STABILITY OF MANDIBULAR ADVANCEMENT SURGERY, BY SAGITTAL SPLIT OSTEOTOMY WITH RIGID AND WIRE FIXATION

A LITERATURE REVIEW

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RESUMO: Este artigo tem por objectlvo rever os estudos cientificos que analisam a estabilidade das osteotomias sagitais para avanço mandibular no tratamento das maloclusões da classe II. São discutidos os factores etiológicos da recidiva dando ênfase ao tipo de fixaçã.o utilizado.

ABSTRACT: The purpose of this review is to evaluate the scientific studies that describe the stability of mandibular advancement surgery by sagittal split osteotomy in the treatment of Class II malocclusions. The factors involved in the etiology of relapse are discussed with enphasis on the fixation type (wire versus rigid fixation).

Palavras-chave: Classe II Esquelética, Ortodontia-Cirúrgica, Osteotomias Sagitais, Recidiva

Key-words: Skeletal Class II, Relapse, Sagittal Split Osteotom, Surgical-Orthodontics

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I - HISTORICAL BACKGROUND

The surgical treatment of the underdeveloped mandible was initially directed at lengthening the body. Early in the century, step sliding osteotomies of the mandibular body were proposed by Von Eiselsberg (1). Later, oblique and L-shaped body osteotomies were described by Limberg (2) and Kazanjian (3). Complications associated with maintenance of contact between the segments (non-unions), soft tissue coverage, and unfavorable muscle pull were common. Because of these problems, operations in the ramus became increasingly popular.

Blair published the first report of ascending ramus surgery for correction of mandibular retrognathia (4). Two cases were presented, in which a horizontal ramus osteotomy was performed by a Gigli saw, above the level of the mandibular foramen. However, a survey of the results showed a high incidence of open bite, relapse, and non-union because of unfavorable muscle pull and minimal bony contact (5).

Limberg (2) suggested a vertical osteotomy of the ramus with the use of costal bone grafts. This method remained largely unused for many years and was later reintroduced by Robinson (6) Robinson and Lytle (7), and Caldwell and Amaral (8), both with and without

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the use of bone grafts. A modification of the original inverted L-osteotomy or C sliding osteotomy was described by Caldwell et al. (9); with this technique many of the previous problems, such as the need for a bone graft, inadequate fixation, loss of gonial angle, and unfavorable muscle pull, have been overcome.

The modern surgical management of retrognathia, however, probably began with the introduction of the sagittal split ramus osteotomy of the mandible, popularized by Obwegeser (10,11) over 30 years ago. The technique was later modified by Dal Pont (12) to provide for broader contact surfaces and to reduce muscular displacement. Additional modifications by Hunsuck (13), Gallo (14), and Epker (15) greatly simplified the procedure, while providing sounder biologic principles by minimizing mucoperiosteum and pterygomasseteric sling detachment. Animal experiments have supported the rationale for such modifications (16,17), showing that complete stripping of the pterygomasseteric sling results in persistent vascular ischemia, leading to osteonecrosis and delayed healing. These studies support the use of a clinical technique of sagittal splitting the mandibular ramus, which maximizes attachment of the pterygomasseteric sling and mucoperiosteum.

A number of methods of skeletal fixation have been developed, in addition to maxillomandibular dental fixation to maximize the stability of mandibular advancement. Different wiring techniques have been proposed to secure the proximal and distal segments, while seating the condyles into the glenoid fossae; these have included circumferential wiring (10), superior border wiring (15), inferior border wiring (18), and circummandibular wires attached to pyriform aperture wires (19). More recently Spiessl (20,21), among others (22,23,24) have recommended rigid internal fixation with bicortical screws to promote more rapid healing and to decrease relapse potential.

