Chapter 109
Temporomandibular Joint (TMJ) Pathologies in Growing Patients: Effects on Facial Growth and Surgical Treatment

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Abstract There are many temporomandibular joint (TMJ) conditions and pathologies that can be present at birth or develop during the growing years that can adversely affect facial growth and development. Some of these conditions can also cause pain, TMJ and jaw dysfunction, and disability. The mandibular condyles, an integral component of the TMJs, are a primary growth center of the mandible. The TMJs are the foundation and support for jaw position, TMJ and jaw function, occlusion, facial balance, normal facial growth and development, as well as comfort. In the presence of TMJ pathology that affects the condyles, growth may be significantly altered creating dentofacial deformities and treatment outcomes for corrective jaw surgery may be unsatisfactory relative to function, esthetics, occlusion, skeletal stability, and pain if the TMJ pathology is ignored. The most common TMJ disorders affecting growth and development can be divided into two basic categories: condylar hyperplasia (over-development) and condylar under-development or resorption. Predictability of results and limiting correction of the jaw and TMJ-related deformities to one major operation can usually best be achieved by waiting until facial growth is normally complete. Some required surgical procedures may have an adverse affect on subsequent facial growth. There are definite indications for early surgery such as ankylosis, growth center transplants (i.e., rib or sternoclavicular grafts), masticatory dysfunction, tumor removal, airway obstruction, sleep apnea, and psychosocial factors. TMJ and orthognathic surgery can be performed safely and predictably at the same operation. The surgical procedures can be separated into two or more surgical stages, but the TMJ surgery should be done first.

Abbreviations

AI/CT	autoimmune/connective tissue
AICR	Adolescent internal condylar resorption
CH	Condylar hyperplasia
JRA	Juvenile rheumatoid arthritis
MRI	Magnetic resonance imaging
TMJ	Temporomandibular joint

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109.1 Introduction

There are many temporomandibular joint (TMJ) conditions and pathologies (congenital and developmental) that can adversely affect facial growth and development. Some of these conditions can also cause pain, TMJ and jaw dysfunction, and disability. Our recent unpublished study reviewed records of 1538 consecutive patients referred to the senior author with TMJ problems (78% female, 22% male). The study revealed that 70% of the patients reported the onset of their TMJ symptoms during the teenage years or earlier, indicating that TMJ pathology is predominately a condition occurring in the second decade of life while growth may still be occurring. In addition, 68% of the patients in the study had co-existing dentofacial deformities. This chapter discusses the most common TMJ pathologies and influence on facial growth and development as well as the effects of surgical management to correct the specific TMJ conditions and associated jaw deformities (Table 109.1).

The mandibular condyles, an integral component of the TMJs, are a primary growth center of the mandible. The TMJs are the foundation and support for jaw position, TMJ and jaw function, occlusion, facial balance, normal facial growth and development, as well as comfort. In the presence of TMJ pathology that affects the condyles, growth may be significantly altered creating dentofacial deformities and treatment outcomes for corrective jaw surgery may be unsatisfactory relative to function, esthetics, occlusion, skeletal stability, and pain if the TMJ pathology is ignored. The most common TMJ disorders affecting growth and development can be divided into two basic categories: condylar hyperplasia (over-development) and condylar under-development or resorption. Condylar hyperplasia includes (1) condylar hyperplasia type 1 (accelerated rate of growth of the normal growth mechanism) and (2) condylar hyperplasia type 2 (condylar osteochondroma or osteoma). Condylar under-development or resorption conditions include (1) adolescent internal condylar resorption (AICR); (2) trauma (e.g., subcondylar mandibular fractures); (3) TMJ ankylosis; (4) malformed or absent TMJs (e.g., hemifacial microsomia and Treacher–Collins syndrome); and (5) connective tissue/autoimmune diseases (e.g., juvenile rheumatoid arthritis and psoriatic arthritis). These conditions may be associated with dentofacial deformities, malocclusion, and TMJ-related symptoms. Patients with these conditions may benefit from surgical intervention including TMJ and orthognathic surgery (corrective jaw surgery).

Our research has demonstrated that TMJ and orthognathic surgery can be performed safely and predictably at the same operation, even in growing patients, but it does necessitate the correct diagnosis and treatment plan, as well as requires the surgeon to have expertise in both TMJ and orthognathic surgery (Wolford et al., 1994a, 1995; Wolford, 1997; Wolford and Karras, 1997;

Table 109.1 Key features of temporomandibular joint (TMJ) surgery in growing patient

1.	Facial and jaw deformities, dysfunction, and pain can occur during growth as a result of TMJ pathology
2.	Surgical correction of jaw deformities without eliminating associated TMJ pathology can have adverse effects on treatment outcomes in reference to function, esthetics, stability, and pain
3.	With the appropriate selection of the surgical procedure and age factors taken into consideration, predictable results can be achieved in growing patients
4.	Orthognathic surgery (corrective jaw surgery) and TMJ surgery are most predictable if done after cessation of growth, but some procedures can be done during growth with predictable outcomes
5.	With the correct diagnosis and treatment plan, simultaneous TMJ and orthognathic surgical approaches provide complete and comprehensive management of growing patients with co-existing TMJ pathology and dentofacial deformities

This table lists the keys features of TMJ surgery in patients during growth (material of the authors)

Wolford and Cardenas, 1999; Mehra and Wolford, 2000; Downie et al., 2001; Morales-Ryan et al., 2002; Wolford et al., 2002a, b, c, 2003a). The difficulty for many clinicians may lie in identifying the presence of a TMJ condition, diagnosing the specific TMJ pathology and selecting the proper treatment for that condition.

Approximately 25% of patients with TMJ pathology/disorders will be asymptomatic, particularly in the growing years, although they may have a dentofacial deformity. These are the patients that can be more troublesome because the TMJ pathology may not be recognized and appropriately addressed, yet these patients may be subjected to orthognathic surgery only. Other patients will have overt TMJ signs and symptoms that could include one or more of the following: progressive facial and occlusal changes; history (previous or current) of TMJ click, pop, or crepitus; decreased jaw function; myofascial pain; TMJ pain; headaches; neck, shoulder, back pain; open bite (anterior, lateral, or posterior); earaches; tinnitus; vertigo; speech articulation disorder, airway problems, etc. Non-surgical TMJ treatment (i.e., splints, physical therapy, biofeedback, acupuncture, chiropractic treatment, orthodontics, and medications) may help the TMJ symptoms, but will not stabilize and eliminate TMJ pathology (i.e., disk dislocation, arthritis, and condylar resorption or over-development). Performing orthognathic surgery only and ignoring the TMJs during treatment or failure to render the correct TMJ management could result in the original jaw deformity and malocclusion redeveloping with worsening TMJ-associated symptoms including jaw dysfunction and pain (Wolford et al., 2003b).

Our research studies (Wolford et al., 2003b) evaluated 25 patients with jaw deformities and TMJ anteriorly displaced disks treated with orthognathic surgery only. Presurgery, 36% of the patients had pain or discomfort. At an average of 2.2 years postsurgery, 84% of the patients had TMJ-related pain, with a 70% increase in pain severity, and 25% of the patients developed relapse of the mandible and anterior open bites from condylar resorption. Twelve patients (48%) required TMJ surgery and repeat orthognathic surgery. Nine additional patients (36%) required long-term medications and/or splint therapy for pain control. These studies demonstrate that performing orthognathic surgery only on patients with co-existing TMJ disk dislocations can result in postsurgical increased pain and skeletal and occlusal instability.

