Int J Clin Exp Med 2014;7(5):1284-1288
www.ijcem.com /ISSN:1940-5901/IJCEM0000348

*Original Article*

# Influence of the design in sagittal split ramus osteotomy on the mechanical behavior

Leandro Pozzer[1], Sergio Olate[2,3], Lucas Cavalieri-Pereira[1], Márcio de Moraes[1], José Ricardo Albergaría-Barbosa[1]

[1]*Department of Oral and Maxillofacial Surgery, State University of Campinas, Brazil;* [2]*Department of Oral and Maxillofacial Surgery, Universidad de La Frontera, Chile;* [3]*Center for Biomedical Research, Universidad Autónoma de Chile, Chile*

Received March 26, 2014; Accepted May 2, 2014; Epub May 15, 2014; Published May 30, 2014

**Abstract:** The aim of this study was to determine the influence of the design of the sagittal split ramus osteotomy (SSRO) on the mechanical resistance to vertical forces. An in vitro study was designed for 30 test specimens. Two osteotomy models were made on two polyurethane hemimandibles, where group I presented a SSRO with an angle at vestibular level between both molars and group II presented a linear SSRO towards the basilar border. In both groups a standard osteosynthesis was performed with a 2.0 system plate and four monocortical screws, establishing sub-groups according to the degree of mandibular advancement: group A without advancement, group B with an advancement of 3 mm, and group C with advancement of 7 mm. Hemimandibles were subjected to a vertical load in the Instron machine until reaching peak load with failure, recording the value of the load and displacement. The data were analyzed with a t-test to establish statistical significance, considering $p<0.05$. The results showed that group II presented the best response to the compressive load, tolerating the highest load values. These results were observed in almost all the groups with statistically significant differences ($p<0.05$). By contrast, group I presented torsional forces prior to reaching system failure. It can be concluded that the osteotomy design influences mechanical resistance and that the linear SSRO offers the best mechanical resistance.

**Keywords:** Sagittal split ramus osteotomy, fixation stability, orthognathic surgery

## Introduction

The sagittal split ramus osteotomy (SSRO) is an established technique in orthognatic surgery. Since its beginnings, the SSRO has proven versatile, efficient and has solved a variety of conditions associated with skeletal anomalies and functional alterations [1].

Additionally, osteosynthesis for the SSRO with plates and screws was a substantial advance in the stability of the technique [2], increasing the procedure's predictability. However, there are still clinical situations that lead to recurrences and complications, such as condylar resorption and segment displacement in the osteotomy [3-5], which still require attention.

Some modifications to the SSRO have been made on the basis of anatomical needs or to improve the results of the procedure [6-8]. However, no adequate mechanical analyses have been conducted to examine differences among them. It can be assumed that changes in the angulation and design of the osteotomy can lead to changes in the containment of forces generated by chewing or muscle movement, and thus influence the onset of complications or post-operative recurrences. Most mechanical analyses have assessed the different types of osteosynthesis, but not the effect of the SSRO design on the mechanical response [9, 10].

The aim of this study was to define the differences in the resistance of vertical loads from two different types of SSRO on an in vitro model.

## Material and methods

### *Groups*

Were used internal rigid fixation with a 2.0 4-hole straight plates with titanium alloy screws

