ORIGINAL ARTICLE

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Hemimandibular elongation: treatment and long-term follow-up

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Structured Abstract
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Objective – To study long-term changes in the mandibular asymmetry of patients with hemimandibular elongation (HE) treated with two-phase surgical orthodontic approach.
Design – Descriptive clinical study.
Setting and Sample Population – Private practice setting. Seven (six females) out of 47 diagnosed and treated patients for severe mandibular asymmetry were included with the following criteria: diagnosis of HE based on clinical, radiological and single photon emission computed tomography bone scintigraphic studies, good quality orthopantomograms (OPT) available at six time-points, two-phase surgical treatment (high condylectomy, HC, and orthognathic surgery, OS) and measurements of maximal mouth opening (MMO) available.
Method – Mandibular ramus height and corpus length were measured on OPTs at six time-points. Ratios between the affected/non-affected sides were calculated.
Results – All patients had progression of mandibular asymmetry before any operation, which finding together with the scintigraphy resulted to the decision to perform HC. Thereafter ramus and corpus asymmetry decreased compared with the initial measurements. After OS, stable symmetry of corpuses and alignment of skeletal and dental midlines were obtained. MMO reduced on average 50% after HC, regained 20% after OS and recovered almost totally at the last follow-up.
Conclusions – High condylectomy to stop excessive growth and OS to correct facial asymmetry is considered successful and necessary treatment for patients with HE. MMO can well recover after surgical traumas. Orthodontists should consider mandibular asymmetry as abnormal and need for surgical treatment if asymmetry is progressive and the ratio between affected/non-affected sides approaches 10%.

Key words: asymmetry; condylectomy; hemimandibular elongation; mandible; orthopantomogram

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Introduction

Facial asymmetry, which is often because of mandibular asymmetry (1), is a naturally occurring phenomenon. It has been shown that healthy young subjects have a statistically significant mandibular asymmetry (2, 3), and that in most individuals the right side of the face is slightly larger than the left side (4). Furthermore, mandibular asymmetry may increase or decrease during growth (2, 3). Despite a statistically significant facial asymmetry, the normal facial asymmetry is only seldom clinically significant and a reason for treatment. No standards, however, exist when normal asymmetry is considered abnormal and requires intervention.

Condylar hyperplasia or condylar hyperactivity named by Obwegeser (5) is a pathological overgrowth condition at the condylar process, which leads to variable abnormal mandibular ⁄ facial asymmetry. Two different forms of condylar hyperplasia have been differentiated based on the clinical and radiological findings: hemimandibular hyperplasia (HH) and hemimandibular elongation (HE) (6).

Hemimandibular hyperplasia is characterized by a three-dimensional enlargement of one side of the mandible, i.e. the enlargement of the condyle, the condylar neck and the mandibular ramus and corpus (7). The mandibular midline is in general not shifted (6, 8). A double contour is noticeable on a lateral cephalogram (LC). The orthopantomogram (OPT) reveals an increased size of the affected mandibular corpus and ramus and increased distance between the tooth root apices and the inferior mandibular border (7) (Fig. 1).

The more common condylar hyperplasia type, HE, differs in its clinical and radiological view from HH. HE is characterized by a horizontal elongation of the affected hemimandible and may affect the condylar neck, the mandibular ramus and corpus (6). The condylar head does not seem to be enlarged in HE. A flattening of the gonial angle on the affected side is observed but the mandibular corpus remains on the same level on both sides, which means that no double contour on LC can be seen (9). Unlike in HH, HE patients do not have an increased height between the tooth root apices and the inferior mandibular border in an OPT examination. Lower dental midline is displaced to the healthy side and the facial asymmetry is very noticeable. A cross-bite is noticed commonly on the unaffected side (Fig. 2). Despite division of the condylar hyperplasia to the two forms, a mixture of these is often clinically seen, called hybrid or mixed form (10).

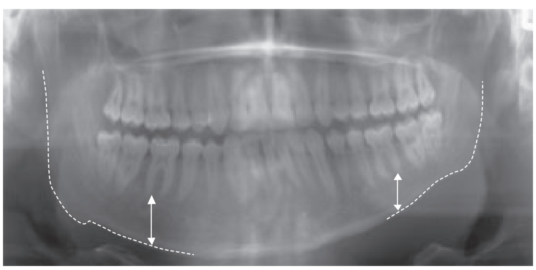

Fig. 1. Orthopantomograms of a patient with hemimandibular hypertrophy with characteristic three-dimensional enlargement of one side of the mandible and increased distance between the tooth root apices and the inferior mandibular border on the affected side.