Another of our studies (Goncalves et al., 2008) evaluated 72 patients who had double-jaw orthognathic surgery divided into three groups. Group 1 had healthy TMJs and received orthognathic surgery only; group 2 had bilateral articular disk dislocation and received articular disk repositioning with the Mitek anchor technique (Wolford et al., 1995; Mehra and Wolford, 2001) concomitantly with orthognathic surgery; and group 3 had bilateral articular disk dislocation and received orthognathic surgery only. Average postsurgical follow-up was 31 months. Postsurgery group 1 with healthy TMJs and group 2 with repositioned disks were very stable, while group 3 had an average of 28% mandibular relapse as a result of condylar resorption. This study demonstrated that orthognathic surgery is a stable procedure for patients with healthy TMJs and for patients with simultaneous TMJ disk repositioning. Patients with preoperative TMJ articular disk displacement who had orthognathic surgery and no TMJ intervention experienced significant relapse.

Our other research studies (Wolford et al., 1994a, 1995, 2002a, b, c, 2003a; Wolford, 1997; Wolford and Karras, 1997; Wolford and Cardenas, 1999; Mehra and Wolford, 2000; Downie et al., 2001; Morales-Ryan et al., 2002) have shown that simultaneous surgical correction of TMJ pathology and co-existing dentofacial deformities performed in one operation provides high-quality treatment outcomes for patients relative to function, esthetics, elimination of or significant reduction in pain, and patient satisfaction. Equivalent results can also be achieved by separating the TMJ and orthognathic surgical procedures into two operations; however, the TMJ surgery must be performed first, with approximately 9 months before performing the orthognathic surgery procedures.

109.2 Age for Surgical Intervention

Predictability of results and limiting correction of the jaw and TMJ-related deformities to one major operation can usually be best achieved by waiting until growth is relatively complete. Although there are individual variations, females usually have the majority of their facial growth (98%) complete by the age of 15 years and males by the age of 17–18 years. Some required surgical procedures, which may have an adverse effect on subsequent facial growth, so performing surgery at earlier ages may result in the need for additional surgery at a later time to correct jaw malalignment and malocclusion that may develop during the completion of growth. There are definite indications for early surgery such as ankylosis, growth center transplants (i.e., rib or sternoclavicular grafts), masticatory dysfunction, tumor removal, airway obstruction, sleep apnea, and psychosocial factors. Wolford et al. have previously published on maxillary and mandibular surgery and the effects on growth in patients with normal healthy TMJs, with guidelines for age when considering surgical intervention (Wolford et al., 2001a, b; Wolford and Rodrigues, 2011).

109.3 TMJ Pathologies That Cause Condylar Over-development

109.3.1 Condylar Hyperplasia (CH) Type 1

CH type 1 is a pathological condition with an acceleration of the normal mandibular condylar growth mechanism causing forward over-growth of the mandible, creating a functional and esthetic facial deformity. CH type 1 usually begins in the second decade of life during the pubertal growth phase and the mandible can continue to grow at an accelerated rate into the mid-20s (Wolford et al., 2009). These patients usually begin with class I skeletal and occlusal relationship and develop a class III relationship, or start as class III but develop a worse class III relationship. Asymmetry of the mandible can occur with unilateral CH or bilateral CH where one condyle grows faster than the opposite side.

Although the condyle usually retains a relatively normal architecture, an increased length of the condylar head, neck, and mandibular body is commonly seen. The normal pubertal growth rate from condylion (posterior top of the condyle) to point B (a specific anatomical point on the anterior mandible) in females is a mean of 1.6 mm per year with 98% of growth complete by the age of 15 years. Males grow at a mean rate of 2.2 mm per year with 98% of growth complete by the age of 17–18 years. The identification of sex hormone receptors in and around the TMJ and the pubertal onset of CH type 1 are strongly suggestive of a hormonal influence in the etiology. Approximately one-third of bilateral CH cases have a familial history.

Histologically, CH type 1 condyles may appear similar to normal bony architecture, but in other cases the proliferative layer may demonstrate greater thickness in some areas and less in others, but cartilage-producing cells may be prevalent at its lower border.

CH type 1 usually occurs bilaterally, but can also occur unilaterally. Common clinical features include the following (Fig. 109.1a, c, e): (1) the mandible grows at an accelerated rate predominately in a horizontal direction, although there sometimes is a vertical directional component; (2) the left and right vertical facial heights are usually relatively symmetric; (3) the mandible becomes protrusive, but if asymmetric CH growth is present, then the mandible will also deviate toward the contralateral side; (4) class III occlusion with anterior and posterior crossbites as well as dental compensations; (5) the mandible continues to grow beyond the normal growth years but usually will

Fig. 109.1 Patient with bilateral active condylar hyperplasia. (**a**, **c**, **e**) This 13.9-year-old female presents with bilateral active condylar hyperplasia, with progressive worsening mandibular prognathism, class III occlusion, anterior and posterior crossbites, as well as dental compensations. The left and right vertical facial heights are relatively symmetric. (**b**, **d**, **f**) The patient is seen 1 year postsurgery demonstrating good facial balance and stability with elimination of the condylar hyperplastic growth pathology (material of the authors)

complete its development in the early to mid-20s as this condition is self-limiting; and (6) asymmetric growth may cause articular disk displacement on the contralateral side from increased joint loading created by the over-growth of the ipsilateral side.

Radiographic features include the following: (1) mandibular prognathism; (2) increased length of condylar head, neck, and mandibular body; (3) in asymmetric cases, the ipsilateral body of the mandible may be more bowed and the contralateral side may be more flat creating significant asymmetry in the mandible; and (4) magnetic resonance imaging (MRI) may show a displaced articular disk on the more normal side in asymmetry cases and sometimes on the ipsilateral side. Serial radiographs (lateral cephalograms, cephalometric tomograms, etc.), dental models, and clinical evaluations are usually the most advantageous methods to determine if the growth process is still active.

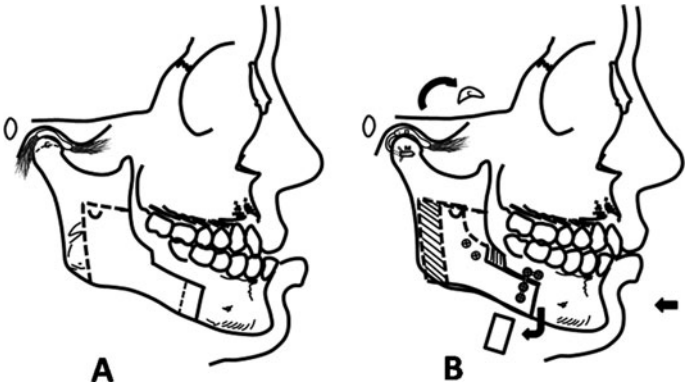

Fig. 109.2 High condylectomy procedure. (**a**, **b**) Active condylar hyperplasia type I creates progressive worsening mandibular prognathism. This condition can be predictably treated with high condylectomies, reposition of the articular disk, and indicated orthognathic surgery (material of the authors)

Treatment of this deformity if growth has stopped involves routine orthognathic surgery. However, if the patient is a teenager or even in their early 20s, the growth process can be active and progressive with two predictable options for treatment:

1. Perform high condylectomies by removing 4–5 mm of the top of the condyles, reposition the articular disks using the Mitek anchor technique (Figs. 1b, d, f and 2a, b), and perform the appropriate orthognathic surgical procedures to correct the jaw deformity (Wolford et al., 2002c, 2009). These procedures can be done in one operation or divided into two operations, but the TMJ surgery must be performed first.
2. Delay surgery until growth is complete. However, since these cases often continue to grow into the mid-20s, the surgery would be delayed until it is confirmed that the growth has stopped. The longer the abnormal growth is allowed to precede, the worse the facial deformity, asymmetry, and dental compensations will become affecting both the hard and soft tissues. This may increase the difficulties in obtaining an optimal functional and esthetic result, besides the adverse effects on the occlusion, dental compensations, and psychosocial development.