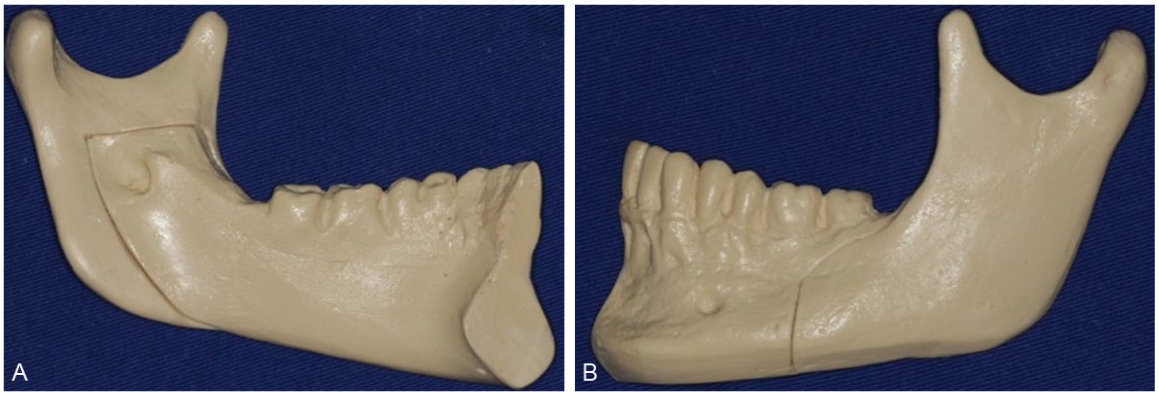


**Figure 1.** Osteotomy from group I consisting of angulations in the vestibular area between the two molars.

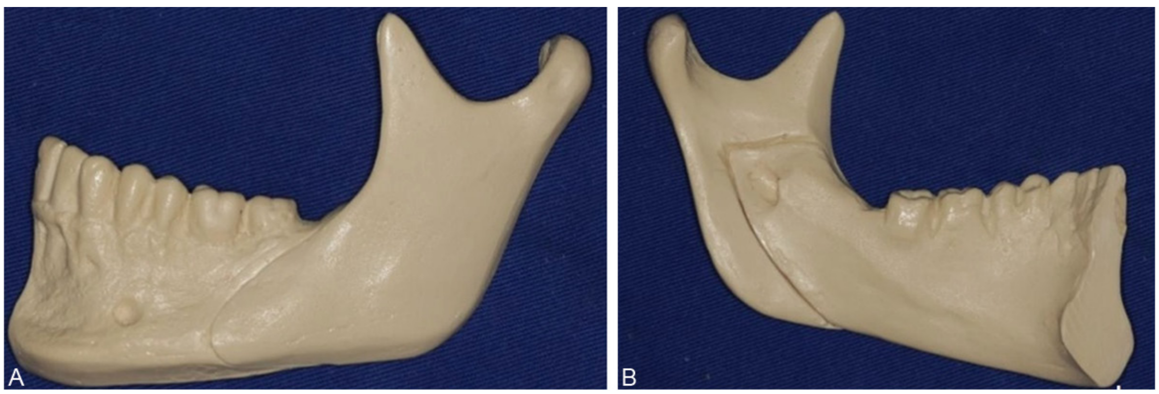


**Figure 2.** Linear osteotomy from group II, avoiding the formation of angles.

(Grade 2 titanium, ASTM F136 - Engimplan®, Rio Claro SP, Brazil), spaced at 7 mm between the meddle hole with a 1 mm profile; all the screws were 5 mm long. For the groups, 30 polyurethane hemimandibles were used (Nacional Ossos®, Jáu- SP - Brazil) and 2 analysis groups were established according to the osteotomy:

Group 1: An osteotomy was performed from the 5 mm above the lingula, moving the saw downwards to 14 mm. Then, sagittal cut was doing it through the lateral area of the second molar and between the two molars, the osteotomy descended perpendicularly to the basilar border, including the medial area of the mandible (**Figure 1**).

Group 2: An osteotomy was performed from the 5 mm above the lingula, moving the saw downwards to 14 mm. The movement was then made sagittally to the distal edge of the second molar and then descended straight to the anterior area, following the oblique line (lateral to the first molar), arriving at the basilar area of the mandible, with no angles created between the osteotomies (**Figure 2**).

