UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ODONTOLOGIA DE PIRACICABA

FERNANDO MATHEUS SANTANA TUNEL

AVALIAÇÃO BIOMECÂNICA *IN VITRO* DA FIXAÇÃO INTERNA ESTÁVEL EM OSTEOTOMIA SAGITAL DOS RAMOS MANDIBULARES PARA AVANÇOS COM GIRO ANTI-HORÁRIO USANDO SISTEMAS CONVENCIONAL E LOCKING

IN VITRO BIOMECHANIC EVALUATION OF STABLE INTERNAL FIXATION OF SAGITTAL SPLIT RAMUS OSTEOTOMY AFTER COUNTERCLOCKWISE MANDIBULAR ADVANCEMENT USING CONVENTIONAL AND LOCKING SYSTEMS

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Dissertação apresentada à Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinascomo parte dos requisitos exigidos para a obtenção do título de Mestre em Clínica Odontológica, na Área de Concentração de Cirurgia e Traumatologia Buco- Maxilo-Faciais.

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ORIENTADORA: PROFª DRª LUCIANA ASPRINO

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PROFª. DRª. LUCIANA ASPRINO

PROF. DR. TIBURTINO JOSÉ DE LIMA NETO

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RESUMO

Na cirurgia ortognática, a rotação no sentido anti-horário proporciona melhor permeabilidade das vias aéreas, o fechamento de mordida aberta e melhores resultados estéticos (Bisase, 2009), no entanto, movimentos do plano oclusal são relativamente instáveis, necessitando de maior rigidez do sistema de fixação. A "técnica híbrida", inicialmente proposta por Schwartz e Relle (1996) combina as vantagens da fixação com parafusos bicorticais com a fixação de miniplacas com parafusos monocorticais. Este estudo teve como objetivo comparar a resistência mecânica de métodos de fixação interna estável aplicadas de forma híbrida em osteotomias sagitais da mandíbula para grande avanço no sentido anti-horário com sistemas de fixação convencionais e locking. Trinta amostras padronizadas de poliuretano de três segmentos foram produzidas a partir de uma mandíbula previamente osteotomizada (Nacional Ossos, Jaú, Brasil). As réplicas de mandíbula foram testadas em máquina universal de ensaios de resistência (Instron 4411- Instron Corp, Norwood, MA). Nesta análise biomecânica in vitro todas as amostras foram fixadas pela técnica híbrida, divididas em seis grupos com cinco mandíbulas em cada, de acordo com o material de fixação testado: grupo I – uma miniplaca reta convencional, grupo II – duas miniplacas retas convencionais, grupo III – uma miniplaca dupla convencional, grupo IV – uma miniplaca reta locking, grupo V – duas miniplacas retas locking, grupo VI – uma miniplaca dupla locking. O grupo 1 apresentou a menor resistência mecânica, havendo diferença ($p>0,05$) na carga necessária para deformar as amostras em 3, 5, 7 e 10 mm nos demais grupos. Além disso, a carga necessária para a deformação de 7 mm foi menor no Grupo IV ($p=0,0448$) do que no Grupo VI. A carga necessária para uma deformação de 10 mm no Grupo I não diferiu da exigida no Grupo IV ($p=0,0754$). A análise dos dados (one-way ANOVA) revelou que a resistência mecânica dos grupos avaliados foram proporcionais as forças necessárias ($p<0,05$) de acordo com as deformações registradas. Considerando isso, conclui-se que a utilização de duas placas e/ou o sistema locking proporciona maior resistência à fixação interna estável em osteotomia sagital dos ramos mandibulares quando comparado com a utilização de técnica híbrida com uma única placa do sistema convencional.

Palavras-chave: Fixação Interna de Fraturas. Cirurgia Ortognática. Osteotomia Sagital do Ramo Mandibular.

ABSTRACT

In orthognathic surgery, counterclockwise rotation provides better airway permeability, open bite closure, and better aesthetic results (Bisase, 2009). However, occlusal plane movements are relatively unstable, requiring greater rigidity of the fixation system. The “hybrid technique”, initially proposed by Schwartz and Relle (1996), combines the advantages of bicortical screw fixation with miniplate fixation with monocortical screws. This study aimed to compare the mechanical resistance of stable internal fixation methods applied in a hybrid manner in sagittal osteotomies of the mandible for large counterclockwise advancement with conventional and locking fixation systems. Thirty standardized three-segment polyurethane samples were produced from a previously osteotomized mandible (Nacional Ossos, Jaú, Brazil). The mandible replicas were tested in a universal resistance testing machine (Instron 4411 -Instron Corp, Norwood, MA). In this in vitro biomechanical analysis, all samples were fixed using the hybrid technique and divided into six groups with five jaws in each, according to the fixation material tested: group I – one conventional straight miniplate; group II – two conventional straight miniplates; group III – one conventional double miniplate; group IV – one straightlocking miniplate; group V – two straight locking miniplates; group VI – one double locking miniplate. Group 1 presented the lowest mechanical resistance, with a difference ($p>0.05$) in the load required to deform the samples by 3, 5, 7, and 10 mm in the other groups. Furthermore, the load required for deformation of 7 mm was lower in Group IV ($p=0.0448$) than in Group VI. The load required for deformation of 10 mm in Group I did not differ fromthat required in Group IV ($p=0.0754$). Data analysis (one-way ANOVA) revealed that the mechanical resistance of the evaluated groups was proportional to the necessary forces ($p<0.05$) according to the recorded deformations. Considering this, it is concluded that the useof two plates and/or the locking system provides greater resistance to stable internal fixation in sagittal osteotomy of the mandibular rami when compared to the use of a hybrid technique witha single plate of the conventional system.