Our studies show option 1 is a highly predictable treatment that will stop the abnormal growth so that the orthognathic surgery can be done at the same time with long-term stable functional and esthetic outcomes (Wolford et al., 2002c). The youngest recommended age for this surgical approach for bilateral CH surgery is 13–14 years for females and 15–16 years for males. With bilateral high condylectomies, the vector of facial growth will change from a horizontal forward growth to a downward and backward vector as the mandibular growth is arrested but vertical maxillary alveolar growth continues until cessation. The recommended age for surgical correction involving unilateral CH surgery is 15 years for females and 17 years for males. Performing the unilateral high condylectomy earlier could result in arresting the growth on the CH side, but the normal side can continue to grow until normal cessation occurs, with the potential of causing asymmetry by the mandible shifting toward the original CH side.

109.3.2 Condylar Hyperplasia Type 2 (Osteochondroma or Osteoma)

These benign tumors can develop in the mandibular condyle causing unilateral enlargement of the condyle and mandible creating significant facial asymmetry and can occur at any age, including the first and second decades (Adzuki et al., 1996; Karras et al., 1996; Wolford et al., 2002b).

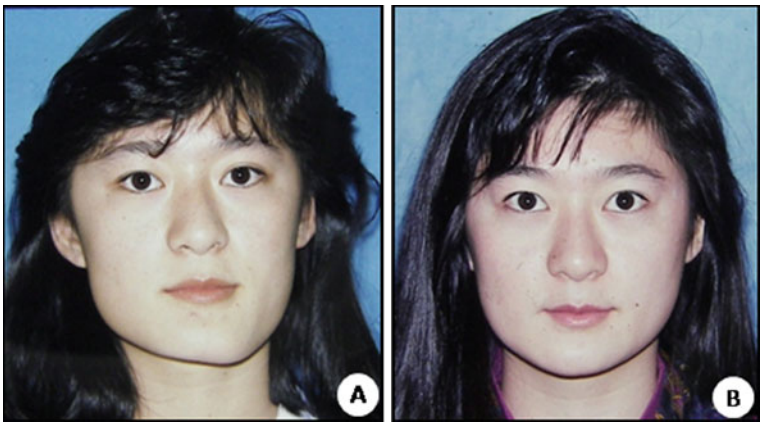

Fig. 109.3 Patient with left-sided mandibular condylar osteochondroma. (**a**) This 15-year-old female had a left-sided mandibular condylar osteochondroma causing severe vertical elongation of the left side of the face. (**b**) The patient had a left low condylectomy, bilateral articular disk repositioning, multiple maxillary osteotomies, bilateral mandibular ramus osteotomies, and left inferior border ostectomy. She is seen 6 years postsurgery with no recurrence of the pathology and good facial balance and occlusion (material of the authors)

Osteochondromas have proliferation of islands of cartilage and bone within the condylar head creating the enlargement. Osteomas are over-proliferation of bone within the condyle causing enlargement, but histologically may appear as normal bone. In both of these conditions, the neck of the condyle usually increases in diameter as a response to the enlargement of the condylar head. The vertical height of the mandibular ramus and body increases as a result of the increased height of the condylar head and neck with excessive vertical alveolar bone growth in both the mandible and the maxilla as a natural response for eruption of teeth trying to close the ipsilateral posterior open bite that commonly develops.

Clinical features of this entity include the following: (1) progressive increase in unilateral facial height and asymmetry (Fig. 109.3a); (2) chin asymmetry vertically and transversely; (3) posterior open bite on the ipsilateral side particularly in more rapid growing pathology; (4) Compensatory ipsilateral maxillary downward growth; (7) mandibular dental midline shifted to the contralateral side; and (8) transverse cant in the occlusal plane.

Imaging features include the following (Fig. 109.4a): (1) enlarged deformed ipsilateral condyle; (2) unilateral increased vertical height of the ipsilateral mandibular condyle, neck, ramus, body, and

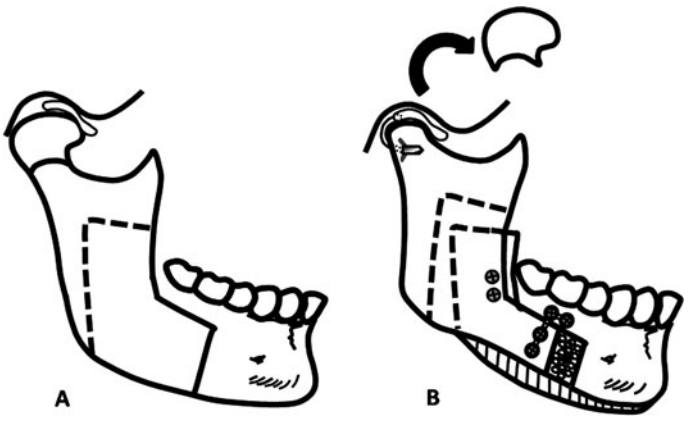

Fig. 109.4 Surgical procedure to treat mandibular condylar osteochondroma. (a, b) A low condylectomy with articular disk repositioning will predictably stop the pathological growth process of an osteochondroma or an osteoma and shorten the vertical height of the ipsilateral side. An ipsilateral inferior border ostectomy will re-establish vertical symmetry of the body height (material of the authors)

chin; (3) increased thickness and length of the ipsilateral condylar neck; and (5) MRI may show arthritis and a displaced articular disk on the contralateral side from the functional over-load caused by the ipsilateral pathology.

The highly predictable treatment protocol advocated by the authors for CH type 2 includes the following: (1) low condylectomy by removing the ipsilateral condyle; (2) reshape the remaining condylar neck to function as the new condyle; (3) reposition the articular disk over the remaining condylar neck and stabilize with the Mitek anchor; (4) reposition the articular disk on the contralateral side, if displaced, with the Mitek anchor; (5) perform orthognathic surgery to correct the maxillary and mandibular asymmetries; and (6) perform an inferior border ostectomy on the ipsilateral side to re-establish vertical balance of the mandible if necessary (Figs. 3b and 4b) (Wolford et al., 2002b). This last procedure may require dissection and preservation of the inferior alveolar nerve. This treatment protocol should provide the best treatment outcome relative to function, esthetics, and elimination of any associated pain and dysfunction (Wolford et al., 1995; Mehra and Wolford 2001; Wolford et al., 2002a, b). Other treatment considerations include condylar replacement with a total joint prosthesis or autogenous tissues such as sternoclavicular grafts, rib grafts, free bone grafts, and pedicled osseous grafts (Adzuki et al., 1996; Karras et al., 1996). The recommended age for surgery when these TMJ pathologies occur in growing patients is 15 years for females and 17–18 years for males. Since these are unilateral TMJ pathologies, the condylectomy will arrest mandibular growth on the involved side. If surgery is done too early, facial asymmetry and occlusal changes may develop as the normal side continues to grow shifting the mandible toward the original pathological side.

