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EPIDEMIOLOGY OF MANDIBULAR FRACTURES AND MECHANICAL EVALUATION OF FIXATION METHODS OF ANGLE FRACTURES IN POLYURETHANE MANDIBLES

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Faculdade de Ciências Médicas

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Orientador: Prof. Dr. Luis Augusto Passeri

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Resumo

Este estudo teve como objetivo avaliar as características epidemiológicas de casos envolvendo fraturas mandibulares e o comportamento mecânico de quatro diferentes métodos de fixação de fraturas de ângulo mandibular. Foi realizado um levantamento epidemiológico sobre os casos de fraturas de mandíbula tratados pela Área de Cirurgia Plástica do Hospital das Clínicas da Universidade Estadual de Campinas (Unicamp). Foram analisados os prontuários de 119 pacientes tratados entre janeiro de 2006 e dezembro de 2011. As fraturas identificadas afetaram principalmente pacientes jovens do gênero masculino. Os acidentes de trânsito causaram o maior número de fraturas, sendo os acidentes de motocicleta a causa mais comum. As regiões mandibulares mais envolvidas foram a parassínfise e o ângulo. O tratamento cirúrgico foi aplicado na grande maioria dos casos. Complicações ocorreram em 36 pacientes (30,2%). As complicações no ângulo mandibular representaram 27% dos casos. A gravidade do trauma e a pouca colaboração dos pacientes foram fatores que contribuíram para o desenvolvimento de complicações pós-operatórias.

Para a avaliação mecânica foram utilizadas quarenta réplicas de mandíbulas confeccionadas em poliuretano. As amostras foram divididas em quatro grupos com diferentes métodos de fixação: uma miniplaca, duas miniplacas dispostas paralelamente, uma miniplaca grade de 4 furos e uma miniplaca grade de 8 furos, todos do sistema de 2,0mm. Os grupos foram submetidos ao teste mecânico em uma máquina de ensaio universal, Instron 4411 (Instron Corp, Norwood, MA), recebendo uma carga vertical linear na região do incisivo e do primeiro molar. A técnica de duas placas paralelas apresentou resistência estatisticamente maior que todos os outros métodos de fixação. Entretanto, as placas grade de 4 furos não apresentaram diferença estatisticamente significante em relação ao grupo de uma miniplaca. As placas grade de 8 furos apresentaram os menores valores de resistência. Desta forma, a técnica de duas placas apresentou melhor comportamento mecânico para a fixação de fraturas de ângulo mandibular.

Abstract

The objectives of this study were evaluate the epidemiological characteristics of cases involving mandibular fractures and to evaluate the mechanical behavior of four different methods of fixation of fractures of the mandibular angle. An epidemiological survey on cases of mandibular fractures treated by the Department of Plastic Surgery, at the Clinical Hospital of University of Campinas, was performed. The medical records of 119 patients treated between January 2006 and December 2011 were analyzed. The fractures mainly affected young male patients. Road traffic accidents caused the largest number of fractures, being the motorcycle accidents the most common cause. The most affected regions were the mandibular angle and parasymphysis. Surgical treatment was applied in most cases. Complications occurred in 36 patients (30.2 %). Complications in mandibular angle accounted for 27 % of cases. The severity of the trauma and uncooperative patients were factors that contributed to the development of postoperative complications.

To the mechanical evaluation, forty mandible replicas made of polyurethane were used. The samples were divided into four groups with different fixation methods: one miniplate, two parallel miniplates, a 3D miniplates with 4 holes and a 3D miniplate with 8 holes, all of them of a 2.0mm system. Each group was subjected to linear vertical loading at the incisal and molar region by an Instron 4411 mechanical testing unit (Instron Corp, Norwood, MA). The technique of two parallel miniplates showed statistically greater resistance than all other fixation methods. No statistically significant difference was observed in 3D miniplates with 4 holes in relation to the group of one miniplate. The 3DPP group showed lower values of strength. Thus, the technique of two miniplates showed better mechanical behavior for the fixation of the mandibular angle fractures.

Sumário

1. INTRODUÇÃO.

Os traumatismos do complexo maxilofacial representam, pela sua elevada incidência, um dos mais importantes problemas de saúde pública no mundo. Estes estão frequentemente associados a lesões funcionais e alterações estéticas, que podem comprometer a saúde geral do indivíduo, bem como seu bem estar social (1).

A população mais acometida pelos traumas de face é composta principalmente por adultos jovens, do gênero masculino, tendo como principais causas os acidentes automobilísticos, agressões físicas, quedas e acidentes esportivos, entre outros (2,3,4,5,6). Entretanto, as características epidemiológicas do trauma facial podem variar de acordo com o ambiente, gênero, idade, condição sócio-econômica e mecanismo do trauma (7).

Levantamentos epidemiológicos realizados no Brasil e em outros países evidenciam uma alta prevalência das fraturas mandibulares quando comparadas às demais fraturas faciais (1, 3, 4, 8). Quanto à localização das fraturas mandibulares, a região de ângulo é uma das mais freqüentemente afetadas. Estas fraturas têm uma prevalência elevada, ocorrendo entre 11% e 42% dos casos (9). Os acidentes automobilísticos, as agressões físicas e as quedas de própria altura representam os principais fatores etiológicos (10). Características anatômicas e biomecânicas, próprias do ângulo mandibular, assim como os altos índices de complicações pós-operatórias, fazem de seu tratamento um verdadeiro desafio para os cirurgiões (9,11).

Historicamente, o tratamento das fraturas faciais passou por diversas modalidades terapêuticas. A evolução destes métodos foi motivada pela busca constante de melhores resultados clínicos, maior previsibilidade de resultados, diminuição da morbidade resultante do trauma, maior conforto do paciente durante seu período de restabelecimento pós-trauma e diminuição do custo total do tratamento (12).

As técnicas fechadas de tratamento como bandagens, dispositivos de fixação externa, splints, bloqueio maxilomandibular (BMM), entre outros, embora muito engenhosas, tinham uma característica em comum: não conseguiam prover uma redução e imobilização adequada dos segmentos mandibulares fraturados (13). Como desvantagens absolutas dos tratamentos fechados, ou conservadores, podemos apontar que o paciente deve permanecer de 4 até 6 semanas sob BMM. Períodos mais prolongados (6 semanas) são necessários em fraturas cominutivas.

Passeri *et al.* (14) avaliaram as complicações em pacientes tratados por meio de fixação não rígida das fraturas de ângulo mandibular. Os autores concluíram que o método de tratamento utilizado apresentou um alto índice de complicações (17%, sendo as infecções a totalidade dos casos), atribuindo isso à técnica empregada e às características da população tratada.

A compreensão dos princípios biomecânicos, o desenvolvimento de novos materiais, instrumentos e técnicas cirúrgicas aperfeiçoaram o atendimento e melhoraram os resultados dos pacientes com trauma de face. Em particular, a introdução da fixação por meio de miniplacas de titânio gerou uma verdadeira revolução no tratamento das fraturas mandibulares.

Embora atualmente exista um consenso sobre a necessidade de redução aberta e fixação interna estável das fraturas de ângulo mandibular, ainda existe controvérsia sobre o melhor sistema de fixação ou a técnica que deve ser utilizada. Assim, diferentes técnicas de fixação têm sido descritas e extensamente reportadas na literatura, apresentando resultados amplamente variáveis e controversos.

Champy *et al.* (15) foram os primeiros a aplicar placas de menor rigidez no tratamento de fraturas mandibulares, preconizando a instalação de uma placa convencional, do sistema de 2,0mm, no bordo superior do ângulo mandibular (linha obliqua). Esta técnica, conhecida como a técnica de Champy, é um procedimento cirúrgico rápido, simples e realizado mediante acesso intra-bucal. Estudos clínicos posteriores confirmaram a sua efetividade (16,17) e, ainda hoje, é

a técnica preferida por muitos cirurgiões experientes (18). No entanto, mesmo com bons resultados, há relato de complicações, como mordida aberta no lado fraturado e infecção no pós-operatório (19).

Com o objetivo de conseguir uma maior estabilidade da fratura e reduzir as complicações associadas, há recomendação do uso de duas placas no tratamento de fraturas de ângulo mandibular. Schierle *et al.* (16) realizaram um estudo biomecânico comparando o uso de uma e duas placas para a fixação de fraturas de ângulo. Demonstraram que os segmentos fixados com uma placa apresentaram um acentuado deslocamento na base mandibular ao longo da linha de fratura, sendo menos estáveis que aqueles fixados com duas placas.

Mas o uso de duas placas tem sido reportado com resultados clínicos bastante diferentes na literatura. Levy *et al*. (20) realizaram um estudo retrospectivo em pacientes afetados por fratura de ângulo, tratados por meio de uma ou duas miniplacas de sistema 2,0mm, associadas ou não com BMM. A fixação com duas placas sem BMM teve o melhor comportamento clinico.

Ellis & Sinn (21) estudaram 65 pacientes com fraturas de ângulo mandibular não-cominutas tratadas com redução aberta, reduzidas e fixadas com duas placas de compressão dinâmica do sistema 2.0mm. Os autores observaram que 21 (32%) pacientes necessitaram se submeter a uma segunda intervenção cirúrgica, para remoção das placas. Áreas de sequestros ósseos foram encontradas na região da fratura durante o procedimento cirúrgico subseqüente. Segundo os autores essa necrose óssea foi provavelmente acarretada pela compressão interfragmentária excessiva do material de fixação.

