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Intraoral mandibular distraction osteogenesis: special attention to treatment planning

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SUMMARY. Purpose: **To demonstrate our experience using internal devices for unidirectional distraction osteogenesis in treating different mandibular hypoplasias (with or without maxillary deformities). An algorithmic table for diagnosis, and treatment planning is presented.** Patients and methods: **Twenty internal distraction devices were used in 16 patients with mandibular hypoplasia. Deficiency in length of the mandible was calculated on three-dimensional computed tomography scans. The device was activated by a transcutaneous pin on the fifth postoperative day. Distraction was achieved at rates of 0.5 mm/12 h. After a variable period of consolidation the devices were removed. Mean follow-up was 18 months.** Results: **Successful distraction osteogenesis was achieved in all patients. No premature consolidation or pseudoarthrosis was observed. Improvement of facial aesthetics was produced in all cases. Final occlusion was excellent in those cases where no simultaneous maxillary deformity was present. Orthodontic treatment was applied in all cases. Results remained stable one year postoperatively.** Conclusions: **The occlusal results obtained in this series show that we can plan distraction as a definitive treatment in cases with isolated mandibular hypoplasia. When an additional maxillary deformity is present, mandibular distraction must be performed first if indicated, but a maxillary procedure will be necessary later.**

INTRODUCTION

Mandibular distraction osteogenesis has shown to be an effective treatment for hypoplastic mandibles. (*Tavakoli* et al., 1998) Although this technique has become very popular in recent years (*Klein* and *Howaldt*, 1996; *Diner* et al., 1997; *McCarthy* et al., 1999; *Rubio-Bueno* et al., 2000), undesirable occlusal changes after distraction have been reported (*Susami* et al., 1999). The need for conventional orthognathic surgical corrections after distraction has been emphasized (*Susami* et al., 1999). The aim of this paper was to analyze our results retrospectively after lengthening the ascending ramus of the mandible using 20 internal distraction devices, with special interest focussed on treatment planning and occlusal changes following distraction.

PATIENTS AND METHODS

Sixteen patients (9–31-years-old) with mandibular hypoplasia presented to the Orthognathic Surgery Unit (Department of Maxillofacial Surgery, Hospital Universitario de la Princesa, Madrid, Spain) for initial evaluation. Clinical examination, radiographic and cephalometric studies, articulated dental casts, and preliminary model surgery were performed according to a protocol for all patients with dentofacial deformities. Additionally, a three-dimensional computed tomography (3-D CT) scan was taken in all patients to plan the procedure (Fig 1). After processing this information, a treatment plan was established following an algorithmic table (Table 1). This plan resulted in elongation of the mandible by distraction in the 16 cases of this series. Twelve patients with unilateral hypoplasia of the mandible underwent lengthening of the ascending ramus using a unidirectional intraoral device (Stratec Medical®, Oberdorf, Switzerland). Bilateral distraction was applied in four cases using the same device. Detailed information about all patients concerning age, sex, diagnosis, degree of lengthening, and duration of follow-up is summarized in Table 2.

In eight patients, mandibular hypoplasia was considered to be isolated (pure mandibular hypoplasia), and distraction was planned as the only surgical treatment.

In another eight patients however, the maxilla was thought to be abnormal also in size and/or position (mandibular hypoplasia associated with maxillary deformity); therefore, the treatment of the mandibular hypoplasia alone by distraction would not correct the malocclusion. An additional maxillary orthognathic surgical procedure was considered to be necessary as a second stage. This was explained to the patient and/or the family before commencing treatment. Maxillary occlusal slope being secondary to