109.4 TMJ Pathologies That Cause Condylar Under-development/ Resorption

109.4.1 Adolescent Internal Condylar Resorption (AICR)

Adolescent internal condylar resorption (AICR) is one of the most common TMJ conditions affecting teenage females. AICR causes mandibular condylar resorption with loss of vertical dimension of the condyle that can create occlusal and dentofacial deformity. This disease process has a 9:1 female-to-male ratio and develops between the ages of 11–16 years (Wolford and Cardenas, 1999; Wolford, 2001). AICR cases are random with no apparent genetic predisposition. AICR is a specific non-inflammatory disease entity different from all other TMJ disease processes that cause condylar resorption. Therefore, it has a specific diagnostic presentation and treatment protocol.

There are specific factors and pre-existing facial morphological characteristics that significantly increase susceptibility to AICR. These factors include the following: (1) teenage females in their pubertal growth phase; (2) dolichocephalic facial morphology (Fig. 5a, c); and (3) no other joints involved (Wolford and Cardenas, 1999; Wolford, 2001, 2003; Morales-Rayan et al., 2002). AICR does not occur in brachycephalic facial types or in skeletal class III relationships.

Although the specific cause of AICR has not been clearly identified, its strong predilection for teenage females in their pubertal growth phase supports a theory of hormonal mediation. Estrogen receptors have been identified in female TMJ tissues and mediate cartilage and bone metabolism (Wolford et al., 1994b; Wolford and Cardenas, 1999; Tompach et al., 2000). An increase in receptors may precipitate an exaggerated response. We postulate that female hormones mediate biochemical changes within the TMJ, causing hyperplasia of the synovial cells stimulating the production of destructive substrates that initiate breakdown of the ligamentous structures that normally support and stabilize the articular disk in position, allowing the disk to become anteriorly displaced.

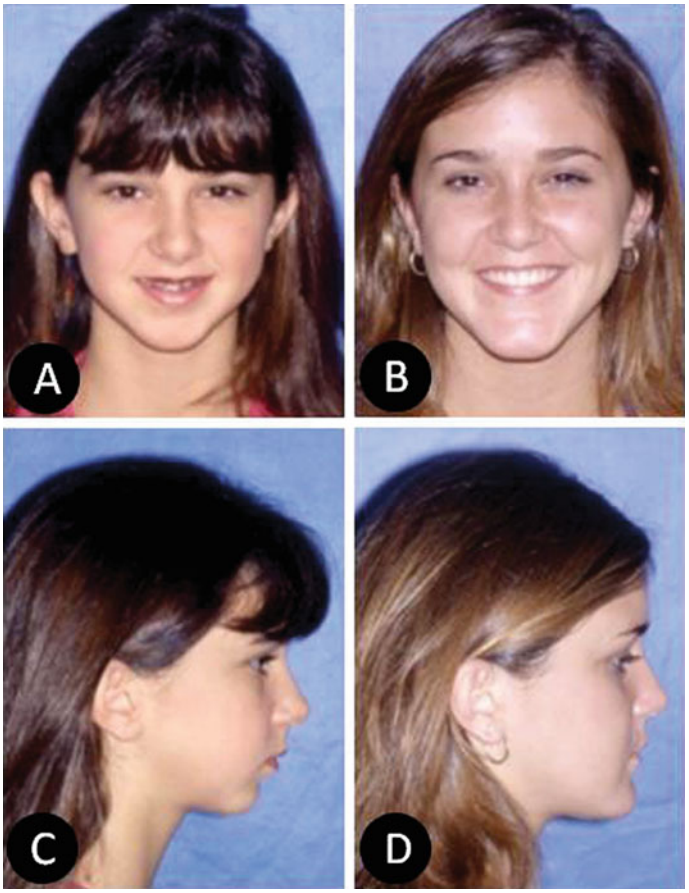

Fig. 109.5 Patient with adolescent internal condylar resorption (AICR). (**a**, **c**) This 13.2–year-old female had AICR resulting in a retruded mandible. (**b**, **d**) The patient is seen 5 years postsurgery for bilateral temporomandibular joint (TMJ) disk repositioning with Mitek anchors, bilateral mandibular ramus osteotomies with counter-clockwise rotation and advancement, maxillary osteotomies, and a chin implant. A predictable and stable result was achieved using the specific protocol for this TMJ pathology (material of the authors)

The hyperplastic synovial tissue then surrounds the head of the condyle. The substrates penetrate through the outer surface of the condyle causing thinning of the cortical bone and breakdown of the subcortical bone. Subsequent functional loading shrinks the condyle in size in all three planes of space without destruction of the fibrocartilage on the condylar head and roof of the fossa, unlike all other arthritides, where the fibrocartilage and cortical bone are destroyed from the top by inflammatory, connective tissue, or autoimmune disease processes. AICR can progress for a while and then go into remission or proceed on until the entire condylar head has resorbed. In cases of remission, subsequent excessive joint loading (i.e., parafunctional habits, stress, clenching/bruxism, trauma, orthodontics, and orthognathic surgery) can reinitiate the resorption process later in life.

Clinical features include the following: (1) condylar resorption occurs at an average rate of 1.5 mm per year causing progressive mandibular retrusion and worsening changes in occlusion and facial appearance; (2) high occlusal plane angle facial morphology (dolichocephalic); (3) class II occlusion with or without an anterior open bite; (4) TMJ-related symptoms, but 25% of cases have no TMJ symptoms; (5) commonly decreased oropharyngeal airway and nasal airway obstruction; and (6) no other joint involvement. Since this condition occurs only in teenagers in their pubertal growth phase, condylar resorption that is initiated in the late teens or at a later age, or where there is multiple joint involvement, is not AICR and may need a different treatment approach (Wolford and Cardenas, 1999; Wolford, 2001).

MRI and radiographic Imaging features include the following: (1) loss of condylar volume in all three spatial planes; (2) poorly defined cortex on the top of the condyles; (3) articular disks anteriorly displaced with amorphous-appearing tissue surrounding the condyle, with or without an increased joint space; (4) high occlusal plane facial morphology; (5) skeletal and occlusal class II relationship; and (6) decreased oropharyngeal airway.

We have previously reported the senior author's protocol for a highly predictable and stable method for treating this specific TMJ pathology by removing the bilaminar pathological tissue surrounding the condyle, repositioning the articular disk, and stabilizing it to the condyle with a Mitek anchor (Wolford and Cardenas, 1999; Wolford, 2001). This treatment method stops the TMJ condylar resorption process and allows the orthognathic surgery to be done at the same operation. In patients with AICR, double-jaw orthognathic surgery is usually indicated with counter-clockwise rotation of the maxillo-mandibular complex to achieve optimal functional and esthetic results (Fig. 5b, d). In growing patients, this approach stops the condylar resorption, but mandibular growth will begin again (Wolford and Cardenas, 1999; Wolford, 2001). The recommended ages for the TMJ surgery to reposition the articular disk and the orthognathic surgery are 14–15 years for females and 16–17 years for males.