Both lag screw and position screw techniques are cunently used for stabilizing sagittal split osteotomies. In lag screw osteosynthesis, a gliding hole in one segment and a threaded hole in the other promote compression of the two fragments. In position screw osteosynthesis the holes in both cortices are threaded, which allows the fragments to be kept a fixed distance apart (25). Among the advantages of lag screw fixation are increased frictional resistance and primary bone healing as a result of compression of the bony interface (26). Potential disadvantages are compression of the inferior alveolar nerve and torquing displacement of the condyles (27), as the result of the fulcrum effect around the most posterior portion of the distal segment, as the mandible is advanced. Position screws may not cause compression of the inferior alveolar nerve and may minimize displacement of the condylar segment as the screw is tightened at the osteotomy site. However, since no compression is generated from a position screw, no frictional resistance will be created at the osteotomy site, and primary bone healing is unlikely (28).

II –COMPLICATIONS OF MANDIBULAR ADVANCEMENT SURGERY

Various authors (29,30) have conducted surveys on the results and complications of the sagittal split ramus osteotomy, and found that the most common complications were regressions and relapse. Later studies by Wang (31), and Martis (32) also found relapse to be a very common finding. Other complications included intraoperative bleeding, edema, trauma to the inferior alveolar and facial nerves, fracture of bony segments, infection, delayed bony union, and problems associated with poor postoperative vascular supply.

III – ETIOLOGY OF RELAPSE

The etiology of postoperative skeletal and dental changes following sagittal split osteotomies for mandibular advancement is very complex. Epker (19) and Bell (33), among others, agree that the problem is multifactorial in nature. The relapse factors most commonly cited in the literature include tension of the connective tissue, the magnitude of the surgical

advancement, counterclockwise rotational movements of the distal segment, improper condylar positioning during surgery and the method of intermaxillary fixation.

A. CONNECTIVE TISSUE TENSION

The suprahyoid musculature has been implicated as one of the major factors responsible for relapse following mandibular advancement surgery (34,35). Suprahyoid myotomies have been advocated by some surgeons as a means of alleviating the potential for distracting forces acting in the advanced mandible (36). However, it has been shown that it is possible for the muscle and connective tissue within the suprahyoid cornplex to adapt to the increased length brought about by mandibular advancement (37).

The elasticity and adaptability of the paramandibular connective tissues have been studied in animal models. McNamara (38) reported that skeletal muscle is the most elastic and adaptive tissue, whereas tendons and periosteum are the least elastic and adaptable. Neuromuscular adaptations were shown to occur quite rapidly, while other connective tissues required several months to adapt. Goldspink (39) reported that the skeletal muscles will adapt to a physiological stretching of up to 40% of their resting length after four weeks of stable skeletal immobilization. Therefore, the suprahyoid muscles exert their relapsing force during maxillomandibular fixation but should be completely adapted after six to eight weeks of immobilization. In contrast the inelastic periosteum and connective tissues exert a constant and prolonged relapsing force upon the distal segment.

Carlson (40) found no stretching within the muscle belly itself, after mandibular advancements of approximately 4 mm in adult rhesus monkeys. Changes were found primarily at the muscle-tendon and muscle-bone interface. With larger advancements, the muscle fibers themselves became stretched, resulting in an elongation of the sarcomeres and decrease in the overlap of the actin and myosin filaments (41).

Schendell and Epker (35) compared 28 patients who had mandibular advancement concomitant with suprahyoid myotomies with a group of patients matched on the basis of amount of mandibular advancement and preoperative mandibular plane angle. They reported no differences on the percentage of relapse and all other parameters between the two groups.

Wessberg (42) analyzed the cephalograms from 16 patients who underwent surgical advancement of the mandible via the modified sagittal split technique. The patients were classified into control and myotomy groups. The control group contained eight patients who were managed only by six weeks of intermaxillary fixation. The myotomy group contained eight patients with similar skeletal deformities who underwent a comparable surgical advancement supplemented by surgical detachment of the geniohyoid and digastric muscles. Similar percentages of postoperative relapse were noted in the two groups, indicating that myotomy does not ensure postoperative stability.

B. PREOPERATIVE MANDIBULAR PLANE ANGLE

Mandibular advancement surgery is generally considered to incur a higher relapse risk in patients with divergent facial patterns and high mandibular plane angles, because of the distal fragment rotation necessary to reduce the dental open bite that is characteristically present (43,44,45).

