat grafts in preventing heterotopic bone, complications at the donor site have been reported to occur in about 10% of patients with abdominal cysts and seroma formation the most common.

The ultimate fate of the transplanted fat around the TMJ is unknown. Studies of fat transplantation to other anatomic areas show a variable amount of resorption, with a decrease in volume ranging from 20 to 75% [73, 74]. As an adjunct to TMJ prosthetic joint reconstruction, the ultimate resorption of a portion of the graft may not be detrimental to the result. If the formation of the initial hematoma, fibrosis, and reactive tissue can be prevented by placement of the fat grafts, there may be reduced incidence of complications.

The most common donor site for fat harvesting is the abdomen, where there is usually abundant or at least adequate fat for most cases. The most common approaches the author uses include the supra-pubic incision, the umbilical or trans-naval incision (Fig. 9.3a–d), or approach through a preexisting scar (e.g., C-section, hysterectomy, appendectomy, abdominoplasty). However, the fat can be harvested from almost any fat source including the buttock, thigh, buccal fat pad, or breast. Following fat harvest, good hemostasis of the donor site is required and a pressure dressing applied
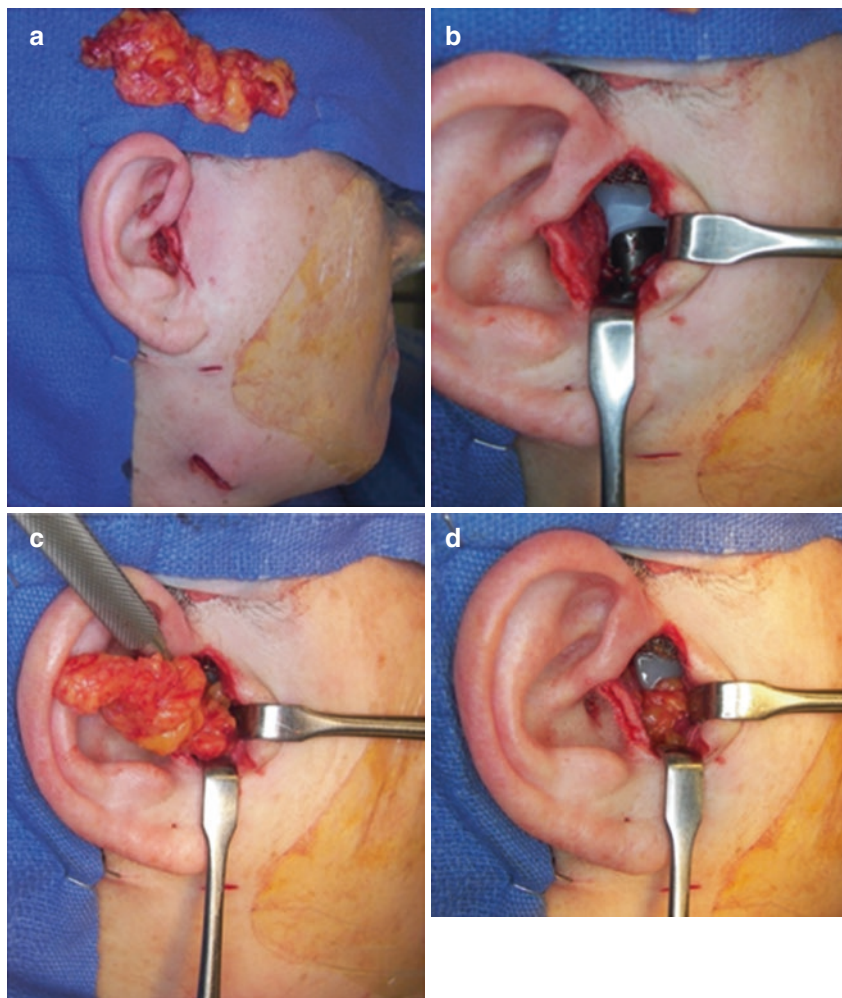
Fig. 9.4 (**a**) Harvested fat ready for implantation. (**b**) Total joint prosthesis visualized. (**c**) Fat packed around prosthesis medially, posterior, anterior, and lateral. (**d**) Fat packing completed

along with an abdominal binder (for abdominal donor site) for 3–4 days postsurgery to prevent hematoma or seroma formation. If adequate hemostasis cannot be achieved, then a drain with negative pressure may be indicated for a few days.

Fat grafts are harvested just prior to graft placement, requiring only about 20 min of additional surgical time. However, some surgeons may prefer to have two surgical teams working concurrently so the overall operation is not prolonged. It is not recommended to harvest the fat grafts prior to beginning the TMJ reconstruction as this would require the grafts to be "on the table" for an extended time period, likely to result in significant loss of graft viability. It will usually take a minimum of 4 h to prepare the TMJs and place the prostheses in bilateral cases, before the fat grafts can be placed (Fig. 9.4a–d). Therefore, procuring the fat graft

just prior to placement will maximize graft viability, an important factor for graft survival. We recommend harvesting the fat graft in bulk and not procuring with liposuction as this can severely damage the fat cells providing poorer quality of results with greater fat resorption.

9.4.4 Ankylosis in Autogenous Reconstruction Versus Total Joint Prostheses (TJP)

The incidence of re-ankylosis following joint reconstruction with CCG or SCG when not using a fat graft has been reported to be 100 and 75%, respectively [75]. Furthermore, the CCG and SCG resulted in excessive growth or relapse, while SCG and TJP reconstruction with fat grafting resulted in stability and no re-ankylosis. Long-term surgical stability and improved subjective and objective outcomes have also been reported in patients undergoing maxillomandibular advancement with TJP when compared to CCG and SCG [76]. The incidence of complications requiring additional surgery has also been reported to be significantly higher in autogenous reconstruction compared to TJP [77].

9.5   Surgical Protocol for Managing Heterotopic Bone

A complication that may be encountered following TMJ reconstruction with autogenous tissues or alloplastic TJP involves heterotopic bone formation in and around the TMJ. This can result in pain and decreased function. When heterotopic bone develops around an autogenous TMJ graft and is symptomatic, the most predictable treatment protocol includes removal of the autogenous graft and heterotopic bone, reconstruction with a total joint prosthesis, and placing fat graft around the articulating area of the prosthesis. Heterotopic bone that forms around a TJP is best managed by debridement and removal of the heterotopic bone and placing a fat graft around the articulating area of the prosthesis. The debridement can usually be done without removal of the prosthesis although if needed the condyle component can be removed to improve access, re-sterilized, and secured back to the ramus with larger screws. The fossa component should not be removed as this would require a new fossa prosthesis as this component cannot be re-sterilized.

