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# Mechanical Evaluation of Different Stable Internal Fixation Techniques of Sagittal Osteotomy in Mandibular Advance

## Evaluación Mecánica de Diferentes Técnicas de Fijación Interna Estable de Osteotomía Sagital en Avance Mandibular

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**CORAL, A. J.; OLIVEIRA NETO, J. L. & CAVALIERI-PEREIRA, L.** Mechanical evaluation of different stable internal fixation techniques of sagittal osteotomy in mandibular advance. *Int. J. Odontostomat., 17(3)*:327-334, 2023.

**ABSTRACT:** The mandibular advancements performed in orthognathic surgeries can be stabilized with several techniques when using stable internal fixation. This study aims to comparatively evaluate, in vitro, the mechanical strength in a polyurethane mandibular model for four fixation techniques for sagittal split ramus osteotomy mandibular. 60 samples were divided into 4 groups, with 15 units for each group: group A, group B, group C and group D. Advances of 5 mm were made for each subgroup and fixed with 2.0 mm system plates and monocortical screws in the replicas of human hemimandibles in polyurethane resin. The samples were submitted to mechanical tests of linear loading, being evaluated the peak load and peak deformation. Technique B presented higher peak load (Kgf) and techniques A and B presented higher peak strain ($p<0.05$). Technique D presented lower peak load and lower peak strain ($p<0.05$). It is concluded that the study based on the development of new techniques for fixation for sagittal osteotomy of the mandibular ramus is of great importance for the advancement of orthognathic surgery, provided by the technical innovation of more favorable plate models.

**KEY WORDS: Mandible, orthognatic surgery, osteotomy sagittal split ramus.**

## INTRODUCTION

The treatment of dentofacial deformities is focused on correcting malocclusion, facial deformity, reestablishing a favorable airway and consequently maxillomandibular relationship by a combination of the work of the orthodontist and the oral and maxillofacial surgeon (Barber *et al*., 1992).

The sagittal osteotomy of the mandibular rami (OSRM) is the most used in orthognathic surgeries, due to the stability obtained by the greater area of bone contact between the osteotomized segments, without the need for bone grafts and the long-term stability (Turvey, 1985).

Several mandibular osteotomy techniques for orthognathic surgery have been proposed, but OSRM was first described in the literature by Obwegeser in 1955 and published in the American literature in 1957 by Trauner & Obwegeser (1957). The original technique consisted of an oblique cut through the lateral cortex of the mandible, from the region distal to the second molar to the mandibular angle, a horizontal cut through the medial cortex, above the lingula, and a sagittal separation between these two cuts, including the lower edge of the jaw.

Dal Pont (1959), Hunsuck (1968), Gallo *et al*. (1976) participated in the modification of the technique aiming at greater ease and fewer complications. Epker (1977) made modifications to reduce the periosteum detachment and the dissection of the pterygo-masseteric loop. Bell & Schendel (1977), Wolford *et al*. (1987) and Wolford & Davis Jr. (1990) also suggested modifications, but the procedure performed

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today is similar to that described by Dal Pont (1959), with minor changes (Araujo, 1999) and may vary according to the option of each surgeon.

Despite the routine use of sagittal osteotomy, there are still a number of controversies and preferences regarding which bone fixation promotes greater stability, with less repercussion, mainly for the condylar position (De Oliveira *et al*., 2016).

Araújo (1999) states that, despite the OSRM being versatile and widely used, some complications may occur, such as sensorineural disorders, torque effect on the condyles and postoperative recurrence.

Some types of materials were used in studies to perform mechanical tests simulating OSRM, such as rib bone, pork jaw and polyurethane jaw. Polyurethanes are from a wide family of polymers that can be potentially useful in tissue engineering in many types of tissues, such as intravenous catheters, vascular grafts, cartilage replacements, artificial hearts, bone, among others (Dias *et al*., 2010). They have mechanical properties, are biocompatible and are also indicated for maxillofacial prosthesis.

Currently, the use of stable internal fixation is used in practically all orthognathic surgery surgical procedures. Therefore, the evaluation of the different forms of fixation, in *in vitro* studies, is of great importance, especially when the studies are aimed at improving the clinical practice of professionals (Brasileiro *et al*., 2009; Sato *et al*., 2010).

