THALITA REGINA VIEIRA E OLIVEIRA

FIXAÇÃO DAS FRATURAS DA SÍNFISE MANDIBULAR:

AVALIAÇÃO MECÂNICA EM MANDÍBULAS DE POLIURETANO

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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Ciências da Cirurgia – área de concentração: Fisiopatologia Cirúrgica, da Faculdade de Ciências Médicas da Universidade Estadual de Campinas para obtenção de título de Mestre em Ciências.

ORIENTADOR: *Prof. Dr. Luis Augusto Passeri*

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Dedicatória

Dedico este trabalho aos meus queridos pais, Reinaldo e Sônia, à minha querida irmã, Bruna, e ao meu querido marido, Renato.

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Epígrafe

"O começo da sabedoria é encontrado na dúvida; duvidando começamos a questionar, e procurando podemos achar a verdade." (Pierre Abelard)

Resumo

Este estudo teve como objetivo avaliar, comparativamente, o comportamento mecânico de quatro diferentes métodos de fixação de fraturas de sínfise mandibular. Quarenta réplicas de mandíbulas, confeccionadas em poliuretano, foram utilizadas para o ensaio experimental. As amostras foram divididas em quatro grupos com diferentes métodos de fixação: uma miniplaca, duas miniplacas dispostas paralelamente, duas miniplacas dispostas perpendicularmente e dois parafusos inseridos pela técnica *lag screw,* todos do sistema de 2,0mm. Cada grupo foi submetido ao teste mecânico em uma máquina de ensaio universal, Instron 4411 (Instron Corp, Norwood, MA), recebendo uma carga vertical linear na região do primeiro molar inferior esquerdo. Os valores das cargas foram mensuradas nos deslocamentos de 1 mm, 3 mm, 5 mm e 10 mm. Os resultados foram comparados por meio da Análise de Variância ($p<0.05$) e do Teste de Tukey. O método que utilizou uma miniplaca mostrou o menor valor de resistência, quando comparado aos outros métodos de fixação. A técnica *lag screw* apresentou resistência estatisticamente maior que as duas placas paralelas, em todos os deslocamentos. As duas miniplacas perpendiculares mostraram menor resistência que a técnica *lag screw*, quando o deslocamento atingiu 1 e 3 mm e resistência estatisticamente semelhante nos deslocamentos de 5 e 10 mm. Entretanto, as duas miniplacas perpendiculares não apresentaram diferença estatisticamente significante em relação ao grupo das duas miniplacas paralelas. Desta forma, a técnica *lag screw* apresentou melhor comportamento mecânico para a fixação das fraturas de sínfise mandibular, que os demais métodos avaliados neste estudo.

Abstract

The aim of this study was to evaluate comparatively the mechanical behavior of 4 different internal fixation methods for mandibular symphysis fractures. Forty polyurethane mandible replicas were used. They were divided in to four groups with different fixation methods: 1 miniplate, 2 parallel miniplates, 2 perpendicular miniplates, 2 lag screws, all of them of a 2.0mm system. Each group was subjected to linear vertical loading at the molar region by an Instron 4411 servohydraulic mechanical testing unit (Instron Corp, Norwood, MA). Load values were measured at 1 mm, 3 mm, 5 mm, and 10 mm of displacement. Means and standard derivations were compared for statistical significance using a variance analysis ($p < .05$) and compared by the Tukey test. The one 2.0-mm miniplate showed the lowest load scores when compared with other fixation methods. The two 2.0-mm lag screw technique showed higher resistance statistically significant in comparison with two 2.0-mm parallel miniplates for all displacements. The two 2.0-mm perpedicular miniplates showed lower resistance than two 2.0-mm lag screw technique when the displacement was 1 and 3 mm, and statiscally similar results at 5 and 10 mm of displacement. However, the two 2.0-mm perpendicular miniplates group was not statiscally different from the two 2.0-mm parallel miniplates group. The lag screw technique showed better mechanical behavior for fixation of symphyseal fractures than the other methods when subjected to linear vertical loading at the molar region.