In cases where the disk is non-salvageable because of severe deformation/degeneration and there is severe condylar resorption, total joint prostheses may be the best treatment method where the TMJ can be reconstructed and the mandible advanced with the prostheses, along with maxillary osteotomies if indicated. Recommended ages for surgery are 14 years for females and 16 years for males.

109.4.2 Trauma

Trauma involving bilateral or unilateral mandibular condylar or subcondylar fractures that are inadequately reduced during the growth years may result in abnormal growth resulting in jaw deformities. These patients may present with (1) retruded mandible; (2) pain and jaw dysfunction; (3) deficient growth on the affected side(s); (4) class II skeletal and occlusal relationships with an anterior open bite; (5) increased occlusal plane angulation; and (6) unilateral fractures may exhibit ipsilateral premature contact of the occlusion, crossbite, transverse cant in the occlusion, and chin shifted toward that side, while on the contralateral side, there may be a lateral open bite.

Imaging features could include the following: (1) evidence of fractured, displaced condyles that may be malpositioned downward, forward, and medial to the fossa; (2) retruded mandible; and (3) decreased vertical ramus/condyle length.

At the initial presentation of the trauma, the options for treating condylar fractures are open reduction, closed reduction, and no treatment. The amount of displacement and the condition of the fracture(s) will affect the necessary treatment. In growing patients, if the condylar segment is not significantly displaced, it may upright and grow relatively normally with conservative, non-surgical management. If the condyle is minimally to moderately displaced, still salvageable along with its articular disk but already healed, then it is possible that orthognathic surgery could realign the jaw structures and position the condyle and disk into the fossa properly. If the condyle is severely deformed and non-salvageable, then reconstruction of the TMJ and mandible may be indicated using a total joint prosthesis and a fat graft. Maxillary osteotomies may also be required to achieve the optimal functional and esthetic outcomes. In bilateral cases, the surgery can be done at 13–14 years in females and 15–16 years in males. Since mandibular growth is adversely affected by these injuries, for unilateral cases, the ideal age for surgical intervention is 15 years for females and 17–18 years for males.

109.4.3 TMJ Ankylosis

TMJ ankylosis usually develops as a result of trauma, inflammation, sepsis, and/or systemic diseases (Tompach et al., 2000). There are two basic types of ankylosis: fibrous and bony. Fibrous ankylosis usually allows some rotational jaw opening, but no translation. Bony ankylosis is caused by bony fusion between the condyle and the fossa or by reactive or heterotopic bone formation between or around the articulating surfaces. Bilateral and unilateral ankylosis can severely limit the functional aspects of the jaws and TMJs. When this condition occurs during the growing years, it can severely decrease growth and developmental capabilities of the mandible with indirect adverse effects on the maxilla. In unilateral ankylosis, the "normal" joint will continue to grow but may be retarded in its true growth potential.

The common clinical characteristics of bilateral and unilateral TMJ ankylosis, particularly when occurring in children, include the following: (1) significantly decreased TMJ and jaw mobility and function; (2) retruded mandible; (3) decreased mandibular growth; (4) high occlusal plane angle and class II occlusion; (4) decreased posterior vertical height of the maxilla and the mandible; (5) poor oral hygiene as tooth brushing is severely restricted; and (6) in unilateral ankylosis, there will be facial asymmetry with the mandible shifted toward the ankylosed side, decreased vertical height of the maxilla and mandible on the ankylosed side as well as a crossbite tendency and a transverse cant in the occlusal plane (Fig. 109.6a, c).

Imaging characteristics in growing patients include the following: (1) evidence of bony ankylosis; (2) decreased vertical height of the face on the involved side(s); (3) jaw asymmetry with the mandible

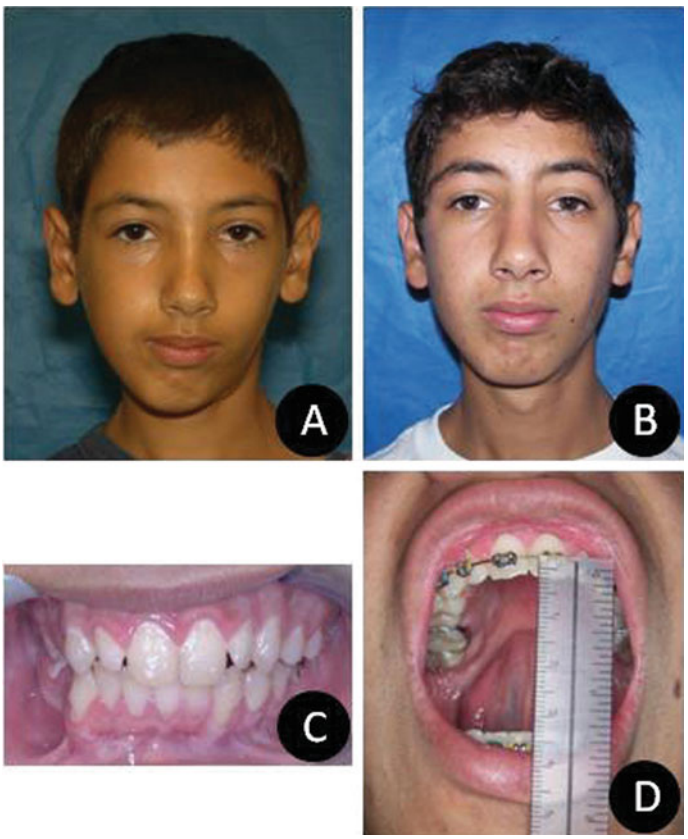

Fig. 109.6 Patient with temporomandibular joint (TMJ) ankylosis. (**a**, **c**) This 12-year-old male developed right TMJ ankylosis at age 1 year secondary to sepsis. He had two failed attempts for correction by rib grafting. He had only 3 mm of incisal opening and was developing significant dental problems as well as sleep apnea symptoms. (**b**, **d**) The patient is seen 3 years post right-side TMJ reconstruction and mandibular advancement with a TMJ Concepts® total joint prosthesis. He has an improved facial balance and good jaw function (35 mm opening) without pain (material of the authors)

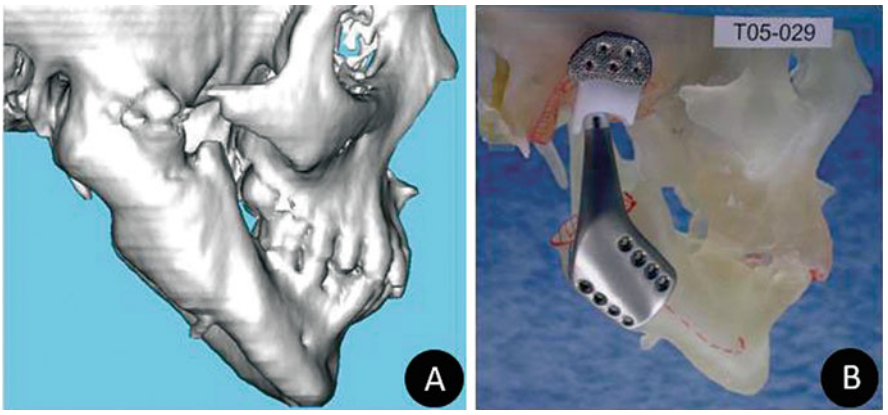

Fig. 109.7 3D radiograph and temporomandibular joint (TMJ) prosthesis. (**a**) A 3D radiograph demonstrates the magnitude of the ankylosis. (**b**) A TMJ Concepts® total joint prosthesis was manufactured to reconstruct the TMJ as well as advance and vertically lengthen the mandibular ramus. Importantly, a fat graft harvested from the buttock was packed around the prosthesis to prevent heterotopic bone from redeveloping (material of the authors)

being shifted toward the unilateral ankylosed side; (4) skeletal and occlusal class II relationship; and (5) microgenia (deficient chin) (Fig. 109.7a).

