Low Condylectomy and Orthognathic Surgery to Treat Mandibular Condylar Osteochondroma: A Retrospective Review of 37 Cases

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Purpose: To evaluate the outcomes from surgical treatment of mandibular condylar osteochondroma (condylar hyperplasia [CH] type 2) using a specific surgical protocol. CH type 2 is a unilateral benign pathologic condition, with progressive proliferation of osseous and cartilaginous tissues in the condylar head. This causes condylar enlargement, often with exophytic growth, resulting in significant facial deformity, pain, and masticatory and occlusal dysfunction.

Patients and Methods: This was a retrospective cohort study of 37 patients (28 females and 9 males), with an average age of 26.3 years (range 13 to 48), with CH type 2, and associated dentofacial deformity. The condylar pathologic features were confirmed by histologic analysis. All patients were treated with low condylectomy, recontouring of the condylar neck to form a new condyle, repositioning of the articular disc over the condylar stump and repositioning of the contralateral disc, if displaced, and any indicated orthognathic surgical procedures. Postoperative follow-up averaged 48 months (range 12 to 288). Patients were assessed preoperatively and at the longest follow-up point for incisal opening, lateral excursions, pain, jaw function, diet, disability, and occlusal and skeletal stability. The pre- and postoperative assessments were compared using paired *t* test.

Results: At the longest follow-up point, a nonsignificant decrease (2.3 mm) was seen in the maximum incisal opening; however, the excursive movements had decreased significantly an average of 2.5 mm on the right and 2.2 mm on the left. A statistically significant improvement was seen in pain, jaw function, diet, and disability. A stable Class I skeletal and occlusal relationship was maintained in 34 of the 37 patients (92%). Two patients developed relatively minor postoperative malocclusions that were managed with orthodontics. In 1 patient, a high condylectomy was performed, and the tumor continued to grow, causing malocclusion and jaw deformity to recur. A low condylectomy and sagittal split were performed 14 months later, with a stable result at 4 years after surgery.

Conclusions: The results of the present study have demonstrated that a low condylectomy procedure with recontouring of the condylar neck to function as a condyle and repositioning of the articular discs, combined with orthognathic surgery, is a viable option for the treatment of osteochondroma of the mandibular condyle and associated jaw deformity.

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Osteochondroma is one of the most common benign tumors of bone, representing approximately 35 to 50% of all benign tumors and 8 to 15% of all primary bone tumors.[1] Osteochondroma of the craniofacial region is rare, with the most common sites of occurrence the mandibular condyle and coronoid process.[1] Ord et al[2] in 2010, reviewed the published data and identified 67 cases of mandibular condylar osteochondroma diagnosed and surgically treated, including their 8 cases.[3-11] Since then, 62 additional cases of surgically treated mandibular condylar osteochondroma have been added to the published studies.[12-18] Yang et al[19] reported a series of 17 patients, exploring the role of computer-assisted surgical planning in the surgical management of mandibular condylar osteochondroma. Meng et al[20] reported a case series of 34 patients diagnosed with osteochondroma of the mandibular condyle and surgically treated. They reviewed the radiographic and clinical characteristics of the tumor. The traditional treatment of mandibular condylar osteochondroma has been condylectomy.[1,4,5] A period of intermaxillary fixation will usually follow, with subsequent use of guiding elastics.[2] Some investigators have reported reconstruction of the condyle with a vertical ramus sliding osteotomy, free autogenous bone graft, costochondral graft, sternoclavicular graft, local pedicled osseous grafts, or total joint prostheses.[1,2]

The present study evaluated the outcomes of a specific treatment protocol used to treat 37 patients with osteochondroma of the mandibular condyle.[21] A low condylectomy was used as the primary modality for elimination of the osteochondroma. The remaining condylar neck was recontoured, over which the articular disc was repositioned. The contralateral disc was repositioned if displaced, and appropriate orthognathic surgical procedures were concomitantly performed to optimize occlusion, function, and esthetics in 1 operation.

Condylar Hyperplasia Classification

Condylar hyperplasia (CH) is a generic term describing conditions that enlarge the mandibular condyle, adversely affecting the size and morphology of the mandible, altering the occlusion, and indirectly affecting the maxilla. This can result in the development or worsening of a dentofacial deformity, such as mandibular prognathism (symmetric or asymmetric), unilateral enlargement of the mandible, facial asymmetry, and malocclusion. Some CH pathologic features occur more commonly within particular age ranges and genders.

Wolford's simple, but encompassing, classification of the various CH pathologic entities,[22] defines the clinical and imaging characteristics, natural progression of the pathologic process, histologic differentiation, and treatment protocols and timing that have been proved to eliminate the pathologic processes and provide optimal functional and esthetic outcomes. The classification also reflects the occurrence rate, with CH type 1A the most frequently occurring and CH type 4 the least common.

CH TYPE 1

The onset of CH type 1 usually occurs during puberty. It is an accelerated and prolonged growth aberration of the "normal" condylar growth mechanism and can occur bilaterally (CH type 1A) or unilaterally (CH type 1B). The growth vector will usually be in a horizontal direction, creating mandibular prognathism, and is self-limiting, with growth termination usually in the early to mid-20s.

CH TYPE 2

This condylar pathologic entity, osteochondroma, is the most common occurring mandibular condylar tumor. It can develop at any age (although more often during adolescence), with a unilateral vertical overgrowth deformity of the jaws, although a horizontal growth vector can occasionally occur. The growth process can continue indefinitely, with progressive worsening of the facial asymmetry.

CH TYPE 3

CH type 3 includes other types of benign tumors that can cause condylar enlargement, such as osteoma, neurofibroma, giant cell tumor, fibrous dysplasia, chondroma, chondroblastoma, arteriovenous malformation, and so forth.

CH TYPE 4

CH type 4 includes malignant tumors arising from the mandibular condyle that cause condylar enlargement, such as chondrosarcoma, multiple myeloma, osteosarcoma, Ewing sarcoma, metastatic lesions, and so forth.

The present study addressed CH type 2. We describe the clinical and radiographic findings, growth characteristics, effects on the jaws and facial structures, and histologic findings. We also present a treatment protocol that has been highly predictable in the elimination of the pathologic features and provides optimal treatment outcomes.

CH type 2 can be subdivided into 2 primary groups according to the tumor morphology. CH type 2A refers to an enlargement of the condylar head and neck with a predominate vertical growth vector of the osteochondroma without significant exophytic tumor development (Figs 1A-C). Unevenness or lumpiness can be present on the condyle. CH type 2B refers to exophytic tumor extensions from the condyle, usually

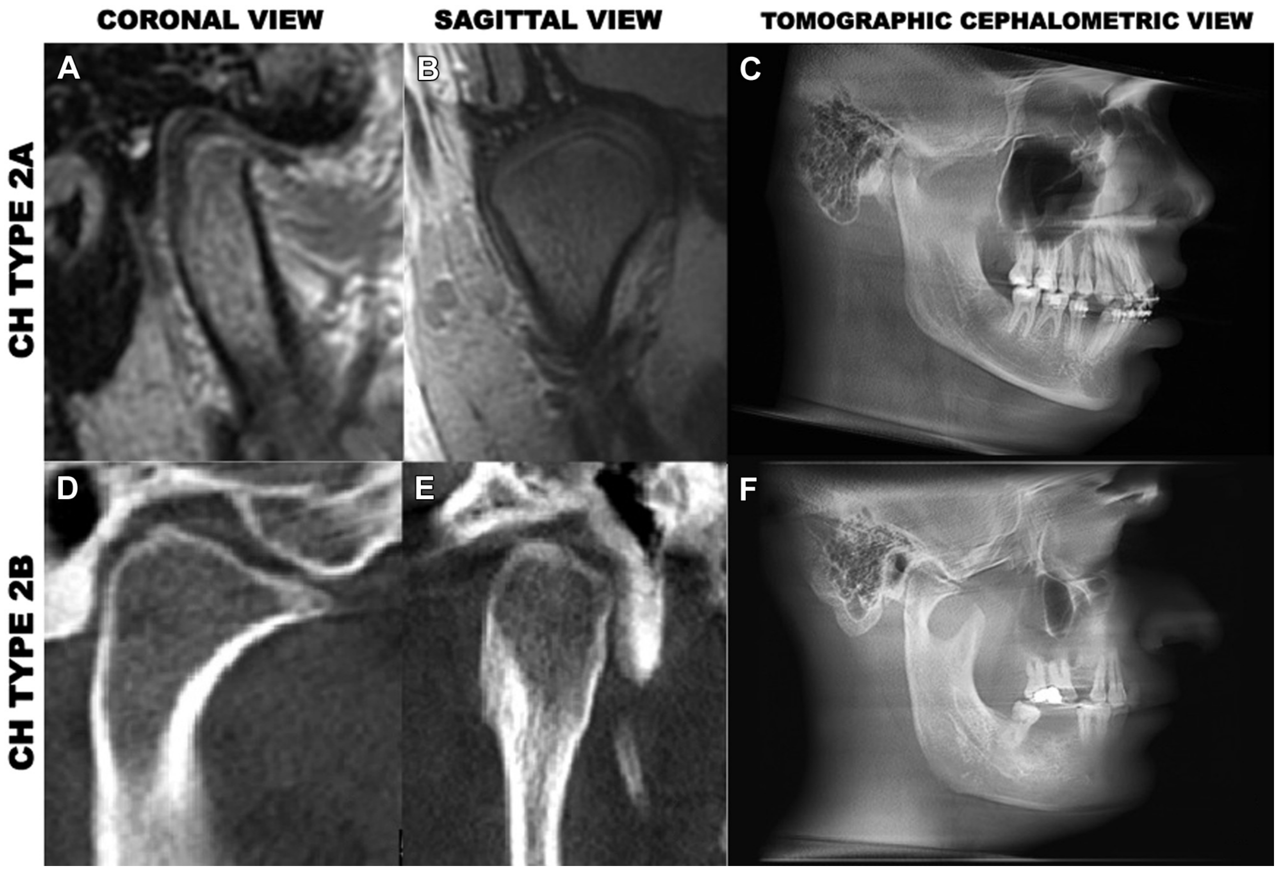

FIGURE 1. Condylar hyperplasia (CH) type 2A. *A,* In the sagittal view, the condyle maintained relatively normal morphology but was vertically elongated, with an increased width of the condylar head and neck. *B,* Coronal view showing the increased vertical height of the condyle and increased transverse width of the head and neck. *C,* Sagittal tomographic cephalogram showing increased vertical height of the mandibular condyle, ramus, and body of the mandible. CH type 2B. *D,* Sagittal view showing exophytic growth off the condylar head and projecting beneath the articular eminence. *E,* In the coronal view, the exophytic growth might not be evident, unless medial or lateral extension of the tumor is present. *F,* Sagittal cephalometric tomogram showing elongation of the head, neck, ramus, and body, with downward bowing of the inferior border and loss of the gonial notch. The coronoid process remained relatively normal in size.

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forward and medially, although they can develop in any direction, with the head becoming significantly enlarged and deformed (Figs 1D-F). These tumors usually have a significant vertical growth vector. However, the exophytic growths, when relatively large, can disarticulate the condyle down and out of the fossa, creating a greater exaggeration of the ipsilateral vertical height of the jaws and face (Figs 2A-F, 3A, 4A).