Sumário

1. Introdução Geral

Fraturas faciais estão relacionadas a injúrias funcionais e estéticas, que podem comprometer a saúde geral do indivíduo, bem como seu bem estar social. A população mais acometida pelos traumas de face é composta por adultos jovens, do gênero masculino, sendo geralmente causados por acidentes automobilísticos, mas também por quedas, agressões físicas, e acidentes esportivos, entre outros (1,2,3,4). Desta forma, podem acontecer isoladamente ou em associação a outras fraturas, como nos casos de politraumatismos (5). Além disso, geralmente estão associadas a abrasões e lacerações da face, bem como a injúrias neurológicas (6).

Segundo o levantamento publicado por Down *et al*. (5), as injúrias faciais ocorrem em proporções significantes nos pacientes politraumatizados. No levantamento publicado pelos autores, das 1088 vítimas incluídas no estudo,15% apresentavam traumas faciais associados à politraumatismos, sendo que a mandíbula foi a região facial mais acometida, seguida pela região zigomática(5).

Estudos indicaram que as regiões faciais com maior taxa de fraturas foram o nariz, o zigoma e a mandíbula (6,7). O levantamento epidemiológico de Haug *et al*. (6), na população norte-americana, encontrou uma proporção entre as fraturas mandibular, zigomática e maxilar de 6:2:1 (6). Na população japonesa, estudos mostraram uma alta incidência de fratura mandibular dentre as fraturas faciais, variando de 56,9 a 68,6% (2, 8).

Na população brasileira, uma análise epidemiológica realizada em São Paulo evidenciou, também, a prevalência das fraturas mandibulares em relação as demais fraturas da região maxilofacial. O estudo mostrou que 44,2%, das 1399 fraturas diagnosticadas, aconteceram na mandíbula, enquanto o complexo zigomático foi o local de 32,5% das fraturas (4).

Ainda é importante ressaltar que a mandíbula pode ser acometida com mais de uma região fraturada, sendo comum a associação entre fraturas condilares e da região de sínfise (9). O estudo de Passeri *et al*. (10) observou que os 352 pacientes avaliados apresentavam 589 fraturas mandibulares, sendo que a maioria deles (49%) apresentou duas fraturas mandibulares concomitantemente (10).

As regiões mandibulares mais frequentemente envolvidas nas fraturas são o colo do côndilo, a sínfise, o corpo e o ângulo (3,4). A etiologia das fraturas mandibulares é muito variada, e os levantamentos epidemiológicos das causas e incidências das fraturas variam com a região geográfica, condição cultural e socioeconômica (11) e a idade (12).

O estudo de Fridrich *et al*. (13) encontrou, dentre as fraturas mandibulares, 26% de fraturas condilares e subcondilares, seguida de fraturas de sínfise e parassínfise em 23,6% dos casos. Quando a causa do trauma estava relacionada a acidente automobilístico, a região condilar (29,8%) e a sínfise (25,9%) foram os locais mais acometidos. Nas fraturas causadas por acidentes motociclísticos, a sínfise foi a mais atingida, sendo o local de 29,7% das fraturas mandibulares.

Recentes levantamentos epidemiológicos realizados no Brasil, mostraram que a sínfise é uma das regiões mais acometidas nas fraturas da mandíbula (4,14). Brasileiro e Passeri (4) encontraram maior acometimento da região do côndilo mandibular, com 15,8%, seguida das fraturas da sínfise, com 13,8%, dentre as fraturas que acometem a região maxilofacial. Enquanto que Martini *et al*. (14), observaram uma ocorrência da fratura da sínfise mandibular de 27,5%, precedida somente pela região do corpo mandibular, com 30,9% dos casos. Em ambos os estudos, o principal fator etiológico foi acidente de trânsito, envolvendo, na maioria dos casos, indivíduos do gênero masculino, com média de 30 anos de idade.

Desta forma, em vista da alta ocorrência de fraturas da sínfise mandibular, torna-se importante a avaliação dos métodos de fixação destas fraturas. Estes métodos de fixação são baseados no princípio de tratamento geral das fraturas, que é a restauração da forma e função, através de uma adequada reparação óssea. Isto inclui redução e estabilização adequada da fratura (15), evitando infecção, má união e interposição de tecido mole (16).

