Technical considerations in distraction osteogenesis


Abstract. Five cases are presented to exemplify technical difficulties and complications which may be encountered when performing distraction osteogenesis in the facial skeleton. The procedure should be performed under close supervision by the surgical and orthodontic colleagues. Errors in the choice of vector may be managed by earlier removal of the distractor and subsequent traction on the previously osteotomized segments using orthodontic appliances and principles. Multiple distractors may be inserted in the same jaw and bimaxillary procedures are possible, increasing the likelihood of encountering technical difficulties. Detailed planning and close follow-up, with early recognition and active management of the complications, may be useful in ensuring a successful outcome of this versatile procedure.

Key words: alveolar atrophy; bimaxillary; distraction osteogenesis; floating bone; mandible; maxilla; multiple osteotomies; vector.

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Introduction

Distraction osteogenesis (DO) is a method of correcting deformities and augmenting deficiencies not only of bone but also of soft-tissue. The indications have expanded greatly. The basic technique of insertion of the device, 5–7 days rest and subsequent activation at the rate of 1 mm per day, followed by a 8–12 week consolidation phase15,16,36, has remained essentially unchanged over the years. Difficulties arise in the selection of the distractor, the vector, the osteotomy site, and patient compliance. Patients should be followed up closely by the operator and an orthodontic colleague. Accurate planning is not able to foresee all eventualities. Interim prostheses may perforate the mucosa, occlusal disturbances may arise, segments may change direction, and equipment may fail. We present a synopsis of our own experience and suggest possible ways of preventing and managing these problems. Use of the ‘floating bone concept’ is a useful tool for correcting unexpected problems.

Complications

These may occur in up to 35% of cases and are related to a learning curve, with most complications documented by colleagues who have inserted less than 10 distractors (57% of those questioned)23. These figures were obtained using anonymous questionnaires and reflects the clinical situation. Only 4% of clinicians have performed DO in more than 100 cases. This group reports a complication rate of 22.8%. A recent review of the literature33 shows similar results. Complications can be classified into immediate, early and late and include the following:

Immediate

1. Damage to the primary (1,9%)23 or secondary dentition including pulp necrosis and loosening

2. Damage to the orthodontic appliance

3. Inability to find the screw-holes after performing the osteotomy12

4. Undercuts

5. Distractor plate or screw fracture 4.5%23

Early

6. Infection 5.2%23

7. Distractor loosening 3%23

8. Paraesthesia 3.6%14,23

9. Problems of compliance 4.7%23

Late

10. Occlusal disharmony5,23,30

11. Tooth elongation by elastic traction

12. Incorrect vector 7.2–8.8%23

13. Relapse 4%13 and up to 50%23

14. Premature bony consolidation 1.9%23

15. Facial nerve damage 0.4%23

16. Condylar resorption32

17. Alterations in the articulation8

18. Atypical facial pain <0.1%23

19. Injury through the distractor29
20. Fibrous union 0.5% \(^{23}\)
21. Quadripareisis <0.1% \(^{23}\)
22. Maxillary sinus perforation <0.1% \(^{23}\)
23. Parotid fistula <0.1% \(^{23}\)
24. Alterations in speech

We do not know how much bone and soft-tissue is retained after distraction. We also do not know how this is aided by the insertion of implants. The rate of distraction is based upon laboratory animal work and differences between facial and long bones in terms of distraction have not been adequately studied, if such exist. The effect of the rate on sensory function of the inferior alveolar nerve has been documented elsewhere \(^{14}\). Multivector \(^{1,39}\) and combined distraction of the mandible and maxilla \(^{2,35}\) increase the risk of problems arising during and after the procedure.

**Case reports**

**Case 1. Insufficient screw length and plate fracture**

A 21-year-old patient presented with a left-sided hemifacial microsomia. Examination of the 3D-milling models suggested distraction at the angle of the mandible \(^{21,27,35}\) of 12 mm, combined with a lateral sliding genioplasty. A TRACK \(^{1.5}\) mm distractor (Tissue regeneration by alveolar callus distraction Köln, Martin Medical, Tuttlingen, Germany) was chosen \(^{9,27}\). At insertion it became apparent that the screw would protrude insufficiently into the vestibulum. No further suitable distractors were available for use and soft-tissue had to be reduced sufficiently to be able to reach the screw on a regular basis. We distracted the segment to 12 mm in 12 days. Application of the screwdriver was associated with severe pain. The patient was lost to follow-up for 6 months and at recall we found a fracture on the superior plate. Removal was technically demanding as there was callus formation over the entire length of the distractor plates and screws. Figures 1 and 2 show the orthopantanograms before and after the procedure. The gonial angle had been distracted insufficiently. Recommendations include the choice of a significantly greater distance of distraction, a different distractor size, better consideration of the soft-tissue relationships in the region of the external oblique ridge and the direction of distraction to achieve a better gonial angle.