The different growth patterns of the tumors for CH types 2A and 2B might be related to the anatomic origin of the tumor on the condylar head, the growth rate, and elongation adaptation of the muscles of mastication and other soft tissues on the ipsilateral side. The constraints of the rate of muscular and soft tissue adaptation and elongation compared with the rate of tumor growth might redirect tumor development in the direction of least resistance: anteriorly and anteromedially. The roof and posterior wall of the fossa and the lateral and medial capsular ligaments could act as barriers, directing the growth forward. We have treated cases with the less common development of the exophytic growths extending laterally and posteriorly.

CLINICAL CHARACTERISTICS

The common clinical features of CH type 2 (Figs 2A-F) include the following:

1. Can develop at any age.
2. Progressive increase in unilateral mandibular vertical height involving the condyle, neck, ramus, body, and dentoalveolus of the ipsilateral mandible.
3. Increased soft tissue volume on the ipsilateral side of the face, including elongation of the muscles of mastication.
4. Low to normal mandibular plane angle facial type morphology.
5. Chin asymmetry vertically and transversely, with a shift toward the contralateral side.
6. Compensatory downward growth of the ipsilateral maxillary dentoalveolus.

FIGURE 2. Case 1. *A,* This 45-year-old woman had right-sided condylar hyperplasia (CH) type 2B with significant facial asymmetry. The chin was 13 mm to the left, and the vertical height of the right mandible had increased 15 mm. *B,* The photograph with her smiling shows the asymmetry and cant in the occlusion. *C,* She had anteroposterior deficiency in the mandible and chin. *D-F,* The cant in the occlusion and the shift of the dental midline and cross bite on the left side are evident. A Class III end-on canine relationship is present on the right side. *G-L,* At 7 years postoperatively, she had improved facial balance and Class 1 canine–molar occlusion. **(Fig 2 continued on next page.)**

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FIGURE 2 (cont'd). **(Fig 2 continued on next page.)**

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7. Lateral open bite on the ipsilateral side, particularly in more rapidly growing tumors.
8. Labial tipping of the mandibular ipsilateral posterior teeth and lingual tipping of the contralateral posterior teeth; the maxillary ipsilateral posterior teeth can tip palatally and the contralateral teeth labially.
9. Transverse cant in the occlusal plane with the ipsilateral side lower than the contralateral side.
10. Usually angle Class I occlusion, but can be Class II or III.
11. Mandibular anterior teeth crowns can be tipped toward the ipsilateral side and the long axis of the roots angled toward the contralateral side.
12. Commonly contralateral temporomandibular joint (TMJ) arthritis and articular disc dislocation from the functional overload that occurs from the ipsilateral tumor, accompanied by

FIGURE 2 (cont'd).

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symptoms such as clicking, popping, TMJ pain, headaches, ear symptoms, and so forth.

Patients will often be referred because of asymmetric facial deformity and TMJ pain. In rare cases, the growth vector will be horizontal, mimicking CH type 1B and resulting in a deviated prognathism.

IMAGING

Radiographically, osteochondroma of the mandibular condyle will be the most easily recognized when exophytic masses have developed off the condyle that could have mixed densities (Figs 1D, 4A). Computed tomography (CT), cone beam imaging, and lateral and anteroposterior cephalometric, panoramic, and magnetic resonance imaging (MRI) examinations can be helpful in evaluating the tumor, especially in the case of large exophytic tumors, with possible involvement of adjacent cranial or vascular structures. The imaging studies can also be used to assess the collateral extent of the dentofacial deformity. The common radiographic characteristics of CH type 2 include *1)* an enlarged, elongated

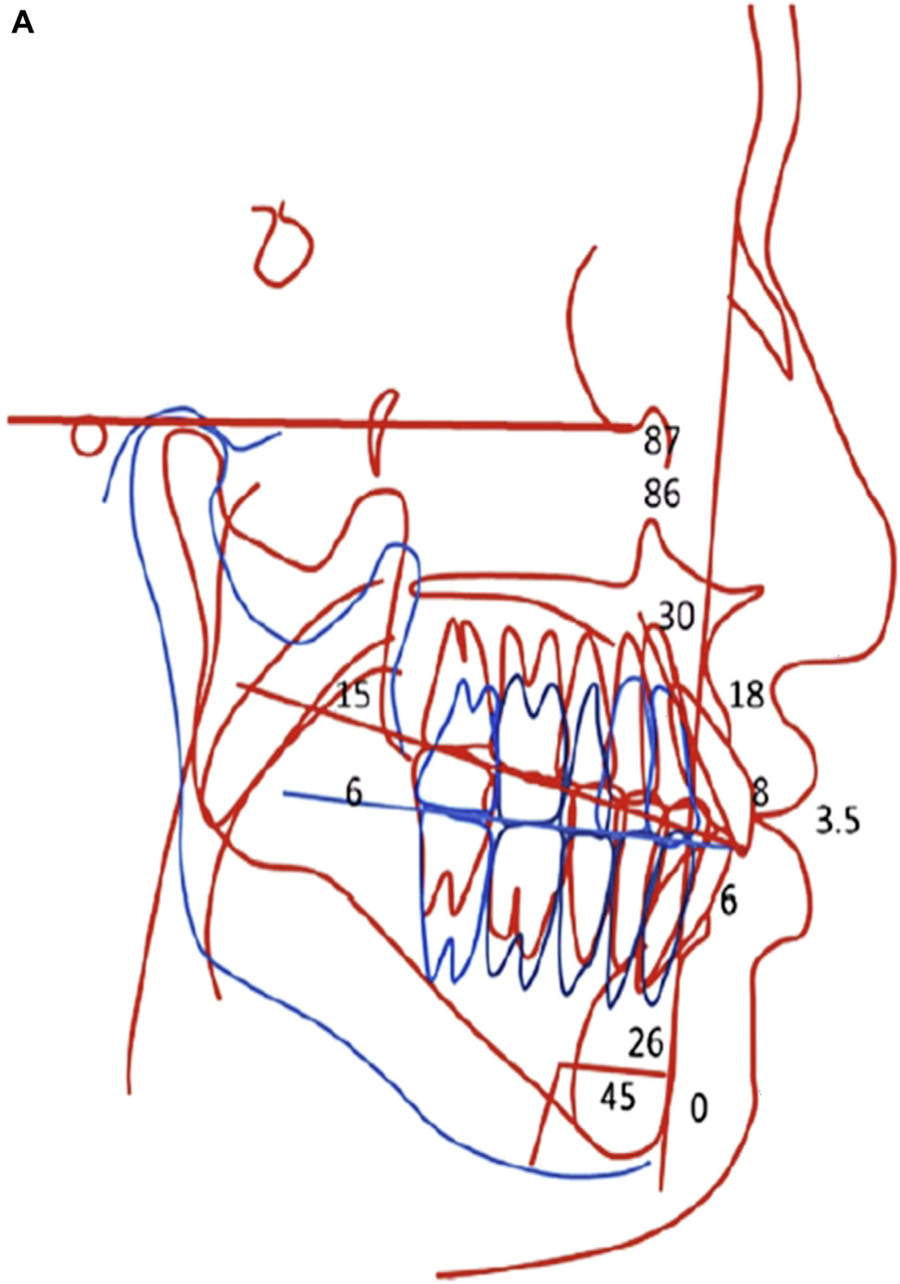

FIGURE 3. Case 1. *A*, Preoperative cephalometric analysis showing increased vertical height at the occlusal plane and inferior border of the right mandible. **(Fig 3 continued on next page.)**

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deformed ipsilateral condyle (CH type 2A; Figs 1A-C), often with exophytic extensions of the tumor off the condyle (CH type 2B; Fig 1D-F, 4A); *2)* increased anteroposterior and mediolateral thickness of the ipsilateral condylar neck; *3)* a progressive increasing vertical height of the ipsilateral mandibular condyle, neck, ramus, body, symphysis, and dentoalveolus (Fig 3A); *4)* an increased vertical height of the ipsilateral maxillary dentoalveolus; *5)* a transverse cant in the occlusal plane; *6)* facial asymmetry; *7)* the posterior border of the ipsilateral mandibular ramus might be more vertical than normal; *8)* the coronoid process usually will be normal in size and might be displaced below the zygomatic arch with elongation of the temporalis muscle; *9)* loss of ipsilateral antigonial notching with downward bowing of the inferior border of the mandible; *10)* the inferior alveolar nerve canal might be positioned adjacent to the apices of the teeth, but more commonly will be toward the inferior border of the mandible; and *11)* the chin will be vertically longer on the ipsilateral side and might be prominent in profile. Unless the tumor is very slow growing, B

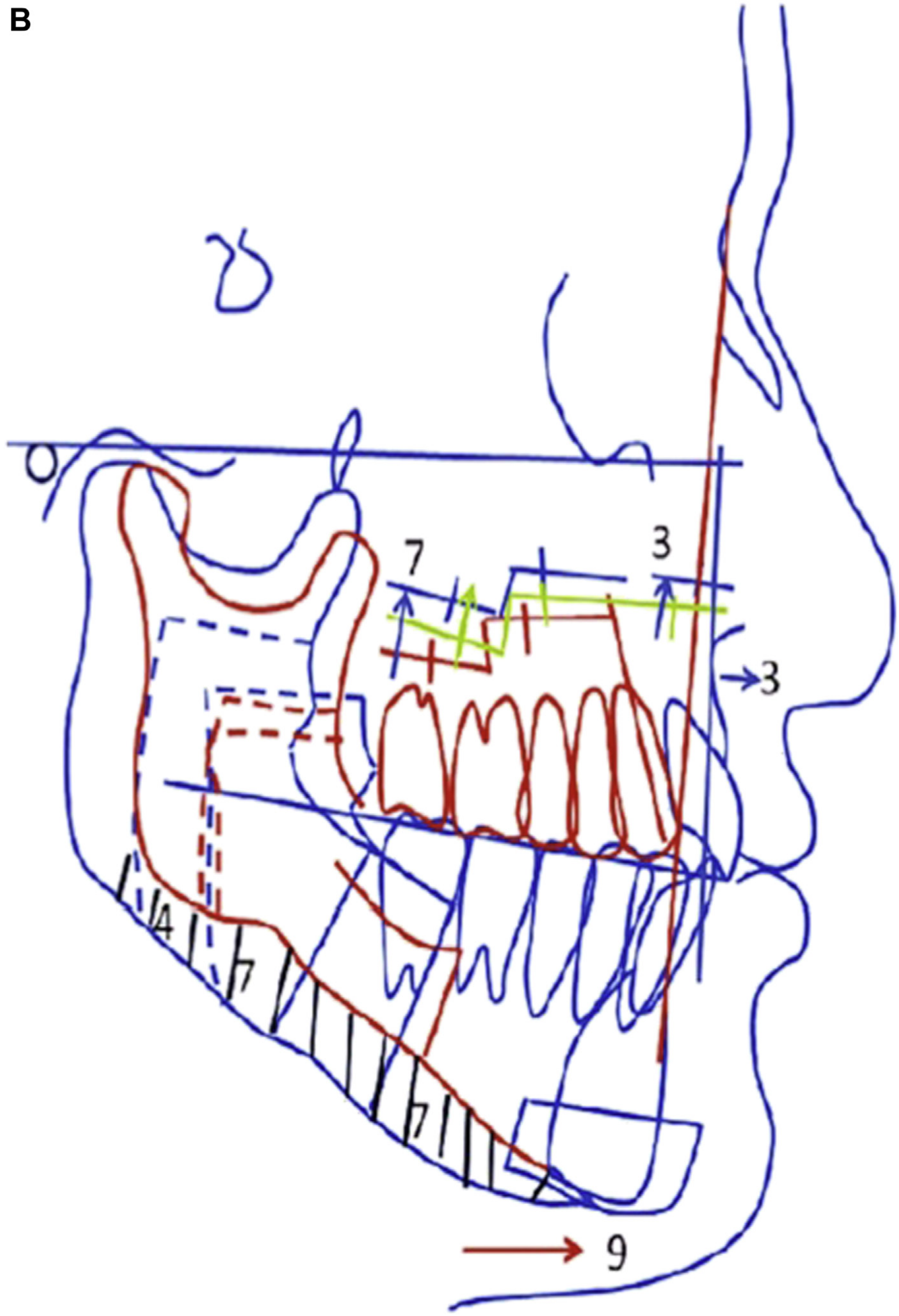

FIGURE 3 (cont'd). *B,* The surgical treatment objective included *1)* right condylectomy; *2)* bilateral disc repositioning with Mitek anchors; *3)* bilateral mandibular ramus osteotomies to level the occlusal plane transversely and anteroposteriorly (AP) and to advance; *4)* maxillary osteotomies to level the occlusal plane transversely and AP and to advance; *5)* right inferior border ostectomy with preservation of the inferior alveolar nerve; and *6)* AP augmentation genioplasty.