Há mais de duas décadas, a redução aberta com fixação interna estável, por meio de placas e parafusos de titânio, tem sido o tratamento de escolha para as fraturas mandibulares (16). Sua grande vantagem é permitir estabilidade e mobilização precoce (17).

Com o intuito de minimizar as forças de flexão e torção, presentes na região anterior da mandíbula, muitos estudos sugerem que a fratura da sínfise deve ser tratada com a utilização de duas placas. Estudos com modelos tridimensionais comprovam que, quando submetida à carga nos pontos de mordida da região dos molares, a maior força de torção ocorre na região sinfisária, além de tensão na borda inferior e compressão na região superior (18).

A importância da localização das placas é comprovada em um estudo de Trivellato e Passeri (19). Utilizando costelas bovinas, os autores encontraram melhor resistência, nas simulações de fraturas, fixadas com placas de titânio, do sistema 2,0mm, quando dispostas paralelamente, de tal forma que uma delas ocupasse a zona de tração (processo alveolar) e outra a zona de compressão (borda inferior da mandíbula), neutralizando as forças de torção. Além disso, o estudo mostrou que melhores resultados são obtidos quando a placa da zona de tensão é fixada com parafusos monocorticais e a placa da zona de compressão com parafusos bicorticais.

As fraturas transversais lineares da sínfise mandibular são tradicionalmente fixadas por duas placas do sistema 2,0 mm, ambas com quatro furos, dois de cada lado da linha de fratura, sendo que uma delas ocupa a zona de

tensão, e a outra, a zona de compressão, de forma que permanecem paralelas entre si (9). Embora esta técnica seja a mais utilizada, poucos estudos existem na literatura sobre a seleção do número e do posicionamento das placas, sendo que esta escolha é feita empiricamente (20).

Em 2006, Kimura *et al*. (20) apresentaram resultados satisfatórios com a disposição perpendicular entre duas placas de quatro furos e quatro parafusos monocorticais, para fixação das fraturas da sínfise, utilizando modelos de elemento finito. Uma das placas era colocada na borda superior e outra na superfície inferior da mandíbula. A separação dos fragmentos da fratura, com a fixação disposta desta forma, foi menor que no modelo fixado com as placas paralelas, embora uma diferença estatística tenha sido encontrada apenas para a fixação com uma única placa (20).

Outra alternativa de fixação, para as fraturas da sínfise mandibular, é a técnica que utiliza parafusos tipo *lag screw*. O conceito da osteossíntese pela técnica *lag screw* exige que a compressão da fratura seja conseguida pela passagem do parafuso, primeiro, através de uma perfuração com o diâmetro externo deste, portanto, sem engajamento, e a seguir por uma perfuração com o diâmetro interno, com engajamento, promovendo tração dos cotos da fratura. A rotação no local da fratura, ao redor de um parafuso, é um fenômeno clínico reconhecido e, por esta razão, um segundo parafuso é requerido, para que isto possa ser prevenido (21,22).

Estes métodos de fixação das fraturas da sínfise podem ser realizados via acesso intra-oral, ou através de alguma laceração proveniente do trauma. O acesso intra-oral é preconizado devido à vantagem de avaliar constantemente a oclusão dentária durante a cirurgia, e, além disso, proporciona benefício ao paciente, uma vez que a cicatriz fica oculta dentro da boca. A abordagem é rápida e simples, com poucas complicações. A lesão do nervo mentual e o mau posicionamento labial podem ser minimizados pela utilização adequada da técnica (23).

Independente do método de fixação, a estabilidade é um fator essencial para o sucesso do tratamento das fraturas de sínfise. Essa estabilidade pode ser avaliada por meio de testes mecânicos. O objetivo destes testes é simular as forças às quais as fraturas mandibulares são submetidas, verificando a resistência do material de fixação e o comportamento da região fraturada. O ponto de incidência da força é importante, e é escolhido de acordo com as cargas geradas durante os movimentos funcionais da mandíbula, como a mastigação, tentando aproximar-se o máximo possível da condição real.

