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Biomechanical evaluation of different osteosynthesis methods after mandibular sagittal split osteotomy in major advancements

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Abstract. The aim of this study was to assess the biomechanical stability of six different osteosynthesis methods after sagittal split osteotomy. Sixty polyurethane hemimandibles were divided into two groups, with six subgroups in each. After 10-mm advancement of the distal segment (group 1) and 10-mm advancement combined with 20° counterclockwise rotation (group 2), the bone segments were fixed using 2.0-mm plates/screws as follows: subgroup A, one conventional straight plate; subgroup B, two conventional straight plates; subgroup C, one conventional sagittal plate; subgroup D, one locking straight plate; subgroup E, two locking straight plates; subgroup F, one locking sagittal plate. The hemimandibles were tested for compressive strength by three-point biomechanical test, until there was 3 mm of displacement between the segments. The fixations showed better performance in group 1 than in group 2 in all cases, with statistical significance for subgroups A, C, and D. In both groups, the use of two straight miniplates showed the most resistance, followed by the sagittal miniplates. However, in counterclockwise rotations, no statistically significant difference was found between two conventional straight plates and the sagittal locking plate. This study shows that the use of two plates is the form of fixation with the minimum displacement. If the clinician opts to use one plate, a sagittal plate is the best alternative.

Key words: rigid internal fixation; mandibular bilateral sagittal split osteotomy; bone plate.

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The sagittal split osteotomy (SSO) is one of the widely used techniques in orthognathic surgery for the correction of dentofacial deformities[1]. The SSO design provides wide bone contact between the bone fragments, which allows stability, early consolidation, and different methods of rigid internal fixation (RIF). Currently, the SSO is used in combination with several movements, including counterclockwise rotation or clockwise rotation of the occlusal plane, associated or not with major mandibular advancements (more than 10 mm). Counterclockwise rotation provides better permeability of the airways, closure of open bite, and also better perception of facial movements, which improves the esthetic results[2,3].

Counterclockwise movements of the occlusal plane are relatively unstable, and such movements require osteosynthesis materials that provide increased bone stability. This movement results in wider displacement between the bone fragments and greater stress on the fixation system as a consequence of stretching of the suprahyoid and infrahyoid muscles. Thus, counterclockwise rotation can be associated with relapse, loss of osteosynthesis, and technique failure[4,5].

RIF osteosynthesis reduces the need and time required for maxillomandibular fixation and the risk of postoperative aspiration, and also improves healing and chewing function. These factors contribute to better performance in the immediate postoperative period[6]. RIF systems with good results are essential for the success of the technique. The fixation of bone segments usually requires bicortical screws or plates with monocortical screws. Bicortical screws present better biomechanical results, higher rigidity, and lower susceptibility to deformation[7,8]. However, some studies have suggested that the difference in strength is not clinically significant when compared to plates, which provide a stable and biologically acceptable fixation[9].

In major mandibular advancements with a wide distance between bone fragments, it is not possible to use bicortical screws alone[10]. The association of miniplates and bicortical screws, known as the hybrid technique, has been shown to provide good results[11]. Other plate designs associated with more screws distributed in a double-Y shape have also demonstrated promising results in terms of improving biomechanics[12,13].

Currently, the use of plates with a locking system helps to prevent misfit and avoids excessive compression of the plates and screws on cortical bone, which can result in osteolysis and a loss of fixation[14].

The aim of this in vitro study was to evaluate the biomechanical stability of six systems of bone fixation after SSO in major advancement of the distal segment with and without counterclockwise rotation of the occlusal plane. This was done through simulation of the masticatory forces under three-point biomechanical testing. Differences in the efficacy of locking and conventional systems were also assessed.

Materials and methods

A total of 60 polyurethane hemimandibles (model 1337-3; Sawbones, Pacific Research Laboratories, Inc., Vashon Island, WA, USA) were divided randomly into two groups. Each group was further divided into six subgroups ($n = 5$ in each). A SSO using the modified technique suggested by Epker was done in each hemimandible[15]. The hemimandibles had a bone-like consistency, with both cortical and medullary layers.

A 10-mm advancement was performed in group 1, while a 10-mm advancement combined with a 20° counterclockwise rotation was performed in group 2, resulting in displacement of 9 mm in the upper region and 12 mm in the mandibular base. Bone fixations were done with 2.0-mm plates and monocortical screws (2.0 system; NeoOrtho, Curitiba, PR, Brazil) as follows: subgroup A, one conventional straight plate and four 5-mm monocortical screws; subgroup B, two conventional straight plates and eight 5-mm monocortical screws; subgroup C, one double-Y sagittal conventional plate and six 5-mm monocortical screws; subgroup D, one locking straight plate and four 5-mm monocortical screws; subgroup E, two locking straight plates and eight 5-mm monocortical screws; subgroup F, one locking double-Y sagittal plate and six 5-mm monocortical screws (Figs 1 and 2).

The plates were placed on each hemimandible. When using two plates, one plate was inserted in the region nearest to the upper edge of the segments, while the other plate was positioned above the inferior border of the mandible. In the case of a single plate, this was inserted between these two regions. The plates were positioned with the aim of obtaining the best biomechanical results, without considering anatomical and clinical factors, such as the inferior alveolar nerve in the one-plate technique and the position of the second plate above the inferior border of the mandible in the two-plate technique.

The osteotomies were conducted using prefabricated templates positioned in the buccal and lingual regions. Basal and lingual osteotomies were done in order to create more uniform fractures and standardized samples.

The replicas were tested in a universal testing machine for compressive strength (Model 4202; Instron, Norwood, MA, USA), according to the method described by Ribeiro-Junior et al. (2010) for the simulation of muscular force[14]. The samples were adapted and positioned in a base fabricated especially for this study in order to conduct the strength test for fixation systems (Fig. 3). The area of condyle resistance in the posterior mandible was transferred to the samples, as well as the resultant of the masticatory forces in the anterior region. The loading cell was positioned in the region of the first molar to simulate food bolus resistance.

An increasing compressive load was applied to the samples until there was 3 mm of displacement between the mandibular segments in both the vertical and horizontal direction. The final force value was registered. Displacements were measured in two areas: the inferior border of the mandible (vertical displacement) and the second molar region in the alveolar ridge (horizontal displacement). Thus, anterior–posterior displacement was assessed in the inferior border of the mandible, while lateral displacement was assessed in the alveolar region, providing a three-dimensional biomechanical analysis.

For accurate measurement of 3-mm displacement between the bone segments, drilling was done at measurement marks. The distance between these marks was measured before each test with a surgical compass. Then, 3 mm was added to this compass, and the test was stopped when one of the marks reached the new parameter established.

Data were evaluated using the Kruskal–Wallis test and Miller's test to compare the subgroups within the same group. The Mann–Whitney test was used to compare the subgroups between groups 1 and 2. The level of significance was set at 0.05.

Results

As show in Fig. 4, group 1 showed greater biomechanical stability than group 2, with statistically significant differences for subgroups A, C, and D. In both groups, the method using two plates was most resistant, followed by one double-Y sagittal plate and then one straight plate (Tables 1 and 2).

The locking system also showed better overall results in all cases when compared to the conventional system in both groups. However, no statistically significant difference was found. The sagittal plate subgroups exhibited better results than the single plate subgroups in both cases (A vs. C; D vs. F), with a statistically significant difference ($P < 0.05$); however the results were not significant when the straight locking plate was compared to the sagittal conventional plate (C vs. D) (Tables 3 and 4).