Keywords: Internal Fracture Fixation. Orthognathic Surgery. Sagittal Split Ramus Osteotomy

SUMÁRIO

INTRODUÇÃO

Na cirurgia ortognática, a osteotomia sagital dos ramos mandibulares bilateral (OSRM) é amplamente utilizada para corrigir assimetrias e deformidades da mandíbula (Borstlap, 2004). É uma técnica versátil, principalmente por manter amplo contato entre ossegmentos, melhorando a reparação e a estabilidade com a fixação interna. Isso elimina a necessidade de fixação intermaxilar no pós-operatório, reduzindo o risco de aspiração, otimizando a função precoce da articulação temporomandibular, facilitando a higiene bucal e melhorando a qualidade de vida dos pacientes no pós-operatório imediato (Ochs, 2003).

A fixação interna da OSRM geralmente envolve parafusos bicorticais ou miniplacas com parafusos monocorticais. Estudos demonstraram que a fixação com parafusos bicorticais tende a ser mais rígida e menos suscetível a deformações do que a fixação com placas monocorticais (Ozden, 2006; Sato, 2010). No entanto, outros estudos sugeriram que não há diferença significativa entre a força da fixação bicortical e uma miniplaca com parafusos monocorticais (Foley,1992; Tharanon,1998). A rotação no sentido anti-horário proporciona uma melhor permeabilidade das vias aéreas, o fechamento da mordida aberta e também melhores resultados estéticos (Bisase, 2009). No entanto, movimentos do plano oclusal são relativamente instáveis, necessitando de materiais de fixação que proporcionem maior rigidez do sistema.

O deslocamento mais amplo entre os fragmentos ósseos e o maior estresse no sistema de fixação, como consequência do alongamento dos músculos supra-hióideos e infra-hióideos podem estar associados à recidiva, perda do sistema de fixação e falha técnica (Arnett, 1993; Ellis 3rd, 2009). Os parafusos bicorticais apresentam melhores resultados biomecânicos, maior rigidez e menor suscetibilidade à deformação (Sato, 2010). No entanto, o estudo de Al- Moraissi em 2016 sugere que a diferença de força não é clinicamente significativa quando comparada a miniplacas e parafusos monocorticais, que fornecem uma fixação estável e biologicamente aceitável.

Mesmo com menor resistência mecânica, o uso de miniplacas com parafusos monocorticais é amplamente utilizado pelos cirurgiões bucomaxilofaciais devido às suas indicações e vantagens: ausência de necessidade de incisões extraorais para uso de trocarter, reduzindo a possibilidade de lesão nervosa ou vascular; adaptação das placas passivamente ao posicionamento dos segmentos ósseos com pouca torção ao nível dos côndilos; redução na possibilidade de lesão ao nervo alveolar inferior, devido aos parafusos serem instalados monocorticamente sem compressão entre os segmentos ósseos (Ueki et al., 2009; Sato et al., 2012b; Ureturk, 2018).

A associação de miniplacas e parafusos bicorticais, conhecida como "técnica híbrida", inicialmente proposta por Schwartz e Relle (1996) combina as vantagens da fixação com parafusos bicorticais com a fixação de miniplacas com parafusos monocorticais. Os parafusos bicorticais posicionais somados à fixação com miniplaca e parafusos monocorticais aumentam as propriedades mecânicas do sistema de fixação. Em 2017, Hernández-Alfaro et al. realizaram um estudo retrospectivo de dois centros de pesquisa demonstrando a estabilidade a longo prazo da técnica híbrida após OSRM com avanços mandibulares, demonstrando como as características positivas de ambas as técnicas de fixação somam-se, minimizando as negativas.

O padrão de fixação dos parafusos bicorticais apresenta algumas desvantagens, como deslocamento do côndilo na fossa articular e lesão por compressão do nervo alveolar inferior.(Sato et al., 2012b). Estudo conduzido em 2018 por Ureturk, utilizando análise de elementos finitos 3D, demonstrou a fixação apenas com parafusos bicorticais aumenta a quantidade de estresse no côndilo. Por outro lado, as técnicas híbridas mostraram-se menos agressivas aos côndilos. Os autores sugerem que nos pacientes com tendência a disfunções temporomandibulares, o uso de técnicas de fixação com miniplacas pode diminuir as forças ao redor do côndilo.

Para entender melhor a biomecânica da fixação da OSRM e melhorar a fixação, muitas vezes são usados experimentos para quantificar e avaliar, embora o método ideal ainda não tenha sido estabelecido. Poucos estudos de avaliação mecânica da fixação interna do OSRM com um reposicionamento no sentido anti-horário foram realizados. A maioria dos estudos tem como foco o avanço ou recuo mandibular sem rotação (Brasileiro,2009; Brasileiro, 2012).

O objetivo deste estudo é comparar a resistência mecânica de seis métodos de fixação interna híbrida em OSRM para grande avanço com rotação no sentido anti- horário com sistemas de placa e parafusos convencionais e locking.