The most predictable treatment for the ankylosed TMJ patient (age 10 years or older) includes the following (Fig. 109.7b): (1) release of the ankylosed joint; (2) removal of the heterotopic and reactive bone with thorough debridement of the TMJ and adjacent areas; (3) reconstruction of the TMJ (and if indicated, advance the mandible) with a total joint prosthesis (TMJ Concepts system); (4) ipsilateral coronoidotomy or coronoidectomy if ramus is significantly advanced or vertically lengthened with the prosthesis; (5) autogenous fat graft (harvested from the abdomen or the buttock) packed around the prosthesis in the TMJ area; and (6) additional orthognathic surgery if indicated including a ramus osteotomy on the contralateral side in unilateral cases as well as maxillary osteotomies and indicated adjunctive procedures (i.e., genioplasty, rhinoplasty, turbinectomies, and septoplasty) (Fig. 109.6b, d) (Wolford et al., 1994a; Mercuri et al., 1995; Wolford, 1997; Mercuri, 2000, 2002; Mehra and Wolford, 2000; Wolford and Mehra, 2000). In ankylosis cases, it is absolutely necessary that fat grafts be packed around the articulating parts of the prosthesis to prevent the reoccurrence of heterotopic and reactive bone as well as minimize fibrosis development (Wolford and Karras, 1997). In some cases it may be necessary to reconstruct the TMJ first followed by secondary orthognathic surgery. Other techniques that have been advocated for reconstruction of TMJ ankylosis include using autogenous tissues such as temporal fascia and muscle flaps, rib grafts, sternoclavicular grafts, and vertical sliding osteotomy (Tompach et al., 2000). The total joint prosthesis with a fat graft packed around it is a superior technique relative to prevention of ankylosis recurrence, improvement in function, and elimination of or reduction in pain. When treating young growing patients (ages 10–14 years), there is no growth potential on the prosthetic side of the mandible (there is also no growth potential with bony ankylosis) and orthognathic surgery is usually necessary but can be delayed until the patient has most of the facial growth complete (females 15 years and males 17–18 years). Then double-jaw orthognathic surgery can be performed, including a ramus sagittal split on the side of the prosthesis to reposition the jaws into the best alignment, or the ipsilateral side can be advanced by repositioning the mandibular component of the prosthesis or fabrication of a new, longer mandibular component. If the ankylosis is not identified until the cessation of growth, particularly in unilateral cases, then the TMJ reconstruction with the total joint prosthesis and orthognathic surgery can be done in one surgical stage.

109.4.4 Hemifacial Microsomia

Hemifacial microsomia is present at birth and is only one of many syndromes that can cause facial asymmetry, but is one of the more common occurring syndromes. It occurs sporadically and can be considered as a nonspecific symptom complex that is etiologically and pathogenetically heterogeneous. Extreme variability of expression is characteristic of this disorder. The condition usually occurs unilaterally but can also occur bilaterally. Hypoplasia or aplasia of the mandible and the condyle, as well as hypoplasia of the maxilla, zygomatico-orbital complex, and temporal bone, contributes to the facial asymmetry. Ear, eye, and vertebral anomalies are common. With growth, facial deformity, asymmetry, and malocclusion worsen.

Clinical features of this birth defect includes the following: (1) unilateral skeletal deficiency including ipsilateral hypoplasia or absence of the mandibular condyle, ramus, and body; (2) hypoplasia of the ipsilateral maxilla, zygomatico-orbital complex, and temporal bone; (3) transverse cant in the occlusal plane and skeletal structures; and (4) significant soft tissue deficiency on the involved side affecting muscles, subcutaneous tissues, and skin volume (Fig. 109.8a, c).

Imaging features include the following: (1) mandibular retrognathism; (2) maxillary and mandibular asymmetry with a combination of vertical, AP, and transverse deformities; (3) hypoplastic or absent condyle, ramus, body, maxilla, and zygomatico-orbital complex (Fig. 109.9a).

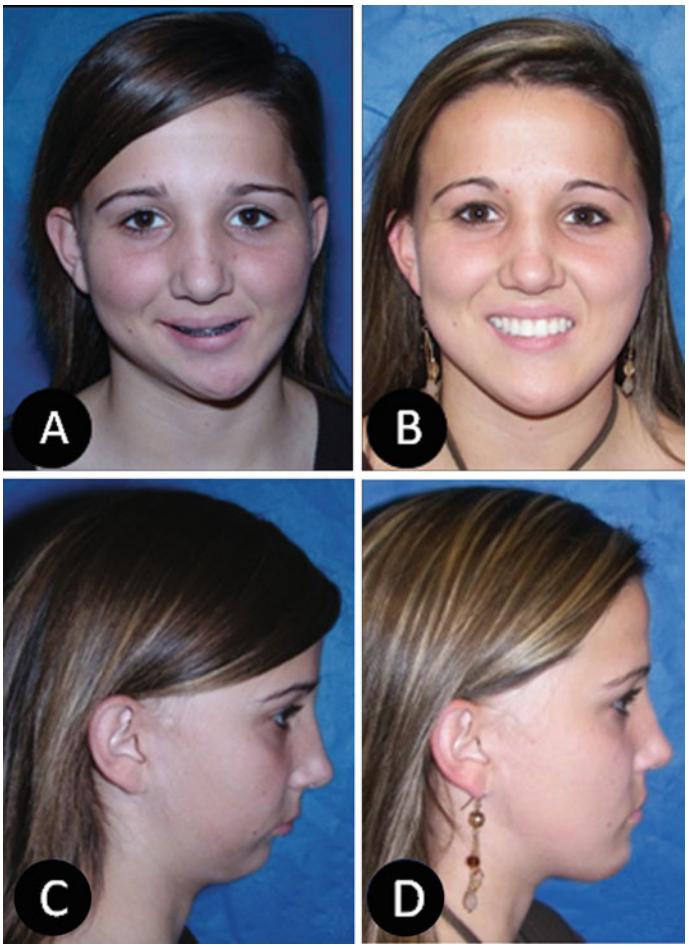

Fig. 109.8 Patient with hemifacial microsomia. (**A**, **C**) This 14–year-old female was born with left-sided hemifacial microsomia. Her left mandibular condyle and ramus were hypoplastic. She had posterior vertical maxillary hypoplasia, significant transverse asymmetry, and retruded mandible. (**B**, **D**) The patient is seen 2 years postsurgery for maxillo-mandibular advancement and asymmetry correction with left TMJ reconstruction with TMJ Concepts total joint prosthesis, fat graft packed around articulating area of prothesis, right mandibular sagittal split osteotomy, and maxillary osteotomies. Facial symmetry is very good (material of the authors)