Usually subjects with abnormal mandibular growth are first observed by an orthodontist who then has the responsibility of the patient's final outcome. Therefore orthodontists have to be familiar with the pathophysiology of condylar hypo- and hyperactivity. An OPT has been considered as a reliable basic tool to study mandibular asymmetries (11–16), particularly in pathological conditions in the vertical direction (12, 14, 15, 17). However, reliability of OPT examination has also been questioned (18). Little knowledge is available on the use of OPT in patients who have severe asymmetry, such as HE.

The purpose of this retrospective study was to study long-term changes in the mandibular asymmetry of patients with HE treated with a two-phase surgical orthodontic approach. Particular attention was paid to study the usefulness of the basic radiological method, OPT, to monitor changes in the mandibular dimensions.

Patients and methods

Patients

The study included treatment records of patients diagnosed with severe, abnormal facial asymmetry between 1997 and 2007 in a private oral and maxillofacial clinic. All subjects were operated by the same surgeon (AZ) and the orthodontic treatment was performed by several orthodontists. A total of 47 patients (28 ♀ and 19 ♂) with HH, HE, or mixed type were diagnosed during this time.

In many patients, the orthodontist had documented unsuccessful treatment with orthodontic⁄orthopaedic appliances and progression of mandibular asymmetry. Therefore, referral to the oral and maxillofacial surgeon had been indicated. Next, radiological and single photon emission computed tomography (SPECT) bone scintigraphy study with ^{99m}Tc methylene disphospho-