Ellis & Walker (22) avaliaram o tratamento de 69 fraturas de ângulo tratadas com duas miniplacas não compressivas de sistema 2,0mm. Os autores observaram que 28% dos casos apresentaram complicações, dentre as quais, em 17 casos foram realizados procedimento de drenagem e em 16 casos foram removidas as fixações. Dentre os casos de reintervenção, apenas 5 pacientes

necessitaram de nova fixação das fraturas. Os autores consideraram a técnica de fácil execução, porém com índices de complicações inaceitavelmente altos.

Schierle *et al.* (16) analisaram pacientes com fraturas do ângulo mandibular tratados com 1 e 2 miniplacas do sistema de 2,0mm, sem a utilização de BMM no período pós-operatório. Os autores não encontraram diferenças significativas em relação às complicações pós-operatórias entre os grupos.

Mais recentemente, o uso de placas grade para fixação tem sido sugerido como alternativa de tratamento. O design desta miniplaca, um sistema de 2 placas reforçadas mediante suportes perpendiculares que as interconectam, favorece a sua maleabilidade e estabilidade em três dimensões, proporcionando teoricamente um aumento da resistência às forças torcionais (23-25).

O primeiro estudo mecânico utilizando miniplacas grade foi descrito por Farmand (26). O autor descreve que essas placas, embora de pouca espessura, são tão estáveis quanto às placas convencionais de sistema 2,0mm. De outro lado, Kalfarentzos *et al*. (25) avaliaram placas grade e as compararam com os métodos de fixação convencionais usando uma ou duas placas. Os autores reportaram uma ótima resistência destes sistemas quando comparado com os métodos de fixação convencionais.

O desempenho clinico das placas grade em fraturas de ângulo mandibular foi avaliada por Feledy *et al*. (23). Neste estudo, as placas grade demonstraram maior estabilidade e resistência quando comparados a sistemas convencionais de fixação com 2 miniplacas do sistema 2,0mm. Posteriormente, Zix *et al.* (27) realizaram uma avaliação, retrospectiva, de 20 pacientes que foram submetidos a redução cruenta e fixação interna de fraturas, usando unicamente miniplacas grade para osteossíntese. Os autores concluíram o estudo afirmando que as placas grade eram adequadas para fixação de fraturas simples do ângulo mandibular, sendo uma alternativa aos sistemas de fixação convencionais. No entanto, o sistema pode ser contra-indicado para fraturas que apresentem insuficiente contato ósseo entre os fragmentos.

Mesmo com a descrição destas excelentes características mecânicas e clínicas, as controvérsias sobre qual seria o método de fixação ideal continuaram. Isto resultou em um crescente interesse por estudos mecânicos. Estes estudos podem avaliar um fator essencial para o sucesso das fraturas de ângulo: a estabilidade. Isto é possível simulando, por meio de ensaios mecânicos, as forças às quais as fraturas mandibulares são submetidas (28). Os dados obtidos podem servir como parâmetros indicativos do comportamento das técnicas e dos materiais testados, antes de serem empregados em humanos.

Embora existam muitas pesquisas baseadas em testes mecânicos que têm estudado o comportamento dos métodos de fixação convencionais, poucos estudos têm avaliado e comparado a resistência e o comportamento mecânico das miniplacas grade nas fixações de fraturas de ângulo mandibular. De fato, poucos cirurgiões tem preferência pelo uso das placas grade (18).

Considerando a alta incidência das fraturas de ângulo mandibular, os altos índices de complicações associadas, e a grande controvérsia ainda existente sobre o método mais adequado para o seu tratamento, torna-se importante a realização de novos estudos, com a finalidade de avaliar a eficácia de diferentes tipos de osteossíntese utilizados.

2. OBJETIVOS

Avaliar características epidemiológicas, métodos de tratamento e as complicações de casos envolvendo fraturas mandibulares e mais especificamente, do ângulo.

Realizar uma avaliação comparativa, *in vitro*, da resistência mecânica à flexão de métodos utilizados na fixação interna estável de fraturas de ângulo, em mandíbulas de poliuretano, por meio de testes de carregamento.

3. CAPÍTULOS

Capítulo I (artigo aceito para publicação no Journal of Craniofacial Surgery)

ETIOLOGY, TREATMENT AND COMPLICATIONS OF MANDIBULAR FRACTURES: A SIX-YEAR RETROSPECTIVE STUDY

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Abstract

The objective of this retrospective study was to evaluate some epidemiological characteristics, surgical treatment methods, and complications of cases involving mandibular fractures. Records from 119 patients treated for mandibular fractures between January 2006 and December 2011, were analyzed.

We find mandibular fractures mostly affect Caucasian (72.2%) men (80.7%). The mean age of the patients was 28.1 years old. Road traffic accidents (RTA) caused

the most fractures (49.5%), followed by physical violence, including gunshot wounds (21%). Motorcycle accidents were the most common cause of RTA (76.2%). The most affected mandibular regions were the parasymphysis (26.9%) and the mandible angle (25.1%). Both surgical and non-surgical treatments were applied (90.4 and 9.6%, respectively). The most common surgical approach was the intraoral (64.9%), using the 2.0-mm fixation system (88.0%). Complications, such as postoperative infections, malocclusion and paresthesia occurred in 36 patients (30.2%).

This research revealed interesting features about the etiology of mandibular fractures that were mostly associated with RTA. Severity of the trauma and noncompliance of the patients were factors that contributed to the development of postoperative complications.

Keywords: Mandible, mandibular fractures, trauma, surgical treatment, epidemiology.

Introduction

Because of their high incidence, injuries to the maxillofacial complex are a major public health problem worldwide. The epidemiological characteristics of these lesions may vary depending on factors such as environment, gender, age, socioeconomic status and mechanism of injury [1].

Analysis of existing literature reveals that the mandible is one of the most affected bones in facial fractures, with a frequency of 36 to 70% [2]. This high rate of fractures can be explained by the unique characteristics of the mandible such as mobility and limited bone support when compared to other facial bones [3].

Increased understanding of biomechanical principles, improvement of materials, instruments, and surgical techniques have improved treatment outcomes of mandibular fractures.[3] Although there is current consensus on the need for open reduction and stable internal fixation of mandibular fractures, there is still controversy over the best fixation system or technique that should be used [4-6].

The aim of this study is to review cases of mandibular fractures to identify patient gender, race, and age; the safety device used; the etiology of trauma; and their treatment methods and associated complications.

Methodology

This research was approved by the Ethical Committee for Human Research, School of Medical Sciences, State University of Campinas (Unicamp) Sao Paulo-Brazil (Project N^0 83897- 2012). The sample was selected from medical records of facial trauma patients treated at the Unicamp Hospital. An electronic spreadsheet of medical records was generated to collect data concerning patient gender, race, and age; etiology of trauma; safety device usage at time of accident; treatment; and complications. Facial trauma was sorted by etiology: road traffic accidents (RTA) involving cars, motorcycles, bicycles, and pedestrians; falls; physical aggression (such as fights, assaults and gunshot wounds) and work accidents. Mandibular fractures were classified according to the fracture location: condylar, coronoid process, parasymphysis, symphysis, ramus, angle and body.

All patients were treated by senior residents of the Plastic Surgery Area, Department of Surgery, School of Medical Sciences, Unicamp. Fixation of mandibular fractures was performed using 1.5-mm, 2.0-mm or 2.4-mm fixation systems. Maxillo mandibular fixation (MMF) was used only in the intraoperative period.

Computerized tomography scans, as well as anteroposterior, lateral-oblique, submental-vertex, and Towne radiographs of the mandible were used to diagnose the fracture and establish a treatment plan. Complications such as suture dehiscence, malocclusion, infection, nonunion, loosed rigid internal fixation (RIF), and presence of scars were recorded. Radiographs were performed during follow-up examinations at intervals of 1, 2, 6, and 12 months, with additional examinations if necessary. Patients with less than 6 months of follow-up were excluded from the study. The procedure was considered successful if the fracture fixation provided stability, and if infection and/or nonunion of the bone fragments was absent.

Results.

Age and sex distribution.

Between January 2006 and December 2011, a total of 119 patients with 167 mandibular fracture lines were identified. Patient age was between 6 and 84 years, with a mean of 28.1 years. Sixty-one percent of our sample was younger than 40 years old. The age group of 20 to 29 years had the peak incidence of mandibular fractures with 44.5% of cases. Caucasian patients (86, 72.3%) were most prevalent, followed by Mestizos (29, 24.4%). The gender ratio was 4.1 men to 1 woman; there were 96 men (80.7%) and 23 women (19.3%).

Etiology

The major cause of mandibular fractures in this study were RTA (59, 49.5%) (Table 1). Motorcycle accidents (45, 76.2%) were the most common cause of RTA. The patients involved in these accidents were primarily young men (68.9%). In patients affected by RTA, 35% were not using safety devices at the time of the accident. None of the bicycling accident victims in the study used a safety device.

Table 1. Etiology of the mandibular fractures.

