How to Avoid Surgical Failures

David M. Sarver and Lew B. Sample

Problems and failures in orthodontic-orthognathic surgical treatment are frequently discussed among colleagues, but not often written about. This lack of documentation may be attributed to a natural inclination for us to report our successes and hide our failures. More positively, we believe the lack of written material on complications probably relates more to the overwhelming success rate in these procedures than to an inclination to hide failures. In addition, some complications are clearly a result of the orthodontic care before and/or after the surgical procedure. This article concentrates on exploring the many complications in orthognathic surgery that are more a result of the orthodontic phase of care, and how the orthodontist can react to and manage surgical complications to achieve a successful result. The more the orthodontist understands the nature of surgical problems, the more able he/she is to manage them. (Semin Orthod 1999;5:257-274.) ***Copyright © 1999 by W.B. Saunders Company***

The topic of complications encountered in orthognathic surgery is one that could fill pages of text. Problems and failures in orthodontic-orthognathic surgical treatment are frequently discussed among colleagues but not often written about. This lack of documentation may be attributed to a natural inclination for us to report our successes and hide our failures. More positively, we believe the lack of written material on complications probably relates more to the overwhelming success rate in these procedures than to an inclination to hide failures. In any case, documentation of surgical complications and/or failures is scant. When the guest editor of this issue of *Seminars in Orthodontics* called to ask if we could write an article on complications in orthognathic surgery, we replied that she had indeed come to the right place, because we certainly have experienced our share of them! Therefore, we accepted this task with the idea that we discuss not only types of complications and why they happen, but also what to do about them.

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1073-8746/99/0504-0007$10.00/0

It is important to point out that surgical complications do not necessarily mean the problem is the responsibility of the surgeon alone. This article concentrates on exploring the many complications in orthognathic surgery that are more a result of the orthodontic phase of care, and how the orthodontist can react to and manage surgical complications to a successful result. The more the orthodontist understands the nature of surgical problems, the more able he/she is to deal with them. In addition, some complications are clearly a result of the orthodontic care before and/or after the surgical procedure.

The purpose of this article is to discuss (1) how to anticipate and avoid common orthognathic surgical complications and (2) how to rectify them once they have occurred. The information is presented with a focus on the clinical aspects of treatment, using case illustrations and appropriate literature. We have selected the most common complexities of combined orthodontic-surgical treatment and address them in this format.

Poor communication can occur between the involved doctors and/or patient. There are many instances of interaction, from who decides on the surgical plan, who makes the occlusal wafer, who does the model surgery, etc. This differs widely depending on the team involved, but it is important to stress that in today's medicolegal and bioethical environment, the patient's understanding and input into the surgical plan are paramount. There is a natural tendency toward paternalism in the doctor-patient relationship, which comes into focus with respect to the information provided to the patient. The doctor who fails to disclose certain facts to the patient is acting paternalistically because the patient cannot choose rationally if he or she is not fully informed. The jurisprudence system in many states has concluded that the doctor as sole decision maker is paternalistic and an abuse of professional authority. Most agree it is now the doctor's legal and moral responsibility to advise the patients of the risk-benefit considerations of treatment and to discuss alternative treatment plans.[1]

Presurgical Treatment

Inadequate Orthodontic Preparation for Surgery

In most cases of skeletal dysplasia, whether in the range of surgical or nonsurgical treatment, dental compensation is a common feature. The forms and expression of this compensation are as complex as the myriad of dentoskeletal problems we face, but there are common patterns frequently encountered. In the diagnosis and proper treatment of these cases, the primary responsibility of the orthodontist is to recognize these compensations and eliminate them, or decompensate them. The range of which compensations are problematic is not concrete, so that the orthodontist and the surgeon must decide how much compensation is acceptable and what is to be done for decompensation. Although we tend to think of these compensations as an anteroposterior consideration (incisor angulation problems), dental compensation can occur in all planes of space.

Anteroposterior Relationships

These are usually defined as incisor inclination patterns.

Class II Problems

The classic pattern of compensation in Class II skeletal patterns is upright maxillary incisors and flared mandibular incisors. Conversely, Class III patients tend to have upright mandibular incisors and flared maxillary incisors. The orthodontist must recognize these compensations and decide what degree of compensation is acceptable and what requires substantive treatment. For example, if the lower incisor flare in the Class II patient is only moderate, what is the value of removing two mandibular premolars to upright the incisors? These decompensation decisions affect the treatment outcome in three basic ways: (1) inadequate incisor positioning can compromise buccal interdigitation; (2) incisor positioning can substantially affect the esthetic outcome; and (3) in certain types of functional problems (obstructive sleep apnea syndrome), esthetic considerations are relegated to a less important priority relative to functional objectives.

Problems created when cases are inadequately decompensated and incisor angulations are not normalized. The idea of the effect of incisor angulation on the core line and perimeter line occlusal characteristics was advanced and best expressed by Andrews.[2] In presurgical preparation for mandibular advancement, maxillary incisors that are not properly torqued or mandibular incisors that are left overly flared may result in the following: (1) insufficient room to provide for adequate advancement of the mandible from the esthetic standpoint, (2) the risk for limiting the success in improving the overall health of our patient. For example, in the treatment of sleep apnea, if the amount of advancement will not be maximized (which is the primary objective), the health of the patient remains compromised, and (3) the inability to achieve Class I buccal segments because the advanced nature of the incisal edge does not permit interdigitation of the buccal segments (Fig 1).

Treatment Strategies to Avoid Complications in Class II Patients

Incisor Decompensation

1. Preoperative use of Class III elastics. Progress through arch wire sequences to full dimension wires to torque upper incisors, while Class III elastics are used to upright the lower incisors, or at least to maintain their axial inclination if it is reasonably acceptable.