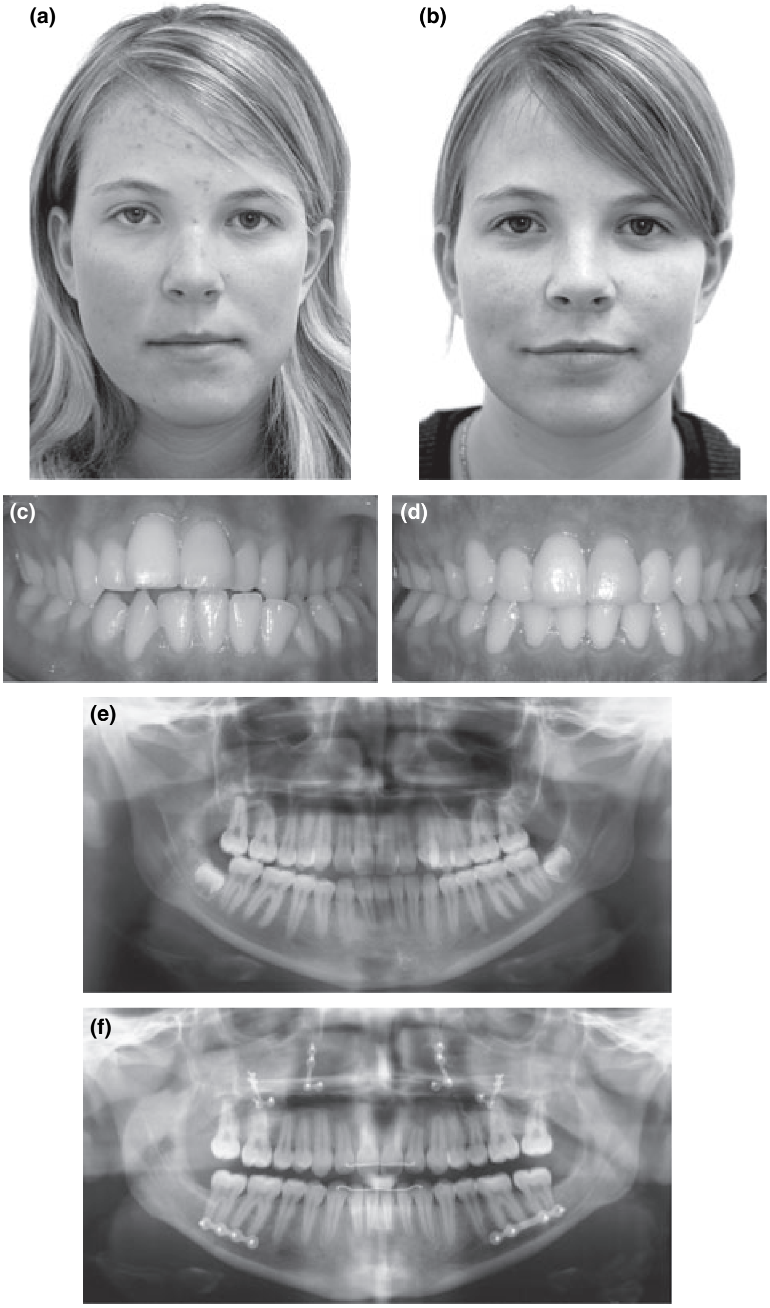

Fig. 2. Abnormal asymmetry of the face⁄mandible (a) because of hemimandibular elongation on the right side in a 16.5-year-old girl with cross-bite and lower dental midline deviation to the non-affected side (c). Before treatment the orthopantomograms (OPT) reveal elongation of the right hemimandible, but no increase in the distance between the tooth root apices and the inferior mandibular border (e). After high condylectomy at the age of 16.8 years, followed by fixed orthodontic appliance therapy, surgical-assisted rapid palatal expansion, BSSO and LeFort I maxillary impaction 12 months later, facial symmetry (b) with alignment of dental midlines (d) can be seen. Measurements on the OPT reveal some ramus height asymmetry, but corpus lengths show perfect symmetry (f) 12 months after the surgical orthodontic therapy.

nate were made in most cases to reveal possible asymmetric growth activity in the mandibular condyles. If difference in the uptake of the radiotracer between the condyles exceeded 10%, as has been suggested to be the cut-off value (19, 20) and further deterioration of asymmetry was noted on the OPT measurements, high condylectomy (HC) was performed on the affected side to stop excessive growth. Usually additional orthognathic surgery (OS) was also needed to correct maxillo-mandibular relationship and compensatory tilting of the maxillary plane. An important part of the clinical examination was to follow the development of the maximal mouth opening (MMO).

Criteria for inclusion in the study were:

- Two-phase operation performed: first HC and about 1 year later OS (bilateral sagittal split osteotomy and LeFort I osteotomy).
- Availability of good quality OPT at six time-points: T1, chronologically the first OPT (obtained on the first appointment at the orthodontist office); T2,

1–2 months before the HC; T3, 1–2 months after the HC; T4, 1–2 months before OS; T5, 1–2 months after OS and T6, at least 12 months post-surgery.

- Availability of SPECT study at T2.
- Lateral cephalograms available at the beginning (T1) and at the end (T6).
- Seven patients (six females) met the inclusion criteria, mean age 16–3 years (13–25 years) at the beginning. Diagnosis of HE was based on the clinical and radiological examination and the scintigraphy. Five patients had the right side affected and two the left side. Average period for the treatment between T1 and T6 was 4 years and 4 months (2.5–9 years).

Method

The present study utilized measurements on OPTs. Ramus height and corpus length were measured manually on the acetate tracing made for each OPT (Fig. 3). The measurements were reduced to actual size by using the magnification factor inherent of the radiological device. A ratio was calculated between the affected and the non-affected side. To study and detect a possible remodelling process of the condyle, particularly after HC, the different tracings were superimposed (with the best fit method). Using LCs at T1 and T6, sagittal position of the maxilla (SNA), the mandible (SNB), and their relationship (ANB), gonial and mandibular angles were calculated. The maximum mouth opening was registered at T1, T3, T5 and T6.

Error of the method

To find out possible distortional effects and particularly difference in the left and right sides, all the OPTs for each subject were scrutinized by measuring and comparing the length of the lower first molar on the right and left sides. In detail, an apical reference line was drawn through the mesial and distal root apices of the lower first molar. The length of the teeth was measured from the mesial cusp to the root apex perpendicular to the reference line (Fig. 3). T-test was used to study possible statistical significance between the lengths of teeth with the aid of a statistical package (SPSS 15.01 for windows; SPSS Inc, Chicago, IL, USA).

To test the reproducibility of the measurements, ramus height, corpus length and lower first molar length were remeasured 1 month later by the same investigator (YD).

Casual errors were assessed using Dahlberg's formula $\sqrt{(\sum d^2/2n)}$ where d is the difference between the first and the second measurements and n the number of double measurements.