For each were do it a master model with the described osteotomy and from these 15 standardized models of each were replicated. Then, each group was subdivided into three (5 sample units in each sub-group), being differentiated in the degree of advancement of the osteotomy:

A: No mandibular advancement

B: Mandibular advancement of 3 mm

C: Mandibular advancement of 7 mm

*Osteotomy fixation*

The osteosynthesis of the SSRO was performed with the routine technique and according to the manufacturer's instructions. For each of the sub-groups, a master model was created, where the osteosynthesis was performed tak-


**Figure 3.** Acrylic model used for the standardized installation of osteosynthesis screws; in this case for group IB.

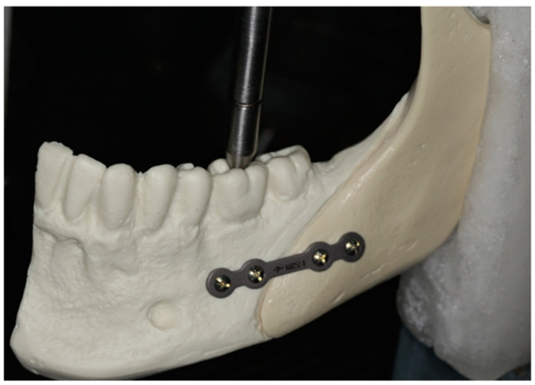

**Figure 4.** Model of vertical force application on the first mandibular molar.

ing care in the plate position. This was 5 mm posterior to the mental foramen, coinciding at one point located 10 mm below the cervical limit of the lower second premolar and 10 mm below the cervical limit of the lower first molar so as to present a standardized location. Then, an acrylic resin surgical guide was created for each master model (Dental Vipi Ltda., Pirassununga, SP, Brazil), which contained the points and guides for drilling holes. In this way, the surgical guide was standardized for each group and used for the osteosynthesis of the remaining mandibles in each sub-group (**Figure 3**).

*Application of the test*

A metallic iron alloy support was constructed, composed of a rectangular base and a vertical horn, giving the mandible rigidity and stabilization at three points of the posterior sector of the condylar neck, mandibular ramus and mandibular angle, avoiding the clockwise rotation of the system during the load.

The mechanical test was performed in the Dental Materials Laboratory of the State University of Campinas using a pressure device with a rounded working part, applying pressure to the central fossa of the lower first molar. A universal test machine was used for the testing (Instron® CO, Canton, Massachusetts, USA (mod. 4411)), programmed with a linear displacement speed of 2 mm/min until reaching peak load and system failure, at which point the failure value was recorded. The test was stopped with final loss of resistance (**Figure 4**).

The statistical analysis was conducted by establishing the relation between the peak load values (n) and the average maximum displacement (mm). The values were analyzed using GraphPad Prism (GraphPad Software, Inc. 7825 Fay Avenue, Suite 230 La Jolla, CA 92037 USA) via a t-test considering a value of $p<0.05$ to obtain statistically significant relations.

## Results

The analysis was conducted without complications, identifying some differences between the two groups. The results for the peak load obtained can be seen in **Table 1**, while in **Table 2** the results of load-associated displacement can be observed. Consistently, the groups without mandibular advancement tolerated a greater peak load compared to the groups with mandibular advancement. By contrast, when the system reached failure, rotation of the dentate segment was observed in the samples of groups IA and IB, reaching torsional vectors at the end of the load stage.

For the statistical analyses, significant differences were observed between groups I and II ($p<0.05$), indicating group II had a greater load resistance. Likewise, the individual analysis of each sub-group identified significant differences favorable to group II, indicating its greater capacity for tensile strength.

## Discussion

The SSRO is an established and versatile technique in the handling of the facial deformities. Modifications to the SSRO have been associated with the aim of decreasing damage to the inferior alveolar nerve, reducing the risk of incorrect fractures, decreasing recurrences, decreasing condylar displacement, and improv-

**Table 1.** The peak load (N) tolerated by each system

| Sub-group | Group I | | Group II | | P |
|---|---|---|---|---|---|
| | X | SD | X | SD | |
| A | 149.30 | 20.21 | 188.45 | 26.90 | 0.034 |
| B | 76.95 | 21.32 | 44.20 | 1.97 | 0.044 |
| C | 54.29 | 54.30 | 57.10 | 57.5 | 0.183 |

