Unilateral condylar hyperplasia is a rare acquired condition characterized by unbalanced vertical and/or horizontal growth of the mandibular condyles. This can result in significant facial asymmetry associated with malocclusion, temporomandibular joint dysfunction, and significant psychosocial distress.1–5

The goal of unilateral condylar hyperplasia treatment is to restore function and to create facial symmetry. Typically, condylectomy, orthognathic surgery, or a combination of both is required. Management is based on whether the disease process remains active or if the excessive growth has ceased (otherwise known as “burnt-out” disease). Most often, treatment is pursued after waiting to ensure the process is no longer progressing (is stable) using orthognathic facial bone correction alone. However, if it is not confirmed that condylar overgrowth has ceased, postoperative condylar growth will lead to recurrent asymmetry (undoing the effect of the jaw surgery). It is therefore critical to ensure that the condylar hyperplasia...
is no longer “active” and rather has “burnt-out” (stopped). Disease activity is assessed using serial clinical and radiologic examinations and/or single-photon emission computed tomography. Single-photon emission computed tomography, using radioactive technetium (technetium-99m), depicts areas of osteoblastic activity, and uptake greater than 10 percent difference (the active condyle, more) is indicative of active unilateral condylar hyperplasia.6,7

If condylar overgrowth is still active, the options are to (1) watch and wait for it to stop, as above, and perform orthognathic surgery only; or (2) perform a high condylectomy in either a staged or a concurrent time with orthognathic surgery. Partial (high) condylectomy, the resection of the top 5 to 8 mm of the hyperplastic condyle, is effective in arresting and preventing relapse of active unilateral condylar hyperplasia.8 To date, there has been no objective evidence to suggest whether facial symmetry is better when comparing treatment of active unilateral condylar hyperplasia (high-condylectomy and orthognathic surgery) versus “burnt-out” unilateral condylar hyperplasia (orthognathic surgery alone).

In this study, we sought to compare postoperative facial asymmetry in patients who underwent surgical intervention for active unilateral condylar hyperplasia (high-condylectomy and orthognathic surgery) with burnt-out unilateral condylar hyperplasia (orthognathic surgery alone). We hypothesized that the correction of facial symmetry would be improved and equivalent regardless of the timing of intervention and treatment strategy used.

PATIENTS AND METHODS

This is a retrospective study approved by the Yale Internal Review Board (HIC: 1101007932). Twenty unilateral condylar hyperplasia patients with progressive mandibular asymmetry and 20 age- and gender-matched controls were included. Unilateral condylar hyperplasia patients were further divided into those who received surgical intervention while their condyles were active (high condylectomy, orthognathic surgery) (group 1) and those treated with only orthognathic surgery after the disease had burnt out (group 2). Patient demographics were obtained from the medical records. All unilateral condylar hyperplasia patients underwent thorough patient history, serial clinical and radiographic examinations, and single-photon emission computed tomography. The disease was considered active if the patients had a single-photon emission computed tomographic scan demonstrating at least a 10 percent difference in the bilateral condylar uptake and/or if there was evidence of clinical progression. Conversely, condyles were determined to be inactive or burnt out with negative single-photon emission computed tomography and/or no evidence of clinical progression based on history and serial examinations (Fig. 1).

Surgical Intervention

Treatment depended on patient age and condylar status. All procedures were performed by a single surgeon at a single institution, thus limiting possible confounding factors. Patients with active condyles received high condylectomies with a component face-lift approach.11 Orthognathic surgery was also performed on patients older than 15 years with confirmed growth cessation.

Those with inactive disease underwent only orthognathic surgery to correct skeletal asymmetry (no condylectomy). All patients undergoing orthognathic procedures had Le Fort I osteotomy, bilateral sagittal split osteotomy, and genioplasty with rigid internal fixation using the same system and application. All procedure types were combined with orthodontics before and/or following surgery.