Results

Measurements of teeth size showed practically no differences on the right and the left sides and on the repeated exposures, thus confirming that distortion because of OPT technique had equal effect on both sides. Measurements errors of tooth length based on double measurements varied between 0.50 and 0.53 mm. Measurement errors of the mandibular corpus length ranged between 0.33 and 0.34 mm, for the mandibular ramus 0.42 and 0.43 mm. These were considered to have had an insignificant effect on the measurements as far as reliability was concerned (Table 1). Mean ratios based on the measurements of the ramus height and the corpus length between the affected and

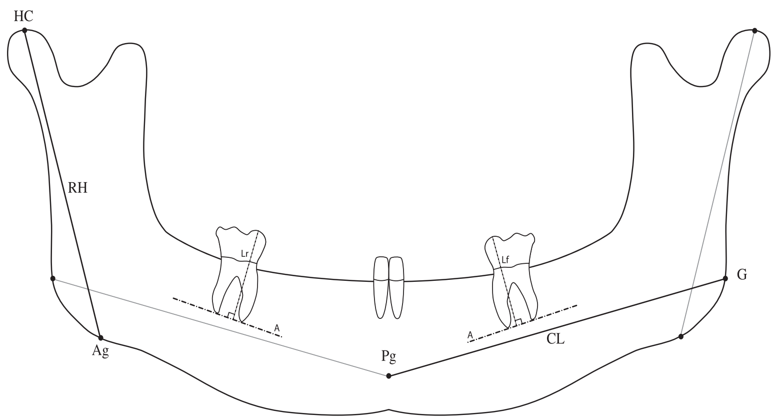

Fig. 3. Measurements on the orthopantomograms (OPTs). Ramus height (RH): distance between the most cranial point of the condyle (HC) and the most inferior point of the gonial angle (Ag). Corpus length (CL): distance between the most dorsal point of the gonial angle (G) and the pogonion point (Pg), which is the middle point of the mandible often seen in an OPT as an white spot in the midline. Length of the lower first molar: perpendicular distance between the mesial cusp and the apical reference line drawn between the mesial and distal root apices.

Table 1. **Measurement errors (in mm) for mandibular and tooth length dimensions based on double measurements**

Measurement errors	
Mandibular corpus	
Right	0.33
Left	0.34
Mandibular ramus	
Right	0.43
Left	0.42
Tooth length	
Right	0.53
Left	0.50

the healthy side are graphically presented in the Figs 4 and 5, respectively. It is noteworthy that a considerable individual variation is seen in the measurements.

Progression of ramus height asymmetry is evident before any operation (T1–T2; Fig. 4). After the HC (T3), decrease in the asymmetry can be seen with further improvement during the follow-up before OS (T4). OS performed on the mandibular corpus and gonial areas does not seem to have an impact on the ramus asymmetry. Some ramus height asymmetry remained even at the latest follow-up (T6). Superimposing of different tracings did not reveal any quantifiable shape changes of the condyle, not even after the HC.

Different course of changes can be seen in the measurements of the mandibular corpus (Fig. 5). Until T4 (before OS), corpus asymmetry seems to increase. OS addressed corpus asymmetry and midline deviation

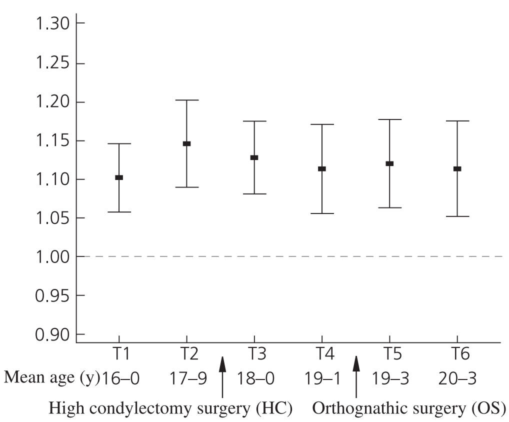

Fig. 4. Mean ratios and 95% confidence intervals for mean calculated between the affected and the non-affected mandibular ramus heights at the six time-points in the seven patients with hemimandibular elongation. High condylectomy was performed after T2 and orthognathic surgery after T4.

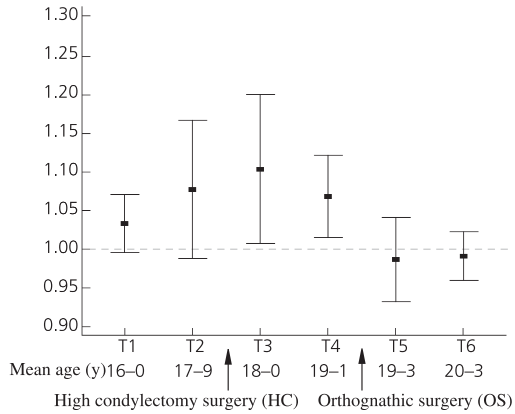

Fig. 5. Mean ratios and 95% confidence intervals for the mean calculated between the affected and the non-affected mandibular corpus lengths at the six time-points in the seven patients with hemimandibular elongation. High condylectomy was performed after T2 and orthognathic surgery after T4.

considerably as evidenced by nearly symmetric mandibular corpus length immediately after the surgery (T5) and at the follow-up (T6) (Figs 2 and 5). Lateral cephalogram analysis (Table 2) shows that three patients had a Class III jaw relationship, two had vertical excess with a tendency for Class III, one had Class II and one Class I.