Heterotopic bone and ankylosis can develop in the coronoid area, although uncommon, following coronoidectomy usually related to an inflammatory process or connective tissue/autoimmune disease, independent of the TMJ pathology (Fig. 9.5a, b). The bone usually develops along the path of the temporalis muscle tendon, even though the muscle may have been previously detached. It can develop in the presence of TMJ reconstruction with either autogenous tissue or TJP reconstruction. In some cases, the bone can extend posteriorly toward the joint. This coronoid-related heterotopic bone can cause pain, headaches, and decreased jaw function. It can usually be identified on CBCT, CT scans, or a panorex. The treatment protocol includes an intraoral approach to the coronoid area with a vertical
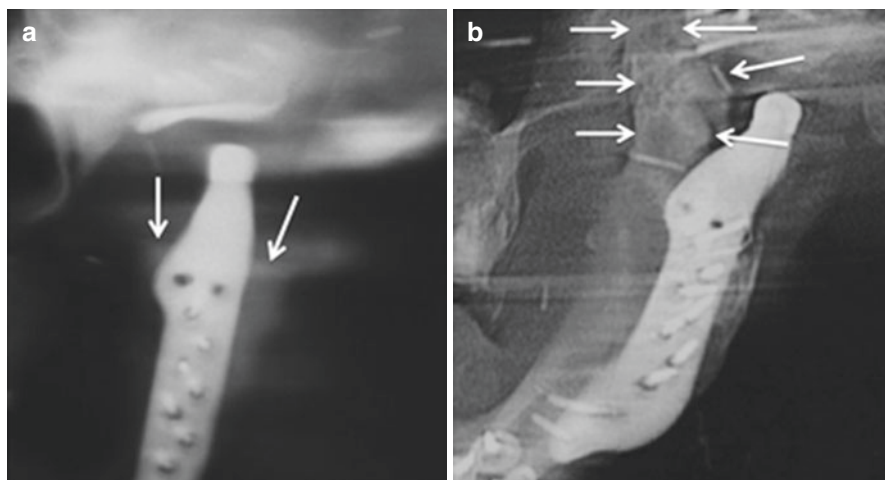
Fig. 9.5 (**a**, **b**) 36-year-old hemifacial microsomia male patient with three failed previous rib grafts to left TMJ, all resulting in re-ankylosis. (**a**) Immediate postsurgery left TMJ tomogram showing TMJ custom TJP, fat graft, and level of bone cut at ramus (*white arrows*). (**b**) Redevelopment of heterotopic bone at coronoid area 6 years postsurgery, causing pain and limited jaw movement (*white arrows*). No bone formation directly around mandibular condylar component where fat grafts were previously placed

incision at the anterior aspect of the ramus, identification and resection of the heterotopic bone, and placement of a fat graft. It remains imperative that the TJP not be exposed during this process.

9.6   Surgical Protocol for Managing TMJ Ankylosis

Two-stage surgery is the most common and more fail-safe approach for patient-fitted prostheses. This may not be necessary for stock prostheses, but the altered anatomy can make a stock joint very challenging or impossible to fit. Stage one surgery involves releasing the ankylosis on a stereolithographic model during planning, duplicating heterotopic and reactive bone removal at surgery, debridement of the joint, recontouring the fossa, and placement of an alloplastic spacer such as silastic or polymethyl methacrylate cement, with or without maxillomandibular fixation (surgeon's option). A CT scan of jaws in the final occlusion or corrected by virtual surgical planning is then completed to produce a 3-D stereolithic model to aid the construction of the TJP to be inserted at stage two surgery (Fig. 9.6a–d).

If orthognathic surgery to correct a dentofacial deformity is also planned, virtual surgical planning (VSP) can then be completed to place the mandible and maxilla into the final position prior to construction of a 3D stereolithic model. If VSP is not available, a stereolithic model can be prepared from the CT scan and the maxillo-mandibular complex repositioned and ramus modified to ensure a 20 mm gap
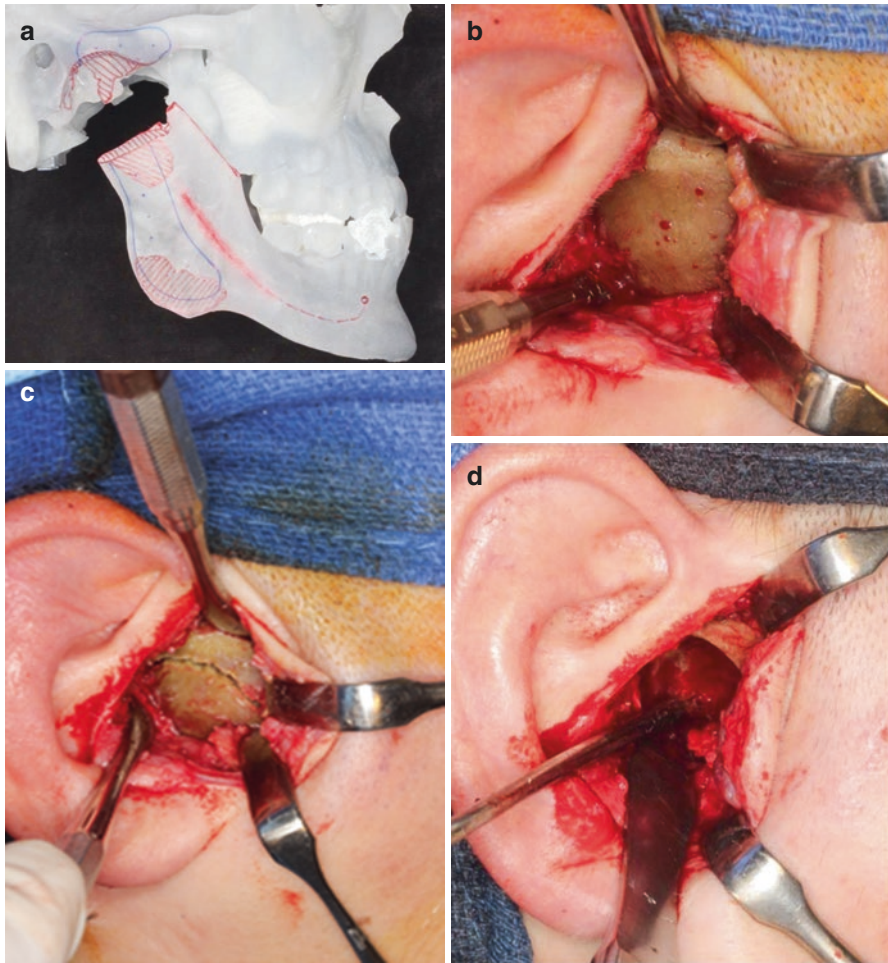
Fig. 9.6 (**a**) Presurgical model preparation with release of ankylosis, removal of condyle and heterotopic bone, joint debridement, creation of 20 mm space between fossa and ramus to accommodate the prosthesis. (**b**) Ankylosis of right TMJ with no clear delineation between condyle and fossa. (**c**) Bone cut through buccal cortex to define inferior rim of fossa. Heterotopic bone carefully removed. 20 mm vertical gap created between fossa and mandibular ramus to accommodate prosthesis. (**d**) Fossa debrided and recontoured to original bone level