Etiology	Patients (n)	%
Road Traffic Accident	59	49.5
Physical aggresion	25	21
Fall	19	16
Bicycle	12	10.1
Worker accident	04	3.4
Total	119	100

Physical violence was the second most common cause of mandibular fractures. Sixteen cases were related to fights (all in men) and 9 cases were related to assaults and gunshot injuries. Nineteen falls were recorded among

patients and were a consequence of home accidents (9 cases), drunkenness (5 cases), or syncopes (5 cases). The most common mandibular fracture site in falls was the condyle (34.2%). Work accidents accounted for 3.4% of mandibular fractures; most were caused by industrial machinery or involved animals in a rural setting.

Chronic substance use was identified in 61 patients (51.3% of total): 33 patients abused alcohol (54.1%) and 23 patients smoked tobacco (37.3%). Five patients (8.2%) reported use of non-intravenous drugs. At the time of trauma, 25 of these patients (21%) were under the influence of alcohol or other substances harmful to health.

Site of fracture

We identified 86 patients with fractures to the mandible only. The most common fracture site was the parasymphysis (26.9%), followed by the angle (25.1%). The anatomical location of the 167 lines of fracture in the mandible is shown in Table 2.

Table 2. Mandibular regions and number of fractures

Mandibular region	Fractures (n)	%
Parasymphysis	45	26.9
Angle	42	25.1
Symphysis	28	16.8
Condyle	26	15.6
Body	23	13.8
Ramus	3	1.8
Total	167	100

Thirty-three patients (27.7%) had mandibular fractures combined with fractures of middle or upper third of the face (Table 3). RTA was identified as the main etiological factor in these patients.

Table 3. Midfacial and Upper facial fractures associated with Mandibular fracture.

Fracture	Number	%
CZO*	37	86
NOE**	2	4.7
Le Fort II	2	4.7
Frontal	2	4.7
Total	43	100

* Complex orbital zygomatic fracture

** Naso-Orbital-Ethmoid fracture

Of the 42 angle fractures, 27 (64.3%) were associated with wisdom teeth in the line of fracture. Only ten patients had a tooth extracted.

Treatment

Sixteen condylar fractures (9.6%), 10 unilateral and 3 bilateral, received conservative treatment through observation, maxillo mandibular fixation (MMF) for 2 or 3 weeks, dietary restriction, physiotherapy and clinical follow-up. The most common associated fracture was of the symphysis (8 cases). All associated fractures were surgically treated.

One hundred fifty one mandibular fractures (90.4%) underwent open reduction and RIF. General anesthesia was administered in all cases. MMF was achieved through application of Erich arch bars or Ivy loops. The main surgical access was intraoral (64.9%). Extraoral access was used in 53 fractures (35.1%).

The fixation system most commonly used was the 2.0-mm system, accounting for 206 straight plates (85.1%), followed by the 2.4-mm system (8.7%, 21 of total). Other systems employed were 7 plates (2.9%) from 2.0-mm systems of various formats, 7 straight plates (2.9%) from the 1.5-mm system, and 1 lag screw (0.4 %).

Treatment methods were established considering fracture characteristics. Fractures of the parasymphysis, symphysis and mandibular body were treated using two plates: the plate positioned on the tension band of the fracture was fastened monocortically, while the plate positioned on the compression area was fastened bicortically. For single fractures of the mandibular angle that exhibited low displacement of the segments, the treatment of choice was reduction by the intraoral approach. Principal fixation techniques were mono and bicortical 2-plate, 2.0-mm (33%) and the Champy technique (31%). Patients that had comminuted fractures, large displacement, and considerable injury to the adjacent soft tissues were treated extraorally, using 2.4-mm system plates.

Ten condylar fractures, 6 unilateral and 2 bilateral, were treated surgically by extraoral access in adult patients who had occlusion changes and subcondylar fractures diagnosis. The most common associated fracture was of the symphysis (4 cases). Retromandibular surgical access was most commonly used (8 cases) and straight 4-hole mini-plate was used for the fixation of these fractures. Only one fracture was treated with two mini-plates.

Complications

Thirty-six patients (30.2%) had one or more postoperative complications (Table 4). The main postoperative complication was infection (36.1%, 13 cases). Minor complications occurred in 26 patients (72.2%) and consisted of malocclusion (9 cases), paresthesia (7 cases) and minor infections (6 cases). Single cases of surgical wound dehiscence, salivary fistula, hypertrophic scar, and TMD were also identified.

Table 4. Postoperative complications

Complication	Minor	Major	%
Infection	6	7	36.1
Malocclusion	9	1	27.7
Paresthesia	7	0	19.4
RIF fracture	0	1	2.8
Cutaneous fistula	0	1	2.8
Surgical wound dehiscence	1	0	2.8
Hypertrophic scar	1	0	2.8
Salivary fistula	1	0	2.8
TMD*	1	0	2.8
Total	26	10	100

*Temporomandibular joint dysfunction

Four cases of malocclusion received outpatient treatment using an elastic guide with favorable resolution. The other five cases were referred for orthodontic treatment. Seven patients exhibited paresthesia of the trigeminal nerve. These patients were monitored for six months after surgery at intervals of 30 days. However, paresthesia was permanent in 3 patients: all were related to parasymphysis fractures. Infections were treated for 7 days with oral antibiotics, drainage and 0.12% chlorhexidine rinses, with favorable resolution. Plastic surgery was offered to treat the single hypertrophic scar case, but the patient declined it.

Ten patients had major complications (27.8%) such as infections (7 cases) cutaneous fistula (1case), RIF fracture (1case) and malocclusion (1 case). These patients required hospitalization and new treatment. Cases of infection required drainage, removal of initial fixation material and re-fixation of fractures. Similarly, the initial fixing material was removed in the RIF fracture and cutaneous fistula cases. The case of malocclusion was treated by surgery to re-fixation of the fracture.

Discussion

During the 6 years of this study, 119 patients were treated for mandibular fractures. Most of the patients were men (80.7%). The man: woman ratio of 4.1:1 was in agreement with other studies [7-12]. This is most likely because men tend to participate in everyday activities that require more physical activity. Additionally, more men than women are involved in traffic accidents and violence [1,8,9,11-13]. In agreement with other research there was a high incidence of mandibular fractures in young populations [8,9,10,13]. This can be explained by the fact that young adults have more social activity when compared with children or the elderly, which makes youth more susceptible to trauma and fractures [14].

RTA were the most prevalent cause of facial fractures. These data are consistent with other studies performed in developed and developing countries[11,15,16-18]. For some authors, the epidemiology of mandibular fractures has changed dramatically in the last years with increased use of safety devices[19,20]. In fact, the frequency and severity of facial fractures by RTA have been in decline since the mandatory use of seat belts and air bags in vehicles. Thus, drivers and passengers are now better protected during accidents.

On the other hand, motorcyclists remain the most unprotected and vulnerable to high-impact collisions. For motorcyclists and cyclists, the helmet is the main safety measure that protects them in case of accidents. Helmets prevent cranial trauma in about 85% of cases and have proven effective in reducing severe facial trauma [21]. Although 87% of motorcycle victims in this study were wearing helmets, they also suffered facial fractures. Design features of helmets (open or closed helmets are allowed by Brazilian law) or misuse of them (many of the patients reported having lost his or her helmet during the accident) could explain these results [23].

In the specific case of cyclists, none of the patients in this study was wearing a helmet at the time of trauma. Similar data have been reported by Zargar *et al*. (2004) [22]. Unfortunately, the use of bicycle safety devices in Brazil is still very limited. The population does not consider bicycle helmet use important.

Additionally, authorities often neglect enforcement of helmet laws. This shows deficiencies in accident prevention education programs.

Alcohol use is a major contributing factor that increases physical aggression and RTA[1]. In agreement with other Brazilian studies, [24,25] we also find that a high number of patients in this study were chronic users of alcohol and/or other substances (51.3%). Furthermore, a very significant percentage of our patients were under the influence of alcohol at the time of trauma (21%), a factor that had a direct relationship with the severity of the injuries.

The anatomic distribution and incidence of mandibular fractures is widely variable. Many authors reported the angle as the most frequently affected site, [9,15,26,27] whereas others reported the mandible body [7,8,28] and condyle [13,18,29,30]. In this study, the parasymphysis was the most frequently affected site (29.9%). The mandibular angle represented the second most fractured region (25.1%). Some characteristics of the angle such as reduced section area and the presence of impacted teeth on the fracture line can predispose this region to fracture [26].

Ellis *et al*. (1985) [8] and de Matos *et al*. (2010) [30] found that 17.2% and 8% of the patients, respectively, exhibited other associated facial fractures, mainly in the zygomatic process. The present study found 27.7% of patients with associated fractures, the most common being the zygomatic complex fracture.

Several studies have shown that there is a direct relationship between the etiology of trauma and regions affected in mandibular fractures. Thus, condylar fractures were the most common in cycling accidents [23] while the angle fractures was related to physical violence [9]. In contrast to these authors, we identify that angle fractures were more related to RTA (42.6%), while condylar fractures were related to falls (34.2%).

Currently, the literature proposes both surgical and non-surgical treatment of mandibular fractures. In our study, only 16 condyle fractures received conservative treatment. These patients had fragments with little or no displacement and the occlusion was not compromised, presented limited occlusion alterations. Although

occlusal alterations were observed after treatment, these did not affect the function of the temporal mandibular joint (TMJ). Other changes such as mandibular deviation when opening the mouth (7 cases), joint/articular noises (3 cases) and mild pain in the TMJ at the fracture site (2 cases) were also observed. These alterations were minor and did not cause serious patient discomfort. According to medical records, all cases evolved favorably and new cases of malocclusion or worsening of the symptoms were not observed during the entire follow-up period.