ARTIGO: IN VITRO BIOMECHANIC EVALUATION OF STABLE INTERNAL FIXATION OF SAGITTAL SPLIT RAMUS OSTEOTOMY AFTER COUNTERCLOCKWISE MANDIBULAR ADVANCEMENT USING CONVENTIONAL AND LOCKING SYSTEMS

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ABSTRACT:

This study aimed to compare the mechanical resistance of stable internal fixation methods applied in a hybrid manner in sagittal osteotomies of the mandible for large counterclockwise advancement with conventional and locking fixation systems. Thirty standardized three- segment polyurethane samples were produced from a previously osteotomized mandible (Nacional Ossos, Jaú, Brazil). The mandible replicas were tested in a universal resistance testing machine (Instron 4411, Norwood, MA). All samples were fixed using the hybrid technique and divided into six groups with five jaws in each: group I – one conventional straight miniplate; group II – two conventional straight miniplates; group III – one conventional double miniplate; group IV – one straight locking miniplate; group V – two straight locking miniplates; group VI – one double locking miniplate. Group I presented the lowest mechanical resistance, with a difference ($p>0.05$) in the load required to deform the samples by 3, 5, 7, and 10 mm. Furthermore, the load required for deformation of 7 mm was lower in Group IV ($p=0.0448$) than in Group VI. The load required for deformation of 10 mmin Group I did not differ from that required in Group IV ($p=0.0754$). Data analysis (one-way ANOVA) revealed that the mechanical resistance of the evaluated groups was proportional to the necessary forces ($p<0.05$). It is concluded that the use of two plates and/or the locking system provides greater resistance to stable internal fixation in sagittal osteotomy of the mandibular rami when compared to the use of a hybrid technique with a single plate of the conventional system.

Keywords: Internal Fracture Fixation. Orthognathic Surgery. Sagittal Split Ramus Osteotomy.

INTRODUCTION

In orthognathic surgery, bilateral sagittal split osteotomy (BSSO) is widely used to correct lower jaw asymmetries and deformities (Borstlap, 2004). This versatile technique maintains broad segment contact, promoting better healing and stability with internal fixation. This eliminates the need for postoperative intermaxillary fixation, reducing aspiration risks, optimizing early temporomandibular joint function, and improving oral hygiene and patients' immediate postoperative quality of life (Ochs, 2003).

Internal fixation of BSSO typically employs bicortical screws or miniplates with monocortical screws. Studies show that bicortical screw fixation is generally more rigid and less prone to deformation than monocortical plate fixation (Ozden, 2006; Sato, 2010). However, some studies suggest no significant strength difference between bicortical and miniplate monocortical screw fixation (Foley, 1992; Tharanon, 1998). Counterclockwise rotation enhances airway permeability, closes open bites, and yields better esthetic outcomes (Bisase, 2009). However, these occlusal plane movements are relatively unstable, necessitating fixation materials for increased bone stability.

Wider displacement between bone fragments and increased stress on the fixation system due to suprahyoid and infrahyoid muscle stretching can lead to relapse, hardware loss, and technical failure (Arnett, 1993; Ellis 3rd, 2009). Bicortical screws offer superior biomechanical results, higher rigidity, and lower susceptibility to deformation (Sato, 2010). Nevertheless, some studies suggest that the strength difference is not clinically significant compared to miniplates and monocortical screws, which offer stable and biologically acceptable fixation (Al-Moraissi, 2016).

Joss and Vassalli (2009) conducted a systematic review noting a higher incidence of skeletal long-term relapse in patients treated with bicortical screws compared to those treated with miniplates and monocortical screws.

In cases of major mandibular advancements with extensive bone fragment distances, the use of bicortical screws alone is limited (Stoelinga, 2003). Asymmetric movements or cases with teeth in the osteotomy site may also preclude bicortical screw placement due to inadequate bone thickness, especially in the lingual area of the distal osteotomy segment or when there's a risk of condylar displacement (Sato et al., 2012a).

Despite lower mechanical resistance, miniplates with monocortical screws are widely used due to their indications and advantages. These include the absence of extraoral incisions, reducing the risk of nerve or vascular injury. Plate bending accommodates step and positional changes of bone segments with minimal torsion at the condyle level and decreasing risk of inferior alveolar nerve injury (Ueki et al., 2009; Sato et al., 2012b; Ureturk, 2018).

The association of mini-plates and bicortical screws, known as the “hybrid technique”, which was initially proposed by Schwartz and Relle (1996) combines the advantages of bicortical screw fixation with fixation of miniplates with monocortical screws. The position bicortical screws added to fixation with a miniplate and monocortical screws increase the mechanical properties of the fixation system.

This technique of fixation has been shown to provide good clinical results (Hernández-Alfaro, 2017). Hernández-Alfaro et al. (2017) in a retrospective 2-center study show the long- term stability of the hybrid technique after BSSO with mandibular advancements, demonstrating how the positive features of both fixation techniques add up, inhibiting the negative ones. The bicortical screws fixation pattern has some disadvantages such as displacement of the condyle in the fossa and nerve compression damage. (Sato et al.,2012b). Ureturk, (2018) using 3D finite element analysis demonstrate that the use of only bicortical screws fixation patterns increase the stress amount on the condyle. On the other hand, hybrid techniques showed less aggressive to condyles. The authors suggest that the patients with a tendency toward temporomandibular disorders, the use of miniplate fixation techniques may decrease the forces around the condyle.

The decision to place a screw in the superior border of the mandibular ramus in the hybrid technique is based on research demonstrating that in an anatomic study of human cadaveric mandibles, the superior border of the ramus has the thickest buccal and lingual cortical bone (Obeid and Lindquist, 1991). Also, retromolar region has excellent accessibility via an intraoral approach (Schwimmer et al., 1994).

