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Factors Affecting the Stability of Bilateral Sagittal Split Osteotomy of a Mandible

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Abstract: Stability of bilateral sagittal split osteotomy (BSSO) is an important goal for every surgeon. In the article factors influencing stability of the surgery result are reviewed. Special emphasis is given to different types of fixation of bone fragments. Their advantages and disadvantages in clinical use are discussed. Relapse after BSSO is usually classified as early and long-term relapse. Early relapse is usually caused by movements at the osteotomy site or temporomandibular joint sag and should be called surgical displacement. Long term relapse happens due to the progressive temporomandibular joint condylar resorption, which causes a lost of condylar and mandibular ramus height. Four different types of fixation were described in orthognatic surgery: rigid intermaxillary fixation, osteosuture, osteosynthesis and fixation with biodegradable materials.

Introduction

Bilateral sagittal split osteotomy of mandible (BSSO) is a surgical method used to correct the sagittal, transversal and vertical position of the lower jaw. Since 1957, when it was introduced by Trauner and Obwegeser [1, 2, 3], it has undergone a number of modifications in surgical technique as well as fixation of the segments. The goal of the operation is the improvement of occlusion and face aesthetic. The multidisciplinary cooperation especially with orthodontics, which consists of preoperative preparation, so-called decompensation and postoperative finishing of treatment, is the must.

As the static and dynamic position of the mandible and the forces transmitted to it, directly by the tension of muscles and indirectly during mastication, are changed significantly, stability of the new jaw position is the main condition for success. Relapse, as the opposite of the stable result, is in certain cases predictable and affectable; in other cases it is highly unexpected. It concerns mostly the long term relapse [4, 5, 6]. Loss of occlusion, changes in the teeth's position within the dental arch and consequently functional and aesthetic disorders result from the large relapse.

In the article, all factors influencing stability of the operation's result are mentioned. Special emphasis is given to different types of fixation of bone fragments, their advantages and disadvantages in clinical use.

Factors increasing the risk of relapse

The stability of BSSO is influenced by the way of fixation of bony fragments, the type of skeletal abnormality, quality of orthodontic preparation, magnitude and direction of movement of bony fragments, change of occlusal plane, soft tissue tension, preoperative impairment of temporomandibular joint, postoperative orthodontic retention, achievement of perfect postoperative occlusion and age of patient in the time of operation. Small posterior-to-anterior facial height ratio, high mandibular plane angle with mandibular hypoplasia, mandibular advancements with counter-clockwise rotation, bigger mandibular advancements and also the

pre-existing temporomandibular join disorders are considered to be unfavourable factors. Relapse consists of skeletal and dental factors and is considered to be clinically relevant if it exceeds 2 mm, otherwise it can be corrected orthodontically [5, 6, 7, 8, 9, 10, 11].

Dental relapse is caused by disharmony in pressure of soft tissue (tongue, lips and muscles) on one side and elastic gingival fibres on the other. Because of that, teeth tend to move back into pre-treatment position [12].

Relapse after BSSO is usually classified as the early and long-term relapse [7, 13].

Early relapse is mostly caused by movements at the osteotomy site (osteotomy slippage) or temporomandibular joint sag and is usually called surgical displacement. Two different types of force vectors interact with healing bone fragments. On one side, the stretched paramandibular connective tissue (skin, sub cutis, muscles and periosteum) tends to deviate the tooth-bearing fragment into its original position; on the other side, osteosynthesis hardware, in some cases skeletal suspension and the condyle if seated into the fossa tends to stabilize the fragments. Disharmony of these forces occurs in case of inappropriate fixation and/or wrong peroperative condylar position. Consequently an early relapse in the first 6–8 postoperative weeks can develop [14].

Progressive condylar resorption, which changes the shape of the condyle with a lost of condylar height is the main cause of the long-term relapse. According to X-ray studies [4, 5, 6, 7, 11, 13, 15] it occurs 6–17 month after the surgery. There is no clear explanation of the phenomenon. Risk factors on the patient's side are age, general diseases, particularly autoimmune ones, and hormones, as well as the inability of chewing muscles to adapt to new position of the jaw in some patients [16, 17]. Among the mechanical factors increasing the risk of relapse it is the peroperative change of condylar position, its compression against the fossa, mediolateral torquing or posterior displacement of the condyle with rigid fixation, blood supply disturbance during surgery, disc dislocation [4, 18, 19] increased intraarticular pressure during loading [8] and unstable occlusion [14, 20, 21]. Borstlap observed factors, which may influence condylar remodelation and resorption on orthopantomographs [4]. Condylar resorption, related in all cases with the relapse was found in 4% of patients. Remodelation, explained as an effort of the temporomandibular joint (TMJ) to adapt by resorption and apposition to the new position without shortening the ramus length, was found in 10% of cases. The higher percentage of women in the group with condyle changes was explained by their different fibrous and cartilage metabolism, different blood supply and also by missing estrogen receptors in TMJ complex in men. The blood level of estrogen and prolactin can effect remodelation. Borstlap documented risk factors of resorption or remodelation to be: young age (under 14 years), steep mandibular plane angle, low facial height ratio (posterior: anterior). Based on study of preoperative and postoperative orthopantomographs, Hwang [6] agreed with him and added another risk factor, namely a posterior inclination of the condyle.