Thus, the aim of this study is to comparatively evaluate, *in vitro*, the mechanical strength in polyurethane mandibular models for four techniques of stable internal fixation of sagittal osteotomy of the mandibular ramus.

## MATERIAL AND METHOD

**Plates and screws.** This research was carried out with 2.0 mm System plates and screws from the company A2 - Medical Supply Comércio e Representação Ltda. (Mogi-Guaçu, São Paulo – Brazil)® and the trademark Signo Vinces® (Campo Largo, Paraná – Brazil). 45 straight plates, 15 double column plates with a thickness of 0.6 mm, 15 double column plates with a thickness of 1 mm and 420 monocortical screws were used to fix the plates.

HALF JAW. Sixty synthetic polyurethane hemimandibles standardized with sagittal osteotomy (Fig. 1) of the commercial brand Nacional Ossos - Franceschi & Costa e Silva Ltda were used. (Jaú, São Paulo – Brazil).

Fig. 1. Polyurethane hemimandible with sagittal osteotomy.

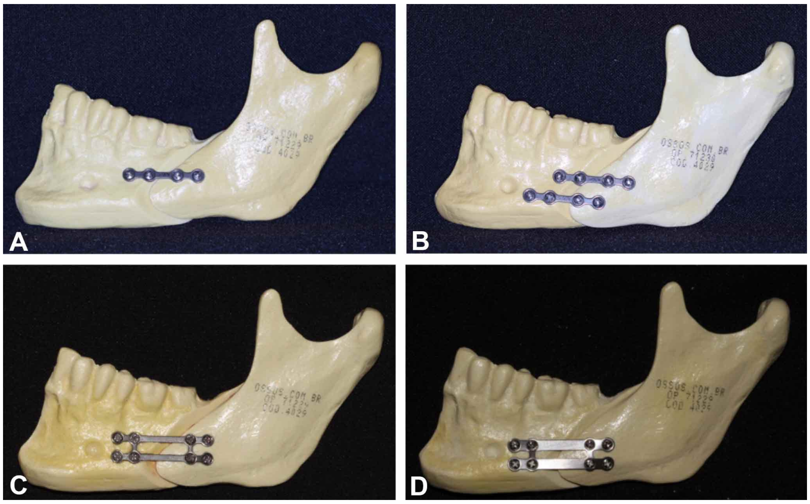


Fig. 2. Four groups: A, B, C e D with fixing the OSRM.

**Sample Preparation.** To perform the tests, the 60 samples were grouped into 4 groups comprising 15 hemimandibles each (Fig. 2).

The groups were divided according to the different fixation techniques:
Group A. System straight plate 2.0 mm; 4 holes; fixed with 5 mm screws of the same system;

Group B. Two straight system plate 2.0 mm; 4 holes; fixed with 5 mm screws of the same system;

Group C. Double column plate 2.0 mm system with a thickness of 1 mm; 8 holes; fixes with 5 mm screws of the same system;

Fig. 3. Jaws inserted into acrylic resin guide.

Group D. Double column plate 2.0 mm system with a thickness of 0,6 mm; 8 holes; fixes with 5 mm screws of the same system.

All hemimandibles were fixed with a 5 mm advance, according to the fixation techniques that were proposed in this study.

From the fixation of the first sample of each group, a colorless chemically activated acrylic resin guide was made to standardize the advancement of drilling and fixation.

For the fixation of the other samples, the two segments that form the hemimandible and the plate(s) were inserted in the acrylic resin guides and drilled using a 2.0 mm system drill, brand A2 - Medical Supply Comércio e Representação Ltda and fixed with screws of the same system (Fig. 3).

For the loading test, the EMIC universal testing machine (Figs. 8 and 9) belonging to the Laboratory of Universidade São Leopoldo Mandic (Campinas, São Paulo – Brazil) was used.

To carry out this test, a support device (Fig. 4) was made to fix the hemimandibles (Usilev Indústria, Comércio e Usinagem Ltda - Piracicaba, São Paulo - Brazil) together with the loading test equipment.

As shown in Figures 5, 6 and 7, with the aid of a rectangular metallic mold (Usilev Indústria, Comércio e Usinagem Ltda - Piracicaba, São Paulo - Brazil), a block of colorless chemically activated acrylic resin was made to allow the positioning of the mandibular branches and standardized fixation on the supports in which they were taken to the testing machine.