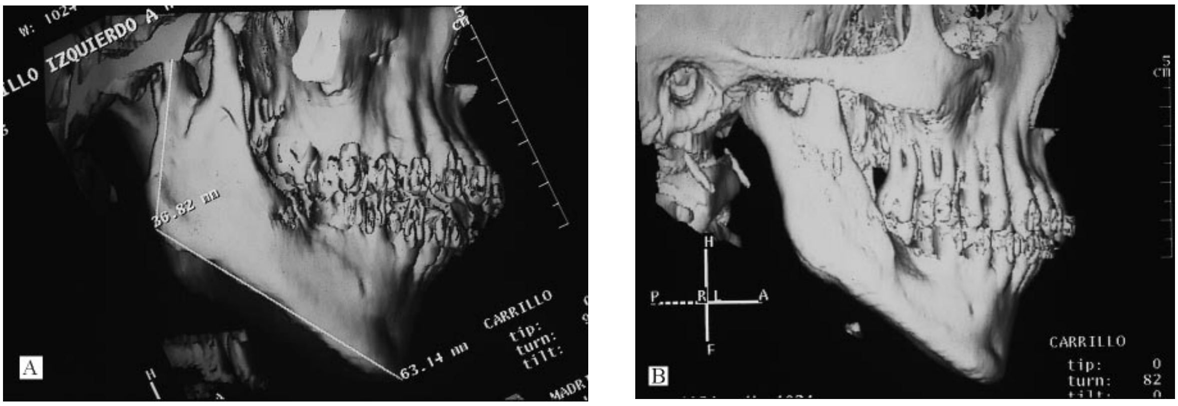
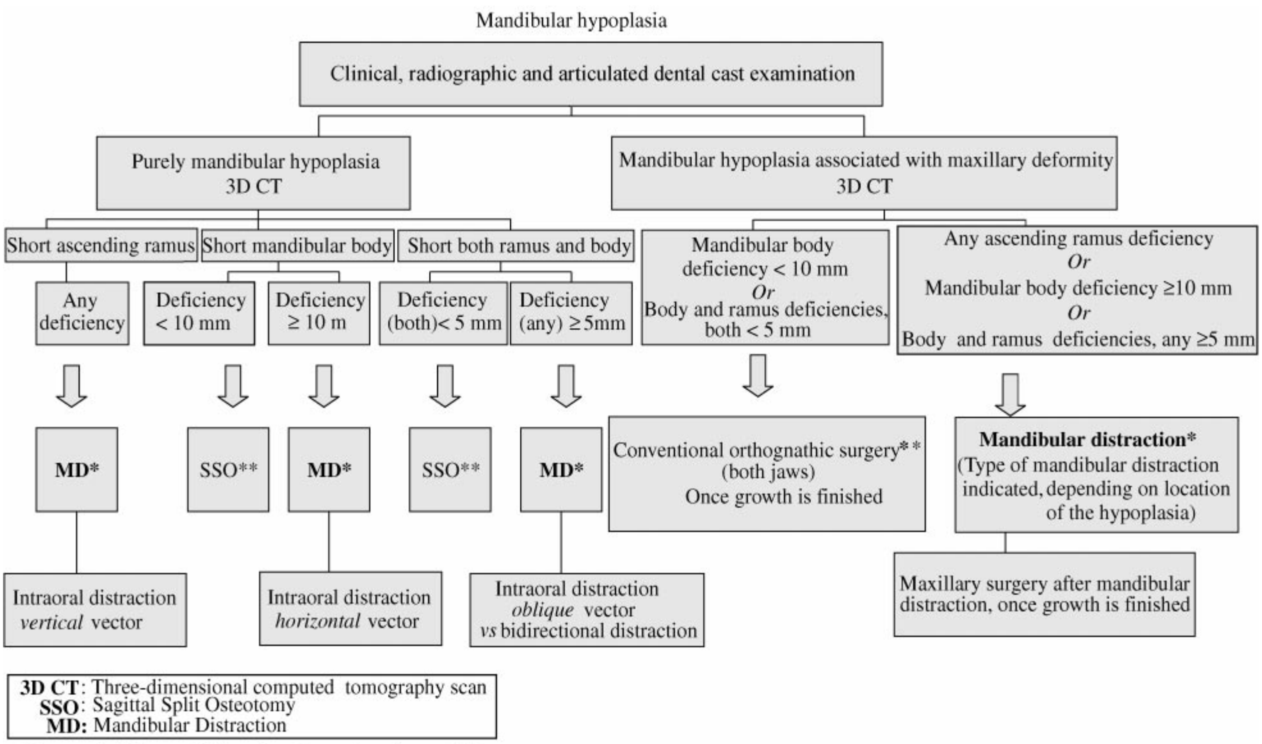


Fig. 1 – Three-dimensional computed tomographic scans of patient number 1 shown in Fig. 2, with hypoplasia of the right ramus of the mandible. (A) Preoperative; (B) Postoperative immediately after removal of the distraction device. Note condyle correctly located in the glenoid fossa.

Table 1 – Mandibular hypoplasia: treatment planning



*Removal of lower third molars 6 months prior to MD.