Currently, the use of locking miniplate/screw system helps to minimize displacementof the segments of bone and improve primary and secondary stability and to prevent misfit and excessive compression on cortical bone, which can result in osteolysis and a hardware failure (Ribeiro-Júnior, 2010; Klein, 2017).

Even showing different results, some single sagittal plates seem to be a reliable option with good biomechanical results to enhance bone stability, especially in locking systems (Pereira Filho, 2013; Klein, 2017).

To better understand sagittal split osteotomy biomechanics and improve fixation, experiments are used to quantify and evaluate it. However, the ideal method remains undetermined. Few studies have evaluated internal fixation of BSSO for counterclockwise rotations, with most focusing on mandibular advancements or setbacks without rotation (Brasileiro, 2009; Brasileiro, 2012).

This study aims to compare the biomechanical stability of six hybrid internal fixation methods in BSSO for significant counterclockwise advancements, utilizing both conventional and locking monocortical plate/screw systems.

MATERIAL AND METHODS

Thirty polyurethane replicas of a mandible were used to obtain standardization of the osteotomy, the simulation surgery was performed in one mandible replica using the modification described by (Epker, 1977). Thirty, three-segment standardized polyurethane samples (FIGURE 1) was produced from that previous osteotomized mandible (Nacional Ossos, Jaú, Brazil) for mechanical tests.

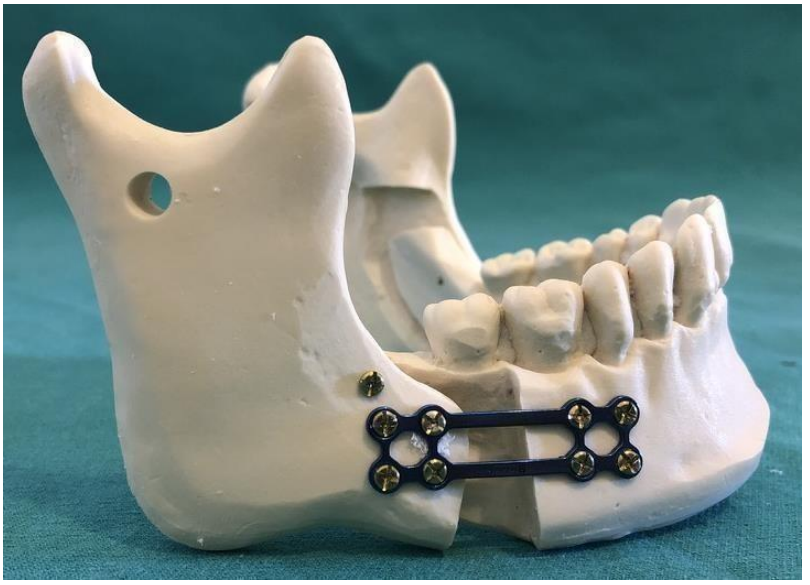
FIGURE 1- Three-segment standardized polyurethane samples, osteotomized using the modification described by Epker (1977).

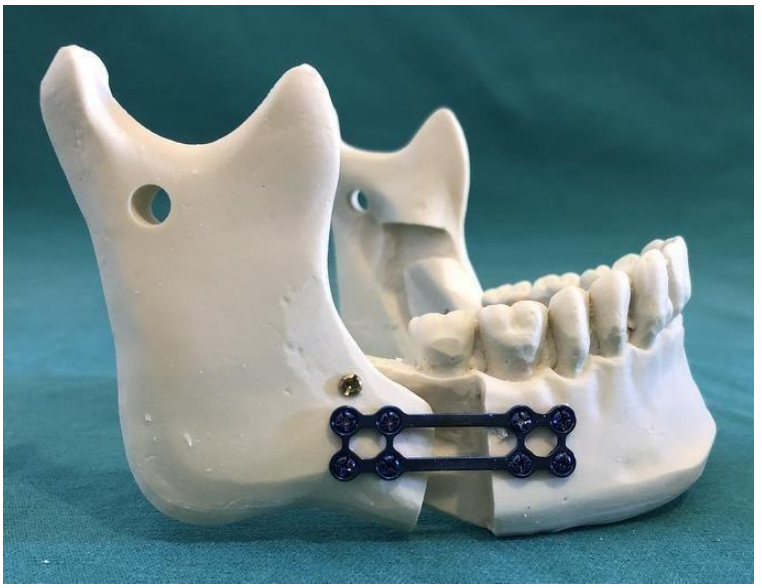
Synthetic bones have a density similar to human jaws allowing for standardization of specimens and homogeneity of the samples (Cristofolini, 2000). The density of the polyurethane mandible replicas was 40 PCF (pounds per cubic feet), as per the specification established for rigid polyurethane materials used as standard material for testing orthopedic devices and instruments (ASTM F1839) (ASTM, 2008). According to Nackaerts et al., 2007 the bone mineral density (BMD) of the mandible ranges from 0.528 to 0.820 g/cm ^{3} and averages 0.661 g/cm^3. Based on this data, artificial bone with a density of 40 PCF (0.64g/cm^3) was used to simulate the BMD of the mandible.

The experimental specimens were divided into six groups with 5 mandibles in each, according to the fixation method tested. The groups are described in Table 1.

Table 1- Distribution of groups.