For the loading test, a speed of 1mm/min (Arnett/Sato) was established, with a 50 kgf bill of lading (Arnett) for application of progressive load on the system. When obtaining the load resistance value, in kg - force, in the peak load and final load, the value of the displacement imposed by the test, in millimeters, was recorded. The load was always applied at a fixed point (central fossa of the lower first molar) that received the load application device (Fig. 10).

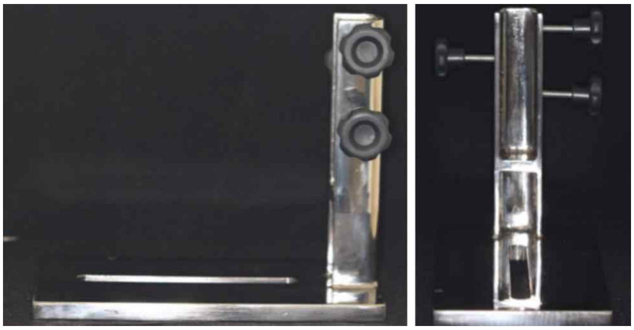
Fig. 4. Support device.


Fig. 5. Metallic mold.

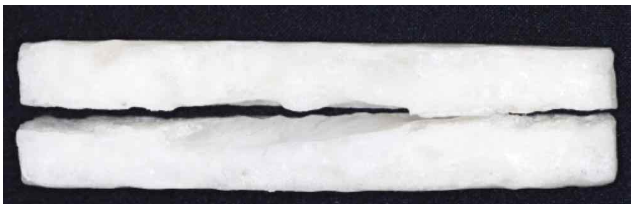
Fig. 6. Acrylic resin base.


Fig. 7. Jaw inserted in acrylic resin base.

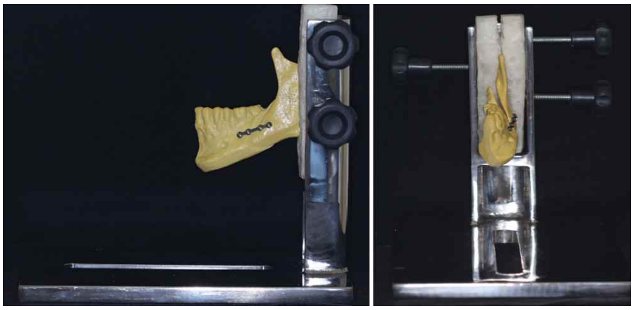

Fig. 8. Jaw inserted into the metal support.

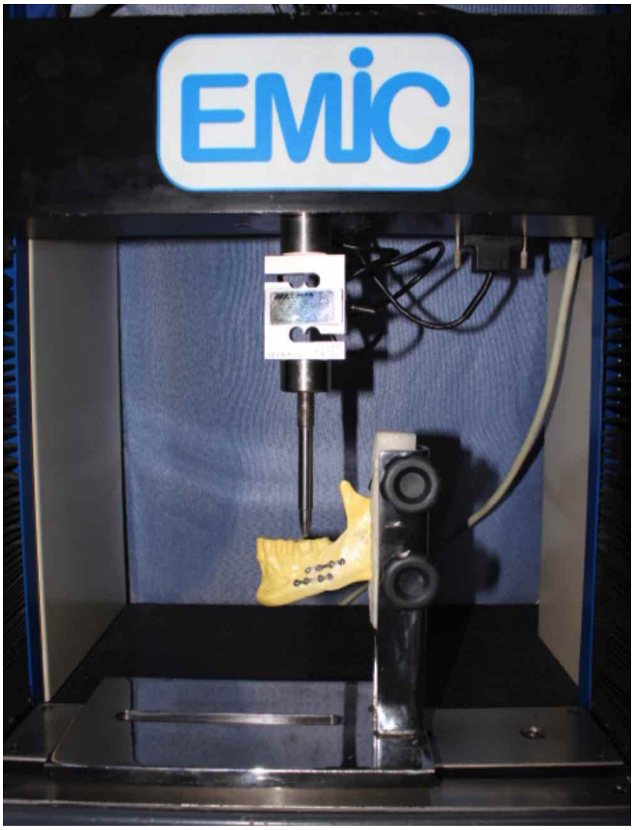


Fig. 9. EMIC machine with jaw under test.