Ive (46), and Kohn (47) found no predictable relationship between preoperative plane angle and relapse. Their results were in conflict with a previous study (48) in which significantly less relapse was found in patients with a low mandibular plane angle than in those with a high mandibular plane angle.

Similar results were found by Schendel (49) in a later study, in which significantly higher mandibular plane angles were found in a subgroup of patients with greater than 50% relapse.

Lake (50) also reported significantly greater skeletal relapse in high-angle cases (-3.2 mm) than in

normal (-1.4 mm) and low-angle cases (0.3 mm). Conclusions must be applied with caution, however, since the high-angle subgroup also exhibited the largest mean magnitude of advancement (7.6 mm) as compared with the normal (5.7 mm) and low-angle (4.7 mm) subgroups.

C. MAGNITUDE OF THE ADVANCEMENT

Poulton (51), Ive (46), Schendell (35), and Epker (52) all agree that as the magnitude of the mandibular advancement increases, the net amount of relapse also increases. Iake and associates (60) reported a moderate association between the magnitude of absolute (mm.) horizontal advancement at Pogonion and the amount of postsurgical relapse ($r=0.6$, $p<0.001$).

Van Sickels (53) reported on 51 patients who underwent mandibular advancements and rigid fixation with three bicortical screws per side. Although most cases were very stable, relapse was noted in several cases. The magnitude of advancement was the only factor that could be used to predict relapse, accounting for 37.9% of the variance in the sample.

D. CONDYLAR POSITION

Distraction of the condylar head from the temporal fossae at the time of surgery has long been known to result in immediate relapse upon the release of intermaxillary fixation (54). Osteolysis of the mandibular condyles years after mandibular advancement surgery has also been reported as a significant factor responsible for long-term tendencies to relapse in certain patients (55,56).

Freihofer (57) followed 38 patients for at least 2 years after surgical correction of retrognathia. They observed changes in the position of the condyles in the glenoid fossae, and poor repositioning of the condyles into the fossae at the time of surgery was thought to be a significant cause of relapse.

In a study using laminographic radiographs Isaacson (58) reported that the condyles were displaced inferiorly an average of 2.2 mm and anteriorly an average of 1.2 mm. There was a mean superior and posterior return equal to the mean surgical displacement, resulting in relapse and anterior open bite.

Kohn (47) also found inferior movement of the proximal segment with displacement of the condyle, occurring at the time of surgery or in the immediate postoperative period. This movement was closely associated with subsequent skeletal relapse of the distal segment.

In a cephalometric study of 52 patients Iake (50) reported condylar displacement at the time of surgery or immediately after surgery in 61.5 % of the patients. Positional change of the proximal segment was the single most important parameter in determining stability or relapse of the advanced mandible.

In another study (35), control of the proximal segment was the most important surgical aspect in determining relapse. In 45 % of the cases with unacceptable results, relapse was related to condylar distraction during surgery or a surgically created increase in posterior face height or both. They recommended a high-low wire fixation technique to reposition the proximal segment up into the glenoid fossa, as described by Epker (19).

A cephalometric and tomographic survey of 44 patients after bilateral sagittal osteotomy to advance the mandible has been reported by Will and associates (59). Contrary to what was expected from previous literature, no significant posterior and superior condylar movement was observed during the surgical interval, averaging less than 0.5 mm. Despite that, the net postoperative relapse of the distal fragment was 2.49 mm, or approximately 37% of the advancement. They concluded that factors other than condylar distraction, were implicated in the relapse process.

E. TYPE OF FIXATION

Wire Fixation and Relapse

In the past, stabilization of osseous segments after

sectioning procedures for correction of mandibular retrognathism was frequently achieved by intermaxillary dental fixation. This practice was based on the rationale that dental structures could provide a stable base for immobilization of mandibular skeletal structures.

Poulton and Ware (34) were the first to show that skeletal changes occur during maxillomandibular fixation. In a report of two *cases* of severe mandibular retrusion, the clinical evaluation of occlusal relationships was not found to be a reliable criterion by which to evaluate skeletal stability.

Various case reports (60,61) confirmed that major skeletal relapse can occur during the period of intermaxillary fixation, accompanied by compensatory tooth movement, in particular maxillary and mandibular incisor inclination changes. The suprahyoid group of muscles was mentioned as the possible cause of relapse.