between the glenoid fossa and the top of the ramus that is required to accommodate the TJP. The TJP can then be manufactured (Fig. 9.7a–c).

Stage-two surgery involves removing the spacer placed at stage one and debridement of the TMJ area. Contralateral mandibular ramus sagittal split osteotomy can be performed in an ipsilateral ankylosis requiring mandibular advancement followed by mobilizing of the mandible with counterclockwise rotation if indicated. Bilateral TMJ ankylosis will not require SSO as the mandible is advanced through the bilateral TJP but coronoidectomies will be necessary. The mandible is then
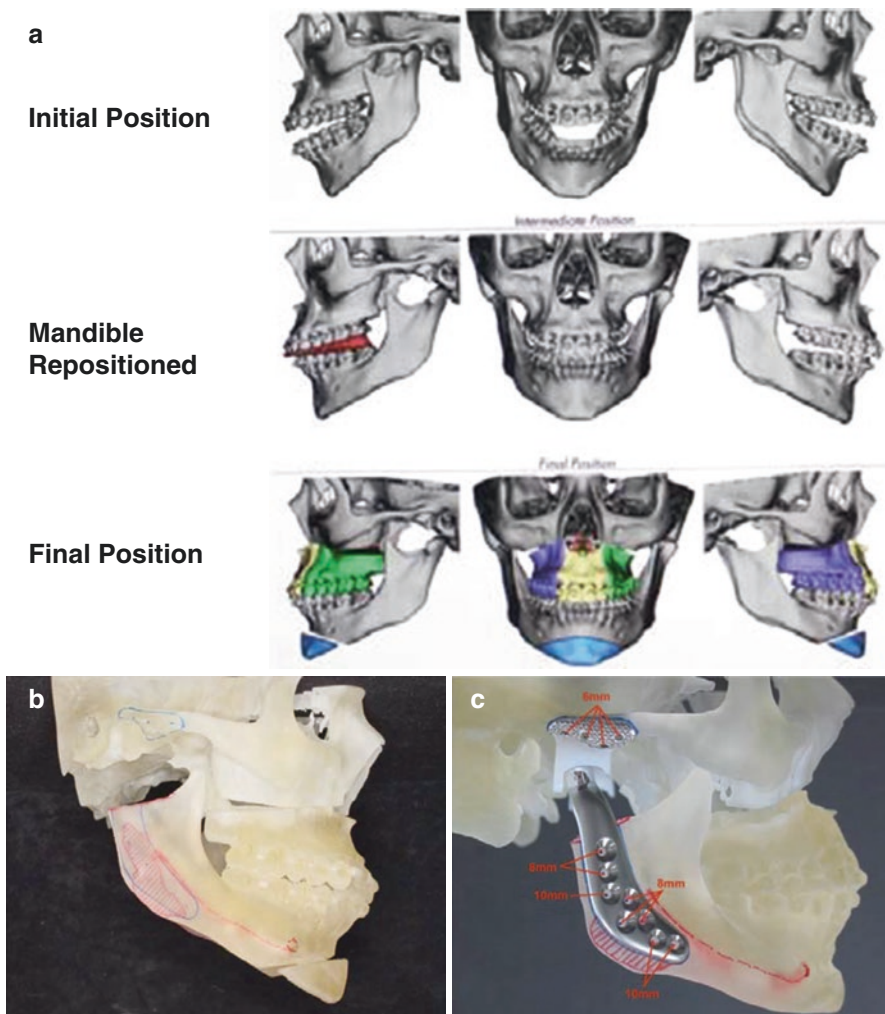
Fig. 9.7 (**a**) Virtual surgical planning (VSP) completed on the computer with the three primary stages printed out. (**b**) Stereolithic model printed with jaws in final position for presurgical preparation. (**c**) TMJ prosthesis manufactured on stereolithic model with suggested screw lengths listed

correctly positioned using the intermediate splint and intermaxillary fixation followed by implantation of the TMJ TJP and packing of fat graft around the articulating area of the prosthesis and closure of the TJP incisions (Figs. 9.4 and 9.6). In unilateral cases, the contralateral sagittal split osteotomy can then be fixated followed by performing the maxillary osteotomies if indicated. An advantage of two-stage surgery in ankylosis cases, particularly with decreased incisal opening that does not allow acquisition of dental impressions and models, is that after stage one, improvement in incisal opening may allow procurement of dental models to

facilitate construction of surgical splints. For one-stage surgery, the splints can be constructed by the VSP company from the computer generated model but are not as accurate.