Group	Fixation Method
I	One four-hole (two proximal and two distal) standard miniplate (10mm bridge) fixed withstandard screws measuring 2.0 × 6.0 mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 
II	Two four-hole (two proximal and two distal) standard miniplates (10 mm bridge in the tension zone and 14 mm bridge in the compression zone) fixed with standard screws measuring 2.0 × 6.0 mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 

III	One eight-hole (four proximal and four distal) standard "sagittal advancement grid miniplate" fixed with conventional screws measuring 2.0×6.0mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 
IV	One four-hole (two proximal and two distal) locking miniplate (10mm bridge) fixed with locking screws measuring 2.0 × 6.0 mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 

V	Two four-hole (two proximal and two distal) locking miniplates (10 mm bridge in the tension zone and 14 mm bridge in the compression zone) fixed withlocking screws measuring 2.0 × 6.0 mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 
VI	One eight-hole (four proximal and four distal) locking "sagittal advancement grid miniplate" fixed with locking screws measuring 2.0×6.0mm + 1 position bicortical conventional screw measuring 2.0 x 12 mm 

The repositioning simulates a mandibular advancement with counterclockwise rotation of the mandible. Acrylic guides were used to standardize the repositioning of the segments, which established 8 mm of advancement at the upper border and 12 mm at the lower border of the distal segment. Other acrylic guides defined the placement of miniplates and screws in the distinct groups (FIGURE 2 and 3)

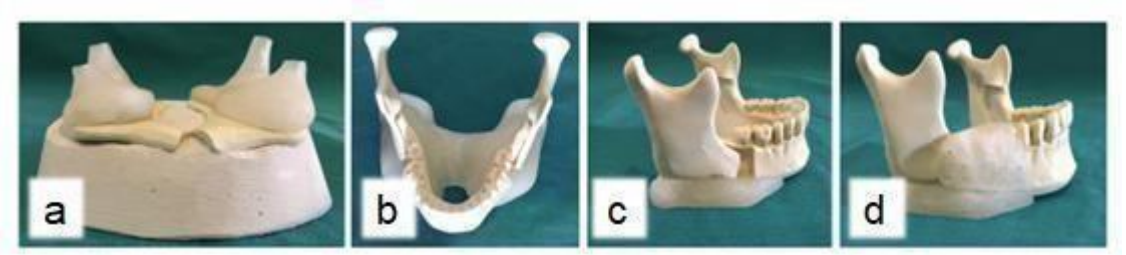


FIGURE 2- Acrylic guides were made through 3d printing to help the operator in each phase of standardization. a) Guide for standardizing holes; b/c) Guide for mandibular advancement; d) Guide for placing platesand screws.

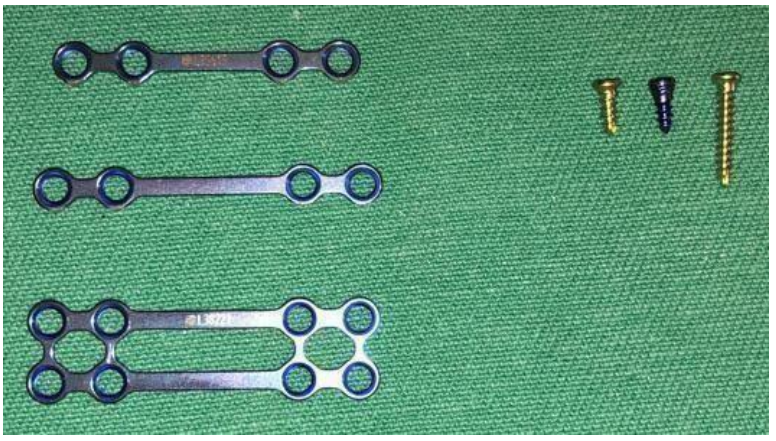


FIGURE 3- miniplates and screws: Four-hole 10mm bridge plate, 4-hole 14mm bridge plate and 8-hole 14mm bridge double plate. 6mm conventional screw (yellow), 6mm locking screw (blue)and 12mm conventional screw (yellow).

The mandible replicas were tested in a universal testing machine for compressive strength (Instron 4411-Instron Corp, Norwood,MA), using a method modified from Nieblerová et al. 2012, using a similar custom-made loading unit and polyurethane full- mandible replicas. The loading unit (FIGURE 4) consists of an aluminum horizontal plate, which served as the base for six vertical aluminum carrier bars.