Maximal mouth opening was reduced on average by 50% after HC. After OS (T5), mouth opening gained 20% achieving about 70% of the initial mean value. At T6, five patients showed 83–95% recovery and two patients showed a gain in mouth opening of +2% and +27% (Table 3).

Discussion

Subjects with facial/mandibular asymmetry form a challenging patient group for every clinician because of the prevalent nature of normal mandibular asymmetry. Sometimes, even in cases of very obvious mandibular asymmetry it is not self-evident whether one side has overgrown or the other undergrown. To confirm diagnosis and more importantly to decide about intervention call for profound understanding of the course of asymmetry. The decision to initiate treatment because of asymmetry has to be carefully considered, as it has been shown that mandibular asymmetry may diminish or appear during growth of healthy subjects (2, 3). In the present study, a two-phase surgical orthodontic treatment protocol and long-term follow-up have been presented for patients with abnormal progressive mandibular asymmetry diagnosed as HE.

Table 2. **Cephalometric measurements (in degree) before treatment (T1) and at the last follow-up (T6)**

	SNA		SNB		ANB		SpaSpp-MeGo		Ar-Go-Me		SN/SpaSpp	
Patient	T1	T6	T1	T6	T1	T6	T1	T6	T1	T6	T1	T6
1	73.6	80.3	75.2	73.7	−1.6	6.6	36.2	27.3	131.9	126.8	8.5	17.4
2	85.1	84.3	83.9	83.7	1.2	0.7	31.5	29.4	132.5	136.4	3.9	8.3
3	78.5	82.5	72.8	77.2	5.7	5.3	45.4	42.1	133.8	132.5	1.1	1.0
4	78.2	82.0	74.0	72.9	4.3	9.0	42.5	38.8	134.7	129.2	2.8	10.4
5	80.5	82.5	76.9	77.5	3.5	5.0	33.5	30.3	125.0	130.2	8.3	10.6
6	81.1	82.4	73.8	77.7	7.3	4.7	30.6	21.6	134.3	130.7	9.6	13.0
7	75.7	80.3	74.8	76.1	1.0	4.2	30.7	28.7	121.5	122.6	5.2	4.8
Mean value	79.0	82.0	75.9	77.0	3.1	5.1	35.8	31.2	130.5	129.8	5.6	9.4
Standard value	82 ± 3		79 ± 3		3 ± 2		28 ± 4		127 ± 5		7 ± 3	

SNA, sagittal position of the maxilla; SNB, sagittal position of the mandible; ANB, maxillo-mandibular sagittal relationship.

Table 3. **Measurements on the maximal mouth opening (in mm) initially (T1), after high condylectomy (T3), immediately after orthognathic surgery (T5) and at the last follow-up (T6)**

Patient	T1	T3	T5	T6
1	48	20	33	49
2	58	25	41	55
3	48	43	32	40
4	45	25	38	57
5	52	25	41	49
6	60	33	45	52
7	63	32	30	57
Mean	53	29	38	51

Orthopantomograms were used as the main tool to study changes in the mandibular asymmetry. Difference in head positioning for repeated OPTs may cause an image distortion and unreliability of the measurements (18, 21–25). In our study, possible distortional effects of the findings were examined by measuring the length of the lower first molar on both sides. The examination confirmed that the found changes and side differences were reliable findings and not because of, for example, positional differences in the repeated exposures at different time-points. However, as vertical measurements are considered to be less affected by the possible change in the positioning than horizontal ones (11–13, 15, 16), measurements of the mandibular corpus may have some inaccuracy because of distortion. New 3D imaging methods such as cone beam computed tomography will probably solve imaging problems, but at the time of the study it was not yet available.

A previous OPT study (2) of normal mandibular asymmetry showed on average 1% mandibular ramus asymmetry among 182 16-year-old healthy subjects. When the most asymmetric 11 subjects of this study (2) were scrutinized ramus height difference was on average 5.7 mm compared with the present mean difference of 8.0 mm at T2. When expressed as percentage the present affected vs. non-affected asymmetry ratio was on average 10%, which can be considered as abnormal mandibular asymmetry.