Asymmetry Analysis

Three-dimensional images were captured preoperatively and at longest follow-up using the Vectra stereo photogrammetry system (Canfield Imaging Systems, Fairfield, N.J.). Images were captured with faces in repose. Control images were obtained from an existing unaffected database. For analysis, three-dimensional images were imported into Mirror medical imaging software (Canfield Imaging). Using a combination of previously described methods,12-14 images were oriented on a three-dimensional axis, and a plane of maximum symmetry was determined based on the upper two-thirds of the face (trichion to subnasale) (Fig. 2). The bottom third of the face (subnasale to menton) was excluded when establishing this plane to allow for evaluation of the extent of mandibular deformity. Allowing the software to calculate the plane of maximum symmetry avoided the inherent errors in trying to manually determine a midsagittal plane. The face was then reflected about this unique plane to create a mirror image. The native face and the mirror image were superimposed (Fig. 3), and the distance between the two surfaces was minimized using a Procrustes “best fit” technique (again, based on the top two-thirds of the face).15-17 Overall discrepancy between the two images was measured
using root-mean-square deviation. High interobserver reliability has been proven for this method in multiple studies.\textsuperscript{12,13} A root-mean-square deviation value of 0 indicates perfect facial symmetry, whereas an increasing root-mean-square deviation corresponds to worsening asymmetry.

Asymmetry analysis was performed on the entire face, including the forehead, orbital, buccal, nasal, and mandibular regions. The otic and cervical regions were excluded. Care was taken to also exclude the hairline, eyes, and eyelashes because of the excess noise generated in these areas.

**Statistical Analysis**

The average root-mean-square deviation was calculated for patients in groups 1 and 2 preoperatively and postoperatively. Paired \( t \) tests were used to evaluate the following outcomes: preoperative symmetry in group 1 versus group 2; preoperative versus postoperative symmetry for both groups; postoperative symmetry in group 1 versus group 2; and postoperative symmetry in group 1 versus controls and group 2 versus controls. Measurements were taken by multiple observers, and interobserver reliability was assessed using...
Pearson correlation coefficient, with an $r$ value of greater than 0.80 representing high positive correlation between raters. Analysis was performed using IBM SPSS Version 25 (IBM Corp., Armonk, N.Y.). All calculated $p$ values were two-tailed, and significance was assigned for a value of $p < 0.05$.

**RESULTS**

Twenty unilateral condylar hyperplasia patients (11 in group 1 and nine in group 2) with a mean age of 23.6 years and 20 age- and sex-matched controls with a mean age of 22.9 years were included in the study. All patients in group 1 had active condyles and received high condylectomy alone or in combination with concurrent or staged orthognathic surgery. Patients in group 2 all had inactive condyles and received only orthognathic surgery. The average age of group 1 and group 2 patients was 24.6 and 21.6 years, respectively. The majority of patients were female (16 of 20), with 10 in group 1 and six in group 2. Of 20 affected condyles, nine were on the left and 11 were on the right. Average time from surgery to longest follow-up was 0.86 year for group 1 and 1.3 years for group 2 (Table 1). One patient experienced postoperative facial nerve weakness that resolved by 6 months. There were no other surgical complications. All patients achieved stable occlusal results and relief of functional symptoms. Preoperative and postoperative images are depicted in Figure 4.

A total of 60 three-dimensional images were evaluated by two observers. The interobserver reliability for measuring facial symmetry was excellent ($r = 0.931$). We first evaluated the facial symmetry in all preoperative patients. The mean preoperative root-mean-square deviation for group 1 and group 2 (unilateral condylar hyperplasia patients with active and burnt-out disease, respectively) were $1.65 \pm 0.60$ mm and $2.42 \pm 0.72$ mm, respectively (Table 1). In contrast, the average root-mean-square deviation for the control group was $0.99 \pm 0.17$ mm. Importantly, the difference between groups 1 and 2 preoperatively was significant, indicating that patients in whom surgery was