**The ramus must be sufficiently broad, thick and well-developed even though it is short for doing SSO. When the deficiency is not great, other aspects have to be taken into account (TMJ symptoms, condylar size, previous surgery…) to decide whether MD is a better option than SSO. The latter must be performed once growth is finished.

unilateral mandibular hypoplasia was not considered an associated maxillary deformity ''necessarily requiring treatment''. The occlusal slope will disappear after distraction due to progressive, spontaneous dentoalveolar growth. (*Rubio-Bueno* et al., 2000).

An intra-oral osteotomy was performed under general anaesthesia. The technique has been previously described and illustrated (*Rubio-Bueno* et al., 2000). Location of the osteotomy and placement of the device must match the treatment plan exactly. In 14 patients (18 distraction devices) a vertical vector was applied; in two patients, an oblique vector was considered to be necessary.

Progressive distraction at rates of 0.5 mm/12 h was initiated after 5 days, first by the medical team, then by the parents or by a friend. Once the planned length was reached, the device was maintained in place for 8–14 weeks.

Table 2 – Unidirectional intraoral ascending ramus distraction: patient data

Case	Age (years)/ Sex	Diagnosis	Maxilla	Vector	Initial height ramus/ distracted length (mm)	Consolidation period (weeks)	Facial results	Occlusal changes	Complications
1	11/F	Hypoplasia of the right ramus, condyle, and the mandibular body, origin unknown	Normal	Oblique	36/17	9	Symmetry	• Temporary posterolateral open bite • Excellent final occlusion	• Temporary hypoaesthesia of the inferior alveolar nerve • Temporary limitation in opening the mouth
2	15/F	Hypoplasia of the right ramus and condyle, post-trauma	Tranverse and anteroposterior hypoplasia	Vertical	45/15	12	Symmetry	• Class III malocclusion (edge to edge) • Surgical maxillary procedure delayed because of the age	• Temporary hypoaesthesia of the inferior alveolar nerve
3	10/F	Hypoplasia of the right ramus and condyle, post-trauma	Normal	Vertical	37/18	9	Symmetry	• Temporary postero-lateral open bite • Excellent final occlusion	• Pain at the ipsilateral TMJ during the first days of the distraction
4	10/M	Left hemifacial microsomia grade IIA	Normal	Vertical	36/17	8	Symmetry	• Temporary posterolateral open bite • Mixed dentition; no anterior open bite or cross bite after MD	• Temporary hypoaesthesia of the inferior alveolar nerve
5	12/F	Hypoplasia of the right ramus and condyle, post-trauma	Transverse hypoplasia	Vertical	40/19	10	Symmetry	• Temporary posterolateral open bite • Crowding of the teeth required orthopaedic expansion of the maxilla	• Pain at the homolateral TMJ during the first days of the distraction • Temporary hypoaesthesia of the inferior alveolar nerve
6	7/M	Hypoplasia of the left ramus and condyle, post-trauma sleep apnoea	Normal	Vertical	34/16	11	Symmetry	• Temporary posterolateral open bite • Mixed dentition; no anterior open bite or cross bite	• Temporary hypoaesthesia of the inferior alveolar nerve • Local inflammation during the first days postoperatively
7	27/F	Hypoplasia of the left ramus and condyle, post-trauma	Transverse hypoplasia	Vertical	45/20	12	Symmetry	• Temporary posterolateral open bite • Surgical maxillary procedure after MD • Excellent final occlusion	• Temporary hypoaesthesia of the inferior alveolar nerve
8	16/F	Hypoplasia of the left ramus and condyle, post-trauma	Transverse hypoplasia	Vertical	42/24	12	Symmetry	• Temporary posterolateral open bite • Crowding required orthodontic treatment • Surgical maxillary procedure after MD	• Temporary hypoaesthesia of the inferior alveolar nerve • Local inflammation during the first days postoperatively
9	11/F	Left hemifacial microsomia grade IIB	Transverse hypoplasia	Vertical	26/32	14	Symmetry	• Temporary posterolateral open bite • Mixed dentition; no anterior open bite or cross bite • Orthopeadic expansion of the maxilla	• Temporary hypoaesthesia of the inferior alveolar nerve

Table 2 – (*continued*)