**Case 2. Unsuccessful distraction osteogenesis**

A 51-year-old patient presented with a left-sided cleft-lip and palate. She had never had an alveolar bone graft performed. The hard- and soft palate had been closed simultaneously at 2 years of age. She had been edentulous for 10 years. We found a severely retruded and atrophic maxilla, as well as a persistent oro-nasal fistula. The SNA was 64°. We performed an alveolar bone graft and closed the oro-nasal fistula. Two months later we applied a RED \(^{*}\) II (Rigid External Distraction II System, Martin Medical, Tuttlingen, Germany) and performed a Le Fort I osteotomy \(^{7,19}\). The alveolar bone-graft site was not absolutely rigid. Two Leipzig rods connected the miniplates with the external distractor. Distraction was performed daily to a total of 19 mm with resulting velo-pharyngeal incompetence \(^{6,7}\). Figure 3 shows the patient in retention at 19 mm of forward distraction. After the retention period of 8 weeks, distractor removal was combined with the insertion of miniplates to minimize or prevent relapse \(^{8}\). At surgery, an anteroposterior defect of 20 mm was noted, suggesting that distraction osteogenesis per se had not taken place. As the final treatment plan includes the insertion of implants, further bone-grafting should have been decided upon at the time of distractor removal in order to ensure sufficient bone volume at the site of the intended implant placement. Furthermore, the intended location of the implants should have been determined at the beginning of treatment in addition the considerations of the lateral cephalometric analysis.

**Case 3. Mucosal perforation by interim prosthesis, accidental damage to adjacent teeth**

A 21-year-old patient presented with loss of the tooth 11 following dento-alveolar trauma. The loss of vertical height precluded implant insertion. A TRACK \(^{1.0}\) mm device (Martin Medical, Tuttlingen, Germany) was inserted. Particular attention was paid to

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*Fig. 1. Orthopantanogram of case 1 before distraction.*

*Fig. 2. Orthopantanogram case 1 after distraction.*
the avoidance of undercuts in performing the osteotomies. An interim prosthesis was fitted at the completion of surgery. Postoperatively we noted a palatal mucosal perforation which was managed by relieving the prosthesis and removing a small amount of bone using a Luhr bone-nibbler. The tooth 12 was shown to be non-vital, but did not show any signs of discoloration. This tooth has not been treated endodontically. The distraction was completed (11 mm) and a Frialit II (Friadent, Mannheim, Germany) implant inserted at the time of distractor removal. It was noted at this procedure that the bucco-lingual dimension was inadequate. We performed an intra-oral bone-graft in the same sitting. The postoperative course has been uneventful.

Case 4. Metal fatigue and worsening of the anterior open-bite

An 18-year-old patient presented with severe mandibular hypoplasia, having already had distraction osteogenesis performed at the angles of the mandible some years previously. A lateral radiograph (Fig. 4) and orthopantogram (Fig. 5) show the patient at the time of presentation. We found an anterior open bite and insufficient archwidth to accommodate the dentition. We performed distraction osteogenesis between teeth 33 and 34 as well as between 43 and 44. There was hardly any interdental bone in these sites and the tooth 34 was loosened during the procedure. We applied a composite resin to the orthodontic appliance to fix the tooth. Due to the prominent rugae, excessive plate-bending was required for accurate and passive adaptation. This resulted in one of the plates fracturing off the distractor. The screws protruded through the lips and this caused the patient significant discomfort. A complex occlusal relationship developed. At the completion of distraction (14 mm on the right, 13 mm on the left) the screws were removed using a wire-cutter. There was a residual anterior open bite. The retention was reduced from 8 to 3 weeks, the distractor removed at this time. Elastic traction was applied via the orthodontic appliance to the osteotomized segment and gradually distracted into the desired occlusal relationship (lateral radiograph Fig. 6 and orthopantogram Fig. 7). Initially the segment was quite mobile, with differences of 3 mm with and without elastics. As the weeks progressed however, and the patient had had the anterior open bite closed, the segment unified and there has been no relapse at 3 months of follow-up.

Case 5. Asymmetric bony requirements

A 43-year-old patient presented with a necrotic bone transplant protruding through a loose implant and an associated mucosal perforation. The intention was to treat an edentulous space left after the loss of teeth 12–14. We removed the implant together with the necrotic bone and were able to achieve healing by secondary intention. An interim prosthesis was fitted. We performed distraction osteogenesis using a TRACK 1.5 mm distractor (Martin Medical, Tuttlingen, Germany). Distally, sufficient bone was present, however, mesially the defect reached almost to the piriform rim. A distance of 9 mm was distracted at the site where sufficient bone was available for attachment of the distractor plates and the patient is presently in retention. The proximal region remains deficient in bone quantity and soft-tissue and we plan to perform a bone-graft at the time of distractor removal and implant insertion.

Discussion

A review of 828 reported cases in the literature from 1966–1999 and attempted to assess the method of distraction osteogenesis as well as the complication rate. Mojid et al. attempted to analyse realistic experiences using anonymous questionnaires. Areas of controversy centre around possible differences between mono- and bicortical
osteotomy, rate and rhythm of distraction, and length of retention. We have
attempted to objectively assess the problems we have had with the technique and
present five illustrative cases. We have
had for example to resort to additional
bone-grafting for all our alveolar bone
distraction osteogeneses although in the
majority of cases these have needed to be
quite small.