2. Extraction of mandibular first or second premolars to provide space for uprighting and

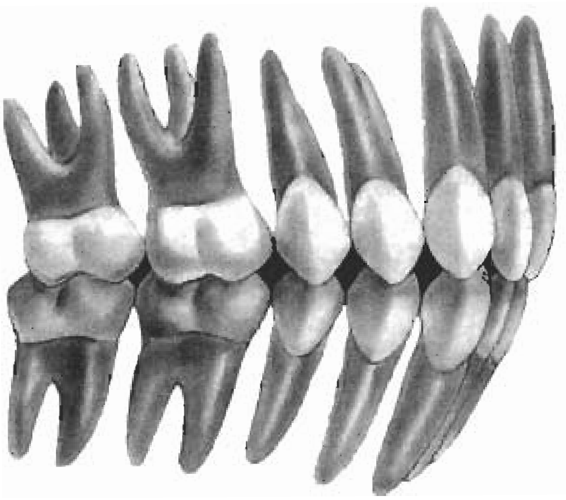

Figure 1. Class I buccal segments are not attainable because the flared lower incisors do not permit interdigitation of the buccal segments. (Reprinted with permission from Andrews LF. Straight Wire: The Concept and the Appliance. San Diego, CA, Wells, 1989.[2])

retraction of the lower incisors. The decision on which teeth to extract depends on the degree of profile convexity and the desirability of how much overjet is required to achieve the desired profile upon advancement of the mandible.

3. The use of Class III elastics with round arch wires effectively flares the maxillary incisors by tipping the crown around the center of mass. The center of rotation should be at the apex of the incisor or above. This approach is used in cases in which we want the maxillary incisal edge to come as far forward as possible. This approach is desirable in the following cases: (1) the patient's profile is very convex, and decompensation with maxillary incisor torque results in only minor overjet. The failure to sufficiently advance the maxillary incisors results in inadequate overjet, which in turn decreases the interincisal distance needed for maximum mandibular advancement. In other words, the occlusion may be improved, but the esthetic outcome is not optimized and (2) when the patient's nasolabial angle is flat or obtuse, as much incisor advancement as possible is desired to improve upper lip projection for esthetic reasons.

4. Preoperative use of coil springs. The use of open coil springs to open space distal to the maxillary lateral incisors to flare maxillary incissors not only proclines the maxillary incisors, but also provides room for error when there is a tooth size discrepancy, because Bolton discrepancies are difficult to visualize in moderate-to-borderline cases.

Class III Problems

Insufficient incisor decompensation in Class III patients in whom maxillary incisors are overly flared or mandibular incisors are unduly upright results in: (1) insufficient negative overjet preparation for adequate advancement of the maxilla or mandibular reduction from the esthetic standpoint; and (2) inability to achieve Class I buccal segments because of the upright nature of the incisal edges not permitting interdigitation of the buccal segments (Fig 2).

Treatment Strategies to Avoid Complications in Class III Patients

To upright flared maxillary incisors, extraction of maxillary first or second premolars is often performed to make space for the retraction and uprighting of the flared teeth. The decision on which premolars to remove depends on the amount of crowding already present and how much retraction of incisors is required. Very often the lower incisors are upright in compensation, and this results in lower incisor crowding. The simple act of unraveling the crowding decompensates the lower incisor angulations. The decision on how far to retract the incisors is a function (as in the Class II patients) of how

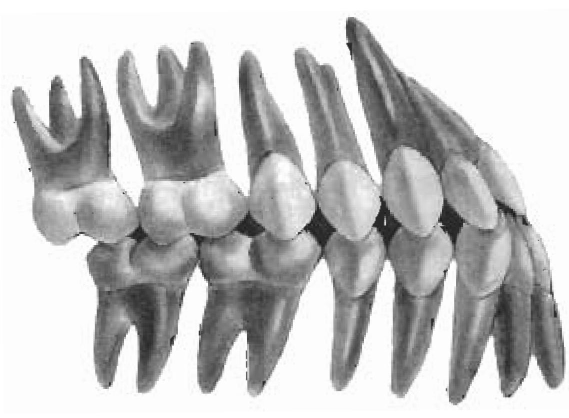

Figure 2. Inability to achieve Class I buccal segments because of the upright nature of the incisal edge not permitting interdigitation of the buccal segments. (Reprinted with permission from Andrews LF. Straight Wire: The Concept and the Appliance. San Diego, CA, Wells, 1989.[2])

much negative overjet is desirable for ideal esthetic improvement. A severely concave Class III profile will require maximum retraction to provide maximum negative overjet. If the profile is very concave and decompensation with lower incisor unraveling results in only minor negative overjet, then failure to sufficiently advance the mandibular incisors results in inadequate negative overjet. This in turn diminishes the interincisal distance needed for maximum maxillary advancement or mandibular reduction. In other words, the occlusion may be improved, but the esthetic outcome is not maximized. When the patient's labiomental sulcus is shallow or flat as a result of the lingually inclined lower incisors, as much lower incisor advancement as possible is desired to improve lower lip projection for esthetic reasons. Increased lower lip projection results in a more natural and desirable curvature to the labiomental sulcus.

In the severely concave profile or in a face that has deep frontal nasolabial grooves (where maxillary advancement could improve the soft-tissue aging effect), other methods may be used to maximize negative overjet. In the case of extraction therapy, and even in nonextraction therapy, use can be made of Class II elastics with round arch wires. This effectively flares the mandibular incisors by tipping the crown around the center of mass. The center of rotation should be at the apex of the incisor or below. Again, this has a dramatic effect on the lower lip and its balance with the chin.

Transverse Relationships

The Class II patient often has narrowing of the maxilla in response to the narrower portion of the mandible being placed in the broader portion of the maxillary arch. In the Class III patient, the maxillary posterior segments are often flared buccally in compensation for the wider portion of the mandible being placed into the narrower aspect of the maxilla. By holding the study models in a simulated Class I relationship, these compensations can be easily recognized (Fig 3).

Figure 3. Transverse problems are first diagnosed by holding the study models together in a simulated Class I relationship. The most commonly found transverse problem is that the maxilla is narrower than the mandible in cases similar to this patient, who is being evaluated for Class II correction by mandibular advancement.

Treatment Strategies to Avoid Complications in Transverse Problems

As in all cases, transverse problems are first diagnosed by holding the study models in a simulated Class I relationship. The most commonly found transverse problem is that the maxilla is narrower than the mandible. In these cases, treatment strategies may include: (1) dental expansion through orthodontic means, (2) two-piece or three-piece maxillary expansion simultaneous with mandibular advancement, (3) staged surgically assisted rapid maxillary expansion before surgery, and (4) mandibular midline ostectomy to narrow the mandible.