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bone scintigraphy will usually show increased uptake, in particular, in the more active tumors (Figs 4C,D).

MRI will show the enlarged ipsilateral condyle. Usually, the articular disc will be in position, even in the presence of a large exophytic tumor (Fig 4A). Less often, the disc will be displaced. The contralateral TMJ might show an anteriorly displaced articular disc and associated arthritic condylar changes (Fig 4B). These changes will be created by the ipsilateral tumor and progressive developing facial asymmetry, with mandibular deviation toward the contralateral side, placing a functional overload of forces on the contralateral TMJ and displacing the disc. In CH type 2A, the articular disc can become posteriorly displaced on the ipsilateral side as the rate of vertical mandibular condylar growth surpasses the

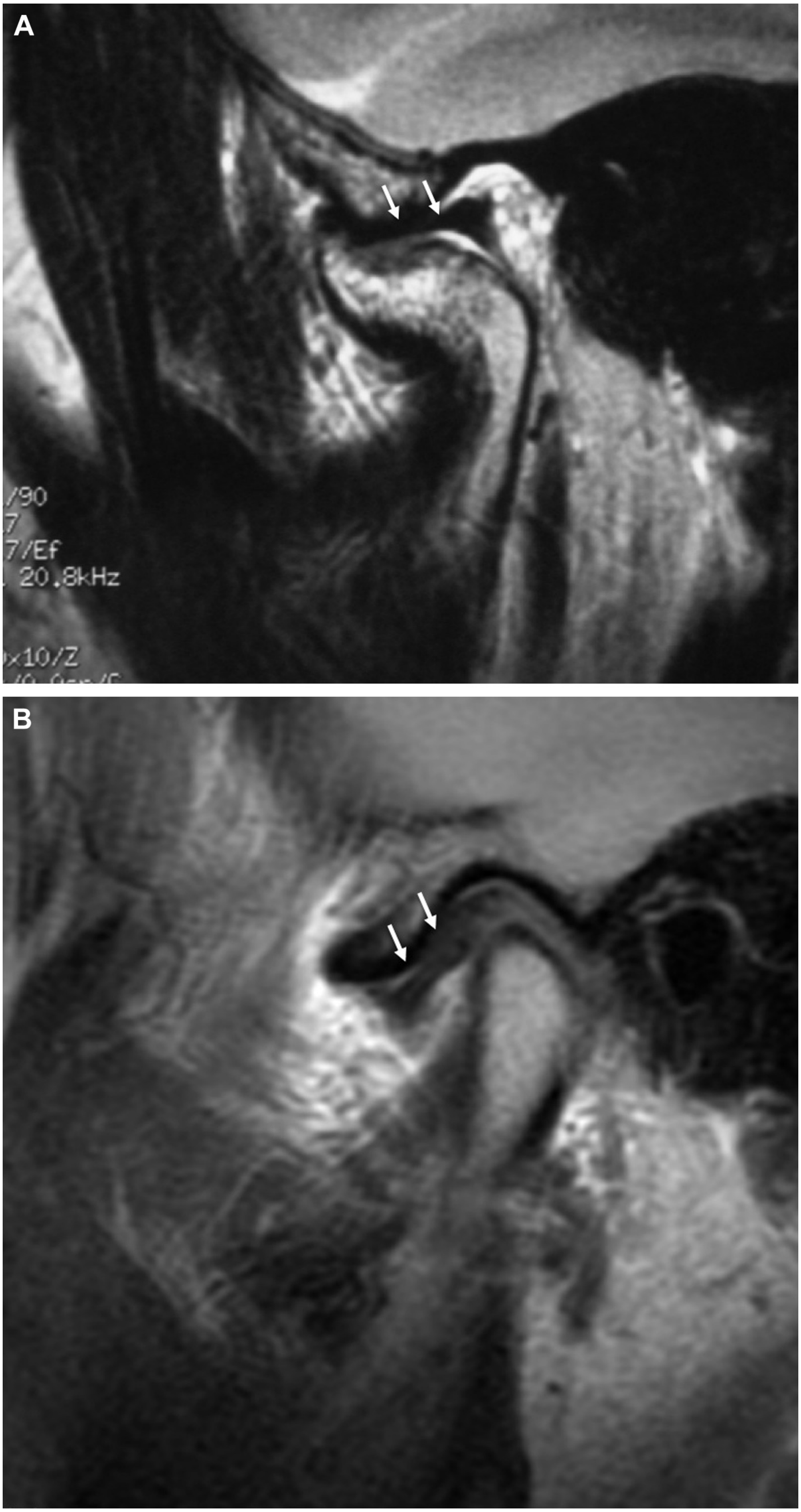

FIGURE 4. Magnetic resonance imaging scans. *A,* The ipsilateral osteochondroma, although quite large, shows that the articular disc is still in position *(arrows)*. The width of the condylar neck is increased. Note the disarticulation of condyle downward out of the fossa from the exophytic tumor growing forward beneath the articular eminence. *B,* The contralateral joint shows a condyle that is smaller, with an anteriorly displaced disc *(arrows)*. **(Fig 4 continued on next page.)**

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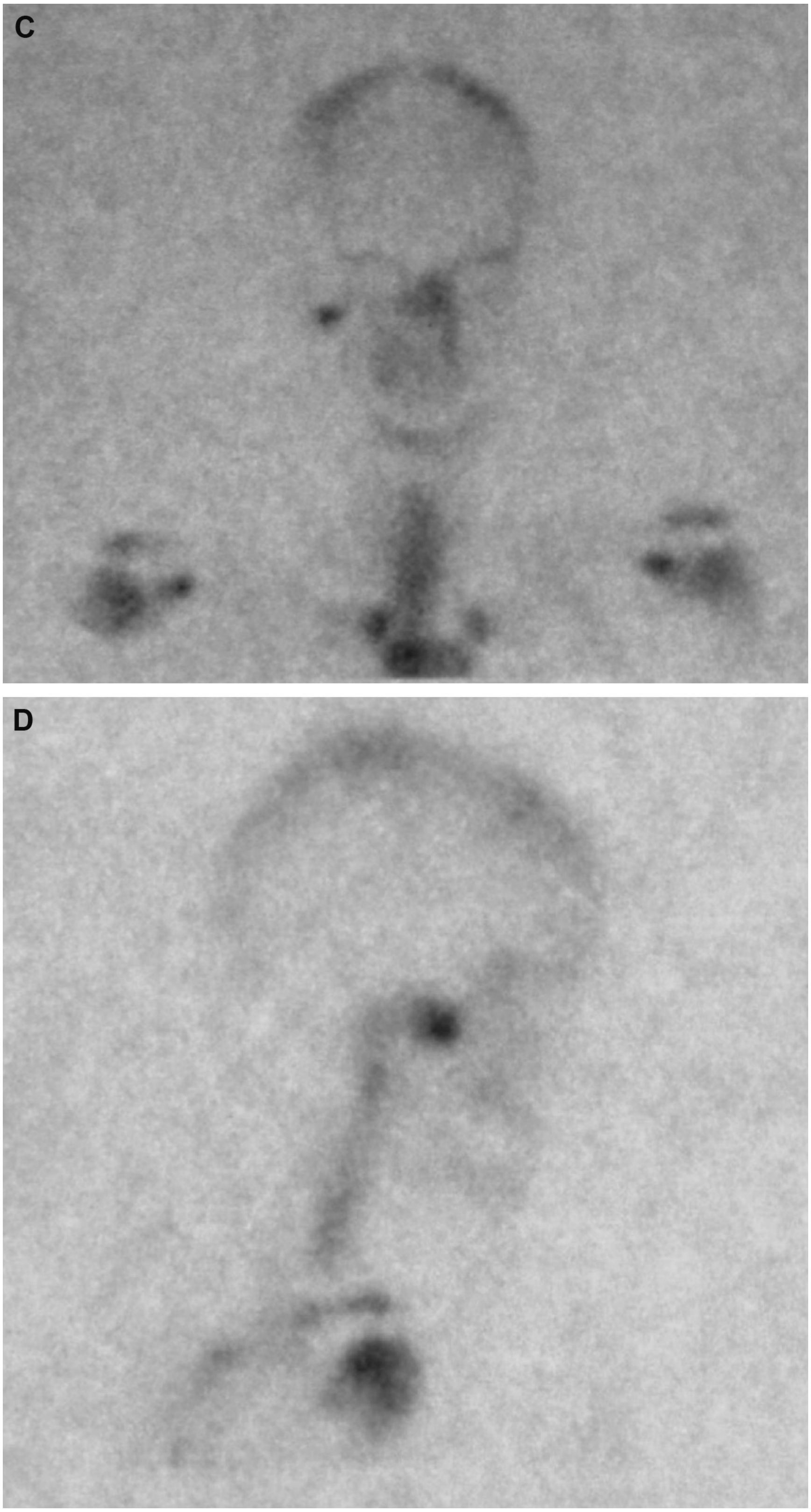

FIGURE 4 (cont'd). *C,D,* Technetium 99 bone scan showing increased uptake associated with right-sided condylar hyperplasia type 2.