Complication rate

The number of complications may be
related to operator experience, as deter-
mining the indication, deciding on the
type of distractor, the vector and rate of
distraction as well as determining the
success of the distraction at the time of
the removal or at the time of, for
example, the implant-insertion are
empirical variables. Four per cent of
centres actively involved in performing
DO can report having performed this
technique in >100 cases. The rest per-
form the technique on a sporadic basis
and may therefore be expected to have a
greater complication rate per case
treated. We have had for example to
resort to additional bone-grafting in all
our alveolar bone distractions and count
this as a complication. Efforts at trying
to circumvent this problem in osteotomy
line design and choice of distractor have
not proven to be successful as yet.

Distraction and patient age

Midline expansion is performed only
after the age of 12 years. Otherwise
there appears to be no age-limit for
the performance of the procedure.
Intra-oral devices for example in the
treatment of mandibular hypoplasia
have been inserted in patients as young
as 8 years although there may be prob-
lems with patient compliance. We there-
fore usually offer this treatment option
to patients older than 10 years of age
and in particular to patients who live
close by.

Forces acting on the distractor

Movement of dentate bone or bone that
is intended for dental rehabilitation is
exposed to a multitude of forces which
determine the final quantity and
position. Attached gingiva and
periosteum is required, and the location
of the incision should be chosen such
that the final restoration may success-
fully be placed. Directional stability
should be ensured in order to counteract
soft-tissue forces which still seems to
be a problem, even after the manufac-
turer has augmented the distractor with
a vertical extension. This is assumed to
be due to metal fatigue and an inability
to overcome the forces.

Expanding indications

If implants have been placed in the
incorrect position, distraction may
present a treatment option for their cor-
rection. DO may also be an option for
retained teeth. Combinations of DO
with other (cosmetic) surgery techniques
such as onlay grafting may occasionally
be required. The screws must
remain accessible throughout and the
limits set by the distractor not be
reached. The choice of distractor should
be adequate to meet the treatment
needs, and not be too large or too small.
Continuous relief of interim prostheses
where used should be performed in order
to avoid mucosal perforation.

Limits of distraction

Geniohyoid musculature can be length-
ened to a maximum of 20% resting
length. The inferior alveolar nerve may
be able to be distracted. Other than
these two limitations, tissue expansion
has shown the immense potential of skin
and subcutaneous tissue for increasing
surface area. The segment must remain
attached to vital tissue. We are not
aware of any other limits to date, and
have not received reports of ischaemic (bone) necrosis after dis-
traction osteogenesis.

Duration of retention

We routinely perform retention for
6 weeks, unless correction of an
incorrectly chosen vector is required. Retention may be longer in patients of the age-ranges 10–12 and 13–16 years.33 Retention in the maxilla after rigid external distraction is only 2–4 weeks,23 in some centres. Longer retention is recommended although this does not decrease the incidence of relapse.

‘Floating bone’

Errors in determining the vector may be corrected by the ‘floating bone concept’ as suggested by Hoffmeister.13 Unsatisfactory positioning of the fragment should motivate the clinician to shorten the retention phase of the distractor to 3–4 weeks and continue distraction using elastic traction and the opposing dentition. The segment should be amenable to elastic traction by providing attachments for the elastics. We have applied this principle using intermaxillary elastic traction devices on fixed orthodontic appliances but have found it difficult to control the movement of the segments, resulting in sub-optimal treatment outcomes. We look forward to further developments in this field.

Follow-up and relapse rate

Of mandibular DO only 26% patients were followed up for more than a year, with a 4% relapse-rate. No relapse was noted in alveolar bone DO group over a follow-up period of 13 months.23 Nevertheless over-correction of alveolar segment distraction is recommended for the same reasons as apply in alveolar bone-grafting. Mofid et al.23 reported a relapse-rate of up to 60% in the maxilla, which concurs with our clinical impression. Overcorrection is strongly recommended.

General remarks

Reports are increasingly able to report bigger series,10,11,20,22,28,34,37,38 pointing to an increasing acceptance of the procedure in routine clinical practice. DO is used sporadically in the majority of cases. The spectrum of indications and innovations is expanding.7,18,19 An entire issue of the aesthetics journal ‘Annales Chirurgie Plastique et Esthetique’ (2001; 46(4) French) was devoted to the technique, yet consisted only of case reports. Representative articles are those of Mofid et al.23 and Swennen et al.33

In conclusion, the avoidance of undercuts, the movement of the segment into the final planned position (and overcorrection) using the distractor at the time of insertion, avoidance of collateral damage and support of the patient throughout the procedure are prerequisites for the performance of this procedure. Clear advantages over conventional osteotomies and bone-grafting are still to be described. It is an unusually complex process which is reserved for the unusual patient to fulfill a complex requirement. DO is a continuous process which requires careful planning and close observation in order to detect errors early. There is a lack of evidence in support of the current method and the above should be seen as a consensus approach. It may be taken into the armamentarium of the treating surgeon as one way of obtaining bone quantity25,26 and movement of tooth- or implant-carrying bone.34,39

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