Poulton and Ware (43) reported skeletal relapses of 50 to 80 per cent following surgical sagittal-split mandibular advancement retained solely by intermaxillary dental fixation. The amount of relapse was reduced to 10 to 30 per cent by the use of a neck brace in the postoperative period.

Schendell and Epker (35) analyzed 87 cases of mandibular advancement, at least 12 months after surgery. Maxillomandibular fixation was used in every patient but skeletal fixation was only used in five patients. Thirty patients relapsed more than 50% and were classified as having unacceptable results.

Ive (46) examined the skeletal and dental changes during fixation in 21 patients. Interosseous and dental maxillomandibular fixation was supplemented by means of a soft cervical collar. The amount of relapse was unpredictable, from 11 % to 71 % with the average being 30%.

Lake and associates (50) evaluated fifty-two patients who underwent surgical advancement of the mandible by sagittal split osteotomy of the mandibular rami. The two segments were held in position with interosseous wires in addition to dental intermaxillary fixation; a soft cervical collar was used postoperatively as an aid in controlling relapse. The mean horizontal relapse represented a 26.2% loss of the surgical advancement and occurred during the intermaxillary fixation period; relative stability was found after the release of fixation. However, the duration, extent, and direction of skeletal change were unpredictable, with wide individual variation in treatment response.

Sandor (62) evaluated two groups of 20 patients after sagittal split osteotomy for mandibular advancement. One group of patients was treated without internal fixation and the second group, with superior border intraosseous osteosynthesis wiring. The mean total postsurgical relapse was 77% in the nonosteosynthesis group, and 23 % in the osteosynthesis group. They concluded that intraosseous wiring between the proximal and distal segments of the mandible is necessary to maintain the advancement.

Mayo (63) examined the stability of the mandible in twenty-four adult female Macaca Mulatta that underwent bilateral sagittal ramus osteotomy and advancement of approximately 6 mm. All animals had dental maxillomandibular fixation, and in half of the animals circummandibular wires connected to pyriform aperture wires were additionally applied. Significantly less horizontal relapse occurred in the group with skeletal wires, suggesting that the use of skeletal suspension wires is advantageous in the prevention of horizontal relapse.

Rigid Fixation and Relapse

The method of internal fixation of fractures by means of metal plates and screws is not new. Kdnig (64), Lambotte (65) and Sherman (66) reported on the use of metal plates in the treatment of fractures early in this century. Schenk and Willenegger (67) described for the first time the so-called contact healing, observed in bone healing under stable osteosynthesis. The healing process of fractures after stable internal fixation has been shown to be different from the healing process during treatment by conservative methods in which there is callus formation, since the fracture is never mechanically neutralized. Under stable fixation, the fracture healing is by primary

intention, but fracture healing by way of callus formation is by secondary intention.

Potential advantages of this technique include reduction or elimination of the need for dental intermaxillary fixation, increased patient comfort, better control of the proximal segment at the time of surgery, more rapid bony healing, and improved stability with reduction of postoperative relapse. Early reports on postsurgical relapse after mandibular advancements using rigid fixation have yielded promising results. Some of these studies reported that the mandible actually moved farther anteriorly during the postsurgical follow-up period. However, the main disadvantage with the use of rigid fixation is that the technique is very exacting and leaves no room for error in planning, surgical execution, or post-surgical occlusion (28,68). Post-surgical orthodontic treatment becomes more difficult if the segments are not properly positioned because rigid fixation prevents any orthopedic movement during the healing phase following surgery (69).

In a preliminary review of nine cases followed for six months after surgery, Van Sickels (68) reported a mean anterior postsurgical movement of 1.16 mm (18%), accompanied by a decrease in the anterior vertical dimension of 1.84 mm (35%).