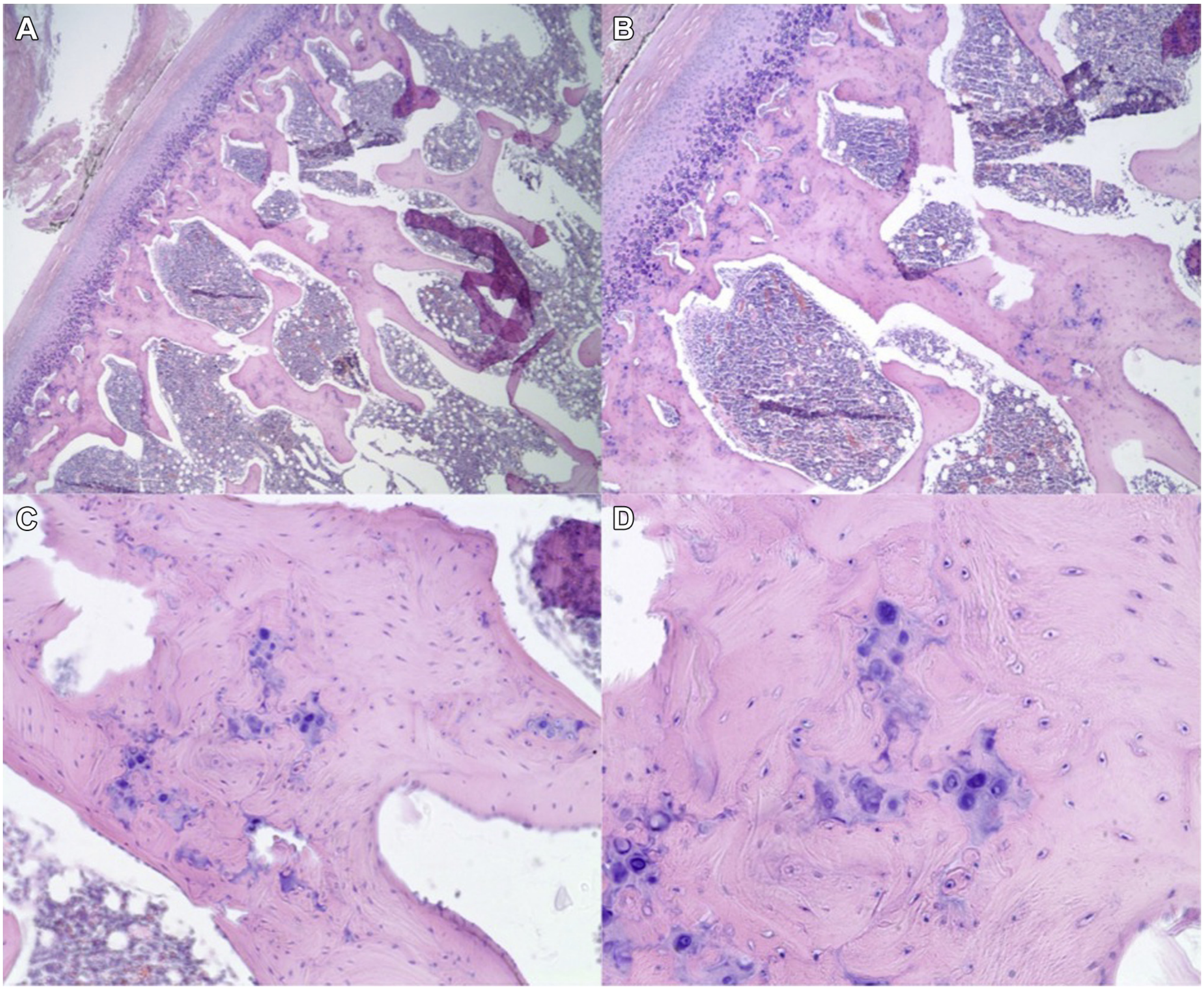

FIGURE 5. Hematoxylin and eosin staining. Original magnification at *A*, ×40 and *B*, ×80 showing a cartilaginous cap that might not be too dissimilar from the normal growth cartilage, although areas of increased thickness could be present. Original magnification at *C*, ×200 and *D*, ×400 showing the endochondral ossification and cartilaginous islands in the subcortical bone. These deeper regions have isolated aggregates of chondrocytes that resemble a growth plate. Endochondral ossification and transition to cancellous bone can be observed.

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rate of upward migration of the posterior ligament attachment, pulling the disc posteriorly.

HISTOLOGIC FINDINGS

Osteochondroma (CH type 2) will include a cartilaginous cap similar to that seen in normal growth cartilage, endochondral ossification, cartilaginous islands in the subcortical bone, and a marrow space contiguous with the underlying bone (Figs 5A-D). It has been reported that the cartilaginous cap can be 1 cm or greater in thickness in the axial skeleton. However, it will tend to be thinner in the maxillofacial region and could even be absent in longstanding cases. Grey et al[23,24] reported that the bony trabeculae often will be thickened and irregular, resulting in a consistently large volume of trabecular bone and a greater than normal percentage of surfaces covered in osteoids. They also reported the presence of an uninterrupted layer of undifferentiated germinating mesenchymal cells, hypertrophic cartilage, and islands of chondrocytes in the subchondral trabecular bone. They made the direct correlation between the scintigraphic activity and the frequency of cartilage islands at depth in the trabecular bone.[23,24] The cartilage islands are minigrowth centers producing bone, causing enlargement of the condyle. As more bone is produced from these islands, additional separation occurs between them, making it more difficult to identify these islands histologically in larger and older tumors.

Malignant transformation has been reported but has been very rare (<1%) in cases of solitary lesions.[9,10] Although a recurrence rate of 2% has been reported for osteochondromas that occur all over the body, no

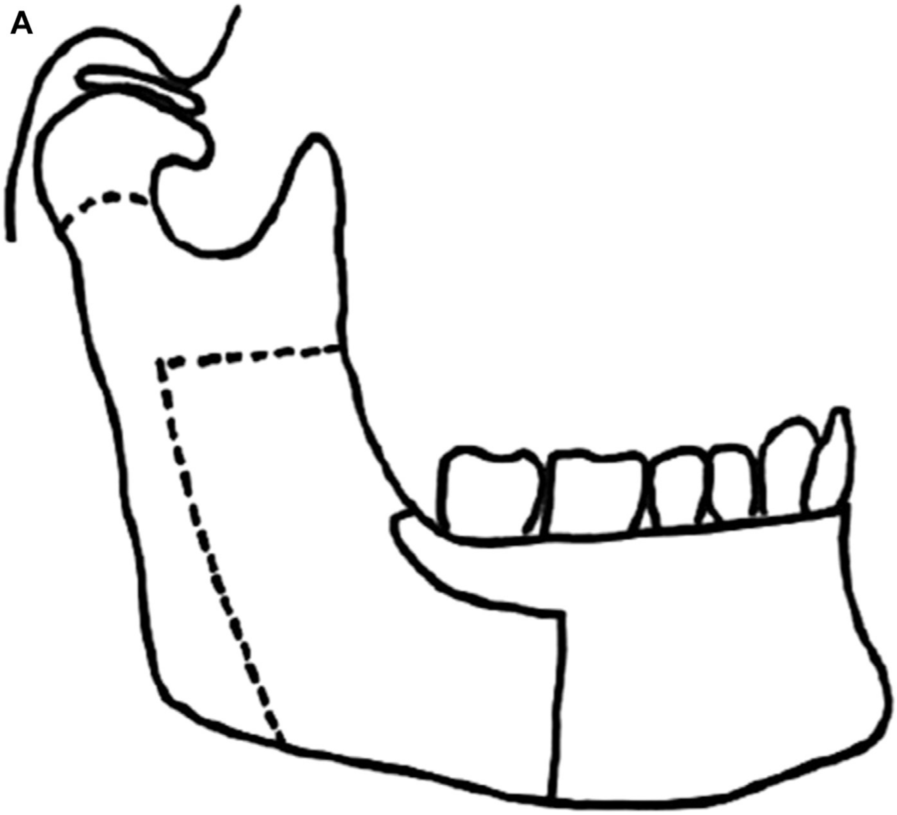

FIGURE 6. *A,* Schematic representation of the osteochondroma with increased vertical height of the condyle, ramus, and body of the mandible. Outlined is the low condylectomy and sagittal split osteotomy. **(Fig 6 continued on next page.)**

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case of either recurrence or malignant transformation has been reported in the mandible.

A typical evaluation for a patient suspected with CH type 2 should include the following:

1. History: age of onset, etiology, progression, previous treatment, current symptoms, other medical conditions.
2. Evaluation of previous records, if available.
3. Clinical examination.
4. Cone-beam imaging and analysis of lateral cephalography, panoramic radiography, and TMJ imaging.
5. MRI analysis to evaluate TMJ pathologic features and disc position and condition.
6. Bone scan, if deemed necessary (we have rarely required this study)
7. Dental model analysis.
8. Establish a comprehensive diagnosis and treatment plan.
9. Monitor growth, development, and pathologic progression during preoperative orthodontic preparation.

Our hypothesis was that the treatment of mandibular condylar osteochondroma using a low condylectomy, disc repositioning, and orthognathic surgery in a single surgical stage would provide a highly predictable method to eliminate the pathologic entity, provide optimal functional and esthetic outcomes, and reduce pain. The specific aims of the present study were to evaluate the treatment outcomes using our surgical protocol relative to gender, age of onset, and age at surgery. We also sought to identify the functional, esthetic, and imaging characteristics; assess the treatment outcomes subjectively and objectively relative to pain, jaw function, diet, and disability; and determine the tumor recurrence rate.

PATIENTS

The records of patients diagnosed with CH type 2 in a single private practice (L.W.) from 1976 to 2011 were retrospectively analyzed. The Baylor University Medical Center institutional review board reviewed the study and declared it exempt from the requirement for patient consent. A total of 93 patients were diagnosed with CH type 2, and 60 were treated surgically. The inclusion criteria included *1)* clinical, radiographic, and histopathologic confirmation of active osteochondroma, *2)* surgery using the study protocol (Fig 6), *3)* adequate pre- and postoperative follow-up

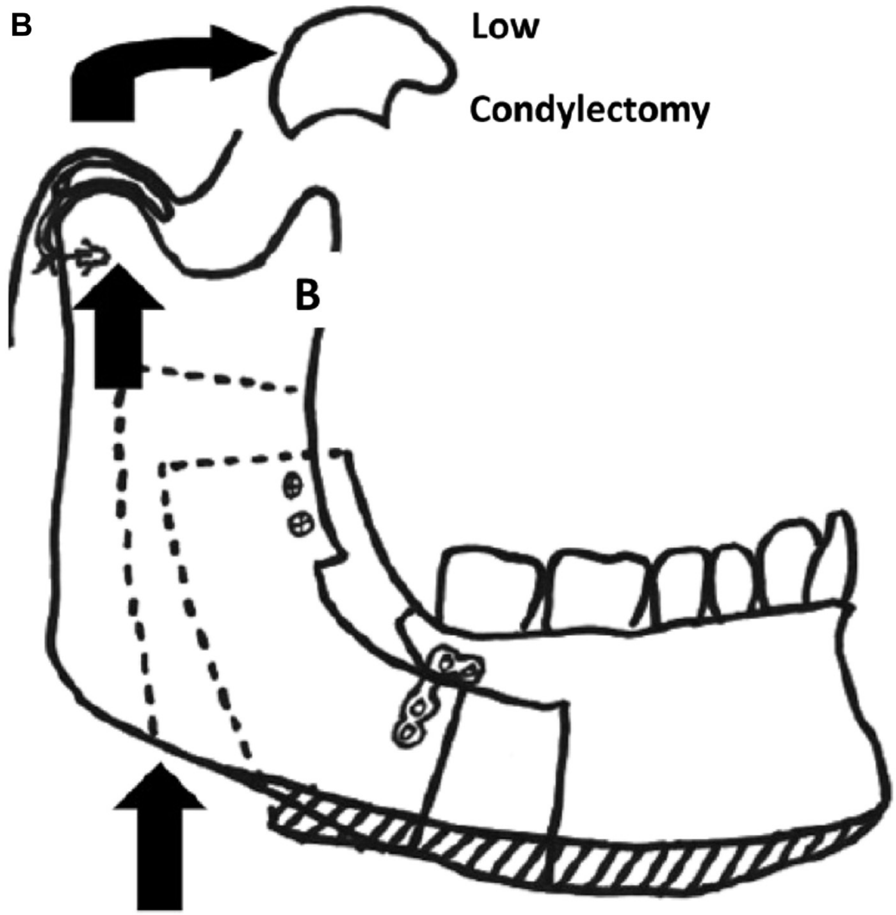

FIGURE 6 (cont'd). *B,* A low condylectomy was performed with removal of the condyle. The disc has been repositioned with a Mitek anchor. The orthognathic surgery, involving sagittal split osteotomy to place the condyle and disc into the fossa, is illustrated, along with the inferior border ostectomy. In most cases, maxillary osteotomies will also be indicated to optimize correction of the facial asymmetry, occlusion, and function.