The expansion of the maxilla may be performed orthodontically and/or surgically, the choice of which usually depends on the magnitude of the expansion needed and the posterior buccal root torque. When the study models are held in a simulated Class I relationship, if the intercanine width is narrow and in crossbite or almost in crossbite, then a two-piece expansion is indicated. If the intercanine width is adequate (be sure to note whether the cuspids are flared bucally or transversely compensated) but posterior crossbite is present, then a three-piece osteotomy is probably indicated. In these types of decisions, model surgery facilitates three-dimensional visualization and helps the clinician avoid complications associated with the failure to recognize transverse compensations.

Vertical Relationships

Incisor Extrusion in Open Bite

In the developing patient, dental compensation for vertical problems may occur. For example, the open bite patient often will show an excessive curve of Spee, characterized by overerupted mandibular incisors, as though the lower incisors are attempting to "keep up" with the maxillary incisors in the developing malocclusion (Fig 4).

Treatment strategies in incisor extrusion cases to avoid complications include orthodontic intrusion of the mandibular incisors and surgical intrusion of the mandibular incisors in cases of severe incisor extrusion.

Failure to Recognize the Need for Multisegmental Orthodontic Alignment and Osteotomy

In the initial diagnostic analysis, the study models should not only be evaluated in a simulated Class I relationship, but it is also useful to place the occlusal plane against a flat surface (a table top, for example) to evaluate occlusal plane discrepancies. Curve of Spee is common in the lower arch, but curve in the upper arch is generally seen in the first and second molar area only. Whereas moderate extrusion of incisors has been shown to be effectively stable,[3] a significant (>2 mm) differential between the vertical height of the incisal edges and the occlusal level of the premolars should not be orthodontically flattened before surgery. This amount of extrusion of the anterior teeth may relapse after surgery, resulting in an anterior open bite.

Figure 5 represents the initial frontal intraoral photograph of a patient referred for correction of an anterior open bite. The occlusal plane was characterized by a differential height between the incisal edges and the occlusal surfaces of the premolars and molars. The anterior segment (cuspid to cuspid) was canted transversely, and the right posterior segment was more inferior than the left. Presurgical orthodontic treatment completely leveled the maxillary arch from molar to molar (Fig 6). The orthognathic surgical procedure included a LeFort I osteotomy with transverse leveling and posterior impaction to close the bite and ramus osteotomies to correct mandibular asymmetry. The postoperative occlusion was very good (Fig 7), but 1 year after appliance removal, the maxillary occlusal plane had relapsed toward its original condition (Fig 8). This patient certainly could have been more successfully treated had we leveled the maxillary

Figure 4. The open bite patient often will show an excessive curve of Spee characterized by overerupted mandibular incisors, as though the lower incisors are attempting to keep up with the maxillary incisors in the developing malocclusion.

Figure 5. The initial frontal intraoral photograph of a patient with an anterior open bite. There was an occlusal plane height differential between the anterior incisal edges and the occlusal surfaces of the premolars and molars. The anterior segment (cuspid to cuspid) was canted transversely, and the right posterior segment was more inferior than the left.

Figure 6. Presurgical orthodontic treatment was designed to completely level the maxillary arch from molar to molar through orthodontic alignment.

Figure 7. After maxillomandibular surgery, the postoperative occlusion was very good and finished easily.

Figure 8. One year after appliance removal, the maxillary occlusal plane had relapsed toward its original condition. Today we would recommend segmentation of the maxilla to level the maxillary occlusal plane rather than the orthodontic leveling.

arch in distinct segments, in this situation segmenting the anterior segment from lateral incisor to lateral incisor and the posterior segments from cuspid to second molar.

Postsurgical Treatment

If complications occur, and indeed they will, the ability of the orthodontist to recover and still deliver an ideal or even acceptable result is an important part of the teamwork of orthognathic surgery.

Appropriate and Inappropriate Orthodontic Finishing Mechanics

The orthodontist should keep basic vectors of force in mind when managing postoperative orthodontic care. For example, a patient who had just undergone orthognathic surgery with maxillary impaction and mandibular advancement for a Class II open bite was referred to the authors for a second opinion. The concern was that the open bite was returning very soon after the surgery had been performed. The surgeon was very experienced and competent, but he was unsure of what might be causing this relapse. Possibilities included surgical relapse or poor condylar positioning, tongue function or posture, or condylar resorption. After questioning the patient extensively, it appeared that after the surgical procedure, the orthodontist was concerned about potential Class II relapse and had placed the patient on cervical headgear because that was his method of treatment for most of his Class II patients. Of course, the downward vector of force of the cervical headgear resulted in extrusion of the posterior maxilla and/or teeth, undoing precisely the direction of the surgery. That the orthodontist was not familiar with appropriate postoperative orthodontic management resulted in the unfortunate need for reoperation.

Admittedly, the latter circumstance is an extreme example. More subtle changes can be caused by postoperative orthodontic therapy, so this phase of treatment should be planned and managed as thoughtfully as the preoperative plan. The effects of certain types of mechanics should be weighed against the potential relapse associated with the particular surgical procedure. For example, Class II elastics have a vertical vector of force as well as an anterior vector. In a case of maxillary impaction and mandibular advancement in which some Class II elastics are needed for some adjustment in the occlusion, it should be borne in mind that these elastics produce a clockwise rotation of the occlusal plane by extrusion of the maxillary anterior teeth and the mandibular posterior teeth. This results in more of the maxillary incisor showing in rest position and an increased gingival display on smile, as well as resulting in detorquing of the maxillary incisor angulations. The extrusion of the mandibular posterior teeth results in rotation of the mandible downwards and backward, resulting in decreased mandibular and chin projection, as well as bite opening.

The extensive postoperative use of Class III elastics also may have similar undesirable effects. Again, in the case of maxillary impaction and mandibular advancement in which Class III elastics are needed for some adjustment in the occlusion, these elastics produce a counterclockwise rotation of the occlusal plane by extrusion of the maxillary posterior teeth and the mandibular anterior teeth. This results in a tendency toward bite opening caused by the extrusion of the maxillary posterior teeth, reversing the effects of the maxillary impaction.