Borstlap mentioned, that "the occurrence of pain and TMJ sounds in the first few months postoperatively are highly suspicious for condylar changes to occur in the next months". On the other hand, he indicates that preoperative problems with TMJ do not increase the risk of postoperative changes [4].

Panula [22, 23] followed a group of patients with TMJ dysfunction treated by orthognatic surgery (operations were either monomaxillar or bimaxillar always with rigid intermaxillary fixation) and compared them with the group without treatment. The majority of patients confirmed regressing disorders 29 months after the operation, on average. Only in 6.7% of patients new symptoms arose, which conformed to the normal situation in the population. There was no new change on TMJ in operated patients, which proved a low risk of new TMJ disorders in patients treated by orthognatic surgery. Patients older then 30 years profited more from the treatment.

Another factor influencing the success of treatment of TMJ disorders was described by Ueki [24]. He compared the group of patients with mandibular setback fixated by one straight miniplate, with the group of patients with the same movement fixated by one miniplate bent in such a way that it respected the original angle of the condylar long axis. The group with a straight miniplate showed the condylar displacement during operation. The group with a bent miniplate showed statistically significant higher decrease of problems, compared to the second group, one year after the operation. It was concluded, that the mediolateral extrusion of proximal segment during operation is an important factor affecting the result of the treatment.

Patients with mandibular advancement and counter-clockwise rotation (CCW) form a specific group. Anterior and cranial movement of the teeth-bearing fragment causes higher tension of paramandibular soft tissues, which causes the tendency to move the segment into preoperative position, according to Arnett. In case of inappropriate fixation early relapse occurs [14].

Also, the risk of long term relapse is higher in these cases. Hwang [5] assume lower density of the trabecular bone on the anteriosuperior surface of the condyle, due to prolonged lower loading. After CCW rotation this part of the condyle is loaded with higher intensity, which may lead to violation of adaptability of the condyle and consequently into aseptic inflammation and resorption of the condyle.

Wolford [11] presented a group, which underwent bimaxillary operation with mandibular advancement of 9 mm, on average, CCW rotation for skeletal class II and anterior open bite. He records preoperative dislocation of TMJ disk with magnetic resonance, which was worsened by the operation and therefore recommends the surgical therapy of TMJ together with orthognatic surgery.

Despite of different results all studies document, that long term relapse occurs. It is important to take this into account, especially in patients with the above mentioned risk factors.

Methods of fixation

Four different types of fixation were described in orthognatic surgery:
1. Rigid intermaxillary fixation
2. Osteosuture
3. Osteosynthesis (metal miniplate with monocortical screws or bicortical screws)
4. Fixation with biodegradable materials (semirigid fixation)

Rigid intermaxillary fixation

Rigid intermaxillary fixation (RIF) is nowadays used only together with osteosuture. In the historical literature, when it was used as the only method of fixation, a relapse of 90% was mentioned [19, 25]. As bone fragments were not fixed at all, they were liable to soft tissue tension, sequent to the new position of the mandible. On the other hand, rigid intermaxillary fixation worked on teeth as orthodontic braces and caused extrusion. After the rigid intermaxillary fixation is removed, the teeth return into their original position and dental relapse joined on the skeletal [19, 25].

Nitzan proved the importance of movements in TMJ for the exchange of synovial fluid and therefore for nutrition of the joint cartilage [8]. Rigid intermaxillary fixation restricted these movements significantly and contributed so to late relapse.

RIF had an important negative psychological impact on the patient and lowered the quality of life [26, 27, 28]. Williams [29] and Kohno [30] proved that it notably increased the resistance in the upper airway (FEV1 decreased of 22.9% and PEF – max peak expiratory flow of 52.1%). It was especially relevant in patients with chronic pulmonary obstructive disease, asthma or bronchial hyper secretion. When RIF was complicated by a simple upper airway catarrh, it could lead also into a respiratory distress syndrome, which threatened patient's lives. Vital capacity decrease lowered patient's physical efficiency and limited everyday activity.

Postoperative RIF impaired the function of the auditory tube and middle ear as it hampered yawning needed to remove secrets produced in the auditory tube and middle ear [27]. Restriction in oral hygiene with precaries and periodontal damnification, together with loss of weight due to changes in food-intake represented other negative impacts [31].