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records, and *4)* a minimum of 12 months of follow-up. Patients underwent radiographic imaging studies, including panoramic radiography, standardized lateral cephalography, standardized lateral cephalometric tomography, or cone-beam CT, preoperatively (T1), immediately postoperatively (T2), and at the longest follow-up point (T3).

A diagnosis of osteochondroma was confirmed in each patient by postoperative histologic examination. One examiner performed all subjective and objective evaluations. The subjective evaluations for quality of life used a numeric analog scale for TMJ pain (0, no pain; 10, worst pain imaginable), headache (0, no pain; 10, worst pain imaginable), facial pain (0, no pain; 10, worst pain imaginable), jaw function (0, normal function; 10, no movement), diet (0, no restriction; 10, liquid only), and disability (0, no disability; 10, totally disabled). The objective evaluations included the maximum incisal opening, lateral excursion, occlusal and skeletal stability, and clinical and imaging evidence of ipsilateral and contralateral TMJ pathologic features. The findings were analyzed, and $P < .05$ was considered statistically significant.

TREATMENT PROTOCOL

The surgical protocol we used was developed by the senior author (L.W.) in 1976.[21] The protocol includes, first, low condylectomy to remove the ipsilateral condyle at the junction of the condylar head and neck and preserving the condylar neck (Figs 6, 7A,B). Second, the condylar neck is reshaped to function as the new condyle. Third, the articular disc is repositioned over the top of the condylar neck and stabilized (Fig 7C). Fourth, the articular disc on the contralateral side, when displaced, is repositioned. Fifth, orthognathic surgery is used to correct the associated maxillary and mandibular deformities. Finally, an inferior border ostectomy on the ipsilateral side is used to reestablish the vertical height balance of the mandibular ramus, body, and symphysis, if indicated (Fig 3). This last procedure requires dissection and

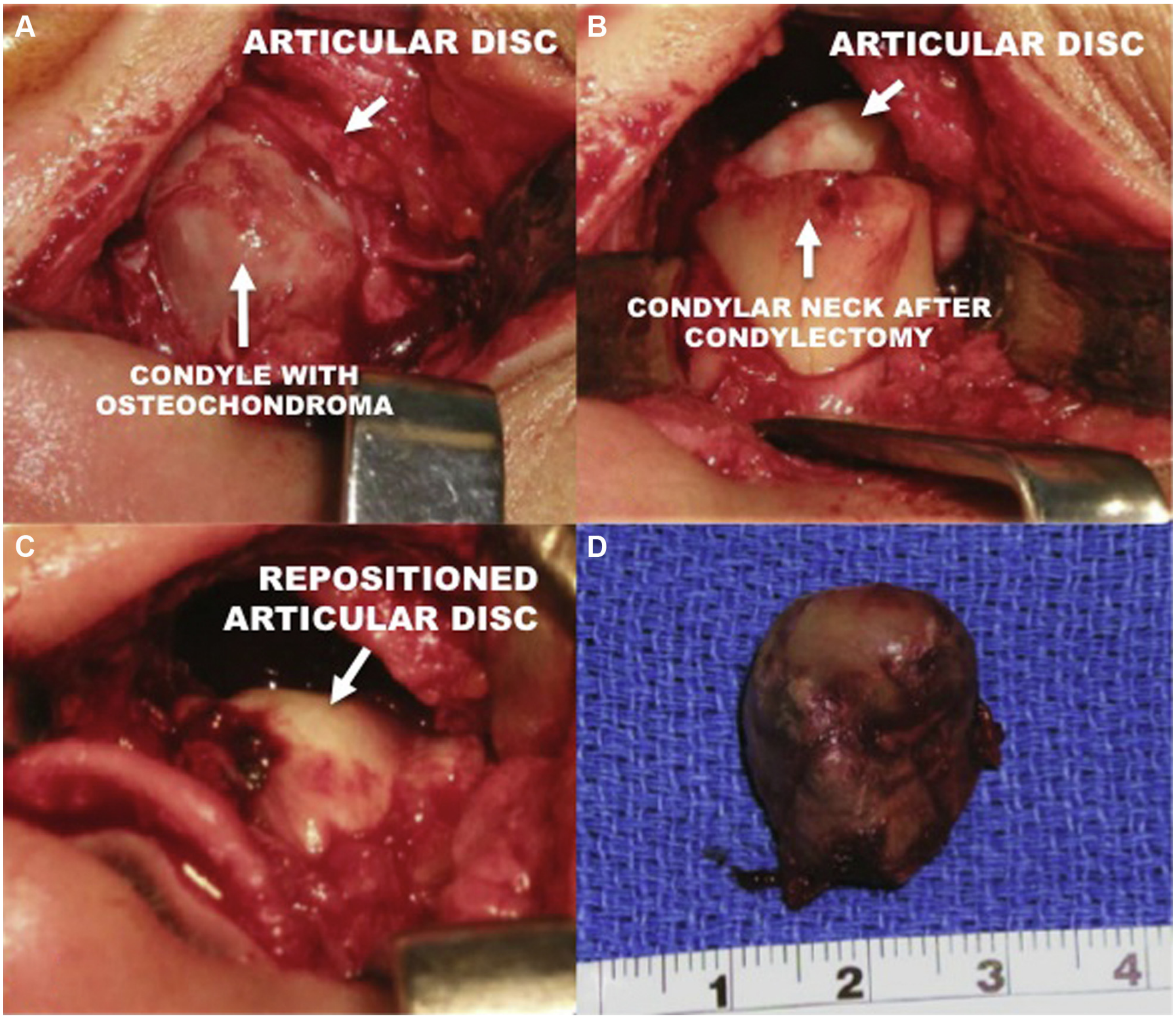

FIGURE 7. *A,* At surgery, the right mandibular condyle with osteochondroma is observed. *B,* Postcondylectomy view showing the remaining condylar neck with an increased width mediolaterally and anteroposteriorly. The condyle was recontoured to resemble the shape of a normal condylar head. *C,* The disc has been repositioned over the top of the condylar stump using a Mitek anchor. *D,* View of the condylar specimen.

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preservation of the inferior alveolar nerve, if it is located low in the mandible, where the ostectomy will be performed. This protocol will provide predictable and stable outcomes (Figs 2G-L). When performing surgery to remove the tumors, the incision for removal of CH type 2A can usually be smaller than that required for a large CH type 2B, which can require greater access because of greater difficulty in removal. CH type 2B might have a greater risk of intraoperative and postoperative vascular and neurologic complications.

Our treatment protocol will allow removal of the tumor, yet still uses the enlarged condylar neck as the new condyle. The articular disc on the ipsilateral side and, frequently, on the contralateral side (if that disc is displaced) will require repositioning and stabilization (Fig 7) to provide the best treatment outcome relative to skeletal and occlusal stability, function, esthetics, and elimination of any associated pain and dysfunction.[25-30] Other treatment options to reconstruct the ipsilateral TMJ have included a TMJ custom-fitted total joint prosthesis or the use of autogenous tissues such as sliding vertical mandibular ramus osteotomy, sternoclavicular graft, rib graft, free bone graft, or pedicled osseous graft. Although we have preferred treating the ipsilateral side with low condylectomy and disc repositioning, if the disc is not salvageable, the TMJ Concepts (Ventura, CA) patient-fitted TMJ total joint prosthesis has been our treatment of choice.[1,31,32]

When CH type 2 is identified during the normal growth years, surgery should be deferred, if possible, until 15 years of age for girls and 17 to 18 years for boys, after normal jaw growth is relatively complete. The severity of the deformity, however, could warrant earlier surgery. If ipsilateral low condylectomy is performed too early while normal jaw growth is still occurring, the risk exists of the contralateral condyle continuing normal growth and shifting the mandible toward the ipsilateral side until growth cessation. However, if surgery is indicated at an earlier age, a high condylectomy can be performed on the contralateral side so that no additional growth will occur and the mandible will remain symmetric. Another option during growth would be to perform the unilateral condylectomy and plan for orthognathic surgery as a second stage after the cessation of growth.

An ideal facial balance can be difficult to achieve postoperatively with the more pronounced vertical facial asymmetries, because of the excessive amount of soft tissue development that will occur on the ipsilateral side. In the axial orientation, the ipsilateral mandibular body will become more curved and the contralateral body contour will be flatter. Thus, with vertically shortening of the ipsilateral bony structures and rotation of the mandible toward the ipsilateral side, excessive soft tissue volume results, including the masseter muscle, which will make the ipsilateral side more bulky, even with the most accurate skeletal correction.

Results

Of the 60 surgically treated patients, 37 (28 females and 9 males) met the inclusion criteria (Table 1). The remaining 23 patients were excluded because of inadequate records, a different protocol used, or fewer than 12 months of follow-up. Most of the excluded patients had been treated earlier when the subjective and objective criteria were not recorded or other records such as radiographs were inadequate. The reported age at the onset of facial asymmetry included 25 patients (68%) aged 7 to 20 years, 9 patients (24%) aged 21 to 30 years, 2 patients aged 31 to 40 years (5%), and 1 patient (3%) aged 41 to 50 years (Table 2). Thus, osteochondroma of the mandibular condyle commonly develops in the second decade of life. The average age at surgery for all operated patients (n = 60) was 26.3 years (range 13 to 48; Table 3), with 38% treated in the second decade, 32% in the third, 17% in the fourth, and 13% in the fifth decade. The long-term postoperative follow-up period averaged 48 months (range 12 to 288). Quality of life was evaluated by measuring multiple variables associated with pain levels and daily function preoperatively and postoperatively. Using a 0 to 10 scale, patients experienced significant improvement from T1 to T3. The TMJ pain change was 3.6 to 0.14, for an improvement of 3.46 ($P < 4.33E\text{-}08$). The headache change was 3.2 to 0.6, for an improvement of 2.6 ($P < 2.7E\text{-}05$). The facial pain change was 3.4 to 0.3, for an improvement of 3.1 ($P < 2.6E\text{-}07$). The jaw function change was 3.7 to 1.5, for an improvement of 2.2 ($P < 7.9E\text{-}07$). The diet change was 3.2 to 0.76, for an improvement of 2.44 ($P < 2.1E\text{-}07$). Finally, the disability change was 2.1 to 0.24, for an improvement of 1.86 ($P < 4.9E\text{-}06$ (Fig 8).

The average preoperative incisal opening was 47.2 mm (range 11 to 55). After surgery, it was 44.9 mm (range 29 to 61), with a statistically insignificant decrease of 2.3 mm ($P < .084$; Fig 9). The average right excursive movement at T1 was 7.8 and at T3 was 5.3 mm, for a statistically significant average reduction of 2.5 mm ($P < 1.0E\text{-}05$). The left excursive movement at T1 was 7.2 mm and had decreased to 5.0 mm at T3, for a statistically significant reduction of 2.2 mm ($P < 9.6E\text{-}07$).

Of the 37 patients, 28 (76%) had contralateral TMJ disc dislocation preoperatively and required contralateral disc repositioning and stabilization at surgery. In addition, 34 of the 37 patients (92%) required concomitant double jaw orthognathic surgery, and 3 patients had undergone mandibular osteotomy without maxillary surgery. CH type 2 had occurred rather equally on the left (46%) and right (54%) sides.