Only one complication was reported. A case of unilateral condyle fracture involving a symphysis fracture evolved into an occlusal alteration after 40 days of treatment, making re-fixation surgery necessary on the symphysis fracture. During the second surgery, the condyle, which was initially treated conservatively, was also surgically addressed.

The conservative treatment, when properly indicated, allows for appropriate patient recovery, reduces morbidity associated with surgery, and reduces costs of resources [31]. Although proper treatment of condylar fractures is still one of the biggest controversies in the maxillofacial literature, multicenter studies have reported satisfactory results for nonsurgical treatments[32]. Postoperative management of non-surgical treatment for other mandibular regions can be especially problematic and associated with a high incidence of complications [33].

The majority of fractures were treated surgically (90.4%) by open reduction and RIF. The preference for surgical treatments is in agreement with other studies [13,15,30]. The intraoral approach was the most common in surgical treatment. This approach is simple, safe, fast, efficient, and avoids scar formation and facial nerve damage. The intraoral approach is also documented in other studies, reporting high success rates [13,15,34].

Fixation was performed according to the location and the characteristics of the fracture. The 2.0-mm fixation system was the most common type used (88%). The use of these systems has shown that the incidence of complications is similar to that reported for other more rigid fixation systems [15].

The Champy technique was used for angle fractures. This technique involves a quick and simple surgical procedure, which is still preferred by many experienced surgeons [35]. Although this technique is related to lower rates of postoperative complications, open bite on the fractured side and postoperative infection have been observed [36,37]. Thus, in our study three complications, one of them major, were related to this fixation technique. The fixation of symphysis, parasymphysis, body fractures and angle fractures, when indicated, was performed using the technique recommended by the AO/ASIF. This system enables favorable conditions to bone consolidation because it acts both in tension and compression zones [5].

For condylar fractures, open reduction and RIF have become standard for the treatment of fractures with displacement in adult patients, mainly involving the neck region and base of the condyle. Biomechanical studies have shown that the use of two 2.0-mm miniplates to treat these fractures provide one of the most stable fixation types [38]. However, in the treated cases of our study, the small size of the proximal fragment did not allow the use of two miniplates. Thus, the majority of these fractures were treated with a single miniplate fastened with 8-mm screws.

Two complications, one major and one minor, were observed for open reduction of condylar fractures. The first complication was a postoperative malocclusion in a condylar fracture that was associated with a symphysis fracture. Physical therapy was performed with elastic bands and the patient was then referred for orthodontic treatment. The evolution of the case was not favorable and a new surgical procedure was realized. The second case was a salivary fistula. No specific treatment was indicated and the fistula self-resolved in 3 weeks. Any other kind of complication, such as temporomandibular joint ankylosis or aesthetic complications were not observed. We believe that physiotherapy and early mobilization is the key in the management of surgical and nonsurgical patients. This is important for the success of treatment and reduction of complications.

The number of complications observed in our study (30.2%) was similar to data from other publications [27,39,40]. We believe that this fact was related to the type

of population that received treatment. The Hospital of Unicamp provides health services to about 3 million people in the city of Campinas and neighboring municipalities. People seeking treatment are generally poor. According Lamphier *et al*. (2003) [27] poor quality of life, bad nutrition and poor patient compliance are characteristics of some populations in large urban centers. Thus, we believe that many of these complications (mostly minor infections, malocclusion and wound dehiscence) could have been avoided if the patients had returned appropriately to their postoperative appointments and carefully followed the post-operative instructions.

Fractures of the mandibular angle have the highest incidence of complications. In agreement with previous publications, [15,26,33] the greatest number of complications was observed in mandibular angle fractures (10 patients, 27.7%). Three of these patients had major infections: one patient had been treated using the Champy technique and the other two using 2.0 mm mono and bicortical 2-plates.These cases required hospitalization for retreatment, which involved extraoral access, removal of the initial fixation equipment and re-fixation of fractures. In these three cases the most likely cause of infection could have also been an insufficient initial fixation. Probably insufficient fixation and infection work synergistically. On the other hand, it is not possible to conclude that the infection would not have happened if the initial fixation had been more rigid [15].

Some authors have reported a relationship between substance abuse and postoperative complications with rates between 11 and 18.5%, with infection being the main complication[25,41]. However, this study did not demonstrate any relationship between social risk factors and complication rates.

The extraction or preservation of third molars (wisdom teeth) present in the line of fracture is still controversial [42,43]. In our study, extraction of impacted third molars was performed if indicated. The decision to extract or not extract depended on excessive mobility, root fracture, periapical pathology, and whether the tooth is necessary or not to achieve fracture stability [19]. The small number of cases

involving third molars in this study does not allow us to draw a conclusion on this subject.

Conclusions

Although traffic regulations have been tightened in recent years, road traffic accidents remain the greatest cause of facial fractures in the studied region. Adequate supervision and continuous educational campaigns could prevent accidents caused by alcohol consumption, reducing the severity of injuries and treatment costs. This would be especially useful for public health services. Patient non-compliance was also a factor that contributed to the high rate of postoperative complications.

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Capítulo II (artigo submetido para o Oral and Maxillofacial Surgery)

EPIDEMIOLOGY AND TREATMENT OF MANDIBULAR ANGLE FRACTURES IN A BRAZILIAN POPULATION

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Abstract

Purpose: This retrospective study relates mandibular angle fracture cases to patient gender, age, etiology of trauma, method of surgical treatment, and surgical complications among patients seen at the University of Campinas.

Material and Methods: From January 2006 to December 2011, 119 patients with mandibular fractures were treated at the Department of Plastic Surgery, School of Medical Sciences, University of Campinas, São Paulo, Brazil.

Results: Of these patients, a total of 42 mandibular angle fractures were reported in 40 patients. The most affected patients were men (82.5%) and/or Caucasian (67.5%). The mean age of the patients was 27 years. The principal causes of the fractures were motor vehicle accidents (35%) or altercations including gunshot wounds (27.5%). Of motor vehicle accidents, motorcycle crashes were the most common (85.7%).Two patients sustained bilateral angle fractures. All patients underwent open reduction. The intraoral approach was the most common (69%). The two-plate 2.0mm system, affixed by mono and bicortical screws (33%) and Champy technique (31%) were common fixation techniques. Complications occurred in 10 patients (25%). Additional surgery was required in 3 patients to resolve these complications.

Conclusions: The outcome of angle fracture treatment is affected by many factors. Proper matching of cases to fixation technique is essential in reducing postoperative complications.

Key Words: mandibular trauma, angle fractures, mandibular angle treatment

Introduction

Owing to their high incidence, injuries of the maxillofacial complex are a major worldwide public health problem. Automobile accidents, assaults and sport accidents are among their main causes [1-5].

Facial fractures often involve the mandible, with a frequency of 36 to 70%[6]. The mandibular angle is one of the most frequently fractured parts of the mandible [3,7]. This high rate of fractures can be explained by unique features of the mandibular angle, as are reduced cross-section at the fracture line, the presence of impacted teeth, as well as difficulties in reduction and fixation make treatment of mandibular angle fractures a challenge for surgeons [7-9].

In recent decades, the treatment of mandibular fractures has gone through a number of changes mainly related to the development of new materials and new

surgical techniques. Surgeons have moved towards using increasingly stable internal fixation for the treatment of maxillofacial fractures, achieving highly favorable results. However, despite the progress, the treatment of mandibular fractures continues to be associated with multiple complications. In particular, surgical fixation of mandibular angle fractures has a high rate of postoperative complications; therefore, the ideal treatment for these fractures remains controversial[10-14].

The aim of this study is to review cases of mandibular angle fractures in light of treatment and associated complications.

Patients and methods

This research was approved by the Ethical Committee for Human Research, School of Medical Sciences, University of Campinas, Sao Paulo, Brazil (Project N^0 83897- 2012).

The study data was obtained from medical records of patients treated for facial trauma at the Clinical Hospital of University of Campinas. From January 2006 to December 2011, 119 mandibular fracture patients were treated by the Senior Residents Staff of the Department of Surgery, School of Medical Sciences, State University of Campinas, São Paulo, Brazil. Of these, 40 patients were diagnosed with 42 mandibular angle fractures. The data recorded included patient gender, age, etiology, method of surgical treatment, and postsurgical occlusal relationship and complications.

The post-surgical complications were classified as minor complications such as dehiscence, local infection and paresthesia or major complications that required further surgical intervention, such as nonunion, loosed fixation material, infection and interfragmentary mobility.

Follow-up examinations were performed 1, 2, 6, and 12 months post treatment, with additional examinations if necessary. Patients with less than 6

months of follow-up were excluded from the study. The procedure was considered successful if the fracture fixation provided stability, was free of infection, and produced proper union of the bone fragments.

Results

Forty patients of the study group (33.6%) were diagnosed with 42 mandibular angle fractures: 35 patients were male (82.5%) and 5 were female (17.5%), with ages ranging from 8 to 84 years. Caucasians were most common among patients (27, 67.5%). No relevant medical history affecting bone healing, such as diabetes or compromised immunity was noted in any of the patients.

The most common cause of mandibular angle fracture was motor vehicle accidents (MVA) (14, 35%) followed by assault (11, 27.5%) (Table 1). Of MVA, motorcycle accidents caused the most fractures (85.7%).