Complications Caused by Inadequate Recognition of the Different Postoperative Characteristics of Wired and Rigid Osteosyntesis With Treatment Strategies

In the use of rigid internal fixation, the gain in rigidity also results in a loss of elasticity. It would be preferable that all surgical cases are perfectly accurate; however, the orthodontist and surgeon cannot realistically expect this in every situation. Rigid fixation (RIF) has without doubt been an advancement. Intermaxillary fixation (IMF), however, is still a frequently used method of osteosyntesis. RIF offers many advantages to the patient and surgical team, but one of the most striking advantages of IMF is the lessened rigidity of the osseous fixation. That is, the osteotomy sites are often still "plastic," and modifiable, and in some cases, this is an advantage. The patient illustrated in Figure 9 is a remarkable example. This mandibular-deficient patient was referred for orthodontic-surgical correction of her Class II malocclusion (Fig 10). This patient was treated in 1980, and a popular theory at that time was that direct wiring of osseous segments would position the condyle in a forced position. With the lack of information on condylar position and its relation to temporomandibular dysfunction, it was proposed that although the teeth would be wired together for a 6-week period, no interosseous wires would be placed, allowing the condylar segment to seek its "true, natural, and muscularly determined position." Although the theory seemed plausible, in reality, the results were very disappointing. After 6 weeks and subsequent release of the IMF, the occlusion was worse than the previous condition (Fig 11). The patient had been converted from a Class II malocclusion to a Class II open bite malocclusion. The contraction of the temporal and masseter muscles at their attachment to the mandibular angle and coronoid process resulted in a counterclockwise rotation of the proximal segment and a clockwise rotation of the distal segment (Fig 12).

The patient was offered the options of reoperation or elastic traction in an effort to remodel the osteotomy site and bring the distal segment

Figure 9. This patient was evaluated for orthodontic-surgical correction of her deficient mandible.

Figure 10. This is the patient's Class II malocclusion after presurgical preparation. Advancement of the mandible through sagittal split osteotomy was planned, and neither interosseous wiring nor rigid fixation was to be used. The surgeon acted on a theory at the time that the act of wiring forces the condyle into an unnatural position, and to wire the dentition together and not place osseous fixation would permit the muscles to "seat the condyles naturally."

Figure 11. After 6 weeks and subsequent release of the intermaxillary fixation, the occlusal relations were worse than the previous condition.

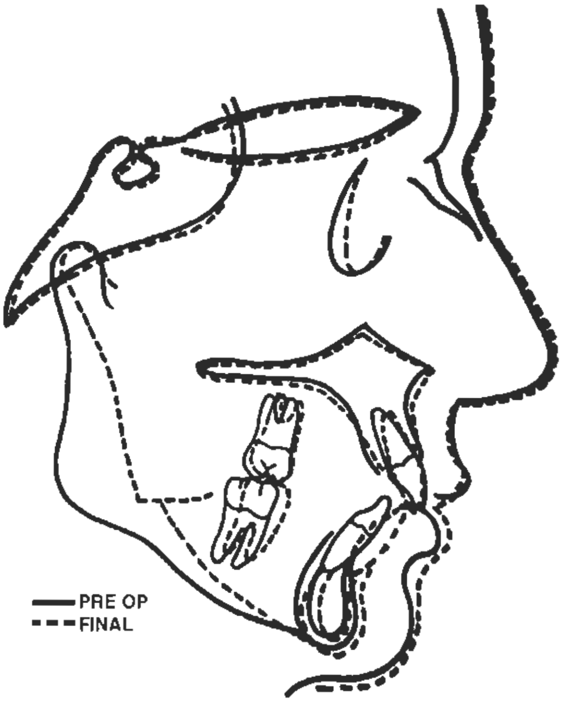

Figure 12. Contraction of the temporal and masseter muscles on their attachment to the mandibular angle and coronoid process resulted in a counterclockwise rotation of the proximal segment and a clockwise rotation of the distal segment, as shown in this superimposition tracing.

Figure 13. Because healing was not yet complete, some plasticity of the healing ramus presented a treatment possibility. We aggressively attempted to correct the problem with elastic traction. Over a 2-week period, the teeth were brought together in occlusion. The result was stable, as represented by this 2-year posttreatment intraoral photograph.

back into place. The patient was not anxious to have additional surgery together with 6 weeks of IMF, so a decision was made to attempt correction with elastic traction. Care was taken to avoid Class II elastics because this would worsen the situation by pulling the mandibular molars up and forward, further rotating the body of the mandible in a clockwise direction. A decision was made to use anterior elastics alone. Over a 2-week period, the teeth were brought together and occluded well (Fig 13), but an esthetic price was paid because the gonial angles were rotated forward and a noticeable defect resulted at the gonial angle. The continuity of the mandibular angle and contour of the jawline disappeared (Fig 14).

Whereas the previous case represented a fairly disastrous surgical outcome that was corrected through postoperative orthodontics and osteotomy sites that were still quite plastic, the following patient illustrates the opposite problem. In the following situation, RIF did not permit much postoperative movement when it would have been advantageous. Figure 15 illustrates the original malocclusion, a Class III open bite. The surgical procedures planned were maxillary advancement with mandibular reduction. Figure 16 represents the 1-week postoperative frontal photograph with poor occlusal relationships and a severe midline discrepancy. The bite was still open, and Figure 17 illustrates the extent to which the Class III malocclusion still existed. The possibilities for the surgical failure in this patient included inaccurate splint construction, inability to place the maxilla and mandible accurately into the occlusal splint, lack of stabilization or fixation of the maxilla, and poor condylar position and placement during surgery.

The original occlusal setup was examined and

Figure 14. Rotation of the gonial angles resulted in a noticeable defect at the gonial angle, and the continuity of the mandibular angle and contour of the jawline disappeared.

Figure 15. This patient presented for correction of her Class III open bite through maxillary advancement and mandibular reduction.

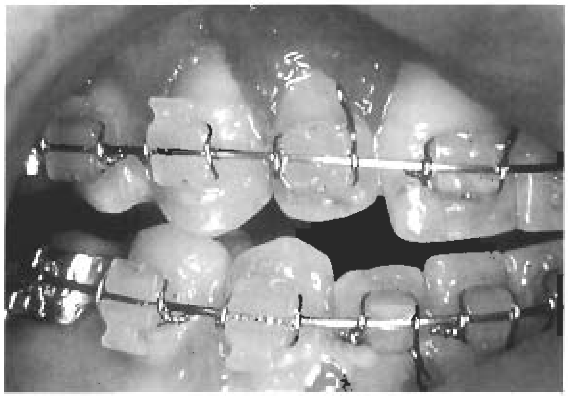

Figure 17. The bite was still open, and the extent of the Class III malocclusion still existing is illustrated.

found to be accurate, and the lack of success was caused by either lack of accurate placement of the teeth and osseous segments into the splint or lack of adequate condylar positioning (seating).