Desta forma, os estudos *in vitro* permitem avaliar o comportamento das técnicas e dos sistemas de fixação, e podem sugerir novos métodos para aumentar a estabilidade na região tratada, por meio da fixação interna estável na prática cirúrgica.

Assim, considerando a alta incidência das fraturas da sínfise mandibular, e que existem poucos estudos que avaliam qual o método mais adequado para o seu tratamento, mais estudos são necessários a fim de avaliar a eficácia dos tipos de fixação.

2. Objetivo

O objetivo deste estudo é avaliar, comparativamente, o comportamento de quatro métodos de fixação de fraturas de sínfise mandibular, em modelos de poliuretano.

3. Capítulo (artigo aceito para publicação em Novembro de 2010 no Journal of Oral and Maxillofacial Surgery)

Mechanical evaluation of different techniques for symphysis fracture fixation – an *in vitro* polyurethane mandible study.

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Abstract

Purpose: The aim of this study was to make a comparative evaluation of the mechanical behavior of 4 different internal fixation systems for mandibular symphysis fractures.

Materials and Methods: Forty polyurethane mandible replicas (Nacional, Jaú, SP, Brazil) were used. They were divided into four groups of different fixation methods: Group (1P) one 2.0-mm miniplate; Group (2PLL) two 2.0-mm parallel miniplates; Group (2PERP) two 2.0-mm perpendicular miniplates; Group (LST) two 2.0-mm lag screw technique. Each group was subjected to linear vertical loading in the molar region in an Instron 4411 servohydraulic mechanical testing unit (Instron Corp, Norwood, MA). The load resistance values were measured at load application displacements of 1 mm, 3 mm, 5 mm, and 10 mm. Means and standard deviations were compared as regards statistical significance, using the analysis of variance ($p < .05$) and compared by Tukey's test.

Results: Group (1P) one 2.0-mm miniplate showed the lowest peak load scores when compared with other fixation methods. Group (LST) two 2.0-mm lag screw technique showed statistically significant higher resistance than two 2.0-mm parallel miniplates for all displacements. Group (2PERP) two 2.0-mm perpendicular miniplates showed lower resistance than two 2.0-mm lag screw technique when the displacement was 1 and 3 mm, and statically significant similarity at displacement of 5 and 10 mm. However, Group (2PERP) two 2.0-mm perpendicular miniplates showed no statistically significant differences when compared with Group (2PLL) two 2.0-mm parallel miniplates.

Conclusions: The lag screw technique showed better mechanical behavior for symphysis fracture fixation than the other systems when the fixation methods were subjected to linear vertical loading in the molar region.

Mandible fractures are among the most common injuries that affect the facial skeleton[1, 2]. The treatment of mandibular fractures is based on the restoration of form and function, seeking suitable bone repair. The basic requirement for optimal function is adequate anatomic shape and stiffness (resistance to deformation under load). After a fracture the transmission of compressive forces can still take place across a fracture plane. The bone remains able to take over the compressive tasks, and the implant must substitute for the lost tensile properties[3]. For over two decades, open reduction with stable internal fixation has been the treatment of choice for mandibular fractures. Correct implant placement is determined by the location and type of fracture and its relationship with the tension zones[3].

The fixation methods can be evaluated empirically by mechanical tests using universal testing machines. Samples made with material that has a modulus of elasticity similar to that of bone are duly prepared to simulate fracture fixation. Thus, it is possible to observe the trend of the fixation system behavior when exposed to load.

The aim of this study was to make a comparative evaluation of the performance of four fixation methods for mandibular symphysis fractures, when subjected to vertical linear force application. For this purpose, four methods of fixation were chosen: only one four-hole miniplate fixed with four 6-mm screws; two miniplates arranged parallel to each other with four holes in each, fixed with 6-mm screws in the tension zone, and 12-mm screws in the compression zone; two perpendicular miniplates with four holes in each fixed with 6-mm screws; and the lag screw technique, which used two 20-mm screws. Thus it was possible to measure the load resistance values of each fixation method at the different programmed load displacements, and evaluate the stiffness. Stiffness is the parameter used to describe the force needed to achieve a certain deformation of a structure, and can be summarized as follows: “Stiffness” = “load” divided by

"deformation", where "load" can be considered to be forces, moments, and stresses; and "deformation" as being displacement, strain, and curvature [4].