Table 1. Etiology of the mandibular angle fractures.

Etiology	**N° of patients**	**%**
Motor Vehicle Accident	14	35
Violence	11	27,5
Fall	10	25
Bicycle	03	7,5
Worker accident	02	5
Total	40	100

Social risk factors at the time of the maxillofacial trauma were found in 10 (25%) of the patients. Alcohol abuse and smoking were observed in 7 patients. Three patients reported use of non-intravenous drugs.

Eighteen patients had an isolated angle fracture (45%). The most common location of associated mandible fractures was the contralateral parasymphyseal region (16 cases, 40%). Six patients (15%) had associated midfacial fractures. Only two patients (5%) had bilateral angle fractures (Table N^{0}2).

Table 2. Number of patients and Mandibular regions.

Mandibular fracture	**Patients (n)**	**%**
Isolated angle	18	45
Angle + Parasymphysis	16	40
Angle + Body	3	7,5
Bilateral Angle	2	5
Angle + Symphysis	1	2,5
Total	40	100

All patients underwent open reduction. General anesthesia was administered via nasotracheal intubation in all cases. Maxillomandibular fixation (MMF) was then achieved using Erich arch bars or Ivy loops. The intraoral approach was the most common (69%). Different methods of fracture fixation were employed: mono and bicortical 2.0 mm 2-plates (33%) and the Champy technique (31%) were the principal techniques of fixation utilized (Table 3).

Table 3. Fixation System utilized in reduction and fixation of angle fractures.

Fixation System	Fractures (n)	%
Mono and bicortical 2-plate, 2.0 mm	14	33,3
Monocortical 1 –plate, 2.0 mm superior border, Champy technique	13	31
Bicortical 1-plate, 2.4 mm inferior mandibular border	5	12
Monocortical 2-plate, 2.0 mm	4	9,5
Bicortical 1-plate, 2.4 mm inferior mandibular border and monocortical 1 –plate, 2.0 mm superior border	3	7,1
Other	3	7,1
Total	42	100

Wisdom teeth were present in 27 fractures (64%). Ten patients had a tooth extracted from within the fracture line; the teeth in the fracture site were left in place in the rest of the patients.

Post-operative complications were identified in 10 patients (25%). Minor complications occurred in 7 patients and consisted of minor infections, malocclusion and paresthesia. Three patients had major complications such as infections and malocclusion, requiring hospitalization. All complications occurred 3 to 12 weeks after surgery.

Four patients were reported to have malocclusion. Two cases of malocclusion were associated with parasymphysis fractures addressed through extraoral access. These cases were treated with elastic guides with favorable results. The other two cases were associated with middle third fractures and were referred for evaluation and orthodontic treatment. One case developed unfavorably, which required surgical repair.

Four patients developed infection. Two patients (in the two-miniplate group) were treated with a 7-day course of oral antibiotics, drainage, and 0.1% chlorhexidine rinses. The infection resolved after the treatment. In the other two cases (one treated by Champy technique and the other with 2 plates) antibiotic treatment and drainage did not resolve the infection, requiring surgical extraoral access, removal of initial fixation material, drainage, and re-fixation of the fracture.

One patient was noted to have paresthesia of the trigeminal nerve. However, this condition was transient; paresthesia faded progressively over time as the patient was followed up for six months after surgery at intervals of 30 days.

We had one case of hypertrophic scar in the two-miniplate group. An aesthetic treatment was offered to solve this problem, but the patient declined it.

Discussion

The two most prevalent causes of fractures in this study were motor vehicle accidents and physical assaults. These data are in contrast with previous studies carried out in Brazil and in other regions of the world [2,14,15]. However, the epidemiological characteristics of facial trauma may vary according to factors such as the environment, gender, age and socioeconomic status of the study population[16].

Several studies have identified the mandibular angle as one of the regions most affected by fractures [2,4,16]. Characteristics of this region, such as reduced cross-sectional area and the presence of impacted teeth can contribute to this area be inclined to fractures [7-9]. In agreement with these studies, we also identified the mandibular angle as the most affected by fractures, affecting 33% of our patients.

The correlation between fractures of the mandibular angle and parasymphysis has been widely reported in the literature [5,14,15]. The same connection was identified in our study, where 37.5% of angle fracture patients also had concomitant contralateral parasymphysis fractures. In contrast to a previous

study[4] that suggests that this association is related to cases of interpersonal violence, our study implicates motor vehicle accidents as the main cause (43.7%).

The conservative treatment or closed reduction is one of the treatment modalities proposed in the literature for mandibular angle fractures. However, management of closed reduction can be especially problematic due to poor nutrition, oral airway compromise and social inconvenience for the patient.[15] In addition, closed reduction produces a high rate of complications, as demonstrated by Passeri *et al* (1993)[10].

Today, open reduction and internal fixation has gained widespread popularity. Advantages of rigid internal fixation include avoidance of MMF, early functioning of the mandible, satisfaction of the patient and shorter periods of hospitalization[17,18]. Closed reduction is only suitable for selected patients as in noncompliant patients, psychiatric patients or drug users [19-21].

In this study, all angle fractures in our population were treated by open reduction. Treatment modalities were established considering the fracture characteristics. Fractures with 1 line and low displacement of the segments were treated by the intraoral Champy technique. Cases that presented comminuted fractures, large displacement, and considerable injury to the adjacent soft tissues were treated extraorally, observing AO/ASIF principles.

Intraoral access was the most frequently procedure used in our study (69%).The preference of intraoral access for the treatment of mandibular fractures has been documented in several studies [4,9,14]. This procedure is less traumatic to the soft tissues compared with the extraoral approach. Unlike extraoral access, which may involve scarring and damage of the marginal mandibular nerve, the intraoral approach is simple, safe, fast, and efficient [22].

The ideal method for the fixation of angle fractures remains controversial [11,13,14,23,24]. Clinical and biomechanical studies have been used in order to evaluate and compare the benefits of different fixation techniques for these fractures, showing different and varied results [24-28]. Champy *et al.* (1978)[29] were the first to

apply less rigid plates in the treatment of mandibular fractures, recommending the installation of a conventional 2.0 mm plate at the upper edge of the mandibular angle by intraoral access. Subsequent clinical studies have confirmed its effectiveness [25,30,31] and, even today, it is the preferred technique of many experienced surgeons [32].

Although the Champy technique is related to lower rates of postoperative complications, complications such as open bite on the fractured side and postoperative infection maybe observed [5,30]. Thus, in our study, three complications, one of them major, were related to this fixation technique.

Shetty *et al.* (1995)[33] reported that the angle fractures treated by the Champy technique were particularly vulnerable to torsional forces. They found that the application of occlusal loads, ipsilateral or contralateral to the fracture line, produced separation and rotation of the segments. They recommend using two plates to achieve greater stability of the fracture. In fact, all biomechanical studies performed to date indicate that two plates are more stable than one for fixation of mandibular fractures [27,34-36].

Although some clinical studies have demonstrated a low incidence of complications using two monocortical plates for fracture fixation of the mandibular angle,[15,37] other studies have shown that the clinical use of this technique has quite dissimilar results. It has been reported that the use of two plates does not produce any advantage in the reduction and fixation of angle fractures that are neither displaced or comminuted [25,38]. Additionally, this technique seems to be related to the higher rate of postoperative complications as infection, malocclusion or the formation of scars [5,11].

Placement of the second miniplate at the lower mandibular border also means increased periosteal stripping, bacterial contamination and more metal applied to the mandible, which theoretically increases the possibility of infection[22]. Ellis (1999)[12] states that the complication rate is high if 2 fixing points are used for reducing angle fractures. However, we found no difference between complications

produced in cases fixed with one or two plates. Probably this is related to the small number of cases involved in our study.

Another controversy involves the supplementation of fixation in mandibular fractures with MMF [39]. Many surgeons still feel that miniplate fixation does not provide adequate stability and required MMF for additional security. For Longwe *et al* (2010)[28] intraoral transmucosal fixation using a 2.0-mm miniplate with monocortical screws in addition to Champy's technique followed by 2 weeks of MMF is a viable treatment for angle mandibular fractures that are neither comminuted nor infected that result in a low complication rate. However, other authors suggest that the addition of MMF did not significantly alter complication rates[18,40]. We believe that the fixation of a fracture provides absolute rigidity and there is no interfragmentary mobility. Therefore MMF can be dispensable. Thus, none of our patients were maintained with MMF after surgery. Only Erich bars were left in place for 4 weeks in 4 patients with multiple fracture lines, as an additional measure to prevent complications.

Treatment of fractures of the mandibular angle has a high rate of post-operative complications. Our study's complication rate (25%) was similar to that of other studies [4,11-14,23]. We believe that the high rate of complications was related to patient non-compliance with post-operative care. Many of the patients in this study were from neighboring small towns and had low socio-economic status.

Post-operative complications like infections are common in patients suffering from multiple or comminuted fractures, which are often associated with MVA [41]. Infection may also be related to the lack of stability of the fracture due to fixation material failure [20,42].

Infections have also been partly related to the extraction of third molars in fracture lines, generating discussions about the most appropriate treatment for these cases [11]. In our study, extraction of impacted third molars in the line of the fracture was performed if indicated based on the principles: excessive mobility, root fracture, periapical pathology and if the tooth is necessary or not to achieve

fracture stability [43]. Thus, only ten patients who exhibited these criteria had a tooth extracted within the fracture line. The teeth in the fracture site were left in place in the other seventeen patients. Three patients who developed infections had a tooth within the line of fracture that was not extracted during initial surgical treatment. Two of these cases required hospitalization for retreatment, requiring extraoral access, initial fixation material removal and refixation of fractures.