If indeed the problem was caused by poor fixation technique, then enough plasticity may exist for the orthodontist to use Class III elastics to try and correct the case. The shortcoming of Class III elastic use is that its vertical component tends to aggravate the open bite, and we decided to remove the fixation plates under local anesthesia and protract the maxilla with a reverse-pull headgear over the ensuing 6-week healing period. Figure 18 illustrates the final outcome, with the Class III relationships improved and the bite moderately closed.

Understanding the postoperative characteristics of the osteotomies involved is an important part of avoiding moderate complications. Table 1 is a general guide for how occlusal wafers might be set up, depending on the clinician's experience and what type of osteosynthesis is chosen. An illustration of this is a complication encountered in the mid-1980s when the commitment was made to RIF as our main method of osteosyntesis. This patient had severe mandibular deficiency (Fig 19) characterized by a significant Class II malocclusion with 11 mm of overjet (Fig 20). Her case was complicated by the absence of most of her posterior teeth. After her presurgical-phase orthodontics had been completed, it was decided to construct her occlusal wafer in an end-to-end relationship, rather than with an ideal overjet. The decision was made because of the magnitude of the advancement, lack of

Figure 16. The result was disappointing: the 1-week postoperative frontal photograph reflects poor occlusal relationships and a severe midline discrepancy. This result was caused by poor surgical management of the positioning of the osseous segments.

Figure 18. The fixation plates were removed under local anesthesia and the maxilla protracted with a face mask headgear over the ensuing 6-week period. The occlusal relations were improved dramatically enough for the patient to refuse reoperation.

Table 1. Recommended Model Placement for Occlusal Wafer Fabrication

Surgical Procedure	*IMF*	*RIF*	*Comment, IMF*	*Comment, RIF*
Mandibular advancement, deep bite	Toward edge to edge, some vertical opening if desired	Ideal OB, OJ no posterior vertical space	Md tends to relapse A-P 25% In deep-bite short-faced patients, we often desire posterior extrusion	Md actually tends to migrate anteriorly; also not very modifiable post-operative, extrusion characteristics
Mandibular advancement, no deep bite	Toward edge to edge, no vertical opening	Ideal OB, OJ, and vertical	Tends to create counter-clockwise rotation leaving posterior vertically spaced and may create open bite relapse	
Maxillary advancement	1-2 mm OJ	Ideal OJ, OB no relapse	Maxilla tends to relapse posteriorly	Anterior plate-posterior wire to permit postoperative adjustment if needed
Mandibular reduction	Ideal OB, OJ 1 mm Some vertical posterior if desired	Ideal OB, OJ 1 mm Some vertical posterior if desired	Very little relapse tendency, but with IMF still plastic and modifiable	Mandible tends to relapse anteriorly, so OJ set-up needed.
Maxillary impaction, autorotation	Ideal OJ, OB Some interocclusal space		Autorotation tends to unseat condyles	
Maxillary expansion	Depends on stabilization for transverse, some interocclusal space to allow crossbite elastics; suggest nasal floor plates with HA interpositional graft.		Some suggest surgically assisted RPE staged before LeFort. We find stability excellent with described system so it is better not to perform two procedures when one will do.	

Abbreviations: OJ, overjet; OB, open bite; IMF, intermaxillary fixation; RIF, rigid fixation; HA, hydroxylapatite; Md, mandible; A-P, anteroposterior; RPE, rapid palatal expansion.

posterior teeth, and the belief that the mandible would relapse posteriorly (based on the data from IMF studies at the time), particularly in an advancement of this magnitude.

The surgical procedure was performed, and the profile improvement was quite significant (Fig 21). However, the occlusion and anterior incisal relations remained in an end-to-end relationship (Fig 22). Rather than experiencing a posterior relapse as was expected, no relapse occurred. It is noted, however, that early data indicated that with RIF, not only does the mandible not relapse, it continues a mild anterior migration.[1] However, the latter may be a tempo-

Figure 19. The profile picture of a patient planned for orthodontics and mandibular advancement.

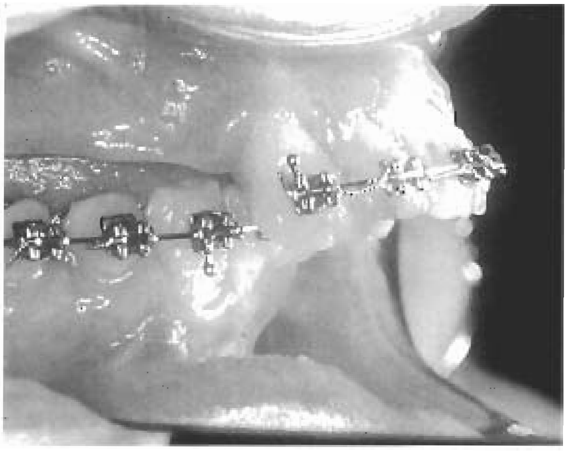

Figure 20. A Class II malocclusion with 11 mm of overjet characterized the occlusion. Because of the severity of overjet and expected relapse based on data from intermaxillary fixation, the occlusal wafer was fabricated with the incisors in an edge-to-edge relationships.

Figure 21. Following mandibular advancement, the profile improved significantly.

rary response because 1 year postoperatively, RIF patients apparently are not much different from those treated with IMF.[5]

The use of RIF dramatically improves the stability of osteotomy movement. This feature of RIF has both a positive and negative aspects. The positive, of course, is the increased stability of the procedure. The negative, however, is the loss of plasticity shown in the previous case. This plasticity helps allow for adjustment for any surgical inaccuracies. The orthodontist should be aware and educated to what can and should be done to adjust for minor complications.

Management of Expected Relapse Patterns

Transverse Maxillary Expansion

Transverse maxillary expansion has often been cited as one of, if not the least stable orthognathic procedures. Widening of the maxilla stretches the palatal mucosa, and its elastic rebound is the major cause of relapse tendencies. Long-term data[5] indicate that 1 year after surgery, approximately 50% of expansion was on average lost, with the greatest relapse occurring in the second molar area, the area that also had the greatest expansion at surgery. Strategies to control relapse include overcorrection, lateral plates, and long-term palatal coverage retention. Surgically assisted rapid palatal expansion has been advocated as a way to improve stability.[6,7] There are no published data from the time of expansion to 1-year follow-up, but only from the time at which orthodontic appliances were removed, long after expansion was complete. In cases in which the orthognathic plan is more than just transverse expansion, surgically assisted rapid palatal expansion is recommended as a staged procedure. That is, one procedure is required for expansion and another operation for the rest of the orthognathic procedure. This has the obvious disadvantage of requiring two procedures when possibly one would suffice, thereby increasing expense and trauma to the patient.