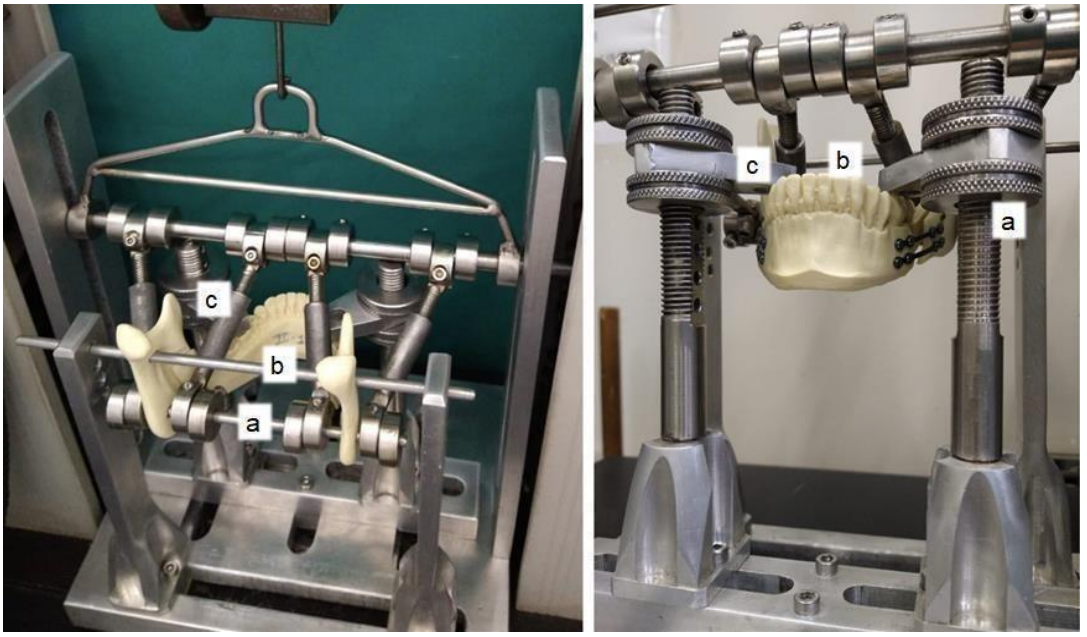


FIGURE 4- a) Two anterior vertical pillars support a stainless-steel shaft (10 mm), which is connected by four supports to another shaft (5 mm) respectively bilaterally connected to the two mandibular angles that represent the forces of the masticatory muscles (pterygomasseteric sling); b) Simulating the temporomandibular joints, an axis (5 mm) passes through the mandibular condyles (made with acrylic guide), being supported by two posterior vertical pillars; c) The resistance to the tooth support fragment was obtained by the anterior adjustable bars. as an occlusal stop at the position of the firstmolar (the center of occlusion force vectors).

The two lateral bars hold a 10mm diameter stainless steel forged axis that is connected by 4 arms to other 5mm diameter stainless steel forged axis (Point A) connecting bilaterally both mandibular angles representing the forces of chewing muscles (pterygomasseteric sling). The two posterior bars hold a horizontal 5mm diameter stainless steel forged axis running through the mandibular condyles, simulating the TMJs (Point B). The anterior bars were usedto hold horizontal adjustable aluminum arms to provide resistance to the teeth-bearing fragment (Point C), as an occlusal stop in the position of the first molar (the center of occlusion forces vectors). An increasing traction load was applied to the samples until there was 3, 5, 7 and 10 mm of displacement and respective force value was registered. A single operator did all laboratory testing.

Statistical Analysis

Descriptive and comparative statistical analyses were previously submitted to Bartlett test for homoscedasticity and Kolmogorov-Smirnov tests for normality. Subsequently, the results were submitted to the two-way ANOVA or one-way ANOVA tests, both of which used the Holm-Sidak test for multiple comparisons. The significance level of 5% was used for all tests, using the GraphPad Prism 8.0 software.

RESULTS

The figure 5 indicates the force required to deform the part according to the studied groups.

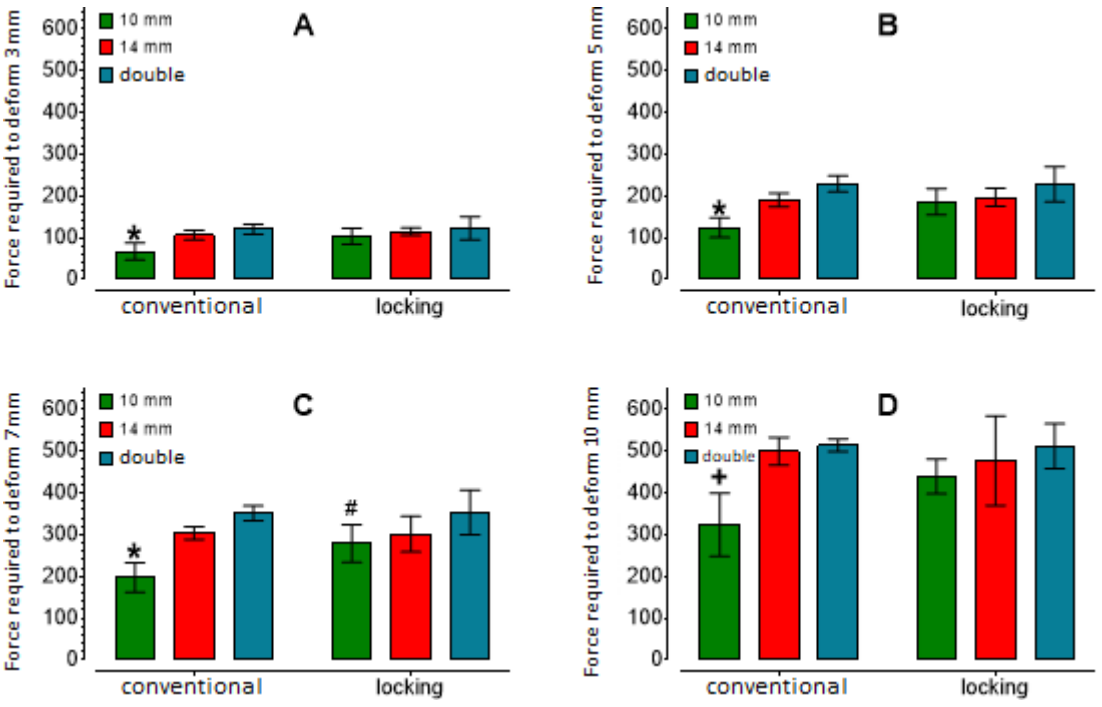


Figura 5. Force (N)- mean ± standard deviation - required to deform the plates by 3 mm (A), 5 mm (B), 7 mm (C) and 10 mm (D), depending on the observed groups. * - statistically significant differencesbetween group I (conventional screw with 10 mm plate) and the other groups; # - statistically significant differences between group IV (locking screw with 10 mm plate) and group VI (locking screw with double plate); + - statistically significant differences between group I (conventional screwwith 10 mm plate) and the other groups, except group IV (locking screw with 10 mm plate).