Case	Age (years)/Sex	Diagnosis	Maxilla	Vector	Initial height ramus/distracted length (mm)	Consolidation period (weeks)	Facial results	Occlusal changes	Complications
10	28/M	Hypoplasia of the right ramus and condyle, post-trauma	Normal	Vertical	48/19	14	Symmetry	• Temporary posterolateral open bite	• Temporary hypoaesthesia of the inferior alveolar nerve
11	10/M	Left hemifacial microsomia grade IIA	Normal	Vertical	36/17	8	Symmetry	• Minimal temporary postero-lateral open bite • Crowding required orthodontic treatment • Excellent final occlusion	• Temporary hypoaesthesia of the inferior alveolar nerve
12	16/M	Hypoplasia of the left ramus and condyle, post-trauma	Transverse hypoplasia	Vertical	50/16	12	Symmetry	• Minimal temporary postero-lateral open bite • Excellent final occlusion	• Temporary hypoaesthesia of the inferior alveolar nerve
13	19/F	Developmental hypoplasia of both rami and mandibular bodies	Normal	Oblique	45/18	10	Great improvement of the profile (chin projection)	• Edge to edge occlusion after distraction 'Stripping' of the lower teeth to increase overjet • Advancement genioplasty after MD	• Temporary hypoaesthesia of the inferior alveolar nerve
14	30/F	Asymmetric hypoplasia of both rami and condyles, post-trauma	Normal	Vertical	51/12 right 45/18 left	14	• Symmetry • Great improvement of the profile (chin projection)	• Crowding required orthodontic treatment	• Temporary hypoaesthesia of the inferior alveolar nerve
15	28/F	Developmental hypoplasia of both rami	Tranverse and anteroposterior hypoplasia	Vertical	44/21	14	Great improvement of the profile (chin projection)	• Surgical maxillary procedure after MD • Crowding required orthodontic treatment	• None
16	29/F	Developmental hypoplasia of both rami	Tranverse and anteroposterior hypoplasia	Vertical	40/20	14	• Great improvement of the profile (chin projection)	• Surgical maxillary procedure after MD • Excellent final occlusion	• Temporary hypoaesthesia of the inferior alveolar nerve

F: female, M: male; EO: extraoral; IO: intraoral; TMJ: temporomandibular joint; MD: mandibular distraction osteogenesis.