The technique for one-stage surgery requires substantial surgeon experience and skill to prevent unfavorable outcomes and complications. A CT scan of jaws and TMJs is completed prior to VSP to complete the ankylosis release and place the mandible in the final position. Conversely, a 3D stereolithic model can be made, and the surgeon can complete the ankylosis release and reposition the mandible manually. The custom-fitted prostheses can then be made. The challenge comes during the surgery in that the surgeon must accurately duplicate the planned surgery from the VSP or stereolithic model during the patient's procedure. Failure to complete this adequately may prevent the custom TJP from fitting. Concomitant orthognathic surgery can also be performed in one-stage surgery although again the surgeon's ability to complete the TMJ and orthognathic surgery depends on the ability to duplicate the planned ankylosis release and bone removal intraoperatively.

With the two-stage or one-stage surgery, if orthognathic surgery is also planned, VSP can greatly assist with positioning the mandible and maxilla in their final position [78–81]. Dental models are procured, dental model surgery performed, and models sent to the VSP Company for incorporation into the computer-simulated model. Obtaining dental models can be difficult or impossible to obtain due to the ankylosis which may influence the choice of one-stage versus two-stage surgery, the possibility for concomitant orthognathic surgery, or the ability to use intraoperative splints. In cases requiring double-jaw surgery with the total joint prostheses, it is usually easier to reposition the mandible to its final position first utilizing the intermediate splint and then placing the TMJ prostheses to stabilize the mandible in its new position, followed by repositioning the maxilla and then other ancillary procedures [80, 81].

9.7   Pediatric Considerations

In pediatric cases with bilateral TMJ ankylosis requiring double-jaw orthognathic surgery, females who are 13 years or older and males 15 years or older can be treated with the adult protocol as described above in a single surgical stage. This is because the total joint prostheses have no growth potential, and the maxilla will have no anteroposterior growth after the Le Fort I osteotomy, so the occlusion will remain stable although the subsequent facial growth vector will be downward and backward until cessation of the vertical alveolar bone growth [82–84]. Unilateral TMJ ankylosis can usually be treated in one surgical stage at age 15 years for females and 17–18 years for males with highly predictable results without potential adverse effects of normal jaw growth of the contralateral mandible. The above referenced ages for surgical intervention are guidelines established by the author, but there may be growth maturation differences for individual patients that require consideration and may alter the timing for surgical intervention. However, in TMJ

ankylosis cases, early surgery may be indicated for functional, pain, or psychological reasons.

It has not been established as to how young a patient can be treated with a total joint prosthesis. However, in younger pediatric cases (ages 6 years or older), the treatment protocol can be separated into two stages. The first surgical stage includes release of the ankylosed TMJ, removal of the condyle, heterotopic and reactive bone, coronoidectomy if the ramus is to be significantly vertically lengthened or advanced, placement of TJP, fat graft and contralateral sagittal split, or inverted "L" osteotomy of the ramus if the mandible is being lengthened. In these younger patients, maxillary osteotomies are not recommended due to adverse effects on maxillary growth.

If surgery is performed at an early age, the patient should be followed until maxillofacial growth has been completed at approximately 15 years of age in females and 17–18 years of age in males [85, 86]. At this point, the residual dentofacial deformity and malocclusion can be reevaluated and corrected by maxillary and mandibular orthognathic surgery. For the second surgical stage, the case is treated as a typical dentofacial deformity case with a sagittal split osteotomy on the contralateral side if the patient was originally with a unilateral ankylosis, mandibular advancement, and maxillary surgery. The advancement of the mandible on the TMJ total joint prosthesis side can be accomplished by one of the four surgical options including extraoral sagittal split ramus osteotomy; intraoral ramus sagittal split osteotomy; advancing the mandible forward relative to the prosthesis by removing the screws from the mandibular component, advancing the mandible, and re-fixating the prosthesis with bone screws to the mandible in its new position; or replacing the mandibular component of the total joint prosthesis with a new longer mandibular component that would be reattached to the mandibular ramus after the mandible is moved into its new position.

Wolford and colleagues [21–33, 75, 76], Mercuri and colleagues [34–44], and others [45–47] have published numerous studies in reference to outcome data using TMJ Concepts patient-fitted TJP. A summary of these publications has produced the following facts in reference to these TJP: (1) TMJ Concepts patient-fitted TJP are superior to autogenous tissues for end-stage TMJ reconstruction relative to subjective and objective outcomes. (2) After two previous TMJ surgeries, autogenous tissues have a high failure rate, whereas patient-fitted total joint prostheses have a high success rate. (3) No donor site morbidity (except for the fat graft donor site). (4) Increased number of previous TMJ surgeries produces a lower level of improvement related to pain and function outcomes compared to patients with zero to one previous TMJ surgeries. (5) Failed TMJ alloplastic reconstruction (i.e., Proplast-Teflon, Silastic, metal-on-metal articulation) can create a foreign-body giant-cell reaction and/or metallosis, best treated by joint debridement and reconstruction with patient-fitted total joint prostheses. (6) Fat grafts packed around the articulating area of the prostheses improve outcomes relative to decreased pain, improved jaw function, and decreased requirement for repeat surgery. (7) Osseointegration of

the TMJ Concepts fossa and mandibular components occurs and is important for long-term stability. (8) Posterior stop on the fossa component is important to stabilize the joint, jaw position, and occlusion. (9) Concomitant orthognathic surgery can be performed at the same time as the TMJs are reconstructed. (10) A 20-year follow-up study demonstrated improvements in pain, jaw function, diet, incisal opening, and quality of life as well as no requirements for prosthesis replacement due to wear or material failure [29].

For adult and most pediatric patients with TMJ heterotopic bone or ankylosis, with or without a coexisting dentofacial deformity, the most predictable method to address the TMJ pathology and jaw deformity includes TMJ reconstruction using patient-fitted TJP, fat grafts packed around the articulating area of the prostheses, and concomitant orthognathic surgery if indicated.

9.8   Case Presentation

A 15-year-old male presented with limited opening, jaw deformity, and difficulty in eating. The right TMJ ankylosis occurred before 4 years of age necessitating a rib graft at 6 years which re-ankylosed. Debridement of the right TMJ at 9 years was followed by re-ankylosis shortly after surgery. At age 15 years, he reported no TMJ pain, myofascial pain, or headaches. Jaw function was self-rated as poor. Examination showed he had a retruded maxilla and mandible, facial asymmetry with the mandible shifted significantly toward the right side. There was a transverse cant in the occlusal plane with the right side being elevated 4 mm compared to the left side. Maximal incisal opening was 12 mm. The patient's diagnoses included right TMJ ankylosis, left TMJ arthritis, and articular disc dislocation without reduction, maxillary anteroposterior and posterior vertical hypoplasia, mandibular anteroposterior and posterior vertical hypoplasia, occlusal cant, high occlusal plane angle, severely decreased oropharyngeal airway, Class I cuspid relationship on the right side, and Class II cuspid relationship on the left side (Fig. 9.8a–g).