Several authors have suggested that extraction of a tooth in the fracture line may contribute to post-operative infection[11,44,45]. For other authors, no significant difference in infection was found [13,20]. Therefore, the relationship between extraction of teeth in the line of fracture and post-operative infection is still controversial.

Four cases of malocclusion were identified among our patients. Three of these cases presented with additional fractures associated with contralateral parasymphysis. These data are consistent with other authors who reported that malocclusion was more frequent when multiple mandible fractures were treated. [42] Therefore, if a malocclusion is present in this type of fracture, it is not possible to determine which fracture caused the malocclusion [5].

The data from this retrospective study has some notable features. The most obvious of these was the high proportion of mandibular angle fracture caused by MVA, followed by assault. Another notable result was that, although the number of fractures treated with 1 or 2 plates was limited in our study, the results showed no difference in complication rates (malocclusion, infection, paresthesia) between both groups. Severity of the trauma and noncompliance of the patients were factors that contributed to the development of post-operative complications.

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Capítulo III (artigo aceito para publicação no *Craniomaxillofacial Trauma and Reconstruction)*

A BIOMECHANICAL COMPARISON OF FOUR MANDIBULAR ANGLE FRACTURE FIXATION TECHNIQUES

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ABSTRACT

Purpose: The aim of this study was to make a comparison of the biomechanical behavior of four different internal fixation systems for mandibular angle fractures.

Materials and Methods: Forty polyurethane mandible replicas were employed with different fixation methods: group 1SP - one 2.0-mm 4-hole miniplate; group 2PPL - two 2.0-mm 4-hole parallel miniplates; group 3DP– one 3D 2.0-mm 4-hole miniplate; and group 3DPP one 3D 2.0-mm 8-hole miniplate. Each group was subjected to incisal or homolateral molar region loading. The load resistance values were measured at load application causing tip displacement of 1, 3 and 5 mm, and at the time at which the system achieves its maximum strength (MS).

Means and standard deviations were compared among groups using analysis of variance and the Tukey test.

Results: Group 2PPL showed higher strength when compared with the other methods for all displacements. For incisal loading, no statistically significant differences were found between groups 1SP, 3DP and 3DPP. For molar loading, group 1SP and 3DPP showed statistically significant differences. For MS testing, group 1SP and 2PPL showed statistically significant differences in incisal loading; group 1SP and 3DP showed no statistically significant differences; and group 3DPP showed lower values of strength.

Conclusions: Two parallel miniplates provide the most favorable mechanical behavior under the conditions tested.

INTRODUCTION

The mandible is one of the most affected bones in facial fractures, with a frequency of 36 to 70%.[1] More specifically, the angle is the most frequently fractured region of the mandible [2,3].

Since Champy *et al* [4] adapted the technique of Michelet *et al* [5], surgeons have increasingly used stable internal fixation to treat maxillofacial fractures, achieving highly favorable results. However, despite progress, the treatment of mandibular fractures continues to be associated with multiple complications. In particular, mandibular angle fractures have high rates of postoperative complications [6].

In this regard, new clinical and biomechanical studies have been used in order to evaluate and compare the benefits of different fixation techniques used in the reduction of mandibular angle fractures, showing varied results [7-11]. More recently, the use of 3D systems has been suggested as an alternative treatment [12-14]. However, the ideal method for fixation of angle fractures remains controversial.

The purpose of the present study is to make a biomechanical comparison of the most clinically accepted internal fixation systems used to reduce mandibular angle fractures and to compare them with two 3D approaches.

MATERIAL AND METHODS

This study used 40 replicas of human mandibles made of rigid polyurethane resin (Nacional, Jaú, SP, Brazil) with properly standardized measurements. The fixing material used consisted of 30 straight miniplates (1 mm x 23.5mm x 5.5 mm) with 4 holes per miniplate, 10 3D plates (1 mm x 20 mm x 11.5 mm) with 4 holes, and 10 3D plates (0.8 mm x 31.5 mm x 10 mm) with 8 holes. All screws were part of the 2.0-mm system and included 200 5-mm long monocortical screws and 40 13-mm long bicortical screws (Engimplan®, Rio Claro-SP, Brazil).

Sample preparation

All mandible replicas were prepared for testing by drilling a socket at the bottom of the condyle and coronoid regions. The models were uniformly sectioned using a saw. To create defects simulating a typical angle fracture, the following points were marked: point (A) was set in the alveolar process 5 mm posterior to the distal face of the second molar. From this point, a line was traced perpendicular to the mandibular base to point (B), which was located inferior to the mandibular base. A third point (C) was marked 10 mm posterior to point B. The sectioning followed the line from point A to point C. Both sockets and fracture line were standardized for the experiment with the help of a prefabricated acrylic resin guide (Fig. 1).

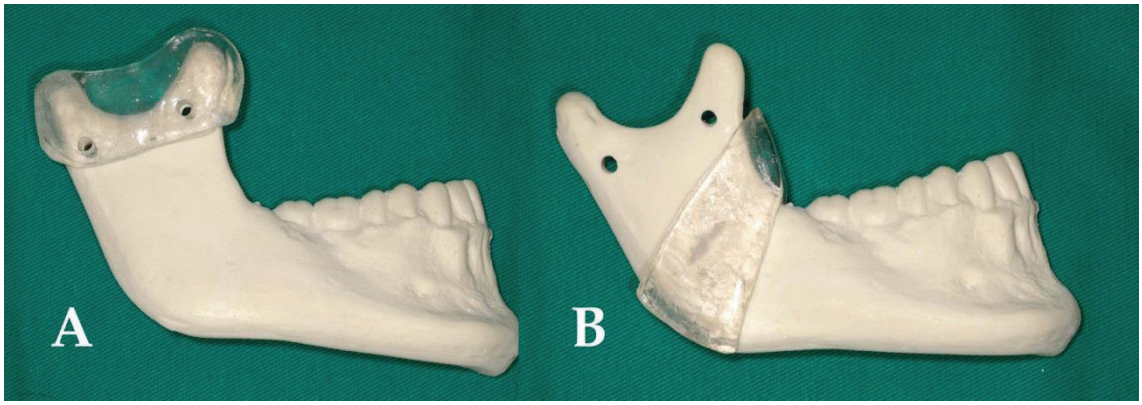

Fig. 1. Prefabricated acrylic resin guides were used to standardize the socket at the bottom of the condyle and coronoid regions (A) as well as the defect-simulating angle fracture (B).

Simulated mandibles were passively stabilized. The plates were then applied across the fissure according to manufacturer instructions. To standardize the plate position, guides made of acrylic resin were made for each group and applied laterally to polyurethane mandibles during fixation (Fig. 2).

Fig. 2. A prefabricated acrylic resin guide was utilized to standardize the position of the plates.

Group 1SP was fixed with one 4-hole miniplate and four 5-mm screws in the region of the oblique line of mandible, as described by Champy. Group 2PPL received two 4-hole miniplates arranged in parallel: the miniplate at the top edge was affixed to the mandible with four 5-mm screws; the miniplate at the bottom

edge was affixed to the mandible with four 13-mm screws. Group 3DP was fastened in the middle of the buccal surface of the mandible with four 5-mm screws. Group 3DPP was fixed with eight 5-mm monocortical screws installed in the mandibular angle neutral zone (Fig. 3). Each group was divided into two subgroups of five models. Therefore, each technique was tested with five independent models; each one was used for one testing procedure only.

Fig. 3. One miniplate on the top edge (1SP), 2 parallel miniplates (2PPL), 3D miniplate four holes (3DP) and 3D miniplate eight holes (3DPP).

A single investigator affixed all plates and screws, thus diminishing variation in the fixation techniques. The biomechanical test was performed at the Laboratory of Dental Materials using a universal testing machine (Instron Universal 4411; Instron Corporation, Norwood, MA)

The fixed mandibles were placed in a metal bracket that allowed the samples to be correctly positioned. A 500 Newton (N) load was applied at a fixed point by a device attached to the load cell (Fig. 4). The machine was programmed to apply a progressive load at a displacement speed of 1 mm/min at the following two points: the first molar or in the central incisors (near and distant point of the system, respectively).

Fig. 4. Sample positioned for mechanical testing in an Instron 4411 machine.

The resistance values were obtained in N when displacement reached 1, 3, and 5mm and at the time at which the system achieves its maximum strength for each sample only once. These values were assessed by Tukey´s test after analysis of variance to detect differences between mean values. SPSS 21 software (IBM® SPSS® Statistics 21) was used, with a significance level of 5% for all tests.

RESULTS

The variance analyses showed that group 2PPL had the greatest biomechanical stability with incisal loading. Group 1SP showed the lowest peak load scores compared with other fixation methods, however no statistically significant differences were found when groups 3DP and 3DPP were compared. No statistically significant difference was found between the groups at 1 mm of displacement while 2PPL plate placement had more favorable biomechanical behavior than the 1SP and 3D groups when displacements were 3 and 5 mm. The results of the statistical analysis are summarized in Table 1.

Table 1. Mean, standard deviation and statistical comparison of vertical incisal loading in groups analyzed.