Because clinical and OPT follow-up revealed progression of the asymmetry, and the SPECT study at T2 verified more uptake of the radiotracer in one of the condyles, two-phase surgical orthodontic treatment was considered necessary. It is noteworthy that in the present diagnostic and treatment protocol, only one scintigraphy was obtained to study growth activity and assist in decision making about treatment timing and method. Further examination on stability and possible growth was carried out by measurements on OPTs unlike recommended by Hodder et al. (19) who suggested serial isotope studies to assess progression of the disease.

If the patients had not become more asymmetric, HC would not have been needed, but only OS to correct facial/mandibular asymmetry. In HC called also condylar shaving, 2–3 mm of the condylar head is removed using, for example, a piezoelectric method as in the present cases. This procedure removes excessively growing condylar cartilage as well as the uppermost part of the subchondral bone. It was interesting to note that a considerable improvement in the ramus symmetry, i.e. further shortening of the excised condyle was noted during the follow-up before OS. This finding can be interpreted as remodelling of the excised condylar head and formation of new articulating cartilage because of maintenance of proper mandibular function, as has been noted in experimental animals (26). Formation of new condylar cartilage remains though only speculative in human beings. Our finding concerning the effectiveness of HC is in line with previous ones which show that removal of condylar cartilage really leads to cessation of growth (27, 28). This finding also shows that condylar cartilage is capable, at least in the pathological condition to cause tissue separating force (29) and to propel the mandible to the non-affected side. From the clinical point of view, it is also important to note that remodelling, that is, further shortening of the excised condyle continued during the follow-up period of 12 months. Despite reduction in the linear measurement, no form or size changes of the condyle could be quantified. Probably, an OPT is not accurate enough to disclose the evident small changes in the condylar head. Because of the further remodelling, OS should not be performed in the same operation or not even shortly after HC.

Because HC can stop only excessive growth, a second operation is needed to correct the mandibular asymmetry and common adaptive changes in the maxilla. Measurements after OS show that an excellent facial symmetry particularly in the mandibular corpus can be achieved, however, some asymmetry in the ramus heights may still remain (Fig. 2). Comparable findings have also been reported in patients with hemimandibular hyperplasia (27, 30).

Measurements of the MMO reveal important and clinically relevant information and agree with previous findings (27). MMO reduced on average 50% immediately after HC because of surgical side effects. At T5, on average 12 months after HC and about 1 month after OS, MMO achieved about 70% of the initial values. At the last follow-up, at least 1 year post-surgery, most of the patients showed more than 90% of recovery compared to the initial values. It is evident that temporomandibular joint (TMJ) functioning can recover well despite the major trauma caused by the HC to the articulating surface of the condyle and a possible minor trauma or change in the condyle fossa relationship in the OS. It has to be pointed out that measuring only maximal voluntary mouth opening is a limited way of looking at TMJ function. However, a change in the MMO, particularly reduction, has been found to be a reliable sign of TMJ involvement (31, 32) and to correlate significantly with pathological magnetic resonance image findings (L. Müller et al., unpublished findings) in patients with juvenile idiopathic arthritis. Thus, based on these findings, MMO as a single measurement can be considered as reflecting TMJ function well.

Conclusions

Based on the treatment and follow-up of seven patients with HE it can be concluded that:

- Assessment on OPT seems to be adequate to monitor changes in the mandibular dimensions, and combined with clinical follow-up and one SPECT bone scintigraphy, the diagnosis of pathologic condylar growth can be carried out.
- Ramus and/or corpus ratio between affected/non-affected side ≥10% measured on OPTs can be considered as an abnormal mandibular asymmetry.
- When the orthodontist encounters a progressive asymmetry approaching 10%, referral to the maxillofacial surgeon is recommended.
- Two-phase surgery, first HC and then OS, is a successful and necessary treatment protocol for HE patients with stable results.
- Maximal mouth opening can recover well after surgical traumas.
- Present findings have to be interpreted with care because of the large individual variation despite the common HE diagnosis.

Clinical relevance

Subjects with mandibular asymmetry form a challenging group of patients because of the prevalent nature of the asymmetry. It is important to diagnose the condition in time and to verify the progression of the asymmetry. In patients with progressive mandibular asymmetry two-phase surgical orthodontic approach is considered a necessary and successful treatment protocol. Excessive condylar growth can be stopped with a HC, while later OS will correct the maxillo-mandibular relationship. Temporomandibular joint function can well recover despite the trauma to the joint.

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