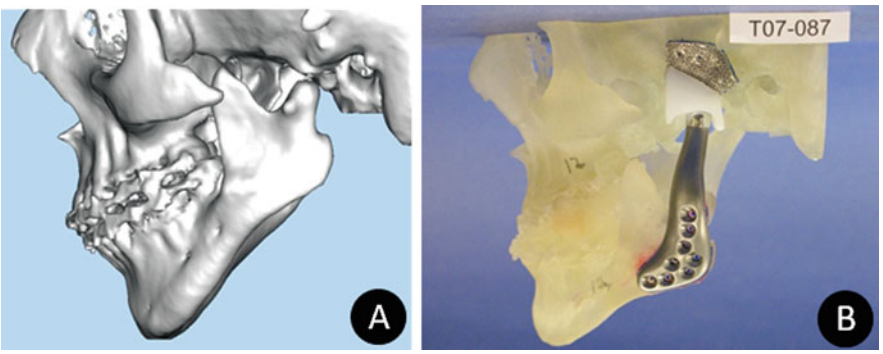

Fig. 109.9 (**A**) A 3D radiograph demonstrates the magnitude of the mandibular retrognathism, hypoplastic condyle, and ramus. (**B**) A custom-fitted TMJ total joint prosthesis (TMJ Concepts® system) was made to reconstruct the TMJ and advance the mandible on the ipsilateral side (material of the authors)

The age at treatment can also affect the treatment protocol. For instance, a hemifacial microsomia patient that is 6–10 years old with absence of the TMJ may benefit from a growth center transplant (sternoclavicular or rib graft) (Wolford et al., 1994b) or distraction osteogenesis. Rib grafts are unpredictable relative to growth and stability. Sternoclavicular grafts have better growth potential similar to normal TM growth. With either graft system there is a possibility that the grafts could overgrow or not grow at all. Patients 10–12 years of age or older with the absence of the condyle will get a much better outcome using a custom-fitted TMJ total joint prosthesis (TMJ Concepts system) to reconstruct the TMJ and advance the mandible on the ipsilateral side (Fig. 109.9b). Deferring treatment until the patient is closer to completion of facial growth (females 15 years old, males 17–18 years old) will help minimize subsequent contralateral normal growth on the treatment outcome. At the same operation, a mandibular ramus sagittal split osteotomy can be performed on the contralateral side along with maxillary osteotomies and other adjunctive procedures (Fig. 109.8b, d). Additional secondary reconstruction may be necessary using bone grafts, synthetic bone, alloplastic implants, etc. to build up the residual deformed bony structures. Soft tissue deficiencies can be reconstructed using fat grafts, tissue flaps, free vascularized grafts, etc., as well as prosthetic ear replacement to complete the facial reconstruction.

109.4.5 Autoimmune, Connective Tissue, and Other Systemic Diseases

Many autoimmune, connective tissue, and other systemic diseases (AI/CT) can affect the TMJs and facial growth such as juvenile rheumatoid arthritis (JRA), psoriatic arthritis, ankylosing spondylitis, Sjogren's syndrome, scleroderma, mixed connective tissue disease, Reiter's syndrome, polyarticular diseases, and Lyme's disease. Peripheral joints are usually symmetrically inflamed resulting in progressive destruction of articular structures and commonly accompanied with systemic symptoms. Severe facial deformity can occur with TMJ involvement.

Clinical characteristics of these conditions usually include the following: (1) progressive mandibular retrusion with worsening changes in occlusion and facial deformity; (2) class II occlusion and anterior open bite; (3) TMJ symptoms; (4) jaw and jaw joint dysfunction; (5) decreased oropharyngeal airway and sleep apnea; and (6) other joints and systems involved (Fig. 109.10a, c, e).

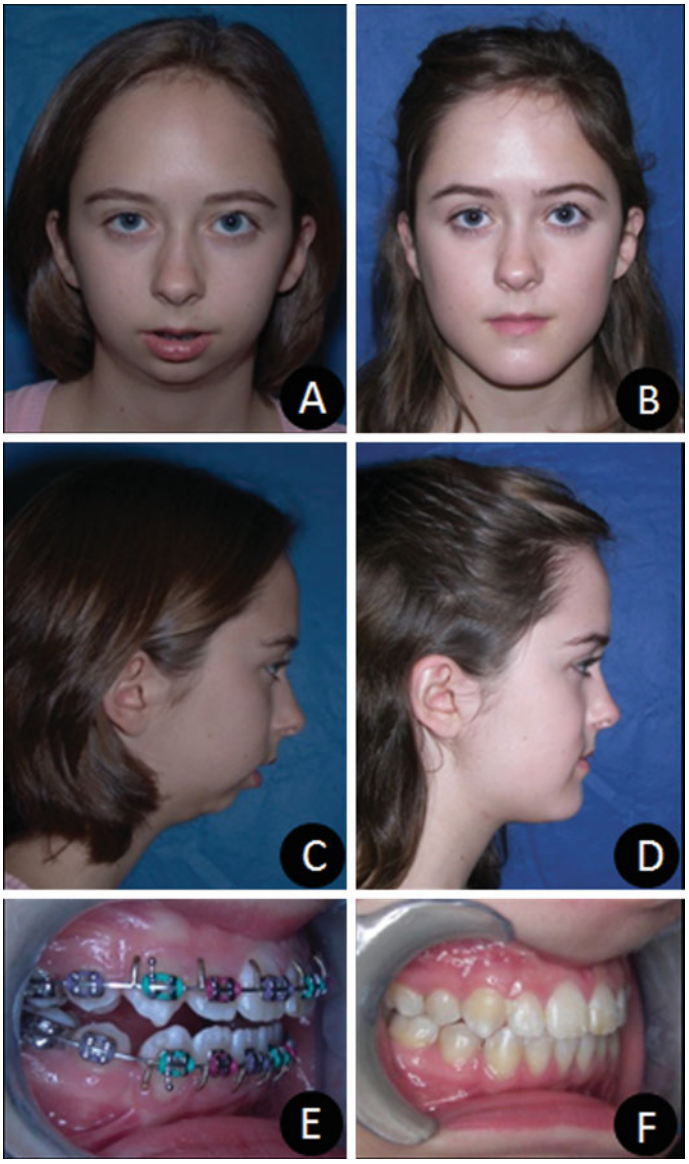

Fig. 109.10 (**A**, **C**, **E**) This 13.8-year-old female had JRA with bilateral temporomandibular joint (TMJ) involvement and almost total condylar resorption. She had retruded mandible and a class II malocclusion with open bite. (**B**, **D**, **F**) The patient is seen 1 year postsurgery that included the following single stage surgery: bilateral TMJ reconstruction and mandibular advancement with TMJ Concepts® total joint prosthesis, fat graft packed around the articulating part of the prosthesis, bilateral coronoidectomy, maxillary osteotomies, and a chin implant (material of the authors)

Imaging features include the following: (1) lose of condylar vertical and medio-lateral dimensions; (2) articular disk may be in position but surrounded by a pannus (reactive tissue) that eventually destroys the disk but also causes severe condylar and articular eminence resorption (Fig. 109.11a); (3) in more severe cases, the condyle may function anterior to the fossa beneath the remaining articular eminence; and (4) skeletal and occlusal class II relationship with an anterior open bite and high occlusal plane angulation.