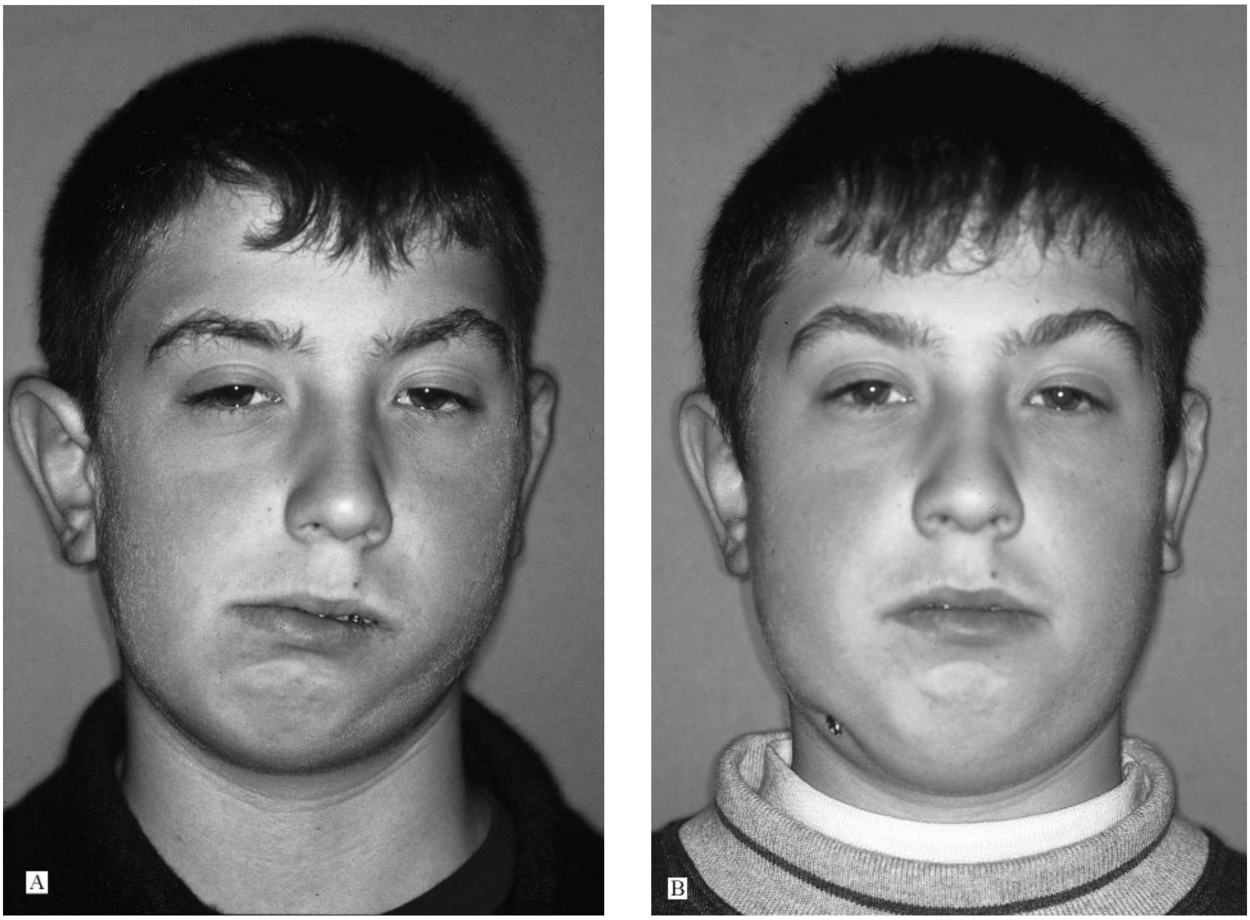


Fig. 2 – 11-year-old patient (case number 1) with condylar hypoplasia of the right side. (A) Preoperatively; (B) Postoperatively after distraction of 20 mm using an internal device. Note symmetry of lip commissures, and shift of chin to midline.

Orthodontic therapy was applied in all cases, before and/or after distraction. Dental crowding and maxillary constriction (the latter found in patient under 12 years of age) were treated as necessary using fixed appliances. Extraction of mandibular premolars was felt necessary in two cases, to enlarge the overjet prior to surgery. In one case, advancement genioplasty was performed at the time of removal of the device. Removal of lower third molars was indicated at least 6 months prior to surgery in order to facilitate screw placement.

Patients were followed up weekly during the active period of distraction, and monthly during consolidation. Panoramic radiographs were taken each week to monitor the active distraction period and each month during the consolidation period. Another 3-D CT scan was taken 4 weeks after removal of the distraction device to compare the changes* (Fig. 1B).

The distraction device was removed under general anaesthesia via an intra-oral approach after a consolidation period of between 8 to 14 weeks after existence of new bone had been radiographically confirmed. The resulting size of the mandible on the postoperative 3-D CT scan was evaluated and compared by the same investigator (PR-B). Mean follow-up was 18 months after removal of the devices, with a minimum of 12 months.

After removal of the distraction devices, all patients were evaluated for facial symmetry, descent of the buccal commissure and gonial angle, and chin rotation to the midline. In bilateral cases, correction of the retrognathic profile was the most important factor. Chin projection, neck-throat profile, increase of the anterior facial lower height and decrease of the labiomental sulcus on the frontal view were carefully evaluated. Facial and occlusal changes were excellent in all cases diagnosed with pure mandibular hypoplasia (Figs 2 and 4). In these patients, no additional surgical procedure was considered to be necessary after distraction. However, in patients with bimaxillary deformity, the residual malocclusion was treated by conventional maxillary surgery 3–14 months after mandibular distraction. In one case, the maxillary surgery was delayed because of the patients age (case 2).

RESULTS

The results were based on clinical and radiographic evaluation using in addition cephalometric tracings,

*The resulting total dose of radiation is felt to be much too high by the Editorial Board.