Of the 37 patients, 34 (92%) maintained a stable Class I occlusion at the long-term follow-up point.

Table 1. PATIENTS DIAGNOSED WITH CONDYLAR HYPERPLASIA TYPE 2 (N = 93)

Variable	Female	Male	Right TMJ	Left TMJ	Contralateral TMJ Disc Displacement
Operated (n = 60)	50 (83)	10 (17)	28 (47)	32 (53)	—
Study cases (n = 37)	28 (76)	9 (24)	20 (54)	17 (46)	28 (76)
Unoperated (n = 33)	19 (58)	14 (42)	16 (49)	17 (51)	—
Total (n = 93)	69 (74)	24 (26)	44 (47)	49 (53)	—

Data presented as n (%).

Abbreviation: TMJ, temporomandibular joint.

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Table 2. REPORTED AGE AT ONSET OF CONDYLAR HYPERPLASIA TYPE 2 (N = 37)

Age Range (yr)	Patients (n)
7-20	25 (68)
21-30	9 (24)
31-40	2 (5)
41-50	1 (3)

Data presented as n (%).

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One boy, treated at 13 years old, had continued to grow after surgery on the contralateral side and had developed a mild asymmetry, with the operated side vertically and anteroposteriorly deficient owing to loss of ipsilateral growth secondary to the condylectomy procedure. However, this was of no concern to the patient, and no additional surgical intervention was required. That same patient had developed a 2-mm anterior open bite owing to early discontinuation of retainers, resulting in orthodontic relapse. This was subsequently corrected orthodontically. Another patient had failed to wear the postorthodontic retainers and had developed a mild malocclusion, subsequently requiring additional orthodontics.

A 17-year-old boy with a progressive, worsening deviated prognathism toward the left had clinical and radiographic compatibility with right CH type 1B. He had undergone unilateral right high condylectomy and double jaw orthognathic surgery using the Wolford protocol for CH type 1. However, the histopathologic findings reported an osteochondroma. Facial asymmetry recurred because the tumor had not been completely removed. Thus, 14 months later, low condylectomy, disc repositioning, and a partial repeat of the orthognathic surgery were completed. He remained stable at 4 years postoperatively.

Of the 60 patients with CH type 2 treated surgically, 50 (83%) were female (5:1 ratio). Of the 93 patients diagnosed with CH type 2, 69 (74%) were female

Table 3. AGE RANGE AT SURGERY FOR ALL OPERATED PATIENTS (N = 60)

Age Range (yr)	Patients (n)
13-20	23 (38.30)
21-30	19 (31.70)
31-40	10 (16.70)
41-56	8 (13.30)

Data presented as n (%).

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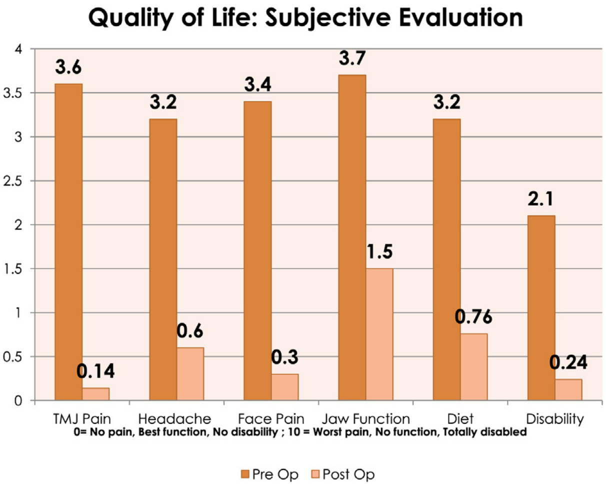

FIGURE 8. Quality of life subjective evaluation (n = 37). Pre Op, preoperatively; Post Op, postoperatively; TMJ, temporomandibular joint.

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(3:1 ratio). In the study group, 28 of the 37 patients (76%) were female (3:1 ratio). These findings illustrate the significantly greater occurrence in the female population (Table 1). Of the 33 patients who had not undergone surgery, 58% were female and 42% were male (6:4 ratio), indicating that males might be less likely to pursue surgical treatment.

CASE 1

A 45-year-old woman (Figs 2A-F, 3A) presented with significant facial asymmetry, with onset around the age of 18 years, and pain as a result of right-sided condylar

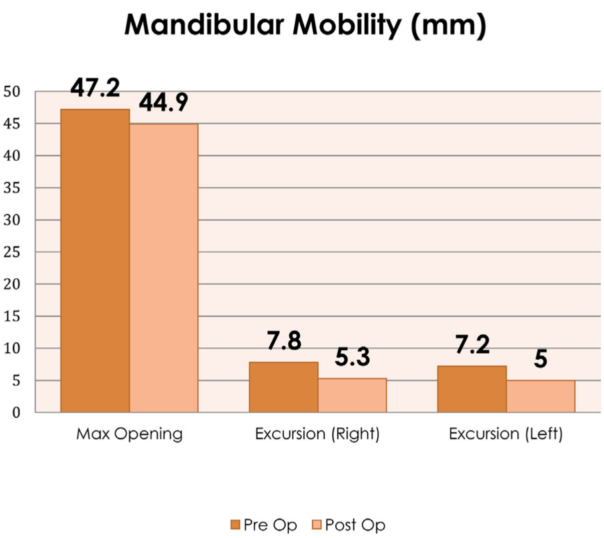

FIGURE 9. Range of motion objective evaluation (n = 37). Max, maximum; Pre Op, preoperatively; Post Op, postoperatively.

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FIGURE 10. Case 2. *A,* View of 21-year-old woman with onset of left-sided condylar hyperplasia type 2A, 2 years before our initial evaluation. She had bilateral temporomandibular joint pain related to bilateral disc displacement. *B,* Facial asymmetry can be seen with vertical elongation of the left side of the face. *C,* In profile, the retruded maxilla and mandible can be seen, as well as the external nasal deformity. *D-F,* She had anterior and left-sided posterior open bites, Class II end-on canine occlusion, with occlusion only on the right first and second molars. *G-L,* The patient was evaluated 5.5 years postoperatively and demonstrated good facial balance and occlusion. **(Fig 10 continued on next page.)**

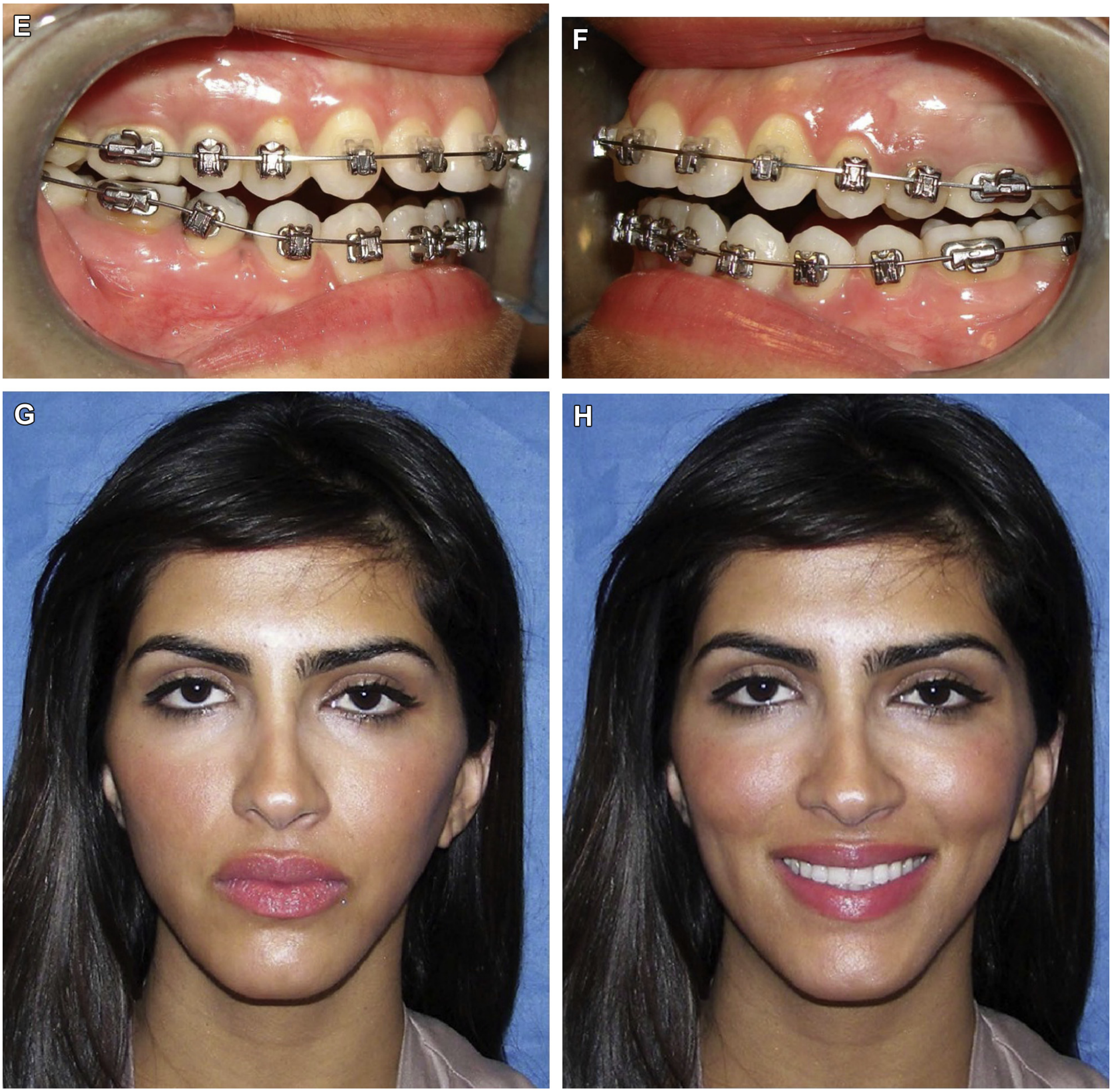

FIGURE 10 (cont'd). (Fig 10 continued on next page.)

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growth, including the development of TMJ clicking, pain, and headaches and slow but progressive worsening facial asymmetry. At the initial consultation, the patient reported a score of 8, 8, 8, 7, 5, and 7 for daily headaches, myofascial pain, TMJ pain, jaw function, diet, and disability, respectively. Owing to the slow growth of her right condylar osteochondroma, the maxilla had adapted in a vertical direction, resulting in no significant right-sided open bite. The incisal opening was 46 mm, the right excursion was 5 mm, and the left excursion was 5 mm. TMJ MRI showed significant vertical and horizontal enlargement of the right condyle and left TMJ arthritis with bilateral disc dislocation. Her diagnosis included right condylar hyperplasia type 2B (with exophytic growth), left TMJ arthritis and bilateral disc dislocation, right mandibular and maxillary vertical hyperplasia and asymmetry, a transverse cant in the occlusal plane, a chin midline shift 13 mm to the left, and TMJ pain, myofascial pain, and headache.

The preoperative clinical and cephalometric analysis showed a significant vertical difference between the elongated right side at the inferior border and at the occlusal plane (Fig 3A). Her treatment plan included preoperative orthodontics to align and level the arches. Subsequently, single-stage surgery was planned,

FIGURE 10 (cont'd).