The patient's treatment plan was as follows:

1. CT scans of jaws and jaw joints (Fig. 9.9a)
2. Cephalometric analysis and surgical treatment objectives (Fig. 9.9b, c)
3. One-stage surgery to:
    (a) Release of right TMJ/mandibular ankylosis with removal of heterotopic bone
    (b) Bilateral TMJ TJP reconstruction and mandibular advancement with counterclockwise rotation
    (c) Multiple maxillary osteotomies to advance in a counterclockwise direction
    (d) Left coronoidectomy

Fig. 9.8 15-year-old male with right TMJ ankylosis, retruded maxilla and mandible, facial asymmetry, and limited jaw function. (**a**) Frontal view, (**b**) frontal view smiling, (**c**) profile view, (**d**–**f**) occlusion
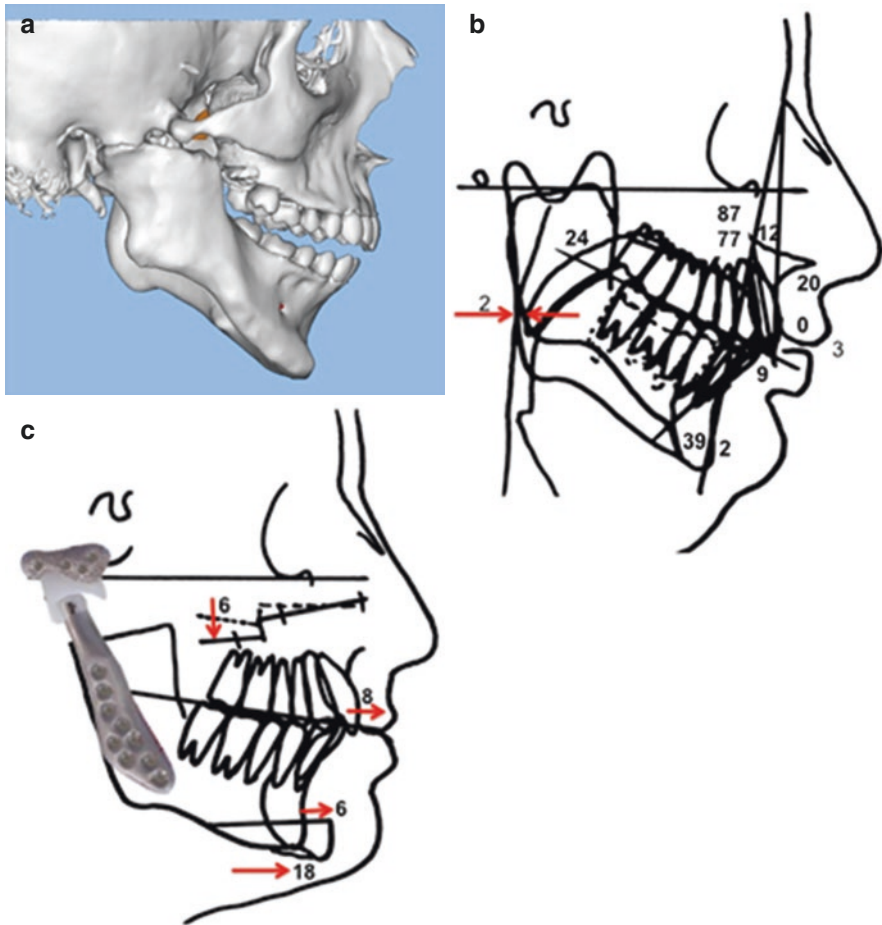
Fig. 9.9 (**a**) Presurgery 3D CT scan shows the ankylosed right TMJ. (**b**) Presurgical cephalometric analysis demonstrating retruded maxilla and mandible as well as the high occlusal plane angle facial morphology. (**c**) The surgical treatment objective demonstrates the counterclockwise rotation of the maxillomandibular complex and bony genioplasty with improved facial balance as the maxillary incisors advance 8 mm, pogonion advances 18 mm, and the occlusal plane decreases 16°
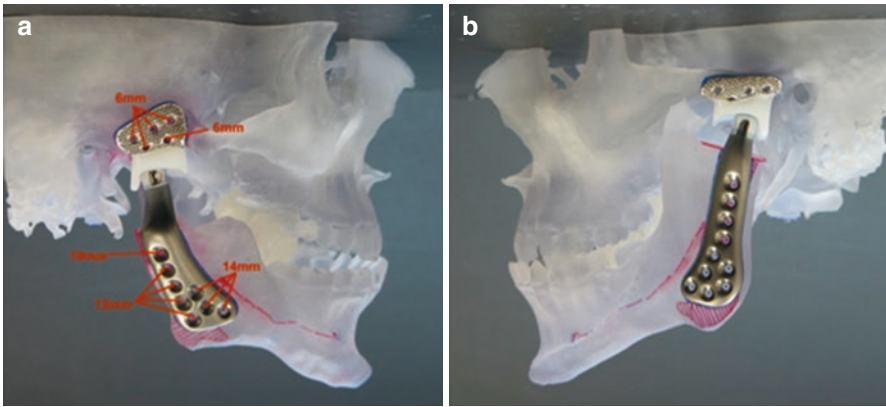
Fig. 9.10 (**a**, **b**) Photos of manufactured TMJ Concepts total joint prostheses on the stereolithic model for this case presentation, (**a**) right TMJ prosthesis, (**b**) left TMJ prosthesis

Fig. 9.11 (**a–f**) The patient is seen 5 years postsurgery with improved facial balance and function: (**a**) frontal view, (**b**) frontal view smiling, (**c**) profile view, (**d–f**) occlusion

(e) Bilateral TMJ fat grafts packed around the articulating areas of the total joint prostheses

(f) Genioplasty (6 mm) (Fig. 9.10a, b)

Follow-up at 5 years revealed a stable result with good facial symmetry, no pain, and normal range of motion (Fig. 9.11a–f).