Peak load (kgf) and peak displacement (mm) were evaluated

**Statistical analysis.** The results obtained were sent for statistical analysis.

All analyzes were performed with the aid of the R program and with a significance level of 5 %. Initially, descriptive and exploratory analyzes were carried out.

As the load and strain data do not meet the assumptions of an analysis of variance (ANOVA) they were analyzed by generalized linear models for the effect of technique. The data were described with

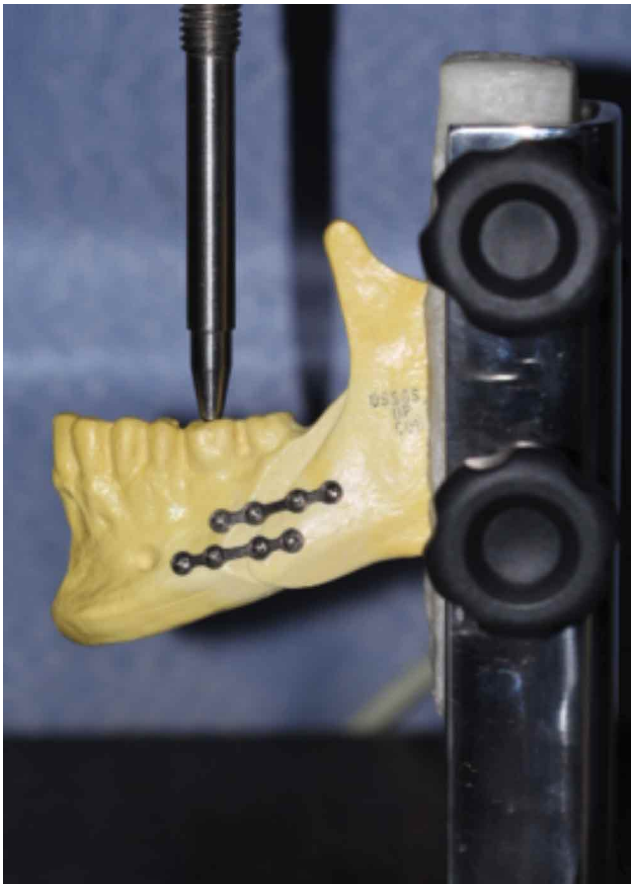

Fig. 10. Tip of the loading device in the central fossa of the mandibular first molar.

means, standard deviations, median, minimum and maximum values of load and deformation.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

## RESULTS

For each sample, a test report was generated as in the following example (Fig. 1), comprising a total of 60 graphs (one for each sample).

All data were tabulated and sent for statistical analysis.

It is observed in Table I and Figure 12 that the peak load was significantly higher when using technique B (2 straight plates of the 2.0 mm system with 4 holes each, fixed with 5 mm screws of the same system) and significantly lower when using technique D (Double column plate with 0.6 mm thickness of the 2.0 mm system with 8 holes fixed with 5 mm screws of the same system), p<0.05. There was no significant difference between techniques A (2.0 mm straight system plate with 4 holes fixed with 5 mm screws from the same system) and C (Double column plate with 1 mm thick system 2.0 mm with 8 holes fixed with 5 mm screws from the same system) and peak load (p>0.05). Peak strain (Fig. 2) was significantly higher in techniques A and B than in techniques C and D. Furthermore, strain was significantly greater in technique C than in technique D (p<0.05).

Table I. Mean (standard deviation), Median (minimum and maximum value) of peak load (Kgf) and peak deformation (mm) as a function of the fixation technique of the sagittal osteotomy of the mandibular ramus (SORM).

| [1]Technique | Peak Load | | Peak deformation | |
|---|---|---|---|---|
| | Average (standard deviation) | Median (minimum and maximum value) | Average (standard deviation) | Median (minimum and maximum value) |
| A | 2.93 (1.20) b | 2.93 (0.82; 5.26) | 9.27 (4,46) a | 9.00 (3.00; 19.00) |
| B | 4.71 (1.92) a | 5.00 (2.18; 7.62) | 8.33 (2,94) a | 9.00 (3.00; 12.00) |
| C | 2.79 (1.18) b | 2.65 (1.52; 6.39) | 5.53 (2,59) b | 5.00 (3.00; 12.00) |
| D | 1.69 (0.56) c | 1.51 (1.19; 2.87) | 4.07 (1,33) c | 4.00 (3.00; 8.00) |
| p-valor | <0.0001 | | <0.0001 | |