**Table 2.** Displacement generated in the systems after application of peak load (displacement measurement indicates system failure)

| Sub-group | Group I | | Group II | | P |
|---|---|---|---|---|---|
| | X | SD | X | SD | |
| A | 10.62 | 1.32 | 12.62 | 1.39 | 0.041 |
| B | 7.48 | 1.07 | 14.24 | 1.64 | 0.038 |
| C | 8.14 | 1.76 | 14.82 | 1.75 | 0.048 |

ing the conditions of osteosynthesis, among others [6-8].

Our analysis model studied the maximum force applied to the model of mandibular advancement with a single plate and four monocortical screws because it was considered that less osteosynthesis material can provide more information about bone support, taking in the findings from other clinical and mechanical investigations [11, 12]. In addition, other authors have indicated that the osteosynthesis model used in our study is one of the weakest among all the systems evaluated mechanically [9, 13], ensuring that the value of the osteotomy can be better evaluated.

Given that Throckmorton et al [14] indicated that in the dental occlusion the posterior forces have a higher load than the anterior forces and following the guidelines of Aprino et al [15] on obtaining maximum loads, the choice was made to analyze to the point of system failure in order to identify the vectors associated with the loss of osteosynthesis.

Osteosynthesis is an important element in the SSRO; having been analyzed in various studies, it has been determined that different types of osteosynthesis (bicortical screws, plates with monocortical screws or hybrid techniques) are efficient in the stabilization of the SSRO [10] and also that metallic and absorbable osteosynthesis can be just as efficient in the stability of the surgery [16]. However, little has been discussed regarding the impact of the osteotomy design on its stability.

In this research, group II, the linear osteotomy, presented a better mechanical behavior in practically all the analyses, probably because the angles produce greater stress points. This has been verified in other mechanical studies associated with dental implants, where the angles of the implant threads showing the greatest stress in vertical or oblique loads [17]. The angles present in the proximal segment of the SSRO may come into contact with the bone of the distal segment so that stress can produce less resistance to the system and stimulate the torsional forces. The torsional force observed in group I, greater than in group II, may be associated with this hypothesis of contact with SSRO angles.

SSRO recurrence has been associated with different factors, such as incorrect condylar position during surgery [4], mandibular condylar resorption [5] and movement in the area of the osteotomy [3], where the role of osteosynthesis is an important factor. Nevertheless, with respect to the last concept, there are no accurate analyses on the role of the osteotomy design, since the variations have not been adequately analyzed from a mechanical point of view.

Recently Enami et al [18] indicated adaptive condylar morphological changes to the SSRO in subjects undergoing orthognatic surgery due to dental occlusion and morphology; however, according to our results, the osteotomy design and torsional forces may again be a variable among these alterations in condylar position, particularly in the initial assessment periods.

Most studies into mechanical stability have been conducted on angular osteotomies similar to those in group I, both in finite analysis and in mechanical models [13], such that it is difficult to find literature to compare our results; this is a challenge to be overcome in future research. The study by Sato et al. [10] has aspects similar to the osteotomy in group II of our study; although limited forces are exerted on the osteotomy, it is observed that the greatest concentration of stress is on the screws and not on the osteotomy, which could favor the stability of the osteotomy in terms of avoiding torsions and better load bearing.

Based on this study, we can conclude that the SSRO design show variations in the force vector distribution when vertical forces are applied at the level of the first molar in the same osteosynthesis system.

### Disclosure of conflict of interest

None.

**Address correspondence to:** Sergio Olate, Facultad de Odontología, Universidad de La Frontera, Claro Solar 115, 4 to Piso, Oficina 20, Temuco, Chile. E-mail: sergio.olate@ufrontera.cl

### References

[1] Sonego CL, Bobrowski ÂN, Chagas OL Jr, Torriani MA. Aesthetic and functional implications following rotation of the maxillomandibular complex in orthognathic surgery: a systematic review. Int J Oral Maxillofac Surg 2014; 43: 40-45.