The patient illustrated in Figure 23 was planned for a two-piece maxillary LeFort I with expansion of the entire maxilla, with 10 mm of posterior maxillary expansion. RIF plates were placed on both the anterior and posterior aspects of the maxilla. Stability of the transverse expansion was poor (Fig 24), with approximately 50% relapse occurring within the first 8 weeks after surgery. Vigorous use of vertical and crossbite elastics was employed with only moderate

Figure 22. The ramus osteotomies were stabilized with rigid internal fixation, and no relapse occurred. Therefore, the edge-to-edge relationship remained. Knowledge of the differences in fixation characteristics is of great importance when planning occlusal setups.

Figure 23. Correction of the bilateral posterior crossbite was planned, with a two-piece maxillary osteotomy with a large expansion of 10 mm.

Figure 24. Even with the use of rigid fixation plates, 50% relapse of the expansion occurred, with poor occlusal results.

success (Fig 25). Although the posterior plates might have provided enhanced stability, in this case they did not and probably limited the plasticity of the osteotomy sites, so that orthodontic remodeling was not successful.

We are faced with the need to improve the stability of expansion, but would like to maintain some plasticity in the system. Based on a 10-year history with maxillary expansion, we are currently using two solutions that appear to be viable methods for stabilizing this procedure:

1. The use of hydroxylapatite (HA) blocks as precut interpositional grafts placed in the interosseous gap created by expansion of the maxilla (Figs 26 and 27). HA possesses the characteristics of high compressive strength, is nonresorbable, and it also does not produce resorption at the HA-bony interface. Whereas this method has dramatically improved stability of the expansion while permitting postoperative adjustment, it has the shortcoming that the HA block can, on occasion, migrate through the soft tissue of the roof of the palate and be exfoliated. The latter rarely occurs, and subsequent stability, in our experience, seems to be unaffected. This complication, however, led to the addition of the second method of stabilizing expansion: the use of nasal floor plates, which not only secure the block, but also add additional stabilization. The surgical splint supplements this, and in the past we have added a transpalatal strut to add strength and to prevent warping or splint distortion. Experience has indicated that this strut was very uncomfortable for the patient, and it was noted in one patient that the strut was too close to the palate with resultant swelling of the palatal soft tissues against the strut producing a dehiscence. A thickened palatal aspect to the occlusal wafer is now recommended (Fig 28) to accomplish the goal of a stronger occlusal wafer without the shortcomings of the transpalatal strut.
2. The use of plates on the nasal floor placed across the midline osteotomy site or the sites of parasagittal cuts. This is preferably performed in combination with interpositional HA blocks.

Figure 25. Vigorous use of vertical and crossbite elastics provided moderate improvement. Although the plates probably enhances stability so that the relapse was not 100%, they may have also limited the ability to remodel the osteotomy sites with orthodontic mechanics. Removal of the plates might have improved the result, but may have also contributed to more instability than could be controlled or overcome.

The use of this system is illustrated in the

Figure 26. The use of a high compressive strength hydroxylapatite (HA) block as an interpositional graft is recommended to assist in stabilization of the maxillary expansion.

Figure 27. In addition to the HA block(s), nasal floor plates are also used to secure the interpositional graft and to add even greater stabilization of the expansion.

patient shown in Figure 29. This patient presented with bilateral crossbite and was prepared for what became an 11-mm maxillary expansion, with the osteotomy performed in the midline. The expansion was stabilized with nasal floor

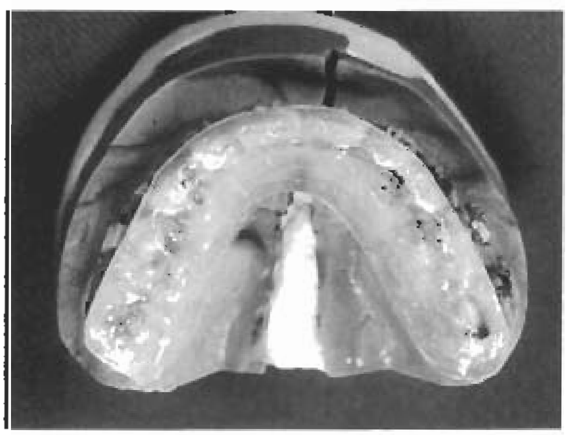

Figure 28. Rather than a transpalatal strut on the occlusal splint, a thickened palatal aspect is now recommended to provide greater strength to the wafer.

Figure 29. This is the frontal dental photograph of an adult patient with a severe bilateral crossbite. Expansion of the maxilla through a two-piece osteotomy was to be stabilized with the use of an HA block and nasal floor plates.

plates and HA blocks, and after 10 years showed excellent stability of the expansion (Fig 30). Whereas few data are available on this stabilization technique, it has become our standard method of osteosyntesis for transverse maxillary expansion.

Maxillary Downgraft Procedures

Inferior repositioning (downgraft) of the maxilla is indicated for the correction of vertical maxillary deficiency (VMD). The downward movement of the maxilla through the Lefort I osteotomy has almost always been considered an unstable procedure, with the downgrafted maxilla migrating superiorly after surgery.

Three approaches to improve vertical stability

Figure 30. The expansion stabilized with nasal floor plates and HA interpositional graft showed excellent stability after 10 years. Although few data are available on this stabilization technique, it has become our standard method of osteosyntesis for transverse maxillary expansion.

have been suggested: (1) placement of heavy fixation bars from the zygomatic arch to the maxillary posterior teeth,[8] (2) interpositional placement of synthetic HA graft to provide mechanical rigidity,[9,10] or (3) use of simultaneous ramus osteotomy to minimize stretching of the elevator muscles and decrease occlusal force until healing is more advanced.[8]

The effectiveness of the use of high compressive strength blocks of HA is well illustrated by the following case. This patient had a severe class II malocclusion characterized by marked mandibular deficiency and severe VMD. The VMD was the source of one of her chief complaints: lack of incisor show at rest and when smiling. Figure 31 illustrates the severity of her VMD because she showed only 2 mm of her maxillary incisor on maximum active smile elevation. Clinically, she showed no incisor at rest, and the incisal edge rested approximately 4 mm above the lip line. Crown length was 10 mm, so the lack of incisor show was entirely caused by her skeletal anomaly.