Distinct vertical letters indicate statistically significant differences between the techniques (p≤0.050. 1A: 2.0 mm straight system plate with 4 holes fixed with 5 mm screws from the same system; B: 2 straight system plates 2.0 mm of 4 holes each, fixed with 5 mm screws of the same system; C: Double column plate with 1mm thickness of the system 2.0 mm of 8 holes fixed with 5 mm screws of the same system; D: Double column plate with thickness 0.6 mm system 2.0 mm 8-hole fixed with 5 mm screws from the same system.

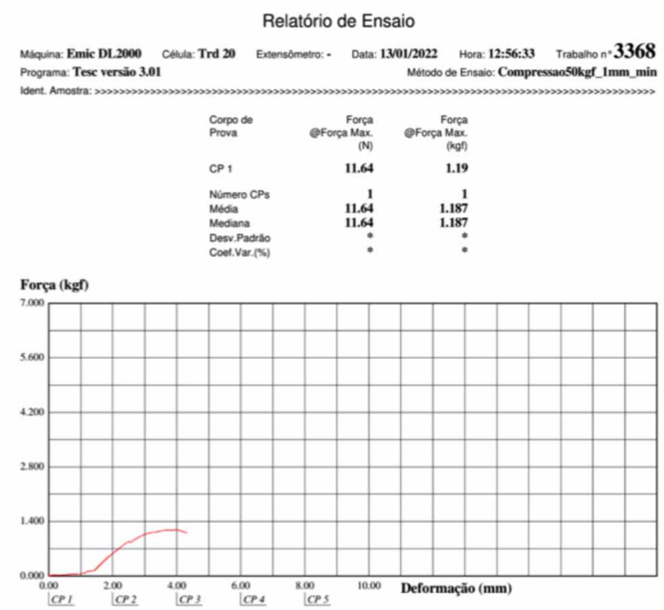


Fig. 11. Test report - Graph of Force (kgf) by Deformation/ Displacement (mm).

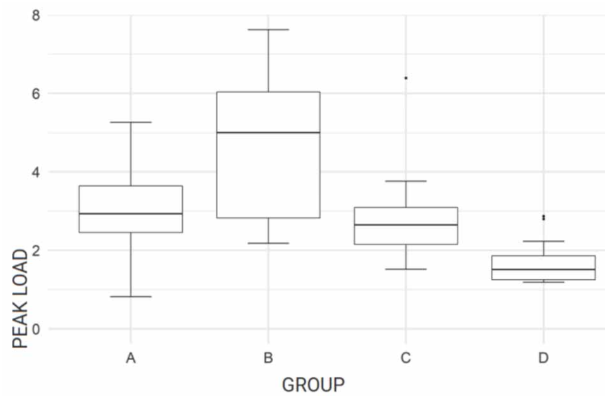


Fig. 12. Box plot of peak load (Kgf) as a function of the fixation technique of sagittal osteotomy of the mandibular ramus (SORM). A: 4-hole 2.0mm straight system plate fixed with 5mm screws from the same system; B: 2 straight system plates 2.0 mm with 4 holes each, fixed with 5 mm screws of the same system; C: Double column plate with 1mm thickness of 2.0mm 8-hole system fixed with 5mm screws of the same system; D: Double column plate with 0.6mm thickness of the 2.0mm 8-hole system fixed with 5mm screws of the same system

## DISCUSSION

The stability and predictability of surgical procedures for orthognathic surgery vary according to the direction of surgical movement, the type of fixation and the surgical technique employed, mainly in that order of importance (Proffit *et al*., 1996). In our study, we evaluated the types of fixation involving the OSRM technique traditionally used for orthognathic surgery.