Materials and Methods

For this study, 40 replicas of human mandibles made of rigid polyurethane resin Nacional[tm] (Jaú-SP, Brazil), with properly standardized measures were used. The fixing material used consisted of 60 straight miniplates, with 4 holes, made of II commercially pure titanium, 160 monocortical screws 6-mm long, 40 bicortical screws 12-mm long, and 20 screws 20-mm long, all of the 2.0-mm system (MDT, Rio Claro, SP, Brazil).

SAMPLE PREPARATION

All polyurethane replicas of human mandibles were evenly split along the mandibular midline between the mandibular central incisors to the base of the mandible, simulating a symphysis fracture. To do this, a diamond disc (Diaflex-F, Horice, Germany), coupled to a handpiece and an acrylic resin guide to standardize the cuts were used. The samples were divided into four groups of 10 mandibles each, and fixed with four different techniques, according to the experimental groups (Table 1). Guides made of acrylic resin were used to standardize the perforations.

Table 1. Groups

Group	Fixation Technique
1P	1 miniplate on the top edge + four 6-mm screws
2PLL	2 parallel miniplates + four 6-mm screws long and four 12-mm screws
PERP	2 perpendicular miniplates + eight 6-mm screws
LST	2 screws: 20-mm *lag screws*

The first group (1P) was fixed with a 4-hole miniplate and four 6-mm screws in the region of the upper edge of the symphysis (Figure 1). The second group (2PLL) received two 4-hole miniplate arranged parallel to each other, one on the top edge and the other on the bottom edge, the first being fixed with four 6-mm screws , and the other with four 12-mm screws (Figure 2). The third group (2PERP) was set by fixing two miniplates perpendicular to each other, each with 4-holes held by four 6-mm screws, one on the top edge and the other at the base of the mandible (Figure 3). The fourth group (LST) was fixed with 2 20-mm screws by the lag screw technique (Figure 4).

Figure 1: Fixation of 1P group, a miniplate in the tension zone. Fracture reduction with the relief of acrylic devices.

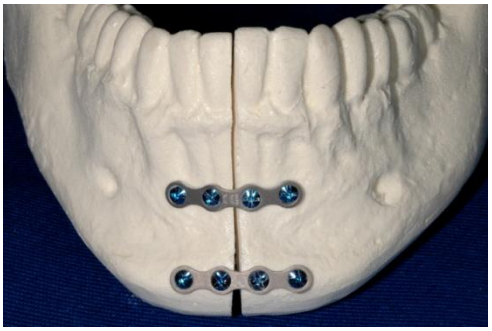

Figure 2: Fixation of 2PLL group, parallel miniplates, one in the tension zone and the other in the compression zone.

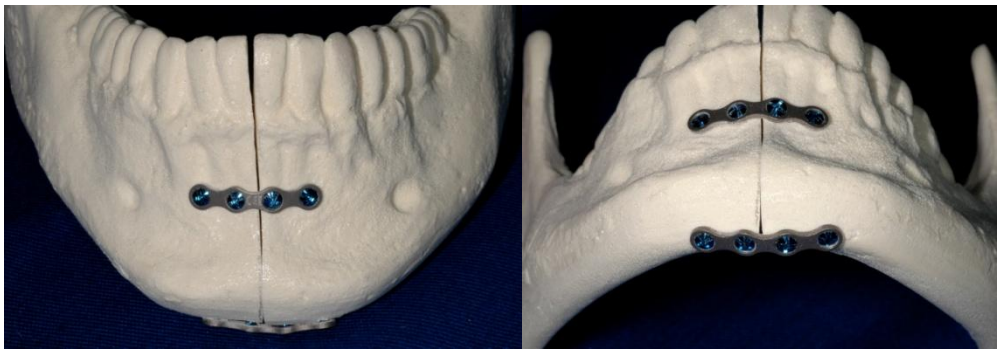

Figure 3: Fixation of 2PERP group, perpendicular miniplates. (a) front view, (b) inferior-superior view.