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including right mandibular low condylectomy with recontouring of the condylar neck (Figs 6, 7), bilateral TMJ disc repositioning with Mitek anchors, bilateral ramus osteotomies to shift the mandible back to the facial midline and level transversely, multiple maxillary osteotomies for transverse leveling and alignment, right inferior border ostectomy (preserving the inferior alveolar nerve), and genioplasty (Fig 3B). Finally, postoperative orthodontics was used to refine and retain the occlusion.

The patient was seen at 7 years postoperatively with stable functional and esthetic results (Figs 2G-L). She rated her headaches at 3 (a decrease of 5 points), TMJ pain at 2 (a decrease of 6 points), myofascial pain at 3 (a decrease of 4 points), jaw function at 4 (unchanged), diet at 4 (a decrease of 1 point), and disability at 2 (a decrease of 5 points). The incisal opening was 40 mm (a decrease of 6 mm), with excursion to the right of 4 mm (a decrease of 1 mm) and to the left of 3 mm (a decrease of 2 mm). Although the quality of life factors had improved significantly, she still had some discomfort and functional issues, likely related to the long-standing TMJ pathologic entity (27 years), including the progressive tumor development and displacement of the articular discs.

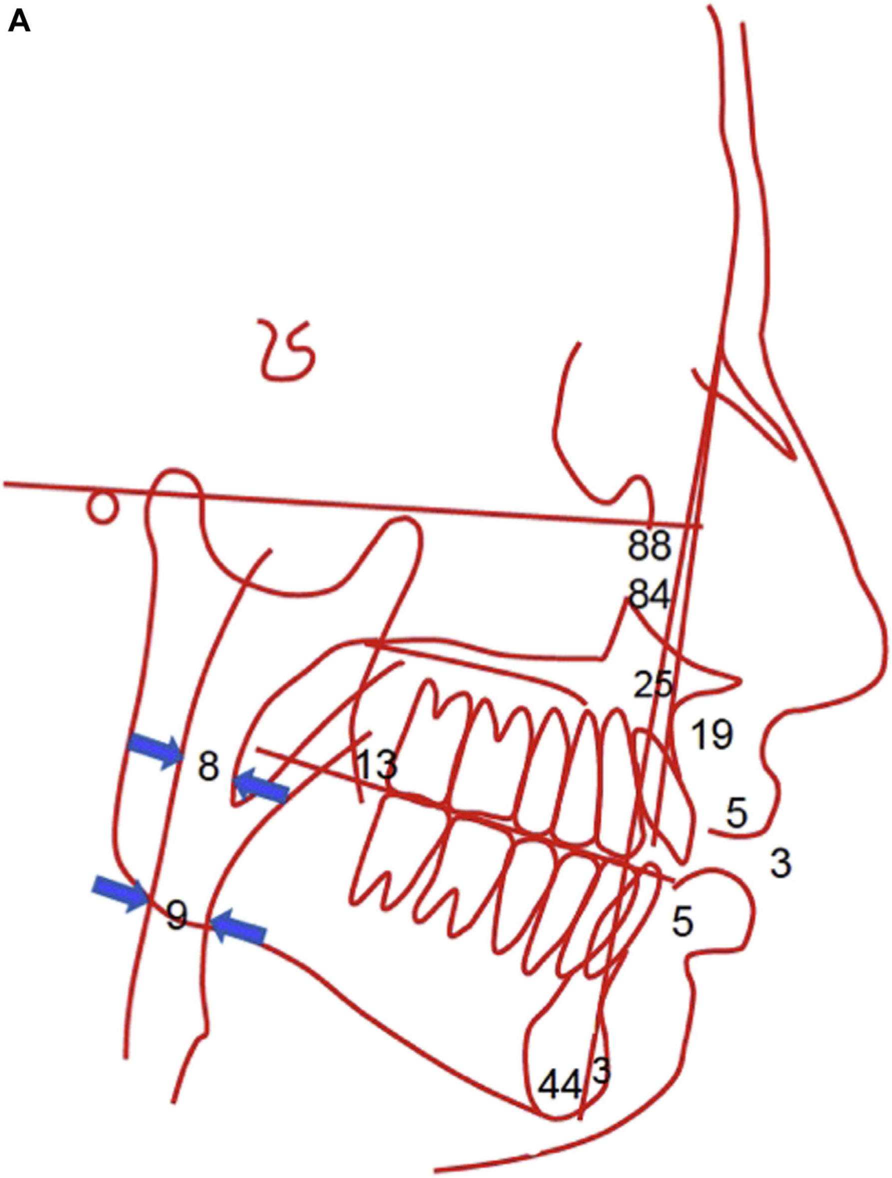

FIGURE 11. Case 2. *A*, Cephalometric analysis showing the retruded position of the maxilla and mandible, with a relatively high occlusal plane angle. **(Fig 11 continued on next page.)**

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CASE 2

A 21-year-old woman (Figs 10A-C) presented with the chief complaints of pain associated with her right TMJ and worsening facial asymmetry, first noticed about 2 years before her initial consultation. The anterior and left side open bites (Figs 10D-F) and associated pain had made it difficult for her to chew. The radiographic evaluation showed vertical elongation of the left condyle. MRI confirmed vertical elongation of the left condyle, with the bilateral TMJ articular discs dislocated anteriorly. Her preoperative diagnosis included left condylar osteochondroma CH type 2A (vertical growth vector without horizontal exophytic tumor growth); bilateral TMJ articular disc dislocation; left mandibular vertical hyperplasia; mandibular asymmetry; maxillary and mandibular anteroposterior hypoplasia; a left posterior and anterior open bite with occlusion only on the right first and second molars; high occlusal and mandibular plane angles (Fig 11A); Class II end-on occlusion; hypertrophied inferior turbinates with nasal airway obstruction; TMJ and myofascial pain; and an external nasal deformity. Her incisal opening was 28 mm, with excursion to the right of 7 mm and the left of 4.5 mm. Her TMJ pain and myofascial pain was scored at 3, jaw function at 8, diet at 6, and disability at 8.

The treatment plan included preoperative orthodontics to align and level the arches. Subsequently,

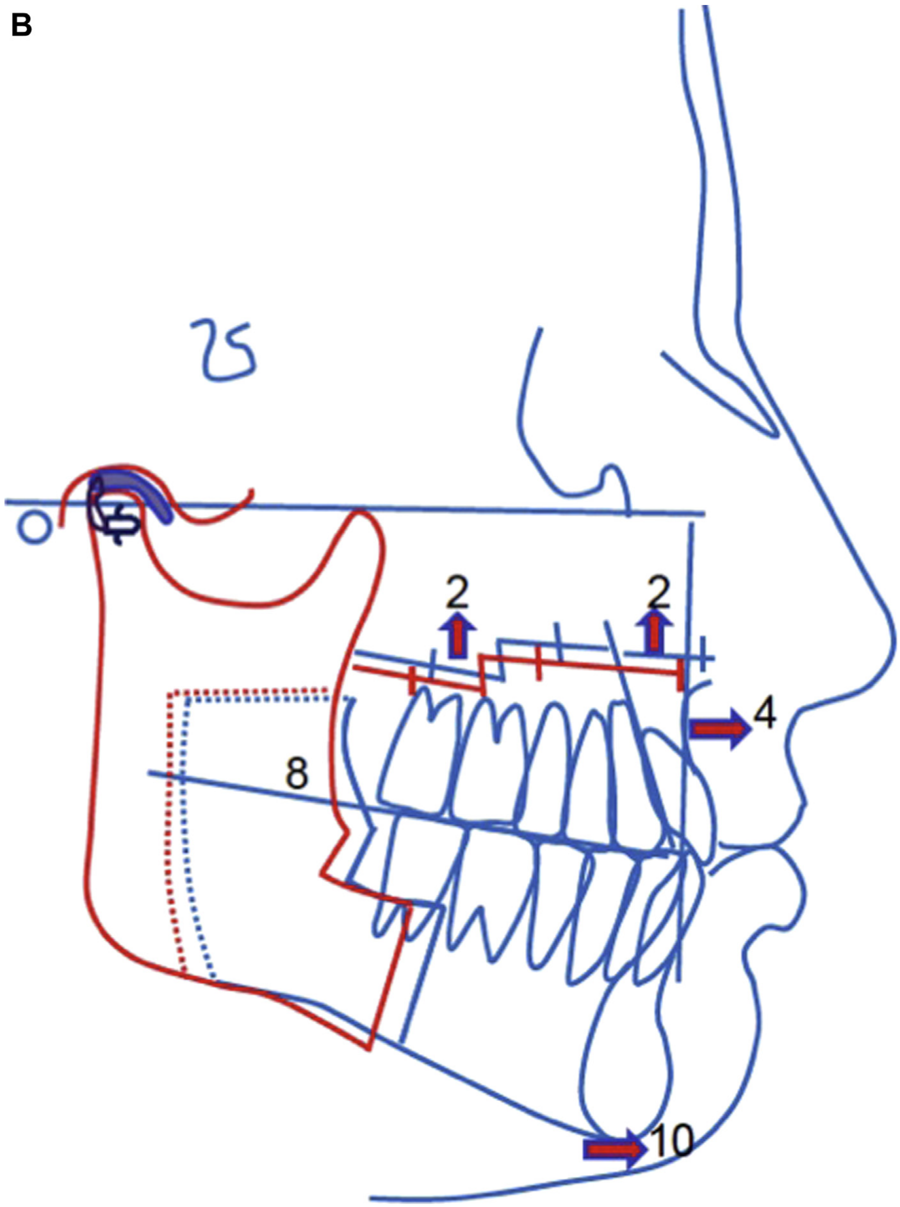

FIGURE 11 (cont'd). *B,* The surgical treatment objective included *1)* left low condylectomy; *2)* bilateral temporomandibular joint articular disc repositioning and ligament repair with Mitek anchors; *3)* bilateral mandibular ramus osteotomies to advance the mandible in a counterclockwise direction, decrease the occlusal plane, and level the mandible transversely; *4)* maxillary osteotomies to advance the maxilla and level it transversely and decrease the occlusal plane angle; and *5)* external rhinoplasty.

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single-stage surgery was planned with left low condylectomy, recontouring of the condylar neck, and bilateral TMJ disc repositioning with Mitek anchors. Bilateral mandibular ramus osteotomies were planned to advance the mandible counterclockwise and decrease the occlusal plane angle and level transversely. Also, multiple maxillary osteotomies were planned to advance the maxilla counterclockwise and decrease the occlusal plane angle and level transversely (Fig 11B). In addition, the patient required bilateral partial inferior turbinectomies and rhinoplasty. Finally, postoperative orthodontics were required to refine and retain the occlusion. Histologic examination of the resected condyle specimen revealed a thickened cartilaginous cap over the head of the condyle and islands of cartilage within the condylar bone (similar to those shown in Fig 5), confirming the diagnosis of osteochondroma. The patient was seen 5.5 years after surgery (Figs 10G-L) and demonstrated good functional and esthetic stability. The incisal opening was 44 mm and excursion 5 mm to the right and 6 mm to the left. She had no TMJ pain, myofascial pain, or headaches, with her score for jaw function, diet, and disability at 0.

Comparing the outcomes for these 2 patients showed that the earlier the treatment is performed, such as in patient 2, the better the outcome relative to the quality of life and pain reduction.