References

1. Hall BK. Cartilage. Biomedical aspects. New York: Academic Press; 1988. p. 322–3.
2. Wolford LM, Cassano DS, Goncalves JR. Common TMJ disorders: orthodontic and surgical management. In: McNamara JA, Kapila SD, editors. Temporomandibular disorders and orofacial pain: separating controversy from consensus, Craniofacial Growth Series, vol. 46. Ann Arbor (MI): The University of Michigan; 2009. p. 159–98.
3. Wolford LM, Movahed R. Concomitant TMJ and orthognathic surgery: diagnosis and treatment planning. Oral and maxillofacial surgery knowledge update. Chicago: AAOMS; 2014.

4. Wolford LM, Dhameja A. Planning for combined TMJ arthroplasty and orthognathic surgery. Ness GM (Guest Ed.). Atlas of the oral and maxillofacial clinics of North America. Philadelphia: WB Saunders Co.; 2011. p. 243–270.

5. Wolford LM. Mandibular asymmetry: temporomandibular joint degeneration. In: Bagheri SC, Bell RB, Khan HA, editors. Current therapy in oral and maxillofacial surgery. St. Louis: Elsevier Saunders; 2012. p. 696–725.

6. Wolford LM. Surgical planning in orthognathic surgery (chapter 60). In: Booth PW, Schendel SA, Hausamen JE, editors. Maxillofacial surgery volume 2. St Louis: Churchill Livingstone; 2007. p. 1155–210.

7. Wolford, LM, Stevo ELL, Alexander CM, Goncalves JR, Rodrigues DB. Orthodontics for orthognathic surgery. In Miloro M, Ghali GE, Larsen P, Waite P, editors. Peterson's principles of oral and maxillofacial surgery. Shelton: People's Medical Publishing House-USA; 2012, Chapter 55. p. 1263–1294.

8. Wolford LM, Fields RT Jr.. Diagnosis and treatment planning for orthognathic surgery. In: Betts N, Turvey T, editors. Volume 2, in Fonseca (Ed.) oral and maxillofacial surgery, Chapter 2. 2000. p. 24–55.

9. Wolford LM, Henry CH, Nikaein A, Newman JT, Namey TC. The temporomandibular joint alloplastic implant problem. In: Sessle BJ, Bryant PS, Dionne RA, editors. Temporomandibular disorders and related pain conditions. Seattle, WA: IASP Press; 1995. p. 443–7.

10. Wolford LM. Temporomandibular joint devices: treatment factors and outcomes. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;83:143–9.

11. Matukas VJ, Szvmela VF, Schmidt JF. Surgical treatment of bony ankylosis in a child using a composite cartilage-bone iliac crest graft. J Oral Surg. 1980;38:903.

12. Dingman RO, Grabb WG. Reconstruction of both mandibular condyles with metatarsal bone grafts. Plast Reconstr Surg. 1964;34:441.

13. MacIntosh RB, Henny FA. A spectrum of application of autogenous costochondral grafts. J Maxillofac Surg. 1977;5257

14. Wolford LM, Cottrell DA, Henry CH. Sternoclavicular grafts for temporomandibular joint reconstruction. J Oral Maxillofac Surg. 1994;52:119–28.

15. Posnick JC, Goldstein JA. Surgical management of temporomandibular joint ankylosis in the pediatric population. Plast Reconstr Surg. 1993;91:791.

16. Pensler JM, Christopher RD, Bewyer DC. Correction of micrognathia with ankylosis of the temporomandibular joint in childhood. Plast Reconstr Surg. 1933;91:799.

17. Lindquist C, Pihakari A, Tasanen A, et al. Autogenous costochondral grafts in temporomandibular joint arthroplasty: a surgery of 66 arthroplasties in 60 patients. J Maxillofac Surg. 1986;14:143.

18. Munro IR, Chen YR, Park BY. Simultaneous total correction of temporomandibular ankylosis and facial asymmetry. Plast Reconstr Surg. 1986;77:517.

19. Perrot DH, Kaban LB. Temporomandibular joint ankylosis in children. Oral Maxillofac Surg Clin North Am. 1994;6:187.

20. Kaban LB, Perrot DH, Fisher K. A protocol for management of temporomandibular joint ankylosis. J Oral Maxillofac Surg. 1990;48:11.

21. Henry CH, Wolford LM. Treatment outcomes for temporomandibular joint reconstruction after Proplast Teflon implant failure. J Oral Maxillofac Surg. 1993;51:352.

22. Wolford LM, Cottrell DA, Henry CH. Temporomandibular joint reconstruction of the complex patient with the Techmedica custom-made total joint prosthesis. J Oral Maxillofac Surg. 1994;52:2–10.

23. Wolford LM, Pitta MC, Reiche-Fischel O, Franco PF. TMJ Concepts/Techmedica custom-made TMJ total joint prosthesis: 5-year follow-up study. Int J Oral Maxillofac Surg. 2003;32:268.

24. Wolford LM, Dingwerth DJ, Talwar RM, Pitta MC. Comparison of 2 temporomandibular joint total joint prosthesis systems. J Oral Maxillofac Surg. 2003;61:685–90.

25. Wolford LM, Pinto LP, Cardenas LE, Molina OR. Outcomes of treatment with custom-made temporomandibular joint total joint prostheses and maxillomandibular counter-clockwise rotation. Bayl Univ Med Cent Proc. 2008;21:18–24.

26. Coleta KED, Wolford LM, Goncalves JR, Santos-Pinto A, Pinto LP, Cassano DS. Maxillomandibular counter-clockwise rotation and mandibular advancement with TMJ concepts1 total joint prostheses: part I skeletal and dental stability. Int J Oral Maxillofac Surg. 2008;38:126–38.

27. Pinto LP, Wolford LM, Buschang PH, Bernardi FH, Goncalves JR, Cassano DS. Maxillomandibular counter-clockwise rotation and mandibular advancement with TMJ concepts total joint prostheses: part III pain and dysfunction outcomes. Int J Oral Maxillofac Surg. 2009;38:326–31.