Figure 4: Fixation of LST group, lag screw technique, (a) front view, (b) side view.

LOADING TEST

To perform the biomechanical test the polyurethane mandibles properly prepared with their respective fixation methods, were placed in a metal bracket that allowed the samples to be correctly positioned to perform the mechanical test (Figure 5). Thus, the mandibles were placed with the occlusal plane perpendicular to the force application device. Next, the samples were subjected to linear vertical force application in the region of mandibular left first molar.

The biomechanical test was performed in a universal testing machine (Instron Universal 4411). The load was applied at a fixed point, by a device attached to a load cell with a force of 50 kg (kgf). The machine was programmed to apply a progressive load at a displacement speed of 10 mm / min.

The resistance values were obtained in kilogram-force, when the displacement reached 1 mm, 3 mm, 5 mm and 10 mm, for each sample only once. These values were assessed by Tukey's test after the analysis of variance to detect differences between the mean values. The SAS 9.01 program was used with a significance level of 5% for all tests. Exponential best-fit tendency curves were constructed to compare experimental values of stiffness among groups according to the load/displacement relationship during vertical loading (Figure 6).

Figure 5: Sample positioned for mechanical testing in the Instron 4411 with the relief of metal support, (a) Instron 4411 (b) approximate view of the sample position.

Results

The values obtained after statistical analysis are presented in Table 2. The results showed a statistically significant difference between the groups with only one fixed miniplate in the upper region of the mandibular symphysis (1P) when compared with the other groups. Of all the groups, Group 1P showed the lowest resistance value for stiffness when subjected to mechanical testing.

Samples fixed with the lag screw technique (LST) showed higher resistance for stiffness in the mechanical test and proved to be statistically better than the group with fixed parallel miniplates (2PLL) in all measured displacements. The group fixed with the perpendicularly arranged miniplates (2PERP) showed lower values than those obtained in the LST group, fixed with the lag screw technique, in the displacements of 1 and 3 mm, and statistically similar in the 5 and 10 mm displacement, although not differing statistically from 2PLL, when the samples were fixed with the miniplates parallel to each other.

Table 2. Summary of Results

	Vertical Loading Value			
Group	**1 mm**	**3 mm**	**5 mm**	**10 mm**
1P (n=7)	0.10±0.03c	0.25±0.06c	0.39±0.12c	0.88±0.35c
2PLL (n=9)	0.19±0.05ab	0.49±0.13b	0.78±0.21b	1.59±0.38b
2PERP (n=9)	0.18±0.05b	0.52±0.22b	0.95±0.28ab	1.79±0.42ab
LST (n=9)	0.26±0.08a	0.78±0.15[a]	1.19±0.23a	2.32±0.41a

Different letters in vertical columns indicate statistically significant difference between groups (ANOVA/Tukey test , $p<0.05$)