Discussion

The surgical management of mandibular condylar osteochondroma was highly predictable using the treatment protocol we have presented. Our protocol includes a low condylectomy for elimination of the osteochondroma; recontouring of the remaining condylar neck to function as the "new" condyle; repositioning the articular disc over the "new" condyle and on the contralateral side, if displaced; and appropriate orthognathic surgery (usually double jaw) concomitantly to optimize occlusion, function, and esthetics and eliminate pain within 1 operation. The surgery can be staged; however, the TMJ surgery should be performed before the orthognathic surgery. We included 37 patients in the present study, with 34 of the 37 having stable skeletal and occlusal outcomes. Of the 3 remaining patients, 2 had required additional orthodontics and 1 had required additional surgery. For the 37 patients, an insignificant decrease was seen in the incisal opening, but a statistically significant decrease was seen in the excursion movements. A statistically significant improvement was seen in pain, jaw function, diet, and disability.

In the entire group of patients diagnosed with mandibular condylar osteochondroma (n = 93), 74% were female and 26% were male. Patient age at the reported onset was 7 to 20 years in 68% of the patients, indicating a predominance of occurrence in adolescent girls. The distribution of the tumor between the right (47%) and left (53%) sides was fairly equal. The contralateral TMJ had coexisting articular disc dislocation in 76% of the patients and had resulted from overload of that joint by the ipsilateral tumor.

The quality of life subjective evaluations demonstrated statistically significant improvement in all areas, including TMJ pain, headaches, facial pain, jaw function, diet, and disability (Fig 8). These changes were expected and compatible with our other TMJ surgery studies.[25-30] Mandibular mobility decreased insignificantly for incisal opening (2.3 mm) from 47.2 to 44.9 mm. The excursive movements decreased significantly, with a change in the right of −2.5 mm from 7.8 to 5.3 mm and in the left of −2.2 mm from 7.2 to 5.0 mm (Fig 9). The decreases in excursive movements were expected and compatible with our previous studies of decreased excursion after open joint surgery with disc repositioning.[25-30] The statistically significant decrease in excursive movements resulted from TMJ surgery in which the ipsilateral joint underwent condylectomy with disc repositioning and the contralateral TMJ underwent disc repositioning in 76% of the patients. The contralateral disc will become displaced by overload to the joint by the ipsilateral osteochondroma forcing the contralateral condyle posteriorly in the fossa, displacing the disc forward. Intercapsular adhesions and scarring of the capsule from the TMJ pathologic features and subsequent surgery were likely the factors decreasing the lateral mobility of the mandible.

Obwegeser and Makek[33] proposed a classification system in 1986 describing 2 different types of hyperplastic mandibular growth anomalies. Hemimandibular hyperplasia included enlargement on 1 side of the mandible as a tridimensional anomaly, involving the condyle, ramus, and body. This created a unilateral vertical deformity, with the maxilla usually following the mandible and creating a transverse cant in the occlusion and jaws. This description is compatible with our classification of CH type 2. Obwegeser and Makek[33] also made a distinction between "exclusive hyperplasia of the condyle" (our CH type 2A) and "osseous tumor with exostosis of the condyle (our CH type 2B). Nitzan et al[34] described CH as a unilateral disorder in which the pathologic features occurs at the head of the condyle, creating facial asymmetry in either the vertical (CH type 2) or horizontal (CH type 1) direction, or a combination of both.

Wolford et al[22] presented a classification for CH that differentiated between the horizontal and vertical growth vectors, which are commonly caused by different TMJ pathologic entities. CH type 1 results in a predominately horizontal mandibular growth vector owing to accelerated and prolonged growth of the "normal" mandibular condylar growth mechanism, causing mandibular prognathism. It can be bilateral (CH type 1A) or unilateral (CH type 1B). CH type 2 is caused by a mandibular condylar osteochondroma that creates abnormal unilateral excessive vertical growth of the mandible, with a unilateral compensatory downward growth of the maxilla. CH type 2 was described in detail in the present report. CH type 3 includes other benign pathologic entities, and CH type 4 includes malignancies that develop in the mandibular condyle and cause condylar enlargement. Our classification for pathologic entities causing CH provides an indication of the rate of occurrence, nature of the pathologic features, abnormal growth process, histologic findings, and treatment considerations that will be most predictable to eliminate the pathologic entity and correct the associated facial deformity.

Many theories exist regarding the etiology and pathogenesis of CH type 2. One proposed theory involves aberrant foci of epiphyseal cartilage on the surface of bone. Proponents of this theory believed that stress in the regions of tendon insertion, where focal accumulations of cells with cartilaginous potential exist, will lead to formation of these tumors, because these lesions often arise at the coronoid process (temporalis muscle insertion) and anteromedial condylar region (lateral pterygoid muscle insertion). Other investigators believed that trauma and infection play a role in the formation of these lesions.[35-37] However, from our study, the preponderance of occurrence in females (74 to 83%) and onset most often in the second decade (68%; Table 3) could indicate a hormonal role in the etiology.

The exophytic growth that frequently occurs with mandibular condylar osteochondroma could tend to develop into areas that offer the least resistance to expansion. Thus, these formations will tend to develop into the anterior and medial aspect of the joint area. The fossa roof and posterior wall and medial and lateral capsules can serve as boundaries, directing the growth anteriorly and medially. These exophytic growth extensions can further displace the condyle and mandible downward and further elongate the ipsilateral side of the face as the tumor grows forward beneath the articular eminence, disarticulating the condyle down and out of the fossa (Fig 4A).

Although a recurrence rate of up to 2% has been reported for osteochondromas that occur all over the body, no case of recurrence has been reported for the mandibular condyle until our report. Only 1 patient in our study with CH type 2A exhibited recurrence. His facial growth pattern and facial morphology were compatible with CH type 1B, with a deviated mandibular prognathism off to the left and no increase in unilateral facial height. He was treated initially with Wolford's protocol for CH type 1 (high condylectomy with removal of the top 4 to 5 mm of the right condyle, disc repositioning, and double jaw orthognathic surgery). The postoperative pathology report, however, indicated an osteochondroma. His facial asymmetry recurred; thus, 14 months later, he returned to surgery, and an additional 8 to 10 mm of the right condylar head was removed, the disc was repositioned, and a partial repeat of the orthognathic surgery was performed. At 4 years postoperatively, he has had no tumor recurrence. This case emphasizes the necessity of performing a low condylectomy to eliminate the pathologic entity.

Our treatment protocol includes performing a low condylectomy at the junction of the condylar head and neck to entirely remove the tumor and preserve the condylar neck. In patients with osteochondroma, the involved condylar head will enlarge, and the neck of the condyle will become thicker anteroposteriorly and mediolaterally. This thickening of the neck makes it feasible to recontour the remaining condylar neck to function as a "new" condyle. If the condylar neck is short vertically, resulting in inadequate clearance of the sigmoid notch region to the articular eminence, the sigmoid notch can be lowered by removing bone from that region to provide appropriate clearance. The articular disc can then be repositioned onto the "new" condyle and stabilized. If the contralateral disc has been displaced and is salvageable, that disc should also repositioned and stabilized using the Mitek anchor technique.

An ipsilateral sagittal split osteotomy should be performed to seat the disc and "new" condylar head into the fossa. Additional orthognathic procedures, as indicated (ie, contralateral mandibular ramus sagittal split, maxillary osteotomies, genioplasty), can be performed concomitantly for correction of any associated facial deformities. The surgery can be performed in stages. However, the TMJ surgery must be performed first, followed at a second stage by the orthognathic surgical procedures. The low condylectomy will remove all remnants of the fibrocartilage from the condyle, resulting in the cortical and medullary bone of the condylar neck in juxta-approximation to the articular disc. Redevelopment of fibrocartilage over the "new condyle" should not be expected. Long-term TMJ CT scans have shown cortical bone on top of the stump covering the medullary bone.

In the present study group, 37 ipsilateral and 28 contralateral joints underwent surgery, for a total of 65 joints. Since using this surgical approach beginning in 1976, the senior author (L.W.) has only re-operated 1 treated joint in the present study group (1.5%). This was the patient who had undergone high condylectomy at the initial surgery and had had continued tumor growth until 14 months later, when a low condylectomy was performed. The low condylectomy with disc repositioning provided good long-term TMJ function and skeletal and occlusal stability for this patient at 4 years postoperatively.

The age at which the surgery should be performed and the period the pathologic entity has been present can have an effect on the severity of the subsequent facial deformity and surgical outcome. Generally, the sooner surgery has been performed after tumor onset, the less deformity will occur, requiring less corrective surgery. However, in adolescents, it might be best to wait, if possible, until 15 years old for girls and 17 to 18 years for boys to allow the growth of the mandible on the contralateral side and maxilla to be close to completion. Females will generally have 98% of their facial growth complete by 15 years of age and males at 17 to 18 years.[38] If surgery must performed earlier, the mandibular growth on the ipsilateral side will be arrested by the condylectomy; however, the contralateral side of the mandible will continue to grow normally, shifting the mandible to the ipsilateral side and causing facial asymmetry and occlusal disharmony. This could require additional orthognathic surgery after growth has finished. However, if a significant facial deformity is developing early during growth, ipsilateral condylectomy and disc repositioning can be performed with or without ipsilateral ramus osteotomy to place the "new" condyle into the fossa. Subsequent orthognathic surgery can be performed after growth completion. Another option would be to perform a contralateral high condylectomy to stop mandibular growth on that side, along with the ipsilateral condylectomy, so that the mandible will remain symmetric.

In cases of an osteochondroma in which the surgeon prefers to remove the condylar head and neck, and autogenous tissue is the only option for reconstruction, we would recommend using sternoclavicular grafts (instead of costochondral grafts) for joint reconstruction, because of their strength and structural, functional, and histologic similarities to the TMJ, including the presence of an articular disc that can be harvested with the graft.[39] However, maintaining the patient's TMJ articular disc and securing it to whatever graft system is used will improve jaw function and comfort in the long term. In cases in which the articular discs are not salvageable, we will use the TMJ Concepts patient-fitted total joint prosthesis because of the highly predictable outcomes.[1,31,32]

The number of reported osteochondroma cases of the mandibular condyle has been increasing in published studies. Although it is difficult to draw concrete conclusions regarding the etiology of the tumor, the treatment of these tumors is well established, with removal of the condyle. The results of the present study have shown that the use of a low condylectomy with articular disc repositioning and orthognathic surgery is a predictable option for treatment of CH type 2. In 28 of 37 operated cases (76%), the contralateral TMJ articular disc was dislocated. At surgery, the contralateral discs were repositioned. Since 1992, the Mitek anchor technique[25-30] has been used to stabilize the discs. This contralateral arthritis and anterior disc displacement results from increased loading of the TMJ by the enlarged ipsilateral condyle. The preoperative TMJ pain noted by most of our patients was associated with the contralateral TMJ. However, our profession has generally ignored this collateral problem.

The use of our protocol for the treatment of osteochondroma of the mandibular condyle has certain advantages. First, it eliminates the TMJ pathologic entity while maintaining native mandibular bone and the articular disc to function as the TMJ. Second, it allows for the concomitant performance of orthognathic surgical procedures for the correction of coexisting dentofacial deformities, enabling restoration of optimal function and facial balance. Third, it eliminates or significantly reduces the patient's pain. Fourth, the surgery can be completed in 1 operation (although it can also be staged). Fifth, it eliminates the need to harvest autogenous grafts, eliminating donor site morbidity. Sixth, intermaxillary fixation is not required after surgery because rigid fixation will be used for stabilization of the required osteotomies. Seventh, the technique effectively maintains the preoperative incisal opening, with an anticipated decrease in excursion. Finally, patients' quality of life will be significantly improved.

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