[2] Van Sickels JE, Richardson DA. Stability of orthognathic surgery: a review of rigid fixation. Br J Oral Maxillofac Surg 1996; 34: 279-85.

[3] Mobarak KA, Espeland L, Krogstad O, Lyberg T. Mandibular advancement surgery in high-angle and low-angle class II patients: different long-term skeletal responses. Am J Orthod Dentofacial Orthop 2001; 119: 368-381.

[4] Reyneke JP, Ferretti C. Intraoperative diagnosis of condylar sag after bilateral sagittal split ramus osteotomy. Br J Oral Maxillofac Surg 2002; 40: 285-292.

[5] Eggensperger N, Smolka K, Luder J, Iizuka T. Short- and long-term skeletal relapse after mandibular advancement surgery. Int J Oral Maxillofac Surg 2006; 35: 36-42.

[6] Epker BN. Modifications of the sagittal osteotomy of the mandible. J Oral Surg 1977; 35: 157-159.

[7] Wolford LM, Bennett MA, Rafferty CG. Modification of the mandibular amus sagittal split osteotomy. Oral Surg Oral Med Oral Pathol 1987; 64: 146-55.

[8] Marquez IM, Stella JP. Modification of sagittal split ramus osteotomy to avoid unfavorable fracture around impacted third molars. Int J Adult Orthod Orthognath Surg 1998; 13: 183-187.

[9] Brasileiro BF, Grempel RG, Ambrosano GM, Passeril LA. An in vitro evaluation of rigid internal fixation techniques for sagital Split ramus osteotomies: advancement surgery. J Oral Maxillofac Surg 2009; 67: 809-817.

[10] Sato FR, Asprino L, Consani S, de Moraes M. Comparative biomechanical and photoelastic evaluation of different fixation techniques of sagital split ramus osteotomy in mandibular advancement. J Oral Maxillofac Surg 2010; 68: 160-166.

[11] Bouloux GF, Chen S, Threadgill JM. Small and large titanium plates are equally effective for treating mandible fractures. J Oral Maxillofac Surg 2012; 70: 1613-1621.

[12] Parascandolo S, Spinzia A, Parascandolo S, Piombino P, Califano L. Two load sharing plates fixation condylar fractures: biomechanical basis. J Craniomaxillofac Surg 2010; 38: 385-90.

[13] Erkmen E, Simşek B, Yücel E, Kurt A. Comparison of different fixation methods following sagittal split ramus osteotomies using three-dimensional finite elements analysis Part 1: advancement surgery-posterior loading. Int J Oral Maxillofac Surg 2005; 34: 551-558.

[14] Throckmorton GS, Buschang PH, Ellis E. Improvement of maximum occlusal forces after orthognatic surgery. J Oral Maxillofac Surg 1996; 54: 1080-1086.

[15] Asprino L, Consani S, de Moraes M. A comparative biomechanical evaluation of mandibular condyle fracture plating technique. J Oral Maxillofac Surg 2006; 64: 452-456.

[16] Yang L, Xu M, Jin X, Xu J, Lu J, Zhang C, Li S, Teng L. Skeletal stability of bioresorbable fixation in orthognathic surgery: A systemic review. J Craniomaxillofac Surg 2013; doi: 10.1016/j.jcms.2013.08.003. [Epub ahead of print].

[17] Chang JZ, Chen YJ, Tung YY, Chiang YY, Lai EH, Chen WP, Lin CP. Effects of the thread depth, taper shape, and taper lenght on the mechanical properties of mini-implants. Am J Orthod Dentofacial Orthop 2012; 141: 279-88.

[18] Enami K, Yamada K, Kageyama T, Taguchi A. Morphological changes in the temporomandibular joint before and after sagittal splitting ramus osteotomy of the mandible for skeletal mandibular protrusion. Cranio 2013; 31: 123-132.