After orthodontic preparation, our surgical plan was a LeFort I osteotomy with a 6-mm downgraft, an 8-mm mandibular advancement, and an advancement genioplasty with a 6-mm downgraft of the chin.

Stabilization of the osteotomies with RIF was used, and Figure 32 shows placement of the HA block at the time of surgery. The final cephalometric radiograph (Fig 33) clearly shows the placement of both the HA blocks and the fixation plates. Because this form of HA is virtually marble-like in consistency, the time required to cut and form the block to fit the downgraft can be lengthy. For this reason, we use mounted model surgery to create a model of the surgery. On the mounted models on which vertical and horizontal reference lines are placed,[11] we make the surgical cut of the LeFort I osteotomy and, using the measurement lines already present on the model, simulates the downgraft and measure the movement desired. This leaves a gap be-

Figure 31. A patient with such severe vertical maxillary deficiency (VMD) that she was able to show only 2 mm of maxillary incisor on smile. Maxillary downgraft was planned.

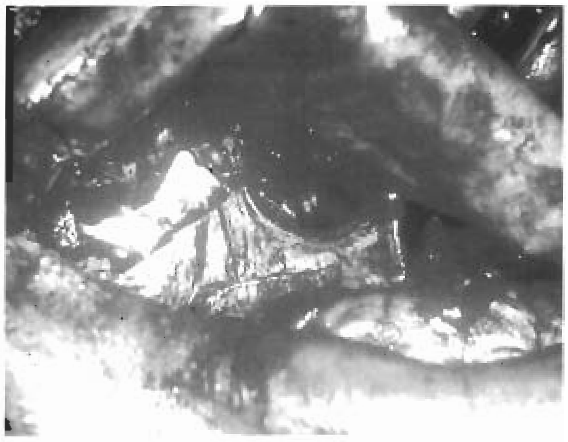

Figure 32. Intraoperative photograph of the placement of the HA block at the time of surgery.

Figure 33. The final cephalometric radiograph clearly shows the placement of both the HA blocks and the fixation plates.

tween the model of the teeth and the upper member of the mounted model, which corresponds to the planned downgraft movement. The HA block can then be shaped to the model simulation before the procedure itself, saving significant time in the operating room that would be needed to shape the interpositional graft.

The dramatic surgical movement in this patient greatly improved the malocclusion (Fig 34) and the vertical position of the maxilla, significantly enhancing the smile esthetics (Fig 35). Cephalometric superimposition of the cephalometric radiographs from the postoperative film to 2-year follow-up show the remarkable stability of this stabilizing design. Long-term stability is indicated in the cephalometric superimpositions (Fig 36).

Postoperative Condylar Resorption

One of the most disappointing occurrences after orthognathic surgery is the long-term resorption of one or both condyles. This causes loss of ramus height, resulting in an open-bite tendency and reduction of mandibular projection.

Possible causes of postoperative condylar resorption. Kerstens[12] hypothesized postoperative condylar resorption (POCR) or atrophy could be secondary to the type of surgery (Class II open bite with bimaxillary surgery), condylar loading, disc displacement, or joint immobilization with IMF.

The literature on these hypotheses is summarized in an effort to take a logical and systematic look at what is probably our most perplexing and challenging complication in orthognathic surgery. Other possible causes, based on other literature and our own experiences, are added.

Method of osteosyntesis as a factor in POCR. In an early study, Bouwman[13] made an effort to

Figure 34. The patient's original Class II deep bite was corrected.

Figure 35. The amount of incisor show at rest and on smile was greatly enhanced.

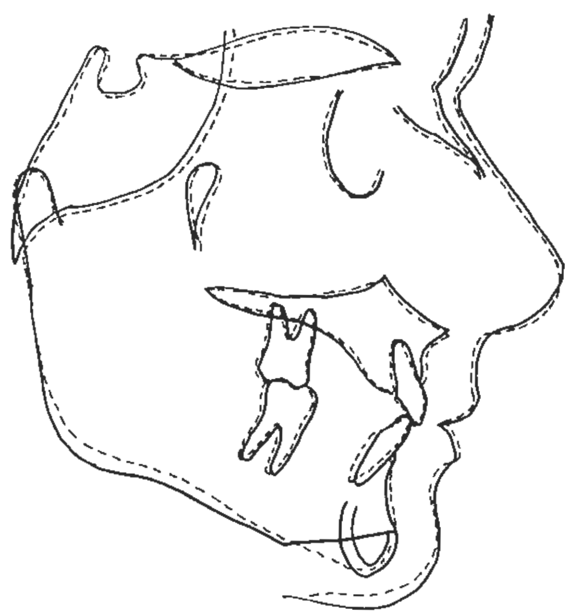

Figure 36. The 9-year cephalometric superimposition indicates excellent stability of the downgraft.

determine the role of the type of fixation in condylar resorption. He investigated whether there was a greater incidence of resorption in IMF compared with RIF cases. More than 1,000 patients who underwent surgery between 1982 and 1992 and were treated with IMF were compared with patients treated between 1988 and 1992 with RIF in the mandible and wire fixation in the maxilla. Condylar changes in volume and shape were found in 3% of the patients, and it was discovered that all of the 3% were high mandibular plane–angle Class II patients. All but 8 of the 32 patients had bimaxillary surgery. Evaluation in more detail of the high-angle Class II group (n = 158 patients) showed 91 patients were immobilized in IMF for 6 weeks, and 24 of these patients (26.4%) experienced POCR. Sixty-seven percent were encouraged to function immediately after surgery and were not placed in IMF for 6 weeks, and 8 patients (11.9%) experienced POCR. From this study, it may be concluded that postoperative condylar changes are more prevalent than most clinicians would have considered, and that the type of fixation is probably a factor in posterior condylar resorption. As a result of the study, the authors recommended returning the patient to function as soon as possible after orthognathic surgery.