28. Wolford LM, Bourland TC, Rodrigues D, Perez DE, Limoeiro E. Successful reconstruction of non-growing hemifacial microsomia patients with unilateral temporomandibular joint total joint prosthesis and orthognathic surgery. J Oral Maxillofac Surg. 2012;70:2835–53.

29. Wolford LM, Mercuri LG, Schneiderman ED, Movahed R, Allen W. Twenty-year follow-up study on a patient-fitted temporomandibular joint prosthesis: the techmedica/TMJ concepts device. J Oral Maxillofac Surg. 2015;73:952–60.

30. Perez D, Wolford LM, Schneiderman E, Movahed R, Bourland C, Perez E. Does unilateral temporomandibular total joint reconstruction result in contralateral joint pain and dysfunction? J Oral Maxillofac Surg. 2016;74(8):1539–47. doi:10.1016/j.joms.2016.02.009.

31. Wolford L, Movahed R, Teschke M, Fimmers R, Havard D, Schneiderman E. Temporomandibular joint ankylosis can be successfully treated with TMJ concepts patient-fitted total joint prosthesis and autogenous fat grafts v12-21-15. J Oral Maxillofac Surg. 2016;74(6):1215–27. doi:10.1016/j.joms.2016.01.017.

32. Wolford LM, Movahed R. Combined TMJ and orthognathic surgery. In: Kademani D, Tiwana P, editors. Atlas of oral and maxillofacial surgery: Elsevier Saunders; 2016. p. 1364–77.

33. Wolford LM. Concomitant TMJ total joint replacement and orthognathic surgery. In: Mercuri LG, editor. Temporomandibular Joint Total Joint Replacement – TMJ TJR. Switzerland: Springer International Publishing; 2016. p. 133–64.

34. Mercuri LG, Wolford LM, Sanders B, White RD, Hurder A, Henderson W. Custom CAD/CAM total temporomandibular joint reconstruction system: preliminary multicenter report. J Oral Maxillofac Surg. 1995;53:106–15.

35. Mercuri LG. Alloplastic temporomandibular joint reconstruction. Oral Surg Oral Med Oral Pathol. 1998;85:631.

36. Mercuri LG. Subjective and objective outcomes for patients reconstructed with a patient-fitted total temporomandibular joint prosthesis. J Oral Maxillofac Surg. 1999;57:1427–30.

37. Mercuri LG. The TMJ concepts patient fitted total temporomandibular joint reconstruction prosthesis. Oral Maxillofac Surg Clin North Am. 2000;12:73.

38. Mercuri LG. The use of alloplastic prostheses for temporomandibular joint reconstruction. J Oral Maxillofac Surg. 2000;58:70.

39. Mercuri LG. The TMJ concepts patient-fitted total temporomandibular joint reconstruction prosthesis. Oral Maxillofac Surg Clin North Am. 2000;12:73.

40. Mercuri LG, Wolford LM, Sanders B, White RD, Giobbie-Hurder A. Long-term follow-up of the CAD/CAM patient fitted total temporomandibular joint reconstruction system. J Oral Maxillofac Surg. 2002;60:1440–8.

41. Mercuri LG, Giobbi-Hurder A. Long term outcomes after total alloplastic TMJ reconstruction following exposure to failed materials. J Oral Maxillofac Surg. 2004;62:1088–96.

42. Mercuri LG, Edibam NR, Giobbie-Hurder A. Fourteen-year follow-up of a patient-fitted total temporomandibular joint reconstruction system. J Oral Maxillofac Surg. 2007;65:1140–8.

43. Mercuri LG. Temporomandibular joint reconstruction. In: Fonseca R, editor. Oral and maxillofacial surgery. Philadelphia: Elsevier ; 2008. p. 945–60.Chapter 51

44. Mercuri LG. End-stage TMD and TMJ reconstruction. In: Miloro M, Ghali G, Larsen P, Waite P, editors. Peterson's principles of oral & maxillofacial surgery. 3rd ed. PMPH, USA Ltd; 2012. Chapter 52. p. 1173–1186.

45. Mehra P, Wolford LM, Baran S, Cassano DS. Single-stage comprehensive surgical treatment of the rheumatoid arthritis temporomandibular joint patient. J Oral Maxillofac Surg. 2009;67:1859–72.
46. Sidebottom AJ, Gruber E. One-year prospective outcome analysis and complications following total replacement of the TMJ with the TMJ Concepts System. Br J Oral Maxillofac Surg. 2013;51:620–4.
47. Murdock B, Buchanan J, Cliff J. TMJ replacement: a New Zealand perspective. Int J Oral Maxillofac Surg. 2014;43:595–9.
48. Wolford LM, Karras SC. Autologous fat transplantation around temporomandibular joint total joint prostheses: preliminary treatment outcomes. J Oral Maxillofac Surg. 1997;55:245–51.
49. Francis MD, Russell RCG, Fleisch H. Diphosphonates inhibit formation of calcium phosphate crystals in vitro and pathologic calcification in vivo. Science. 1969;165:1264–6.
50. Ritter MA, Gioe TJ. The effect of indomethacin on para-articular ectopic ossification following total hip arthroplasty. Clin Orthop. 1982;167:113–7.
51. Durr ED, Turlington EG, Foote RL. Radiation treatment of heterotopic bone formation in the temporomandibular joint articulation. Int J Radiat Oncol Biol Phys. 1993;27:863–9.
52. Jensen AW, Viozzi CF, Foote RL. Long-term results of radiation prophylaxis for heterotopic ossification in the temporomandibular joint. J Oral Maxillofac Surg. 2010;68:1100–5.
53. Roychoudhury A, Parkash H, Trikha A. Functional restoration by gap arthroplasty in temporomandibular joint ankylosis: a report of 50 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;87:166–9.
54. Erol B, Tanrikulu R, Görgün B. A clinical study on ankylosis of the temporomandibular joint. J Craniomaxillofac Surg. 2006;34:100–6.
55. Topazian RG. Comparision of the gap and interposition arthroplasty in treatment of temporomandibular ankylosis. J Oral Surg. 1966;24:405–9.
56. Yazdani J, Ali Ghavimi M, Pourshahidi S, Ebrahimi H. Comparison of clinical efficacy of temporalis myofascial flap and dermal graft as interpositional material in treatment of temporomandibular joint ankylosis. J Craniofac Surg. 2010;21:1218–20.
57. Mehrotra D, Pradhan R, Mohammad S, Jaiswara C. Random control trial of dermis-fat graft and interposition of temporalis fascia in the management of temporomandibular ankylosis in children. Br J Oral Maxillofac Surg. 2008;46(7):521–6.
58. Dimitroulis G. The interpositional dermis-fat graft in the management of temporomandibular joint ankylosis. Int J Oral Maxillofac Surg. 2004;33:755–60.
59. Dimitroulis G, Trost N, Morrison W. The radiological fate of dermis-fat grafts in the human temporomandibular joint using magnetic resonance imaging. Int J Oral Maxillofac Surg. 2008;37:249–54.
60. Kaban LB, Perrott DH, Fisher K. A protocol for management of temporomandibular joint ankylosis. J Oral Maxillofac Surg. 1990;48:1145–51.
61. Kaban LB, Bouchard C, Troulis MJ. A protocol for management of temporomandibular joint ankylosis in children. J Oral Maxillofac Surg. 2009;67(9):1966–78.
62. Balaji SM. Modified temporalis anchorage in craniomandibular reankylosis. Int J Oral Maxillofac Surg. 2003;32(5):480–5.61.
63. Blair VP. Operative treatment of ankylosis of the mandible. Trans South Surg Assoc. 1913;28:435.
64. Murphy JB. Arthroplasty for intra-articular bony and fibrous ankylosis of the temporomandibular articulation. JAMA. 1914;62:1783.
65. Merikanto JE, Alhopuro S, Ritsila VA. Free fat transplant prevents osseous reunion of skull defects. A new approach in the treatment of craniosynostosis. Scand J Plast Reconstr Surg. 1987;21:183–8.
66. Saunders MC, Keller JT, Dunsker SB, Mayfield FH. Survival of autogenous fat grafts in humans and in mice. Connect Tissue Res. 1981;8:85–91.
67. Yamaguchi M, Matsumoto F, Bujo H, Skibasaki M, Takahashi K, Yashimoto S, Kchinose M, Saito Y. Revascularization determines volume retention and gene expression by fat grafts in mice. Exp Biol Med. 2005;230:742–8.