Osteosuture

Osteosuture by steel wires was traditionally used for fixation of the bone fragments after mandibular setback. It meant inferior or superior border wires, figure-of-eight wiring circummandibular wiring [20]. A horizontal relapse between 20–50% was described for mandibular advancement with osteosuture [18], therefore it was usually joined with either RIF or skeletal fixation. Watzke [19] explained the cause of instability as contraction of chewing muscles resulting from reaction on sagittal split osteotomy of the mandible. These muscles (m. masseter, m. pterygoideus medialis and m. temporalis) remained attached only to the

proximal segment and rotated it cranially and ventrally. Osteosuture was not enough stable to avoid these movements and so the postoperative position of the condyle changed even if it was appropriate during the surgery. Noncontact condylar sag is another cause of osteosuture instability, according to Arnett. When there was no contact between condyle and articular fossa after the operation in either the anterioposterior or in the mediolateral plane, the condyle returned into its original position soon after the operation. Osteosuture could not avoid that. In the beginning this relapse was not necessarily seen as it was covered by dental compensation, but it arose after the removal of RIF or orthodontic braces [14].

Dolce [18] followed 34 patients for 5 years with mandibular advancement fixed with osteosuture. He reported clinically relevant relapse (larger than 2.2 mm, which was 40% of the advancement) in half of them. It always occurred in the first two postoperative years.

Berger [7] presented statistically significant relapse in the group of 54 patients with mandibular advancement, but it never exceeded the clinically relevant value. Watzke [19] presented osteosuture to be stable enough to fix the fragments of the mandible, relapse occurred only up to 15% of the advancement. It is the only work with such a low relapse and committed by heterogeneity of the group.

Politi [15] followed a group of 37 patients with mandibular progenia treated by bimaxillar operation. In 20 of them, fragments were fixated by osteosuture. On average, the horizontal relapse achieved 48% and was compensated by dental component. In his opinion postoperative clockwise rotation of proximal segment was not a cause of relapse as osteosuture allowed local adaptation in the osteotomy line.

Osteosynthesis

Osteosynthesis means fixation of bone fragments by miniplates or bicortical screws. Earlier, those were produced by stainless steel, nowadays from titanium and its alloys. This method is reliable and stable, even if some disadvantages exist: palpability of osteosyntetic material [32], sensibility of surrounded tissues in cold ambient, interference with CT and MRI examination [33], accumulation of corrosive products in surrounding or distant tissues [33] adherence of bacteria [34], adaptation of bone microstructure to buttress of rigid material [34, 35, 36]. These disadvantages can only be eliminated by removing the fixation in the second operation. In the lower jaw either one or more miniplates with monocortical screws or 2 or 3 bicortical screws are used to fix the fragments.

Bicortical screws osteosynthesis

Stability of bicortical screws osteosynthesis was proved repeatedly [18, 19, 27, 37, 38, 39]. In most cases, screws of 2 mm in diameter were applied in reverse L position which meant 2 screws above the inferior alveolar nerve and one below it. According to Maurer study [40] of finite element analysis this position provides

the highest resistance to chewing forces. Ekrmenn [41, 42] and Chuong [37] proved the same result with mandibular setback and advancement using finite element analysis, as well.

Hoffmann has not found any clinically important relapse in the group with mandibular advancement in the first year after the operation. Dolce [18] found clinically relevant relapse in 23% out of 91 patients, followed for 5 years after the mandibular advancement. He described a temporary forward movement of the mandibular symphysis and explained it as a compensation of operation condyle compression in the first 6 postoperative months. Then the mandible returned back and around the 5th year it was stabilised in the original postoperative position. The observed postoperative change of incisal overjet was caused by dental changes, not by skeletal relapse.

Among the main risks of bicortical screws it is the possibility of inferior alveolar nerve injury [9, 27, 39]. Ochs [39] did not recommend the use of bicortical screws on small overlaps of bone fragments, in large or asymmetric movements and if impacted third molars were present. Borstlap [9] rated as the main disadvantage of bicortical screws a higher rotation of the condyle, compared to miniplates, due to the compression of proximal segments and consequently a higher risk of condyle resorption and the need of extraoral incision to place screws. Sheperd [27] described the possibility of intraoral placement of screws, but this yields a higher time demand. Therefore, bicortical screws are not widely used in their typical compressive function, but are more frequently employed as lag screws only.

Ayoub [43] followed a group of 15 patients with mandibular setback in average 5.7 mm for progenia. He proved mediolateral torquing of condyle during fixation, which was one of important relapse factor. Average relapse moved around 2.5 mm.