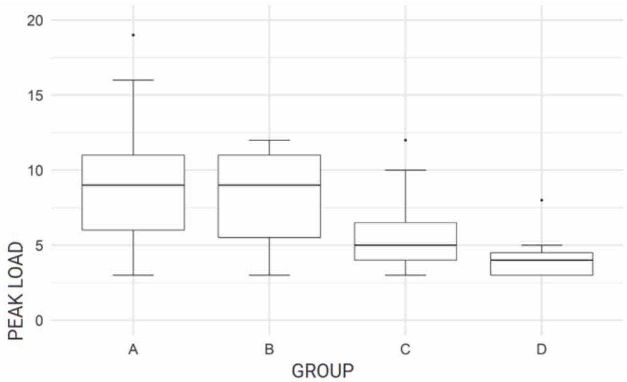


Fig. 13. Box plot of peak deformation (mm) as a function of the fixation technique of sagittal osteotomy of the mandibular ramus (SORM). 1A: 4-hole 2.0mm straight system plate fixed with 5mm screws from the same system; B: 2 straight system plates 2.0 mm with 4 holes each, fixed with 5 mm screws of the same system; C: Double column plate with 1mm thickness of 2.0mm 8-hole system fixed with 5mm screws of the same system; D: Double column plate with 0.6mm thickness of the 2.0mm 8-hole system fixed with 5mm screws of the same system.

All studies analyze peak load, which may include among other items such as final displacement, final load and peak displacement (Anucul *et al*., 1992; Peterson *et al*., 2005; Sato *et al*., 2010; Assis, 2017).

Assis (2017), carried out a study involving five OSRM fixation techniques evaluating maximum force in three displacement variables 1, 5 and 10 mm; De Oliveira *et al*. (2016) evaluated the mechanical strength involving 6 fixation techniques with advance variables of 1, 3 and 5 mm; Brasileiro *et al*. (2009) compared *in vitro* strength for maximum load recording at 1 mm, 3 mm, 5 mm and 10 mm of displacement; Sato *et al*. (2010), Peterson *et al*. (2005) and Van Sickels *et al*. (2005) evaluated the mechanical strength involving fixation techniques for 5 mm advances, without variables. A maioria dos estudos simula avanços de 5 mm, como realizado no nosso estudo (Anucul *et al*., 1992; Brasileiro *et al*., 2009; Sato *et al*., 2010).

In the study by De Oliveira *et al*. (2016), the evaluation of the mechanical behavior of six forms of internal fixation applied to replicas of hemimandibles when subjected to a vertical loading test was carried out and as a result it was given that two plates arranged in parallel or a grid plate are more effective. efficient for fixation of sagittal osteotomy, being coincident with the results of this research, in which two straight plates showed greater peak load.

Peterson *et al*. (2005) stated in his study that throughput load/peak load is the most important measurement when considering biomechanical investigations. This is the load at which permanent deformation starts, indicating System failure.

Ribeiro-Junior *et al*. (2012) tested several methods of osteosynthesis for the reduction of OSRM. A multiparametric comparison showed a statistically significant difference between the groups that used 2 4-hole miniplates, as analyzed in our study, or that used the hybrid technique (a 4-hole miniplate with 1 bicortical screw), in relation to the groups that used only a 4 or 6 hole straight plate.

Studies concerning plate and screw fixation compared to bicortical screws showed that the resistance is constantly lower for miniplate (Anucul *et al*., 1992; Peterson *et al*., 2005; Sato *et al*., 2010).

Bicortical screws have the ability to limit the action of flexion and torsional forces, due to their three-dimensionally distributed insertion. Sato *et al*. (2010), states that the use of miniplates with monocortical screws is based on the material being inserted at a point (the miniplate between the segments) provides greater torsional movement and, consequently, less resistance to the system. The photoelastic tests proved that, in the case of miniplates, all the stress is concentrated around the fastening system, which results in the lower mechanical strength of this technique compared to positional screws.

According to studies, the technique given by Spiessel (1974), in which only bicortical screws are used for fixation, presents favorable results in relation to resistance, but has the disadvantages of the possibility of temporomandibular disorders due to condylar torque and damage to the alveolar nerve, lower due to compression.

Also, in some situations, miniplates are a better choice than positional screws, such as in cases of high movement and asymmetry. (Van Sickels *et al*., 2005).