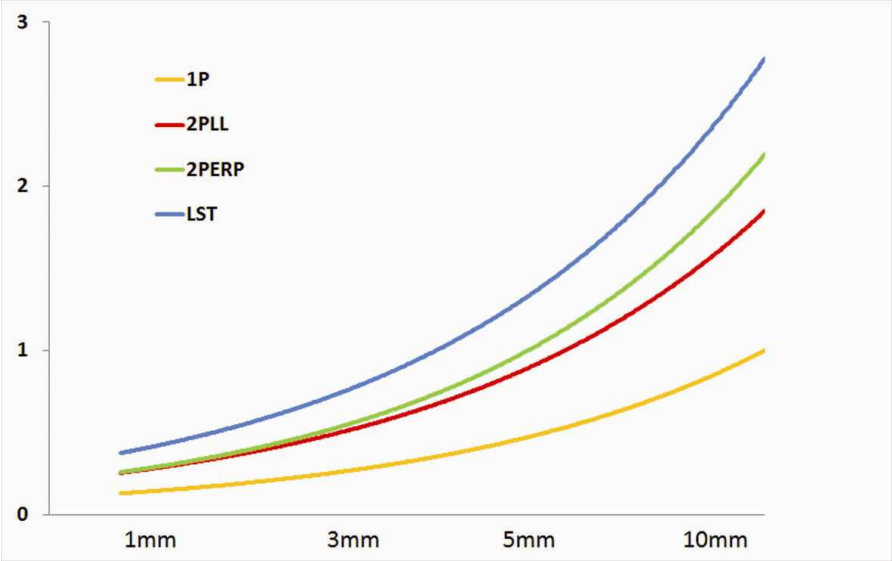

Figure 6: Vertical loading best-fit exponential tendency curves

Discussion

Although there are many scientific researches that have studied the behavior of fixation methods in the maxillofacial region when subjected to mechanical tests, few are related to fixation of fractures of the mandibular symphysis. These fractures have a high prevalence rate, as found in recent epidemiological surveys conducted in Brazil, which found percentages of 13.8% and 27.5% for symphysis fractures [5,6]. Thus, the study of treatment forms that allow an adequate fixation is of great importance.

Mandibular symphysis fractures present a behavior differing from those of the mandibular body and angle. According to the study of Tams et al (1996) the symphysis region presents one of the highest negative bending moments in comparison with the other mandibular regions, generating stress at the inferior edge and compression at the superior edge. There are practically no shear forces in this region of the mandible, and torsion moments are present in the symphysis with greater intensity than in the other mandibular regions. The study points out that the bending moments are 1.5 times greater than the torsion moments in the anterior region of the mandible [7].

Based on these considerations, the mechanical behavior of the fixations could be better evaluated. In this study it was observed that fixation with one miniplate in the compression zone of the symphysis, without acting on its tension zone, was insufficient to ensure the stability of fixation in a linear fracture of the mandibular symphysis, as it had the lowest resistance values in the mechanical test, being statistically lower than all groups in all displacements. The miniplates arranged parallel to one another, occupying the area of compression and the tension zone, showed superior results in comparison with a single miniplate. However, this technique showed statistically lower results than the lag-screw technique, which proved to be statistically superior to the use of parallel miniplates in all displacement measurements. Nevertheless, modification of the technique, using miniplates arranged perpendicularly, showed statistically similar results to

those obtained with the lag-screw technique, specifically in displacements of 5 and 10 mm. Thus, the perpendicular miniplate system appears to provide satisfactory stability, showing higher resistance values. As in the case of the parallel plates, the perpendicular plates and the lag screw technique acted in the tension zone of the mandibular symphysis, emphasizing the need for fixation in the tension zone for better system stability. In Figure 6, it can be observed that these fixation methods were shown to be superior with regard to the values for stiffness. That is to say that it required a greater amount of force to displace the samples with fixation in the tension zone. Therefore, it was verified that these system may to contribute to stability as they act in an endeavor to ameliorate the negative bending moments that occur in the symphysis region irrespective of the occlusal point (bite point) at which force is applied on the mandible[7].

The fixation methods were chosen based on the most widely used techniques for the fixation of symphysis fractures. Linear transverse fractures of the mandibular symphysis are traditionally fixed by 2 miniplates of 2.0-mm system, both with four holes, two on each side of the fracture line, one of which occupies the area of tension, and the other, the compression zone, as was used in the 2PLL Group[8]. Although this technique is the most widely used, there are few studies in the literature about the selection of the number and positioning of the miniplates, and this choice is made empirically[9]. Further studies with regard to providing other miniplates, positioning and screws may suggest the most appropriate techniques, with greater stability to promote fracture healing.