Kirkpatrick (70) analyzed twenty non-growing patients who received surgical mandibular advancements with rigid fixation. There was a mean surgical advancement of 5.71 mm and a mean increase in the lower facial height of 1.88 mm, with a mean downward and backward rotation of 2.01°. After six months there was a mean horizontal postsurgical relapse of 0.42 mm and a mean increase in the lower face height of 0.21 mm. Both were statistically insignificant. Although the mean postsurgical change in the mandibular plane angle (+0.55 mm) was found to be statistically significant, it was considered to be clinically insignificant. They concluded that surgical mandibular advancement with rigid fixation was a very reliable and stable procedure.

Van Sickels (53) reported the results of fiftyone patients who underwent mandibular advancements and rigid fixation with three bicortical screws per side. The average magnitude of the surgical advancement was 4.6 mm. Postoperatively, there was a mean additional advancement of 0.4 mm, which was not statistically significant. However, relapse was noted in several cases. The only factor that could be used as a predictor of relapse was the magnitude of the advancement, accounting for 37.9% of the variance in the sample.

Caskey (71) examined the cephalometric records of twenty patients who underwent mandibular lengthening stabilized with rigid internal fixation. The mean horizontal advancement at pogonion was 4.8 mm. All operations were performed by the same surgeon. No genioplasties were included but nine patients had received midline splits of the mandible. Postoperative horizontal changes, measured at Pogonion were not found to be statistically different from zero. No significant correlations could be detected between horizontal relapse and amount of advancement, preoperative mandibular plane angle, or changes in gonial arc radius.

Gassmann (72) evaluated fifty mandibular advancement cases involving a bilateral sagittal split osteotomy with rigid fixation. Thirteen patients (26%) showed relapse of 25 % or more and served as the relapse group. Twelve patients showed no relapse and served as the comparison group. The majority of relapse (68%) was found to occur in the first six weeks after surgery. Multiple regression analysis for the relapse group showed that magnitude of the advancement, increasing gonial arc, and changing mandibular plane significantly accounted for 84.9% of the variance observed in relapse.

In another retrospective study, Kierl (73) examined the lateral cephalometric radiographs of nineteen individuals, 3 years postsurgically. The mean amount of sagittal surgical advancement was 6.7 mm, and the mean amount of postsurgical relapse was 1.3 mm, representing a 14% relapse of the original surgical advancement. Fourteen cases relapsed in the posterior direction, with 2 relapsing more than 50% of the surgical advancement. The amount of surgical advancement was the only variable that showed a significant relationship with postsurgical relapse. Their study did

not support the earlier impression that the rigid fixation technique provides consistently stable postsurgical results.

Watzke (74) evaluated and compared the effects of lag screw (Group L) and position screw (Group P) fixation on postsurgical stability following bilateral sagittal split osteotomies for mandibular advancement, at least one year after surgery. The mean horizontal and vertical changes at point B were 5.4 mm and 3.7 mm, respectively, for group P and 5.3 mm and 4.0 mm, respectively, for group L. No statistically significant differences were found between the two groups, regarding the postsurgical movement of Point B or the mandibular incisor. However, the inclusion of 66.7% of patients with genioplasties in Group P, and only 15.4 % ín group L, complicates interpretation of their data.

Wire Fixation V s. Rigid Fixation

Few studies have compared the stability of mandibular advancement after sagittal osteotomy with rigid internal fixation and conventional wire osteosynthesis.

Thomas (69) examined lateral cephalometric radiographs of thirty-four patients for differences in early skeletal and dental changes; fourteen patients received rigid internal screw fixation and twenty conventional wiring. They found that the wire group exhibited greater anterior dental compensation, posterior-inferior relapse at the symphysis, loss of posterior facial height and increased mandibular steepness. Skeletal changes were significantly greater than those seen in the rigid group, and the dental changes approached the level of statistical significance. They concluded that rigid fixation improved stability over that possible with wire osteosynthesis. However, long-term data has not been reported.

Ellis III (75) examined the short term stability of the mandible following sagittal split osteotomy in 22 adult rhesus monkeys that underwent advancements of 4 to 6 mm. Six animals had dental maxillomandibular fixation alone. Six animals had dental plus skeletal maxillomandibular fixation with circummandibular wires connected to pyriform aperture wires. Ten animals had rigid internal fixation with bicortical bone screws without maxillomandibular fixation. The results showed that rigid internal fixation and the use of dental plus skeletal maxillomandibular fixation were both equally effective in preventing postsurgical relapse. However, in the animals in which only dental maxillomandibular fixation was used, a mean horizontal relapse of 1.8 mm (28%) was found; there was also a mean increase of 6^0 in the mandibular plane angle and a mean increase of 11^0 in the ramus-corpus angle.