Miniplate osteosynthesis

Also the method of rigid osteosynthesis with a miniplate and monocortical screws was generally considered to be stable enough. Usually 1 or 2 miniplates on each side of the mandible are used [38, 39, 44, 45]. Foltan shows early postoperative stability on 24 patients with mandibular advancement of 5.2 mm, on average [46].

Bosrtlap [4, 9, 44] divided 222 patients with mandibular advancement into two groups: Firstly, the stable group, with horizontal relapse of maximally 1 mm. Secondly, the relapse group, for all other cases. The stable group consisted of 84% of patients, with average advancement of 5.2 mm and relapse 0.4 mm. In the relapse group, the mandible was advanced by 7.8 mm on average and the relapse was in the range of 1.8–3.3 mm.

Stoelinga [45] emphasised the advantages of miniplates, like a reduction of skin scars, easier correction of malposition of the distal segment compared to bicortical screws and easy removal of osteosyntetic material.

Ueki [24] proved the stability of miniplates in a study with 20 patients with mandibular setback of 6.7 +/- 3.2 mm. He recommended using prebent

miniplates, which guarantee smaller condyle rotation and therefore lower risk of TMJ remodelation.

Resorbable materials

Resorbable materials have only been used for a short time in BSSO fixation. From the chemical point of view, they consist of a co-polymer of lactic and polyglycol acid in a varying ratio. It was presumed that they sufficiently stabilise the fragments in the first 6–8 weeks after operation and then completely dissolve into water and carbon dioxide, which eliminates the necessity of the second operation [47, 48, 49]. Ewards [48] showed complete dissolution of miniplates and screws in 8 out of 12 patients within 2 years. Two patients underwent a second operation and no remains of the material were seen, in one volunteer a biopsy at the place of screw insertion was performed with histological finding of trabecular bone.

Not all studies are so optimistic. Norholt [32] mentioned an inflammatory reaction due to the foreign body in 2 out of 30 patients. He used the 2.0 mm LactoSorb system, other information about composition and size of the degradation products is not given. Maurer valued the mechanical quality of the material [50, 51]. On an FEA model of the mandible it was proven that all tested bicortical screws (PLLA with 2.7 mm diameter, Isosorb with 3.5 mm diameter, BioSorb FX with 2.4 mm diameter and Lactosorb with 2.5 mm diameter) were able to neutralize higher masticatory forces than were proven in early postoperative weeks.

The long term stability of resorbable materials was usually evaluated only clinically [34, 47, 49, 52]. None of these authors had seen postoperative movement in the osteotomy line or bigger relapse in the period of 2–24 months after operation. Mainly bicortical screws in the reverse L configuration were used, but a fixation failure was found in some patients. Turvey [52] observed fixation failure in 3 patients out of 74. In two of these cases, the failure occurred in syndromic patients; in the third case an urgent re-intubation due to laryngospasmus caused the failure. We found 2 studies proving stability of resorbable materials with X-rays. Mathews [33] compared 11 patients with a mandibular advancement of 3–8 mm, fixed by 3 bicortical screws (SR-PLLA) with a similar group where titanium bicortical screws were used. In 12 months he did not find a statistically significant difference in relapse. Ueki [53] compared two groups of patients with a mandibular setback, one group with a titanium miniplate and one group with resorbable plates. He did not prove skeletal relapse in the first postoperative year in any of the patients. As far as we know, there is no radiological study of the long term stability until now.

Conclusion

We reviewed the literature concerning stability and clinical characteristics of different types of osteosynthesis after BSSO.

Rigid osteosynthesis slowly replaced osteosuture since the nineteen-eighties. Its proponents affirm that rigid osteosynthesis changes bone healing and eliminates relapse. These studies prove an increase of stability even if the effect is not as strong as it was expected. Complete elimination of rigid intermaxillary fixation is therefore considered the main advantage of this method. Early relapse, caused by movement in osteotomy line can be expected mainly with osteosuture, with rigid osteosynthesis, on the other hand, late relapse, caused by TMJ condyle resorption plays a more important role.

Indication of bicortical screws versus miniplates to fixate bone fragments remains an issue. Even if FEA studies prove higher resistance of bicortical screws to occlusal forces, studies done in vivo do not prove higher relapse with the use of miniplates. Maurer explains this fact by low occlusal force (65+/–43N) in the first 6 postoperative weeks.

Resorbable materials eliminate some disadvantages of titanium osteosynthetic materials, like the palpability of miniplate and screws in the face, hypersensitivity, CT and MRI scan artefacts, cumulation of corrosive products in local or distant tissues, bacteria adherences and adaptation of bone microstructure to buttress of rigid material. Therefore, there is no need for a second operation. On the other hand, resorbable materials are relatively new materials and all authors agree on the need of further studies of both biological characteristics and long term stability.

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