Case types more at risk for POCR. The idea that Class II high-angle patients are more at risk for POCR was first evidenced by the aforementioned study by Bouwman.[13] In addition, De Clercq et al[14] studied more than 350 patients, 95 of whom had bimaxillary procedures and 29 of whom were in the high-angle Class II category. Twenty-three of these patients had open bites, whereas six patients had normal or deep overbites. Fourteen patients experienced no condylar changes at all, whereas 6 patients had less than 2 mm of resorption. However, 9 patients had more than 2 mm of condylar resorption, and all were women with open bites preoperatively.

However, conflicting data are found from long-term data from the University of North Carolina (UNC). The long-term data from the UNC database show a reduction in mandibular length occurs between 1 and 5 years postsurgery in approximately 10% of the patients who had surgical mandibular advancement, either alone or in conjunction with superior repositioning of the maxilla.[15,16] Clinical relapse, indicated by a change in dental occlusion, was noted in only half of those with mandibular shortening, ie, this occurs in approximately 5% of the patients. Therefore, even though the previous studies suggested condylar resorption is most likely to occur in long-face patients with two-jaw surgery, the UNC data do not support this. The prevalence was the same in patients with short or normal face height who had only mandibular surgery as in those with a long-face problem that required two-jaw surgery.

Preoperative presence of internal derangement as a risk factor for POCR. It has also been suggested that long-term condylar changes are more likely to occur when internal derangement of the temporomandibular joint (disc displacement) exists, but this also is not clear. The study of De Clercq et al[14] indicates there appears to be no statistical correlation between internal derangement and condylar resorption in orthognathic surgery. Case reports have been published[17] in which patients with a history of bilateral or unilateral temporomandibular joint internal derangement before orthognathic surgery have shown postoperative resorption of the affected joints. The linkage of the two events is attributed to avascular necrosis (AVN) or osteochondritis dessicans of the mandibular condyle. Advocates of AVN suggest that AVN results from microinfarcts of vascular channels in the narrow spaces because of their collapse from excessive load under occlusal function, metabolic disease states, or vascular compromise from diminished blood supply.[18] The mechanism of AVN is well understood in such other joints as the hip, but the relationship between AVN and the condyle has not been clearly established. It is postulated that osteochondritis dessicans may result in chronic inflammation of the synovial and disc tissues, causing the spread of inflammation and resulting in degenerative changes in the cartilage covering of the condyle. In advanced cases, these changes are believed to progress to necrosis of the bony articular surfaces.

The relationship of internal derangement to condylar resorption is attributed to the inability of a notably displaced disc to effectively distribute synovial fluid over the condylar surface. The articular surfaces of the synovial joints receive their nourishment from the meniscus, and the displacement of the disc may result in necrosis of the fibrocartilage covering a cortical layer of the condyle. This may result in necrosis and resorption of the condylar head, with subsequent relapse of the surgical procedure.

Link and Nickerson[19] have shown a high incidence of preoperative internal derangement in orthognathic surgical patients. In a study of 39 Class II patients, 32 patients had arthrographic confirmation of bilateral internal derangement and 38 patients had at least unilateral internal derangement. Five patients had significant arthrosis that led to significant mandibular relapse. The case population was mixed as follows: Class II open bite, 8 patients; Class II without open bite, 22 patients; Class I open bite, 3 patients; and mandibular asymmetry, 6 patients.

The investigators concluded that postoperative internal derangement should not automatically be assumed to be caused by orthognathic surgery, but that postoperative symptoms should be considered a risk factor of the new loading of joints after skeletal reconstruction. The relationship between internal derangement and postcondylar resorption, therefore, has not been thoroughly investigated, and much remains to be learned about these relationships.

Treatment strategies when POCR is encountered. In cases in which POCR has occurred, it is recommended no immediate action be taken. It is prudent to stop and consider that the resorption may not be idiopathic, but may be from a number of causes, some local and some systemic. It is recommended that rheumatoid and lupus factor screening be performed to rule out the possibility of systemic disease, and that in many cases, treatment be discontinued to not further load the joints. Although there is no clear evidence that loading of the joints either produces resorption or exacerbates the resorption, splint therapy is often recommended for that purpose. It is the authors' recommendations that the cessation of treatment follow a POCR event for the following reasons: (1) to place as little mechanical force on the joints as possible, and (2) to permit serial cephalometric tracking of further skeletal changes. If treatment is still under way, superimposition of serial cephalograms will not serve as a valid indicator to when the process has ceased.

Other tests for cellular bone activity may be performed, such as a technetium radioisotope bone scan. Once it has been determined that the resorption has stopped, retreatment may be considered.

Kerstens et al[12] postulate "an imbalance between stress applied to the joints and the joint's ability to tolerate that stress could give rise to osteoarthrosis. This imbalance may occur because of autorotation of the condyle after superior repositioning of the maxilla in combination with the change in condylar position after sagittal splitting of the ramus. However, LeFort I osteotomies without sagittal splitting show no osteoarthrotic changes of the condyles in our material." Merkx and Van Damme[20] suggest "the sagittal split osteotomy for correction of relapse caused by condylar resorption seems contraindicated. Whenever reoperation is necessary, the LeFort I or a mandibular segmental osteotomy is the procedure of choice." Therefore, we would conclude that if reoperation were to be performed, this literature would direct us to trying to limit the procedure to a maxillary osteotomy if at all possible.

Conclusion

Complications in orthognathic surgery occur, and although some of these complications can be avoided, some can not. The objective in this report is to provide the reader with the information that should help minimize the number of problems encountered by appropriate pre- and postoperative orthodontic treatment and maximum communication between members of the treatment team. The natural conflict of the surgeon's resistance to "the orthodontist telling me how to do surgery" and the orthodontist's complaint that "they didn't put it where I wanted it!" is well recognized. It is considered that the orthodontist must find his/her comfort level in how much responsibility he/she wishes to assume, but also should appreciate that it is not in the patient's best interest for the orthodontist to permit all decision making (and thus the burden of responsibility) on the surgeon. Various complications in combined orthodontic and orthognathic procedures relate to the orthodontist at primarily two points in the overall treatment of the patient, namely the preoperative phase and postoperative phase. The focus of this report is on the orthodontist's role in preventing and managing complications encountered in orthognathic surgery. We hope to have provided our experience with complications, illustrated by cases in which real problems were encountered.

and how we dealt with them. Although most of us do not embrace the idea of showing our problems or difficulties, in 20 years of treating surgical-orthodontic patients, the complications encountered were excellent learning opportunities.

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