Different results were reported by Moenning (76) in a retrospective study of twenty-eight patients treated by sagittal split osteotomies for mandibular advancement, a minimum of six months postsurgically. The patients were divided into two equivalent groups of twelve patients, one of which had been treated with rigid fixation and the other with inferior border wiring and anterior skeletal fixation, by means of circummandibular and pyriform aperture wires. The mean horizontal relapse at point B was 1.5 % for the rigid group and 26.8 % for the wire osteosynthesis group. This difference was found to be statistically significant. However, underestimation of relapse may have occurred, since the time at which the preoperative cephalograms were taken varied from 3 days after the surgery to as late as 41 days after the surgery.

Stability and clinical results in a large sample of patients who underwent bilateral sagittal ramus osteotomy for mandibular advancement were recently reported by Watzke (77). The patients were grouped by the method of fixation (screws vs. wire) and matched for the amount of advancement. There were thirty-five patients in each group and the age, sex, and presurgical mandibular plane angle distributions were similar for both groups. In the first 6 weeks postsurgery, the screw fixation group was found to be more stable horizontally and vertically than the wire group, but between 6 weeks and 1 year, the wire group showed recovery. No significant differences in stability, incisal opening, and clinical results were found between the groups, 1 year following surgery.

IV - SOFT TISSUE CHANGES

Surgical procedures to correct skeletal deformities result in changes in shape and position of the overlying soft tissues. Evaluating and predicting these changes provides the clinician, as well as the patient, with some idea of the esthetic changes that can be expected following treatment.

Lines (78) studied the soft tissue changes in nine cases following mandibular advancement surgery; postoperative radiographs were taken at least three months after surgery. The soft tissue pogonion was found to follow the hard tissue pogonion in a nearly 1:1 ratio; the mean lower lip change was 62% of the lower incisor acvancement.

Quast et al. (79) analyzed serial cephalograms of eighteen patients after mandibular advancement surgery. It was found that soft tissue pogonion and inferior labial sulcus followed hard-tissue pogonion and point B in almost a l:l ratio. The short-term soft tissue mean changes (3.7 months postsurgery) were greater than the long-term mean changes (18 months postsurgery). They stressed the need for long-term prediction data to supplement the short-term data base.

Hernandez-Orsini (80) described the short term (2.7 months postsurgery) and long-term (14 months postsurgery) soft tissue profile changes in thirty-one patients after mandibular advancements using rigid fixation. The soft tissue landmarks overlying skeletal structures were found to follow their hard tissue counterpart in a l:l ratio in the horizontal direction. The average ratio between lower lip and mandibular incisor change was 0.43:1.00. Short-term soft tissue changes were found to be stable when compared to long-term changes.

V - CONCLUSIONS

Traditional orthodontic treatment of adult patients with severe Class II malocclusions, as a result of mandibular deficiency, has involved extraction of maxillary premolars and retraction of maxillary incisors. Results were often unacceptable leaving some patients with inadequate function and a compromise of profile as well as frontal facial esthetics.

Various surgical procedures have been developed to achieve these goals. Due to its versatility and relative ease of use, the sagittal split ramus osteotomy of the mandible has become the most widely used technique. The skeletal and dental stability associated with the procedure has been the object of numerous studies, and the discouraging effects of various types of relapse are well known.

The introduction of more predictable and biologically sound surgical procedures to advance the mandible has created new and exciting possibilities of achieving optimal occlusion and facial esthetics. The topic of this study, stability of the mandible after advancement, has undergone a resurgence of interest in the past several years, owing to the emerging use of rigid fixation.

New surgical techniques should reduce morbidity and also improve results when compared with those they are designed to replace or modify. A critical reevaluation is therefore required of each innovative surgical technique, rather than a reliance on the subjective observation that the modification itself improved the success of the operation.

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