Group	Vertical Incisal Loading Value		
	1mm	3mm	5mm
Group 1SP	1.62 ± 0.7[a]	3.88 ± 1.1[b]	5.79 ± 1.5[b]
Group 2PPL	2.99 ± 0.4[a]	7.48 ± 0.9 [a]	11.76 ± 2.6[a]
Group 3D	1.89 ± 0.7[a]	4.42 ± 0.6[b]	6.84 ± 1.8[b]
Group 3DPP	2.95 ± 1.4[a]	4.42 ± 1.3[b]	5.8 ± 0.4[b]

NOTE. Different superscript letters in a column indicate statistically significant differences between groups (analysis of variance and Tukey´s test, $p < 0.05$).

When analyzing the maximum resistance, the group 2PPL showed the best mechanical behavior. Groups 1SP and 3DP did not show statistical differences. Group 3DPP showed the lowest resistance values. The mean and standard deviation of the maximum resistance, as well as the final displacement for each system are shown in Fig. 5 and 6 respectively

In molar loading, no statistically significant differences were found among groups 2PPL, 3DP and 3DPP at 1 mm displacement. Group 2PPL presented statistically significant higher bending stiffness compared to all groups when displacements were 3 and 5 mm. Groups 1SP and 3DP showed no statistically significant difference. The results of the statistical analysis are summarized in Table 2.

Table 2. Mean, standard deviation and statistical comparison of vertical molar loading in groups analyzed.

	Vertical Molar Loading Value		
Group	1mm	3mm	5mm
Group 1SP	2.56 ± 1.5[b]	9.66 ± 3.2[b]	19.19 ± 5.3[b]
Group 2PPL	6.64 ± 2.5[a]	17.31 ± 3[a]	24.93 ± 2.2[a]
Group 3D	4.06 ± 0.5[a,b]	10.1 ± 0.8[b]	14.43 ± 0.8[b,c]
Group 3DPP	4.31 ± 1.5[a,b]	8.76 ± 1.6[b]	11.06 ± 1.9[c]

NOTE. Different superscript letters in a column indicate statistically significant differences between groups (analysis of variance and Tukey´s test, $p < 0.05$).

When analyzing the maximum resistance, groups 1SP and 2PPL were not show statistically different. Similarly, groups 1SP and 3DP showed similar values and without statistical significance. In the other hand, group 3DPP showed lower values of mechanical resistance. The mean and standard deviation of the maximum resistance, as well as the final displacement for each system are shown in Fig. 5 and 6 respectively.

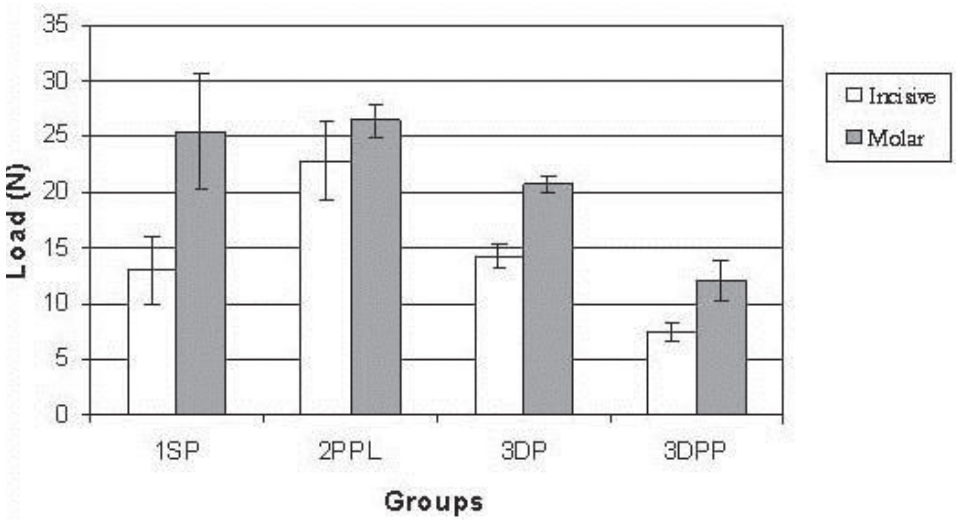

Fig. 5. Mean and standard deviation of the maximum resistance reached for the incisal and molar loading in each group.

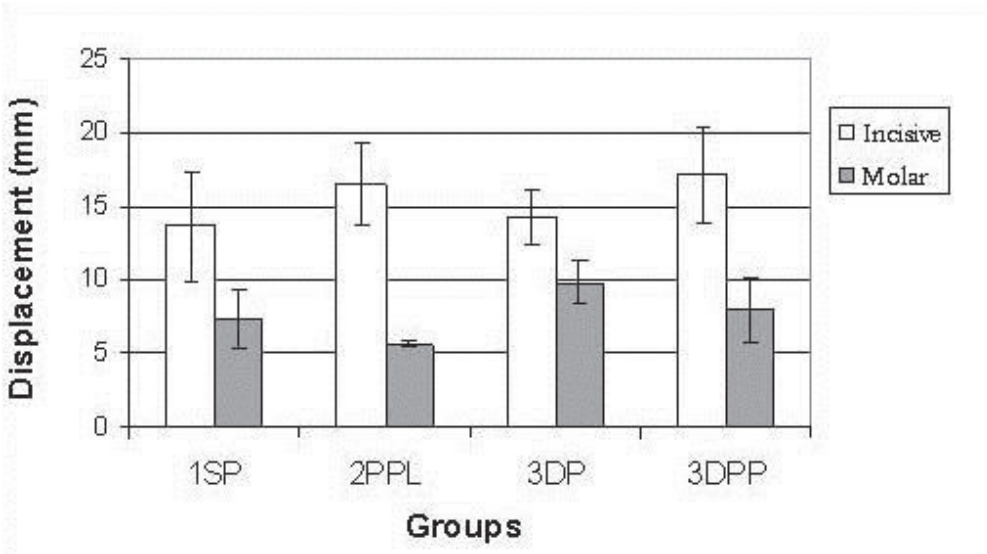

Fig. 6. Mean and standard deviation of the vertical displacement upon reaching the maximum resistance for incisal and molar loading in each group.

DISCUSSION

A high percentage of all mandibular fractures involve the angle [2,15]. Recent epidemiological studies in different regions of the world confirm this marked prevalence [3,16]. The angle possess some particular features which differentiates it from other mandibular areas, like a reduced section area at the fracture line and the presence of impacted teeth, factors that would potentially affect treatment results [2]. In fact, the treatment of these fractures is associated to high rates of post-operatory complications [6,15].

Although there are many studies that have analyzed the mechanical behavior of different fixation methods, few have evaluated the 3D systems in the fixation of mandibular angle fractures. In order to optimize clinical procedures in the treatment of this type of fracture, we studied the mechanical behavior of 3D plates and compared them with conventional fixation techniques.

Although it is true that clinical investigations are most desirable for the study of fixation materials, it is difficult to compare and interpret the majority of clinical results because of differences among study populations [9]. On the other hand, biomechanical studies can use standardized samples, which eliminates variability seen in populations. This makes such studies a trustable tool in evaluating the resistance of the materials and fixation methods.

Like in other studies [9,13,17] we chose synthetic polyurethane mandibular replicas a substrate because they are made of the best material considered the choice material for *in vitro* studies [18]. Such replicas mimic some of the variables of human mandibular bones, thus representing the anatomy on its real dimensions and proportions [9]. This standardization eliminates many variables associated to the use of animals and cadaver bones [13]. In addition, they can be acquired and used quickly, thus avoiding ethical and legal challenges present in the use of other biological substrates.

However, in this study we observed some difficulties during the preparation of the models, especially during its adaptation to the metal bracket previous to performing the tests. The posterior part of the condyle of many of these mandibles had to be lightly reshaped in order to correctly position them.

The widely known biocompatibility of titanium, as well as its physical and chemical properties, makes it the material of choice for fixation and osteosynthesis. Titanium plates and screws are easy handled and are adaptable. In addition, they provide excellent primary stability for the surgical reduction of fractures [19].

The fixation methods analyzed in this study were chosen based on techniques most widely used by maxillofacial surgeons and new treatment proposals for the fixation of mandibular angle fractures. Champy *et al* [4] were the first to apply less rigid plates in the treatment of mandibular fractures, recommending the installation of a conventional 2.0 mm plate at the upper edge of the mandibular angle. Clinically, the Champy technique involves a quick and simple intraoral surgical procedure. Subsequent clinical studies have confirmed its

effectiveness and, even today, it is the preferred technique of experienced surgeons [20,21].

Some authors showed that angle fractures treated using Champy's technique were particularly vulnerable to torsion forces. In order to avoid such eventualities, they recommended the use of two plates: one in the tension area and the other in the compression area at the inferior edge of the mandible. In this way, it is possible to achieve a good anatomic repositioning of the fracture, thus avoiding separation and rotation of the segments [11,22,23]. In accordance with these authors, we found that 2PPL had superior mechanical resistance when compared to 1SP. However, both groups behaved similarly in the maximum resistance in molar loading test.

Although fixation of angle mandibular fractures with 2 plates presents clear biomechanical advantages, it is also linked to a high rate of post-operative complications [24,25]. In clinical situations, some considerations should be taken in count, such as the use of a trocar to install the second plate. Also, surgical trauma is greater and the procedure time can be longer. Additionally, the possibility of bacterial contamination, edema, hematoma and lesions of the marginal mandibular nerve is also greater [26].