Kimura et al. (2006) obtained satisfactory results with the arrangement of two four-hole miniplates perpendicular to the fracture, with four monocortical screws in each miniplate for symphysis fracture fixation. In this study, this technique showed the best results in the analysis using finite element models. The perpendicular fixation provided less separation of fracture fragments when compared with parallel fixation, however, statistical difference was found in the group with only one miniplate. In the perpendicular miniplates, screws are able to

transmit the stress of masticatory load to the miniplate, due to its long axis being parallel to the force. Thus, when the miniplate is firmly fixed, stress can be better supported, favoring stability. The results of the present study, as in the study of Kimura et al. (2006), also showed a better behavior of the perpendicular miniplates when compared with the parallel miniplates. Although statistical difference was found only in comparison with Group 1P fixed with only one miniplate, the perpendicular miniplate group showed statistically similar resistance values to those presented by the lag-screw technique group, especially at larger displacements of 5 mm and 10 mm[9].

The Group in which the lag-screw technique was used, showed the best results. The highest values of resistance to the mechanical test were obtained by samples in this group, which presented a statistical difference when compared with the one and two parallel miniplate groups at all displacements evaluated. In comparison with the perpendicular miniplate group values, a statistical superiority was observed when the Lag screw technique was used at 1 and 3 mm displacement. As was the case in this study, Madsen et al (2008), found better results for the lag screw technique. Among other parameters, the study evaluated the yield load rate when the force was applied in the molar region in polyurethane mandibles. The 2.4-mm lag screw technique proved to be the stiffest and the strongest, since it required a greater load than the other fixation systems evaluated, namely: two 2.0-mm locking miniplates, two 2.0-mm nonlocking miniplates, one 2.4-mm dynamic-compression plate, and arch bars with lingual splint, for permanent deformation [10].

This outcome may be related to the concept of osteosynthesis with lag-screws, since this procedure leads to traction of the stumps, promoting a compression and fixation of the fracture[11]. The type of compression generated by a lag screw is referred to as static interfragmental compression. It is static because it does not change significantly with load[3].

However, it is important to note that the laboratory measurements, such as those used in the present study, are only auxiliary methods to determine the potential of fixation systems, however, they should be cautiously extrapolated to the clinical behavior of real systems, since the substrate can generate interference.

Various types of substrates for the fabrication of the samples have been used in several studies, and at all times, those with characteristics more similar to those of bone were sought. The modulus of elasticity is an important factor for the choice of material. In this study, samples were prepared using polyurethane mandibles, with a modulus of approximately 0.07 GPa. This value falls within the considerations of Cordey (2000), when he said that the elastic modulus of human bone ranges from less than 0.1 GPa (bone marrow) to 2 GPa (cortical bone)[12].

However, during sample preparation it was possible to identify some differences between drilling bone and polyurethane, and the value of a sample in the group fixed with the lag-screw technique dropped. This sample had inadequate fixation since it did not promote fracture alignment and contact between the mandibles. This failure was possibly due to difficulty in adapting the technique to this substrate, since it requires engagement of the screw in only one fracture of the stumps, leaving the screw without intimate contact with the structure around the first segment, which has the same outside diameter as the screw.

Other samples showed faults while they were being produced, displaying visibly inadequate simulated fracture reduction, or improper positioning of the sample on the metal support. In the first case, namely polyurethane, it was necessary to adapt the performance of the technique to a substrate that differed from bone. In the second case, the steel screws, which set the polyurethane mandible in the condyle and coronoid region of the metal bracket on the right side of the sample, did not promote adequate stability to enable a correct mechanical test to be performed.

Thus, within the limitations of this study, it could be concluded that fixation of a linear fracture of the symphysis is more resistant to mechanical testing when fixed with the lag-screw technique; this type of fracture presents very little resistance when mechanically fixed with only one miniplate; the miniplates in a parallel or perpendicular arrangement showed similar mechanical resistance, while the perpendicular arrangement showed slight superiority in comparison with the parallel arrangement.

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4. Conclusão Geral

Com base nos resultados obtidos neste estudo, pode-se concluir que as fraturas de sínfise mandibular apresentam maior resistência mecânica quando fixadas com a técnica *lag screw*, quando comparada às demais fixações, sendo que as fixações com placas paralelas e perpendiculares apresentaram resistência mecânica semelhante entre si, com discreta superioridade do modelo perpendicular em relação às placas dispostas paralelamente. O uso de uma única placa apresentou os menores valores de resistência mecânica.

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6. Anexos

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