68. Trevor PB, Martin RA, Saunders GK, Trotter EJ. Healing characteristics of free and pedicle fat grafts after dorsal laminectomy and duratomy in dogs. Vet Surg. 1991;20:282–90.
69. Qi Z, Li E, Wang H. Experimental study on free grafting of fat particles. Zhonghua Zheng Xing Shao Shang Wai Ke Za Zhi. 1997;13:54–6.
70. Wolford LM, Morales-Ryan CA, Garcia-Morales P, Cassano DS. Autologous fat grafts placed around Temporomandibular Joint (TMJ) total joint prostheses to prevent heterotopic bone. Bayl Univ Med Cent Proc. 2008;21:248–54.
71. Wolford LM, Cassano DS. Autologous fat grafts around Temporomandibular Joint (TMJ) total joint prostheses to prevent heterotopic bone. In: Shiffman MA, editor. Autologous fat transfer. Berlin/Heidelberg: Springer; 2010. p. 361–82.
72. Mercuri LG, Ali FA, Woolson R. Outcomes of total alloplastic replacement with periarticular autogenous fat grafting for management of reankylosis of the temporomandibular joint. J Oral Maxillofac Surg. 2008;66:1794–803.
73. Carpaneda CA, Ribeiro MT. Study of the histologic alterations and viability of the adipose graft in humans. Aesthetic Plast Surg. 1993;17:43–7.
74. Horl HW, Feller AM, Biemer E. Technique for liposuction fat reimplantation and long-term volume evaluation by magnetic resonance imaging. Ann Plast Surg. 1991;26:248–58.
75. Wolford LM, McPhillips A, Rodrigues D. TMJ ankylosis in children: comparison of 3 methods of joint reconstruction. AAOMS. 2009.
76. Frietas RZ, Mehra P, Wolford LM. Autogenous versus alloplastic TMJ reconstruction in rheumatoid-induced TMJ disease. J Oral Maxillofac Surg. 2002;58:43.
77. Saeed N, Hensher R, McLeod N, Kent J. Reconstruction of the TMJ Autogenous compared with Alloplastic. Br J Oral Maxillofac Surg. 2002;40:296–9.
78. Xia J, Ip HH, Samman N, et al. Computer-assisted three-dimensional surgical planning and simulation: 3D virtual osteotomy. Int J Oral Maxillofac Surg. 2000;29:11.
79. Gateno J, Xia J, Teichgraeber J, et al. Clinical feasibility of Computer-Aided Surgical Simulation (CASS) in the treatment of complex cranio-maxillofacial deformities. J Oral Maxillofac Surg. 2007;65:728.
80. 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;71:2123–9.
81. Movahed R, Wolford LM. Protocol for concomitant temporomandibular joint custom-fitted total joint reconstruction and orthognathic surgery using computer-assisted surgical simulation. Oral Maxillofac Surg Clin N Am. 2015;27:37–45.
82. Wolford LM, Karras SC, Mehra P. Considerations for orthognathic surgery during growth, part 1: mandibular deformities. Am J Orthod Dentofacial Orthop. 2001;119:95–101.
83. Wolford LM, Karras SC, Mehra P. Considerations for orthognathic surgery during growth, part 2: maxillary deformities. Am J Orthod Dentofacial Orthop. 2001;119:102–5.
84. Wolford LM, Rodrigues DB. Orthognathic considerations in the young patient and effects on facial growth. In: Preedy VR, editor. Handbook of growth and growth monitoring in health and disease. New York: Springer; 2012. p. 1789–808.
85. Riolo ML, Moyers RE, McNamara JA, Hunter WS. An atlas of craniofacial growth: cephalometric standards from the University School Growth Study, The University of Michigan. Ann Arbor, MI: University of Michigan; 1974. p. 105–6.
86. Wolford LM, Rodrigues DB. Temporomandibular Joint (TMJ) pathologies in growing patients: effects on facial growth and development. In: Preedy VR, editor. Handbook of growth and growth monitoring in health and disease. New York: Springer; 2012. p. 1809–28.