Regardless of the inferior results regarding strength for miniplates, several studies have shown that, during the first postoperative weeks, there is a significant reduction in masticatory forces, and thus, miniplates are able to provide sufficient stabilization during the initial stages of repair. bone (Stoelinga & Borstlap, 2003; Van Sickels *et al*., 2005).

In the study by Blomqvist & Isaksson (1994), the stability given for both miniplates with monocortical screws and for the use of bicortical positional screws portray the absence of differences in terms of clinical stability over time.

The use of miniplates fixed with monocortical screws has the advantage of less compression between the segments, which could cause injuries to the inferior alveolar nerve and lower condylar torque (Demircan *et al*., 2020).

Similar studies have analyzed the mechanical strength in different fixation techniques, but the results cannot be exactly compared due to different methodologies.

## CONCLUSION

It is concluded that the study based on the development of new techniques for fixation for sagittal osteotomy of the mandibular ramus is of great importance for the advancement of orthognathic surgery, provided by the technical innovation of more favorable plate models.

**DECLARATIONS.** All authors contributed and read the entire article and agree with the submission, Ana Júlia Coral, José Lopes de Oliveira Neto, Lucas Cavalieri Pereira. The study was not carried out in humans, and ethics committee approval was not required. The research was funded by the authors themselves, declaring that there are no financial and personal relationships with other people or organizations that could unduly influence this work.

**CORAL, A. J.; OLIVEIRA NETO, J. L. & CAVALIERI-PEREIRA, L.** Evaluación mecánica de diferentes técnicas de fijación interna estable de osteotomía sagital en avance mandibular. *Int. J. Odontostomat., 17(3)*:327-334, 2023.

**RESUMEN:** Los avances mandibulares realizados en cirugías ortognáticas pueden estabilizarse con varias técnicas cuando se utiliza fijación interna estable. Este estudio tuvo como objetivo evaluar comparativamente, *in vitro*, la resistencia mecánica en un modelo mandibular de poliuretano para cuatro técnicas de fijación para la osteotomía sagital de la rama mandibular. Se dividieron 60 muestras en 4 grupos, con 15 unidades para cada grupo: grupo A, grupo B, grupo C y grupo D. Se realizaron avances de 5 mm para cada subgrupo y se fijaron con placas de sistema de 2,0 mm y tornillos monocorticales en las réplicas de hemimandíbulas humanas en resina de poliuretano. Las muestras fueron sometidas a pruebas mecánicas de carga lineal, siendo evaluadas la carga máxima y la deformación máxima. La técnica B presentó mayor pico de carga (Kgf) y las técnicas A y B presentaron mayor pico de deformación (p<0,05). La técnica D presentó menor carga máxima y menor tensión máxima (p<0,05). Se concluye que el estudio basado en el desarrollo de nuevas técnicas de fijación para la osteotomía sagital de la rama mandibular es de gran importancia para el avance de la cirugía ortognática, proporcionada por la innovación técnica de modelos de placas más favorables.

**PALABRAS CLAVE: mandíbula, cirugía ortognática, osteotomía de rama sagital dividida.**

## REFERENCES

Anucul, B.; Waite, P. D. & Lemons, J. E. *In vitro* strength analysis of sagittal split osteotomy fixation: noncompression monocortical plates versus bicortical position screws. *J. Oral Maxillofac. Surg., 50(12)*:1295-9, 1992.

Araujo, A. *Cirurgia Ortognática*. Santos, Santos Livraria, 1999. pp.113-4.

Assis, G. M. *Análise Mecânica da Resistência de Fixação na Osteotomia Sagital do Ramo Após Diferentes Movimentos de Avanço Mandibular: Estudo In vitro*. Dissertação Mestrado em Saúde Coletiva. Natal, Faculdade de Odontologia, Universidade federal do Rio Grande do Norte, 2017.

Barber, H. D.; Wilmot, J. J.; Scott, R. F.; Fonseca, D. J. & Vig, C. W. L. The dentofacial deformity program of the University of Michigan: Organization, analysis of data, and benefits of program. *Int. J. Adult Orthod. Orthognath. Surg., 7(2)*:119-28,1992.

Bell, W. H. & Schendel, S. A. Biological basis for modification of the sagittal ramus division operation. *J. Oral Surg., 35(5)*:362-9, 1977.