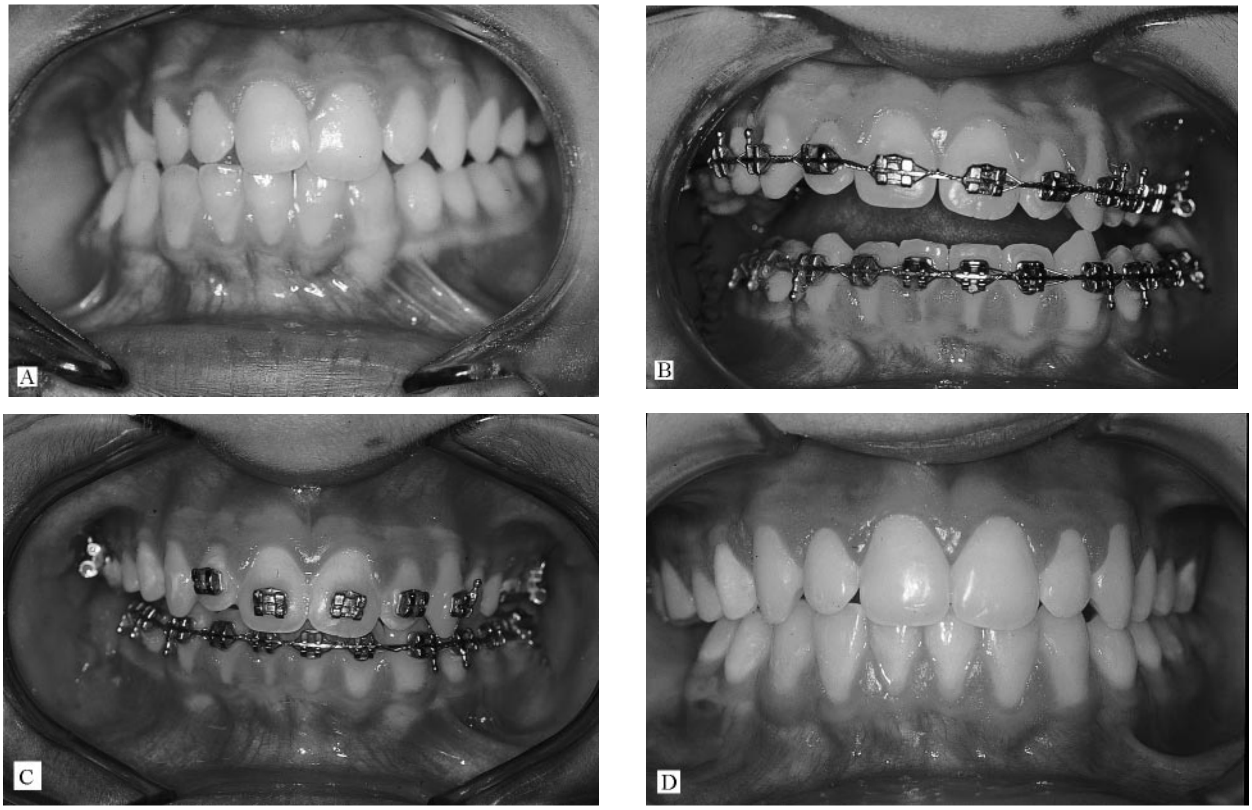


Fig. 3 – Dental occlusion (of patient depicted in Figs 1 and 2). (A) Preoperatively; note the lateral cross bite on the right (hypoplastic) side.(B) Dental occlusion during distraction. The posterior and lateral open bite is increasing due to lengthening of the ascending ramus. (C) Occlusion 17 weeks later. Vertical compensatory maxillary growth nearly finished. (D) Final occlusion.

articulated dental casts, and 3-D CT scans. Successful distraction osteogenesis was achieved in all patients (Table 2). The amount of mandibular lengthening ranged from 15 to 32 mm. No premature consolidation or pseudoarthrosis was observed. The buried distraction device allowed the patients to carry out their normal activities without discomfort.

In unilateral cases, the faces became symmetric. A posterior and lateral open bite resulted on the lengthened side (Fig. 3). In all these patients, this posterior open bite disappeared as a result of dentoalveolar growth (*Rubio-Bueno* et al., 2000). In cases with pure mandibular hypoplasia, final occlusion after distraction was good (Fig. 3D). When a class II malocclusion was present before treatment, lengthening of the ascending ramus of the mandible produced a progressive change to a class I occlusion, and achieving a satisfactory overjet and overbite. Stability was confirmed after a minimum of 12 months of follow-up (Fig. 3). Some patients with bimaxillary hypoplasia developed a contralateral cross-bite (transverse maxillary hypoplasia) or an edge to edge malocclusion (antero-posterior maxillary hypoplasia) after distraction. In these cases, additional treatment had to be directed to correct the size and position of the upper jaw.