The most predictable treatment for the TMJ affected by AI/CT diseases includes the following: (1) reconstruction of the TMJ (and if indicated, advance the mandible) with total joint prostheses (TMJ Concepts system) (Wolford et al., 1994a; Mercuri et al., 1995; Wolford, 1997; Mercuri, 2000, 2002; Mehra and Wolford, 2000; Wolford and Mehra, 2000); (2) coronoidectomies to maintain function of the temporalis muscles if the rami are significantly advanced or vertically lengthened with the

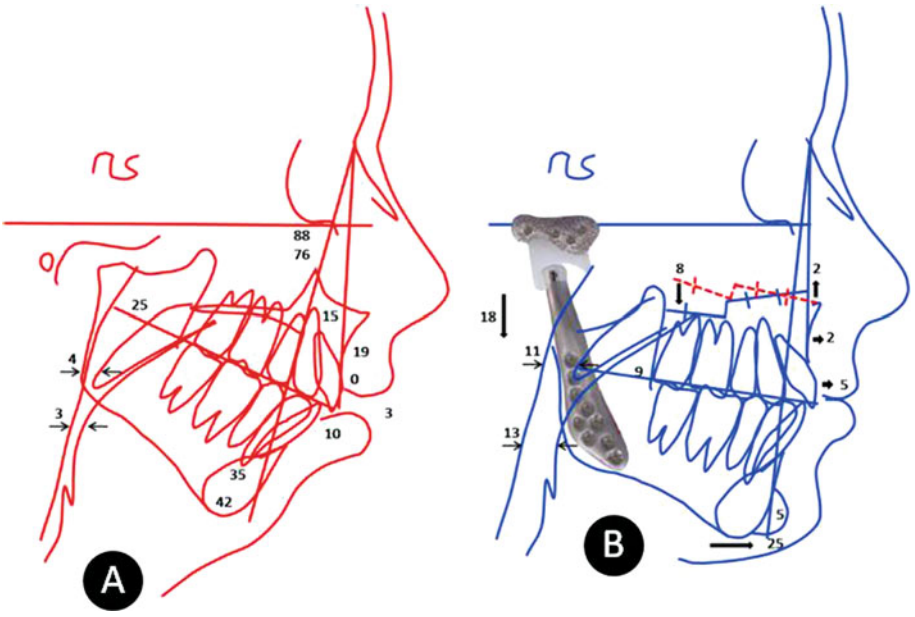

Fig. 109.11 Presurgical and postsurgical cephalometric tracings. (**A**) The cephalometric tracing shows the retruded mandible, the maxillary hypoplasia, and the obstruction of the airway. (**B**) The postsurgical tracing shows the surgical changes including mandibular advancement with counter-clockwise rotation of the maxillo-mandibular complex using TMJ Concepts® total joint prosthesis, maxillary osteotomies, and a chin implant. Note the improved oropharyngeal airway. (material of the authors)

prostheses; (3) autogenous fat graft packed around the prostheses in the articulation area (Wolford and Karras, 1997; Wolford and Cassano, 2010); (4) additional orthognathic surgery if indicated including maxillary osteotomies (Figs. 109.10b, d, f and 11b) and additional adjunctive procedures if indicated. Since an inflammatory process is a factor in these diseases, reactive or heterotopic bone may tend to form around the prosthesis, so it is necessary that fat grafts be packed around the articulating parts of the prostheses to prevent bone formation and fibrosis (Wolford and Karras, 1997). Others have advocated TMJ reconstruction using autogenous tissues such as temporal fascia and muscle flaps, rib grafts, sternoclavicular grafts, and vertical sliding osteotomy. However, the disease process that created the original TMJ pathology can attack the autogenous tissues used in the TMJ reconstruction causing failure of the grafts. We have successfully treated JRA patients (ages 12–14 years and older) with the protocol described above in one stage with good functional and esthetic results without requiring a secondary procedure (Mehra et al., 2009). These cases are predictable when performed at age 14 years or older in females and 16 years or older in males. However, the vector of facial growth will change in younger patients to a downward and backward direction.

Our studies (Mehra and Wolford, 2000) show good outcomes in treating connective tissue/autoimmune diseases affecting the TMJ with custom-fitted total joint prostheses (TMJ Concepts system) for TMJ reconstruction and mandibular advancement, fat grafts, and simultaneous maxillary orthognathic surgery. Our other studies (Wolford et al., 1994a, 2003a; Wolford, 1997) demonstrated good outcomes using these custom-fitted total joint prostheses and orthognathic surgery in treating many different TMJ disorders.

Our initial study (Wolford and Karras, 1997) evaluated the efficacy of using fat grafts around the prostheses and demonstrated significant improvement in function and decrease in pain in 15 patients

when using the fat grafts as compared to 20 patients who did not receive fat grafts. Other studies (Wolford et al., 2008; Wolford and Cassano, 2010) evaluated postsurgery outcomes of 115 patients that received fat grafts around the prostheses with an average postsurgery follow-up of 31 months. There was significant improvement in jaw opening and function postsurgery with no radiographic or clinical evidence of heterotopic bone or significant fibrosis.

109.5 Conclusion

TMJ conditions and pathologies can be present at birth or develop during growth creating facial deformities. During the past three decades, major advancements have been made in TMJ diagnostics and the development of surgical procedures to treat and rehabilitate the pathological, dysfunctional, and painful TMJ. With the appropriate selection of the surgical procedure and age factors taken into consideration, predictable results can be achieved in growing patients (Table 109.1). Research has demonstrated that TMJ and orthognathic surgery can be performed safely and predictably at the same operation, but it does necessitate the correct diagnosis and treatment plan, as well as requires the surgeon to have expertise in both TMJ and orthognathic surgery. The surgical procedures can be separated into two or more surgical stages, but the TMJ surgery should be done first. Poor TMJ surgery outcomes usually are related to wrong diagnosis, wrong surgical procedure, poorly executed surgery, surgical complications, inadequate follow-up care, and/or unrecognized or untreatable local and/or systemic factors. With the correct diagnosis and treatment plan, simultaneous TMJ and orthognathic surgical approaches provide complete and comprehensive management of growing patients with co-existing TMJ pathology and dentofacial deformities.

109.6 Applications to Other Areas of Health and Disease

Normative features of growth

Psychological adaptation and quality of life in impaired growth.

People with significant jaw deformities associated with TMJ pathology causing abnormal jaw growth may also suffer from psychosocial problems associated with poor self-image.

Adolescence

Male and female bone growth patterns in Chinese children and adolescents

Facial growth aberrations associated with TMJ pathology causing facial deformities often develop during childhood and adolescence.

Growth factors and endocrine control and regulation of growth

Endocrinology of male and female puberty

Several specific TMJ pathological processes begin during pubertal growth and are likely related to endocrine regulatory or dysfunctional factors.

Summary Points

- There are many congenital and developmental TMJ pathologies.
- TMJ pathology occurs predominately in females with the onset of symptoms predominately in teenagers.
- Two basic categories of TMJ pathology: condylar hyperplasia (over-development) and condylar under-development and resorption.
- Simultaneous TMJ and orthognathic surgery can be done at the same operation.
- Correcting TMJ pathology closer to cessation of normal growth years will provide better predictable results compared to earlier surgery.
- Earlier surgery during growth may be indicated for functional, esthetic, and psychosocial reasons.
- 25% of patients with significant TMJ pathology may have no symptoms.
- Performing only orthognathic surgery in the presence of TMJ pathology that is not addressed will usually result in poor quality outcomes relative to function, esthetics, and pain.

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