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**Table 1. Patient Demographics and Outcomes**

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of patients</td>
<td>11</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Average age at surgery ± SD, yr</td>
<td>24.6 ± 15.7</td>
<td>21.6 ± 5.9</td>
<td>24.7 ± 13.2</td>
</tr>
<tr>
<td>Length of follow-up ± SD, yr</td>
<td>0.86 ± 1.2</td>
<td>1.3 ± 1.1</td>
<td>N/A</td>
</tr>
<tr>
<td>Mean preoperative RMSD ± SD, mm</td>
<td>1.65 ± 0.60</td>
<td>2.42 ± 0.72</td>
<td>0.99 ± 0.17</td>
</tr>
<tr>
<td>Mean postoperative RMSD ± SD, mm</td>
<td>1.13 ± 0.29</td>
<td>1.40 ± 0.34</td>
<td>N/A</td>
</tr>
</tbody>
</table>

RMSD, root-mean-square deviation; N/A, not applicable.
delayed until the overactive condyles had burnt out had more severe facial asymmetry before any surgical intervention was performed \( (p = 0.011) \) (Fig. 5).

Postoperatively, the root-mean-square deviation for both surgical groups decreased to 1.13 ± 0.29 mm and 1.40 ± 0.34 mm. These changes reflected significant improvements when compared to their preoperative values \( (p = 0.0069 \) for group 1 and \( p = 1.74 \times 10^{-4} \) for group 2). When postoperative root-mean-square deviations were compared to each other, there was no significant difference found between groups \( (p = 0.062) \). Importantly, however, notable differences were identified when the postoperative values were compared to those of the controls. More specifically, group 2 was found to have significantly worse postoperative symmetry when compared to controls \( (p = 4.75 \times 10^{-4}) \). Meanwhile, there was no significant difference found between the postoperative group 1 patients and the controls \( (p = 0.089) \) (Fig. 5).

**DISCUSSION**

Unilateral condylar hyperplasia is a rare, idiopathic cause of mandibulofacial asymmetry associated with significant functional, aesthetic, and psychological issues. Surgery in combination with orthodontia is required to correct acquired facial asymmetry and improve function and occlusion. The condition may be addressed at two distinct time points in disease progression; early, while hyperplasia is still active; and in a delayed fashion, after growth has burnt out.

Currently, there is no consensus regarding the ideal time point for intervention. Recommendations in the literature are derived largely from case studies or small series’ and all are based on subjective functional outcomes. Although some prior
studies have suggested that early surgery is preferable for unilateral condylar hyperplasia,\textsuperscript{1,3} the majority of practitioners seem to favor a “watch-and-wait” approach, allowing unilateral condylar hyperplasia to first “burn out” before completing orthognathic surgery alone. In some instances, patients present with already inactive disease that can only be addressed with orthognathic surgery. Performing a high condylectomy to arrest growth in the active phase is still debated, and performing this procedure in combination with orthognathic surgery is avoided perhaps because of the increased complexity and technical challenge.

There are no existing studies evaluating timing and treatment strategy (in active and stable unilateral condylar hyperplasia) relative to degree of facial asymmetry correction. As such, the purpose of this study was to directly compare facial symmetry following treatment during active versus burnt-out unilateral condylar hyperplasia.

Both treatment methods resulted in significant improvements in facial symmetry, but earlier intervention (with both high condylectomy and orthognathic surgery) demonstrated the most statistically improved facial symmetry, which was no different from unaffected norms. The burnt-out group (orthognathic-alone), still maintained some persistent facial asymmetry postoperatively compared to normal controls (even with a corrected cant, occlusion, midline, and chin point). Collectively, these results suggest that high condylectomy with or without orthognathic surgery in the setting of active unilateral condylar hyperplasia is more effective at restoring facial symmetry than orthognathic surgery alone performed after unilateral condylar hyperplasia has burnt out.