In bilateral cases, the lower third of the face became more prominent, especially in profile. No anterior open bite developed. On the contrary, during distraction, the pre-existing anterior open bite was closed due to lengthening the ascending ramus; this allowed anterior rotation of the mandible, closing the pre-existing anterior open bite whilst advancing the chin and mandibular body.

No permanent sensory nerve complications were noted in any of the patients; however, temporary hypoaesthesia of the inferior alveolar nerve was reported in 14 cases. This neurosensory disturbance resolved spontaneously in 2–6 weeks. All adult patients experienced TMJ pain during activation. In those cases in which respiratory symptoms were present due to the hypoplastic mandible, these dissappeared completely after distraction.

No secondary osteotomy in the mandible was necessary to correct occlusion in any case. After removal of the distraction device, the bone gain remained constant during the observation period (mean 18 months; minimum 12 months). At present, facial and occlusal changes are stable. No facial or occlusal relapse was observed in any case, even following major lengthening (in children).

DISCUSSION

When appropriately planned, performed and controlled, predictable results can be obtained by

Fig. 4 – 20-year-old patient (case number 8) with condylar hypoplasia of the left side associated with maxillary hypoplasia. (A) Preoperative frontal view (B) Postoperative frontal view after unilateral mandibular distraction of 24 mm using an internal device.

mandibular distraction. However, it is not yet 'a farewell to major osteotomies' (*Molina* and *Ortiz Monasterio*, 1995). Even though distraction offers considerable advantages, conventional surgical techniques are still indicated in many cases. Whilst interesting clinical reports on mandibular distraction have been published, clinical indications have not been widely agreed upon yet.

When is mandibular distraction indicated?

It is essential to distinguish a malocclusion following mandibular distraction produced by a lack of careful planning, from a malocclusion in which mandibular hypoplasia is associated with maxillary deformity. For example, an anterior open bite following mandibular distraction is considered an undesirable complication due to posterior rotation of the mandibular body around the pins; we think that this complication is avoidable if stability of the distraction devices is guaranteed during the entire consolidation period. However, if a previous maxillary tranverse deficiency existed, malocclusion will persist following mandibular lengthening. This has to be recognised and explained to the patient and/or the family prior to treatment. It is important in the case of maxillary deformity that mandibular distraction has to be compared with bimaxillary osteotomy, especially when mandibular hypoplasia is mild.

In our decision table (Table 1), distraction is proposed for those mandibular hypoplasias in which conventional surgical techniques are associated with a high degree of relapse. Factors associated with relapse have been major mandibular advancements, upward and forward (counterclockwise) movements, and cases with high Frankfurt mandibular plane angles (*Arnett*, 1993). Other factors cited in the literature as related to advancement relapse are pre-existing TMJ pathology. Condylar compression may be more likely to progress to condylar resorption when anterior disc displacement is present prior to surgery (*Arnett*, 1993).

It has been demonstrated that up to 10 mm of ascending ramus height can be obtained without significant relapse by the sagittal split osteotomy under certain conditions (*Carlotti* and *Schendel*, 1992). The ramus must be sufficiently broad, thick and well developed even though it is short. A small and abnormally shaped ramus as seen in hemifacial microsomia is a contraindication (*Carlotti* and

Schendel, 1992). However, in our experience, lengthening of the ascending ramus is difficult to perform technically, due to the poor extensibility of the pterygomasseteric sling. It may be also followed by condylar sag, postoperative TMJ symptoms and relapse. For these reasons, and as distraction is achieving excellent results with minimal morbidity, it is *currently* considered as the best option in all cases in which lengthening of the ascending ramus of the mandible is necessary, even with deficiencies lower than 10 mm.

When stability of mandibular advancement following bilateral sagittal split osteotomy was evaluated, the magnitude of advancement had the highest correlation with relapse. (*Van Sickels* et al., 1988) Advancements greater than 6 mm have been reported to relapse (*Van Sickels* et al., 1986). But since in our experience, surgical split osteotomy is a safe technique for mandibular advancement of up to 10 mm, we prefer it in the absence of contra-indications (e.g. TMJ symptoms, or degenerative condylar changes). In patients with larger deficiencies, or when factors related to relapse are present, distraction osteogenesis is proposed as being the best alternative. One of the main advantages is that bony augmentation is obtained by just a minor surgical procedure. Sagittal split osteotomy has proved to be a successful method, but the amount of bone is the same at the end of the procedure. Sagittal split osteotomy only achieves a change in position of the distal fragment.