Blomqvist, J. E. & Isaksson, S. Skeletal stability after mandibular advancement: A comparison of two rigid internal attachment techniques. *J. Oral Maxillofac. Surg., 52(11)*:1133-7, 1994.

Brasileiro, B. F.; Grotta-Grempel, R.; Ambrosano, G. M. B. & Passeri, L. A. An *in vitro* evaluation of rigid internal fixation techniques for sagittal split ramus osteotomies: recoil surgery. *J. Oral Maxillofac. Surg., 67(4)*:809-17, 2009.

Dal Pont, G. Retromolar osteotomy for prognathism correction. *Minerva Chir., 14*:1138-41, 1959.

De Oliveira, L. B.; Reis, J. M.; Spin-Neto, R.; Gabrielli, M. A.; Oguz, Y. & Pereira-Filho, V. A. Mechanical evaluation of six techniques for stable fixation of the sagittal split osteotomy after counterclockwise mandibular advancement. *Br. J. Oral Maxillofac. Surg., 54(5)*:573-8, 2016.

Demircan, S.; Uretürk, E. U.; Apaydın, A. & S¸en, S. Fixation methods for mandibular advancement and its effects on temporomandibular joint: a finite element analysis study. *Biomed Res. Int., 2020*:2810763, 2020.

Dias, R. C. M.; Góes, A. M.; Serakides, R.; Ayresa, E.; Oréfice, R. L. Porous biodegradable polyurethane nanocomposites: preparation, characterization, and biocompatibility tests. *Mat. Res., 13(2)*:211-8, 2010.

Epker, B. N. Modifications in the sagittal osteotomy of the mandible. *J. Oral Surg., 35(2)*:157-9, 1977.

Gallo, W. J.; Moss, M.; Gaul, J. V. & Shapiro, D. Modification of sagittal ramus-split osteotomy for retrognathia. *J. Oral Surg., 34(2)*:178-9, 1976.

Hunsuck, E. E. An intraoral sagittal division modified to correct mandibular prognathism. *J. Oral Surg., 26(4)*:250-3, 1968.

Peterson, G. P.; Haug, R. H. & Van Sickels, J. A biomechanical evaluation of bilateral sagittal ramus osteotomy fixation techniques. *J. Oral Maxillofac. Surg., 63(9)*:1317-24, 2005.

Proffit, W. R.; Turvey, T. A. & Phillips, C. Orthognathic surgery: a hierarchy of stability. *Int. J. Adult Orthodon. Orthognath. Surg., 11(3)*:191-204, 1996.

Ribeiro-Junior, P. D.; Magro-Filho, O.; Shastri, K. A. & Papageorge, M. B. Which kind of miniplate to use in mandibular sagittal split osteotomy? An *in vitro* study. *Int. J. Oral Maxillofac. Surg., 41(11)*:1369-73, 2012.

Sato, F. R.; Asprino, L.; Consani, S. & de Moraes, M. Comparative biomechanical and photoelastic evaluation of different fixation techniques of sagittal split ramus osteotomy in mandibular advancement. *J. Oral Maxillofac. Surg., 68(1)*:160-6, 2010.

Stoelinga, P. J. W. & Borstlap, W. A. The attachment of sagittal split osteotomies with miniplates: The versatility of a technique. *J. Oral Maxillofac. Surg., 61(12)*:1471-6, 2003.

Trauner, R. & Obwegeser, H. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. *Oral Surg., 10(7)*:677-89, 1957.

Turvey, T. A. Intraoperative complications of sagittal osteotomy of the mandibular ramus: incidence and management. *J. Oral Maxillofac. Surg., 43 (7)*:504-9, 1985.

Van Sickels, J. E.; Peterson, G. P. & Holms, S. An *in vitro* comparison of a reconstruction system. *J. Oral Maxillofac. Surg., 63(11)*:1620-5, 2005.

Wolford, L. M. & Davis Jr., W. M. The mandibular inferior border split: a modification in the sagittal split osteotomy. *J. Oral Maxillofac. Surg., 48(1)*:92-4, 1990.

Wolford, L. M.; Bennett, M. A. & Rafferty, C. G. Modification sagittal split osteotomy of the mandibular. *Oral Surg. Oral Med. Oral Pathol., 64(2)*:146-55, 1987.

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