These findings are likely attributable to (1) delayed intervention leading to greater disease progression and worse preoperative facial asymmetry and/or (2) a less comprehensive repair (specifically, not addressing the increased condylar mass and neck length) secondary to skipping high condylectomy. As unilateral condylar hyperplasia progresses, mandibular lateralization leads to worsening skeletal and occlusal compensation. This progressive deformity and deflection results in worsened mandibular asymmetry and compensatory shifts of the maxilla and soft tissue. This worsened starting point possibly makes it more difficult to achieve complete symmetry postoperatively.

In addition, orthognathic surgery alone cannot alter the head and neck of the condyle or the deflection of the lateral ramus. These intrinsic temporomandibular joint and proximal ramus changes continue to impart some facial asymmetry appreciated in the soft tissues despite orthognathic improvement at the maxillomandibular level.

There may be disadvantages to operating during the active phase of unilateral condylar hyperplasia. The high condylectomy procedure reproducibly arrests condylar growth\textsuperscript{15}—but if performed too conservatively, it is theoretically possible that condylar growth could continue or reactivate. In such a scenario, an additional corrective procedure could be needed. Surgical risks can be present as well (e.g., facial nerve injury, scarring, and hematoma) while accessing the temporomandibular joint. In our cohort that underwent high condylectomy, no patients in the active unilateral condylar hyperplasia group experienced recurrent asymmetry following treatment. Scars healed well and were imperceptible, without objection by any of the patients.

Despite the potential disadvantages, patients who receive high condylectomy to actively arrest unilateral condylar hyperplasia experience far less facial deformity as a result of the disease. Early intervention also shortens the amount of time a patient must live with detectable facial asymmetry and functional symptoms. These benefits are of importance because facial symmetry is intimately correlated with attractiveness. Among the facial features that most affect detection of asymmetry are the oral commissure, nasal tip, and chin—all of which can be affected significantly by unilateral condylar hyperplasia.\textsuperscript{18} Addressing worsening asymmetry early can help alleviate or prevent psychosocial distress associated with noticeable deformity of these features.

Limitations of this study include analysis of only soft tissue and the decision to evaluate asymmetry in the face as a whole. In this instance, symmetry of soft tissue was evaluated because all patients had three-dimensional images available for analysis. Postoperative computed tomographic scans were not taken routinely in this group—especially for younger patients undergoing only high condylectomy—and would be needed for three-dimensional analysis of skeletal changes. Given limited imaging, soft-tissue symmetry was used as a proxy for underlying skeletal symmetry.

In addition, root-mean-square deviation was generated for the entire face and never examined in a segmented fashion by region. Regional analysis of bony and soft tissues preoperatively and postoperatively would contribute to a better
understanding of exactly where asymmetry persists in these patients (especially in group 2). Further analysis of both skeletal changes and regional soft-tissue changes (in addition to the effect of one on the other) would be needed to confirm the cause of persistent asymmetry in burnt-out patients and could then be used to direct more targeted surgical correction.

Despite these limitations, results of this study provide compelling evidence that early intervention confers a significant advantage in both preventing severe facial deformity and ultimately achieving a more symmetric outcome in patients with unilateral condylar hyperplasia. Although both of our groups experienced significant improvement in facial asymmetry postoperatively, only those who received intervention with high condylectomy while their condyles were still actively growing were able to achieve symmetry comparable to unaffected controls. In light of these findings, better understanding and awareness of this condition within the field is justified in the interest of early diagnosis, prevention of functional and psychological symptoms, and achieving optimal surgical outcomes.

CONCLUSIONS

Patients with end-stage unilateral condylar hyperplasia have more severe facial asymmetry that is more difficult to normalize, compared to earlier intervention during active unilateral condylar hyperplasia. These findings suggest that, if possible, corrective intervention is preferable during active unilateral condylar hyperplasia.

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PATIENT CONSENT

Patients or parents or guardians provided written consent for use of patients’ images.

REFERENCES