It was possible to observe that was no influence ($p>0.05$) of the types of screws or plates on the force required to deform the piece by 3, 5, 7 and 10 mm, except for group 1,which presented the lowest force when compared to the others. Additionally, the force required for the 7 mm deformation was lower for Group IV ($p=0.0448$) than for Group VI.The force required for a 10 mm deformation in Group I did not differ from that required in Group IV ($p=0.0754$).

The differences between the forces required for the different deformations (3, 5, 7 and 10 mm) are shown in Figure 6. Data analysis (one-way ANOVA) revealed that the mechanical resistance of the evaluated groups was proportional to the necessary forces ($p<0.05$) according to the recorded deformations.

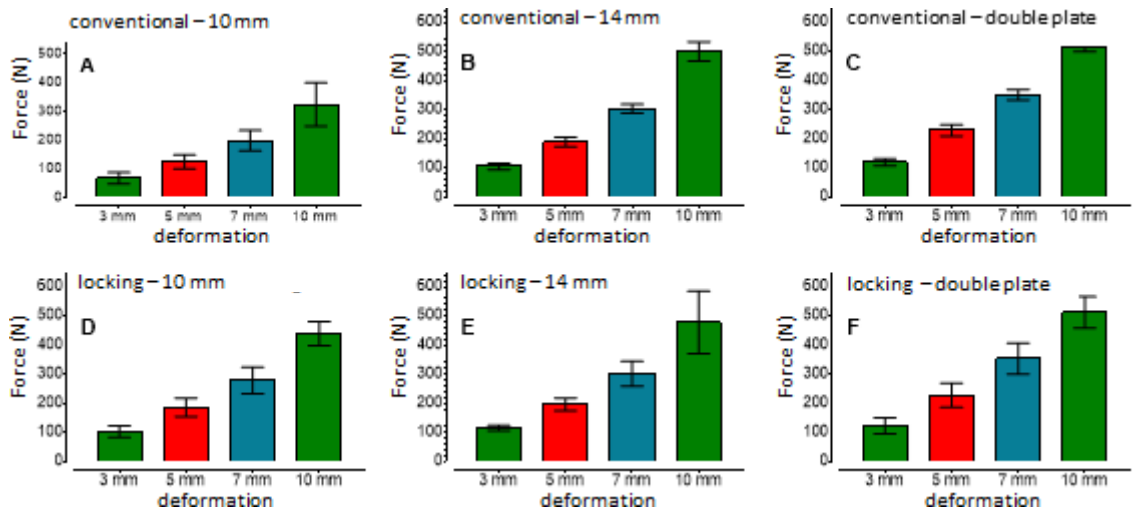


Figure 6. Force (N) - mean ± standard deviation - required to deform the pieces by 3 mm, 5 mm, 7 mm and 10 mm, for Groups I (A), II (B), III (C), IV (D), V (E) and VI (F). For all groups, the force (N) required for deformation was significantly greater as deformation size increased (3 < 5 < 7 < 10 mm).

DISCUSSION

The use of a custom-made loading unit and replicas of a complete polyurethane jaw was adapted by Nieblerová et al. 2012. The main modification was the adaptation of the complete mandible to the support, as well as the creation of a diagonal axis to resemble the insertion of the pterygoid muscles.

Regarding the loading unit adapted from Nieblerová et al., 2012, there was an attempt by the authors to bring the study as close as possible to the process of both mastication of the food bolus and stabilization through the masticatory muscles, through modifications both inthe support of the prototype as in the force vectors. Therefore, a prototype was created in which there were supports both for maintaining the unit as a wholeand for generating force in various vectors. The authors did not find any work in the literature with an equal prototype, especially with the stabilization proposal used.

According to the study by Carvalho et al., 2021 through a similar study, it was concluded that the hybrid fixation technique presented better performance in relation to thestudied groups. In the present study, the objective was to compare and evaluate whether there would be an advantage in using the locking or conventional system with the hybrid fixation technique, as well as whether the different fixation materials would have any statistical difference between them. In the present study, the data showed that there was significant difference between using the locking system or the conventional one in conjunction with the hybrid technique, as well as there was difference between the types of miniplates used.

As in the work by Carvalho et al., 2021,there was no fracture and loss of material or prototypes, only the deformation of the miniplates used with maintenance of the integrity of the fixation was observed.

The use of the locking system, as well as the hybrid technique according to Ozden et al., 2006 and Sato et al., 2010, can generate a high overload in the condylar region. According to the result found by the authors, it can be inferred that it is much safer, from a biological point ofview, to use the conventional system in the hybrid technique than the locking system.

The main limitations of the present work still lie in the absence of a standard structure based on the literature for biomechanical evaluation between works in a standardized way,since in the literature there are several different structures, as well as the absence of standardization in the prototypes. The authors believe that the idealized support has advantages, but still needs improvements, such as a mobile structure to facilitate movementand insertion for prototype assembly, portability and, ideally, a way to evaluate the transverse movement of the food bolus and not only in the areas of molars and incisors.

Another important factor, in the authors' conception, reflecting on future studies is the evaluation of the hybrid technique using conventional and locking system in comparison with conventional fixation also using locking and conventional system, in this way we could distinguish whether the stability achieved in the present work would really be statistically different or not independent of the material and quantity/type of material used in relation to fixation by conventional technique. After all, both the biological and financial factorsassociated with the use of a smaller amount of fixation components are quite valid and mustbe sought by the surgeon.