Distraction osteogenesis is safer as far as the alveolar nerve is concerned (*Rubio-Bueno*, 2000). Even though the majority of patients (14, 87%) in the present series suffered mild hypoaesthesia of the inferior alveolar nerve immediately after surgery, it was limited to between 2–6 weeks. Nerve transection or long-term nerve disturbance did not occur. Although current technical refinements have also reduced nerve damage after sagittal split ramus procedures, even experienced surgeons report a 2–3.5% incidence of nerve transection (*Turvey*, 1985; *Van Merkesteyn* et al., 1987) and up to 85% incidence of long-term dysfunction (*Walter* and *Gregg*, 1979; *MacIntosh*, 1981; *Nishioka* et al., 1987).

The risk of transecting the inferior alveolar nerve with mandibular distraction techniques can be diminished by separating the bony fragments with the activation screw, until the nerve is identified before completing the osteotomy. A blind cut may injure the alveolar nerve, and should be avoided.

How we plan and perform mandibular distraction

Even though external distraction devices have been used previously, unidirectional internal distraction devices show considerable advantages, and at present are our treatment of choice. In our opinion, stability is the most important advantage of internal devices (*Rubio-Bueno* et al., 2000) and is essential for a successful osteogenesis (*Karaharju-Suvanto* et al., 1992). The internal device used in this series allows up to 40 mm lengthening of the ramus with vertical or oblique vectors. If a horizontal vector is required, a different device would be necessary, like the one proposed by *Mommaerts* (1998). Even though we included in our decision table the possibility of using bidirectional distraction, we had no cases with severe mandibular hypoplasia affecting both ramus and body. Oblique vectors are preferred in those cases in whom both rami are short but the mandibular body deficiency is less critical. By modifying the inclination of the distraction vector, impressive lengthening and advancement have been achieved in the ascending ramus and the mandibular body respectively.

However, the need for another operation to remove the device remains a significant disadvantage. Efforts are been made to improve the device with the aim of avoiding this second operation. Whenever possible, this opportunity is taken to perform another surgical procedure if necessary (e.g. maxillary osteotomy or genioplasty).

Long-term results

During the distraction and consolidation phases of mandibular distraction, multiple imaging modalities have been used to assess and quantify bone deposition. Ultrasonography has been shown to be very useful in monitoring the distraction callus (*Juenger* et al., 1999); it appears that ultrasonography is highly informative regarding ossification of the callus and this information can be provided earlier by ultrasonography than by conventional radiography. (*Juenger* et al., 1999). We are now applying this technique as a clinical routine in our mandibular distraction patients; however, standard radiographic investigations are still mandatory for callus distraction follow-up and for evaluation of undesirable movements of the bony fragments during the distraction procedure.

Three-dimensional scanning has been recommended to evaluate growth after distraction (*Kusnoto* et al., 1999). In our series, pre- and postoperative 3-D CT scans have been taken in every patient, but follow-up was short. In a few years, growth will be analyzed in these patients. No relapse was observed in any case, even in children. However, distraction has not been performed long enough to enable us to report upon completion of growth after distraction. Parents must be told that further procedures may be necessary in the future.

No major complications were seen in this series. Facial and occlusal changes were stable for at least 12 months. Stability of distraction has been related to the final occlusion (*Susami* et al., 1999). These authors state that good results must be obtained in the first place not only regarding aesthetics of the face but regarding occlusion as well. To achieve both are the two major goals as is avoidance of a major surgical procedure in the mandible.

CONCLUSION

Distraction osteogenesis is not a one-step procedure and requires careful planning. If vectors are accurately designed, the occlusion following mandibular distraction can be as precise as that seen with conventional orthognathic procedures. Internal devices can be used even in very hypoplastic mandibles, and the stability provided is excellent. Understanding that mandibular distraction is a safe option changes the algorithm of treatment. The occlusal results obtained in this series show that we can plan distraction as a definitive treatment in cases with isolated mandibular hypoplasia. When an additional maxillary deformity is present, mandibular distraction must be performed first and the maxillary procedure should follow. Lengthening of the ascending ramus of the mandible by conventional procedures is unstable, while advancement of the mandible is stable. Therefore, distraction osteogenesis is proposed for lengthening the ascending ramus and for advancements if associated with significant changes in the mandibular occlusal plane. Growth after distraction, TMJ response, and new miniaturized appliances are some of the many areas of research for the next years.

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