Finally, the authors advocate that the use of the hybrid system should be carried out considering associated biological factors, as well as the type and range of movement. Therisk of condylar overload should never be overlooked. The hybrid technique may be an option, primarily being used with a conventional fixation system, but future studies are needed to broadly measure the biological effectiveness in relation to the conventional sagittal split ramus osteotomy fixation technique.

COMPETING INTERESTS

None of the researchers or the institutional promoters declare any interest or bias on the results of this research.

CONCLUSION

It is concluded that the use of two plates and/or the locking system provides greater resistance to stable internal fixation in sagittal osteotomy of the mandibular ramus when compared to the use of a hybrid technique with a single plate of the conventionalsystem.

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CONCLUSÃO

Vale ressaltar que a escolha do método de fixação, quantidade e tipo de placas e parafusos deve levar em consideração fatores intrínsecos associados como carga mastigatória, padrão das osteotomias, assim como fatores extrínsecos como disponibilidade do material, custo do material, sendo necessário uma avaliação individualizada para cada quadro clínico e paciente.

Conclui-se que a utilização de duas placas e/ou o sistema locking proporciona maior resistência à fixação interna estável em osteotomia sagital dos ramos mandibulares quando comparado com a utilização de técnica híbrida com uma única placa do sistema convencional.

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ANEXOS

Anexo 1 - Relatório de similaridade

AVALIAÇÃO BIOMECÂNICA IN VITRO DA FIXAÇÃO INTERNA ESTÁVEL EM OSTEOTOMIA SAGITAL DOS RAMOS MANDIBULARES PARA AVANÇOS COM GIRO ANTI-HORÁRIO USANDO SISTEMAS CONVENCIONAL E LOCKING

RELATÓRIO DE ORIGINALIDADE

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3	G.B.G. Klein, G.C.B. Mendes, P.D. Ribeiro Junior, A. Viswanath, M. Papageorge. "Biomechanical evaluation of different osteosynthesis methods after mandibular sagittal split osteotomy in major advancements", International Journal of Oral and Maxillofacial Surgery, 2017 Publicação	2%
4	Leandro Benetti De Oliveira, Jose Mauricio Nunes Reis, Rubens Spin-Neto, Marisa Aparecida Cabrini Gabrielli et al. "Mechanical evaluation of six techniques for stable fixation of the sagittal split osteotomy after counterclockwise mandibular advancement", British Journal of Oral and Maxillofacial Surgery, 2016 Publicação	2%

Anexo 2 – Comprovante de Submissão do Artigo

Journal of Craniofacial Surgery

IN VITRO BIOMECHANIC EVALUATION OF STABLE INTERNAL FIXATION OF SAGITTAL SPLIT RAMUS OSTEOTOMY AFTER COUNTERCLOCKWISE MANDIBULAR ADVANCEMENT USING CONVENTIONAL AND LOCKING SYSTEMS

--Manuscript Draft--

Manuscript Number:	
Full Title:	IN VITRO BIOMECHANIC EVALUATION OF STABLE INTERNAL FIXATION OF SAGITTAL SPLIT RAMUS OSTEOTOMY AFTER COUNTERCLOCKWISE MANDIBULAR ADVANCEMENT USING CONVENTIONAL AND LOCKING SYSTEMS
Short Title:	IN VITRO BIOMECHANIC EVALUATION OF STABLE INTERNAL FIXATION OF SAGITTAL SPLIT RAMUS OSTEOTOMY AFTER COUNTERCLOCKWISE MANDIBULAR ADVANCEMENT
Article Type:	Original Article
Keywords:	InternalFracture Fixation; Orthognathic Surgery; Sagittal Split Ramus Osteotomy
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Manuscript Region of Origin:	BRAZIL
Author Comments:	I am pleased to submit our manuscript. We believe that our manuscript will contribute valuable insights to the ongoing discourse in the field of oral surgery and offer practical solutions for improving patient care. Thank you for considering our submission. We look forward to your feedback
Suggested Reviewers:	
Abstract:	This study aimed to compare the mechanical resistance of stable internal fixation methods applied in a hybrid manner in sagittal osteotomies of the mandible for large counterclockwise advancement with conventional and locking fixation systems. Thirty standardized three- segment polyurethane samples were produced from a previously osteotomized mandible (Nacional Ossos, Jaú, Brazil). The mandible replicas were tested in a universal resistance testing machine (Instron 4411, Norwood, MA). All samples were fixed using the hybrid technique and divided into six groups with five jaws in each: group I – one conventional straight miniplate; group II – two conventional straight miniplates; group III – one conventional double miniplate; group IV – one straight locking miniplate; group V – two straight locking miniplates; group VI – one double locking miniplate. Group I presented the lowest mechanical resistance, with a difference ($p>0.05$) in the load required to deform the samples by 3, 5, 7, and 10 mm. Furthermore, the load required for deformation of 7 mm was lower in Group IV ($p=0.0448$) than in Group VI. The load required for deformation of 10 mm in Group I did not differ from that required in Group IV ($p=0.0754$). Data analysis (one-way ANOVA) revealed that the mechanical resistance of the evaluated groups was proportional to the necessary forces ($p<0.05$). It is concluded that the use of two plates and/or the locking system provides greater resistance to stable internal fixation in sagittal osteotomy of the mandibular rami when compared to the use of a hybrid technique with a single plate of the conventional system.