Faced with the difficult choice of using one or two plates, new 3D fixation systems have been recently proposed as an alternative treatment for mandibular angle fractures. These plates have a low profile and are strong but malleable [27]. In theory, the three-dimensional design of this plate allows it to stabilize both the tension and compression areas that are present in fractures.[12-14].

In an *in vitro* study, Kalfarentzos *et al* [13] evaluated 3D plates of 4 and 8 holes and compared them with fixation methods using one or two plates. The authors reported excellent mechanical behavior of these systems when subjected to flexion and torsion forces. In another study, Alkan *et al* [11] did not find significant differences when fixations with two plates and the 3D plates with 8 holes were

compared. In clinical studies, 3D systems demonstrated greater stability and resistance in comparison to one- or two-plate systems [12,27,28].

In contrast with these studies, we found that the 2PPL group gave better results. High resistance values were obtained by this group for incisal loading, showing a statistically significant difference with all the other groups in displacements of 3 and 5 mm. Similarly, this group also showed the best results for molar loading, with superior resistance values and statistical significance when compared with the groups 3DP and 3DPP.

When we compare groups 3DP and 3DPP we found that both groups had very close resistance values that were not significantly different for all displacements. Our results support the results reported by Kalfarentzos *et al.* [13]

In contrast to the results of Alkan *et al* [11], we found that group 1SP showed better mechanical behavior than 3DPP for displacements of 5 mm with molar loading. This observation could be related to the position and orientation of the plates [29]. Thus, 1SP would be installed in a more favorable area according to the "ideal lines of fixation" described by Champy. In contrast, plate 3DPP is much more distant from these lines, installed in a neutral zone. This affirmation can be proven when we analyze the mechanical behavior of 3DP plates. This group, where the plates were installed in a position closer to the "ideal lines of fixation", presented resistance values that were not significantly different from those measured for group 1SP for all displacements, even those greater than 5 mm.

When the maximum resistance of the systems was evaluated, group 3DPP showed the lowest resistance values for both molar and incisal loading; the resistance values were statistically significant when compared to other groups. We believe that the lower profile of the plate (0.8 mm) may be related to the poor performance of the system. For some authors, a lower profile could have been compensated by the bars that interconnect the plates in 3D systems, which are used for strengthening of the structure [28]. However, the number of bars present in

the evaluated 3DPP plates (4 straight and 2 curved at the edges) apparently did not have a positive influence in the mechanical behavior of them.

Finally, during experimental execution it was possible to observe a relationship between the lever arm and the mean resistance value found when the force was applied to the molar or incisal region. The greatest resistance was found in the molar area for all the evaluated groups. This can be interpreted as a positive outcome for clinical situations, because the greatest load during mastication is found in this region [30].

It is important to note that the laboratory techniques, such the mechanical assays used in this study, are only auxiliary methods that determine potential differences among the different fixation systems. Therefore, the results of this study should be prudently extrapolated to clinical situations, where the fracture characteristics, material availability, patient status, surgeon preferences, and other factors should be considered in order to determine the best treatment method.

In conclusion, the present study demonstrated that two parallel miniplate techniques had statistically greater resistance to compression loads than the Champy technique and 3D fixation systems. In addition, Champy technique and 3DP plates did not show statistically significant differences.

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4. DISCUSSÃO

O estudo das fraturas mandibulares representa um capítulo extenso e ainda bastante controverso perante a literatura científica, sendo alvo de uma porcentagem considerável de pesquisas clínicas e laboratoriais na Cirurgia Buco-Maxilo-Facial. Sua ocorrência, etiologia, tratamento e complicações atrai interesse considerável da especialidade (14, 21,22).

Apesar de a mandíbula possuir uma estrutura óssea densa e resistente, ha muitos estudos epidemiológicos que citam este osso como o de maior incidência de fraturas em traumas em face, apresentando uma frequência de 36 a 70% (29). As razões para esta alta incidência podem ser explicadas pelo formato em arco aberto que este osso apresenta, assim como, pelo fato de a mandíbula encontrar-se projetada no terço inferior da face, tornando-a vulnerável à ação direta de forças mecânicas (13).

As características epidemiológicas do trauma facial podem variar dependendo de fatores como: ambiente, gênero, idade, condição sócio-econômica e mecanismo do trauma (7). Os dados referentes ao gênero em nosso estudo apontam que o gênero masculino apresenta um predomínio maior sobre o feminino, sendo numa proporção de 4:1(3,4,5).

A maior incidência de fraturas mandibulares foi observada em adultos jovens, do gênero masculino com idade entre 20 e 29 anos (3,5). O que provavelmente justifica este resultado é o elevado nível de atividade social e esportiva, quando comparado com outros grupos etários.

Estudos em diversas regiões do mundo identificaram os acidentes de trânsito (21% a 45%) e as agressões físicas (28% a 38%) como os principais fatores etiológicos do trauma facial (2,3,4). A frequência e a gravidade destas

lesões por acidentes de transito têm estado em declínio, desde o aumento das campanhas para o uso obrigatório de cintos de segurança e *air bags* nos veículos (2), assim como da conscientização para se evitar o uso de bebidas alcoólicas ao dirigir. Embora a aplicação das leis de trânsito no Brasil tenha se tornado mais rígida, principalmente a partir da alteração do código de trânsito de 1997, nós também identificamos os acidentes de trânsito como a etiologia mais comum do trauma facial. Nossos resultados concordam com outros estudos realizados no Estado de São Paulo e em outros estados do Brasil (7,11,30).

A maioria das fraturas ocasionadas por acidentes de trânsito em nossa região de estudo foi consequência de acidentes motociclísticos (76.2%), com prevalência de adultos jovens. A falta de experiência no trânsito, a condução imprudente e o tipo de serviço para o qual as motos são utilizadas, podem explicar esses resultados (8). Embora 87% dos pacientes vítimas de acidentes motociclisticos estavam usando capacetes, eles também sofreram fraturas faciais. Segundo Olson *et al*. (31), o uso destes dispositivos diminui a mortalidade, mas não reduz significativamente o número de fraturas, apontando a velocidade como fator determinante para o número e gravidade das lesões.

As agressões físicas também se apresentam como etiologia das fraturas de face, principalmente com o aumento da violência e por consequência, das agressões corporais. Levantamentos recentes no Brasil demonstram que essas agressões têm sido altamente prevalentes (4,30). Em concordância com estes estudos, as agressões físicas ocuparam o segundo lugar dentre as maiores causas de fraturas mandibulares em nossa amostra. Nossos resultados apontam que a grande maioria dos casos esteve relacionada à violência interpessoal, todas no gênero masculino. No entanto, consideramos que especial interesse deve ser tomado nos casos de trauma ou fratura reportada em mulheres e crianças, perante a eventualidade de se tratar de casos de violência doméstica ou do gênero. A violência doméstica é uma situação médico-legal relevante e deve ser abordada de uma forma crítica, estabelecendo-se protocolos (incluindo serviço de assistência social, apoio psicológico e jurídico) para lidar com esses casos.

As regiões mandibulares mais frequentemente afetadas por fraturas variam segundo os estudos de cada centro. Em nosso levantamento, a parassínfise e o ângulo da mandíbula apresentaram-se como os locais mais suscetíveis as fraturas mandibulares, com diferenças porcentuais insignificantes (26.9% e 25.1%, respectivamente). Outros estudos identificaram o corpo (1,31) e ainda outros, o côndilo mandibular (Brasileiro &Passeri *et al.*, 2006) como as regiões mais afetadas.

O ângulo mandibular é uma das regiões mais frequentemente afetadas por fraturas, representando de 20% a 36% de todas as fraturas mandibulares. Características únicas desta região, como a reduzida área de secção na linha de fratura, transição da direção do contorno ósseo, passando do corpo (horizontal) para o ramo (vertical) e a presença de terceiros molares, são fatores que influenciam para que esta região seja uma área suscetível a fraturas (5,9). Em concordância com estes estudos, um terço de nossos pacientes foi acometido por estas fraturas. Os acidentes de trânsito foram o principal fator etiológico (35%, sendo os acidentes motociclisticos os mais prevalentes), seguido pelas agressões físicas (27%).

Tratamento das fraturas de mandíbula

Os objetivos atuais do tratamento das fraturas mandibulares são a restauração da função, aparência e o reparo da fratura permitindo ao paciente um retorno precoce da função, com um mínimo de complicações e deficiências durante esse período. Estes objetivos podem ser atingidos mediante a redução aberta e fixação interna estável (FIE) das fraturas (32).

O tratamento cirúrgico ganhou espaço rapidamente com a introdução da fixação interna. Desde a adaptação, por Champy *et al.* (15), da técnica de Michelet *et al.* (33), a fixação de fraturas por meio de miniplacas e parafusos intra-ósseos, gerou uma verdadeira revolução no tratamento das fraturas faciais, e com elas, as mandibulares. Esta modalidade de tratamento elimina o período de

bloqueio maxilo-mandibular BMM, proporcionando uma redução e estabilidade pós-operatória de ótima qualidade, facilitando assim a recuperação precoce do paciente. Desta forma, a redução aberta associada a FIE tornou-se o tratamento padrão para fraturas do complexo maxilofacial.

O tratamento dos pacientes desse estudo recaiu em grande maioria (90,4%) sobre a utilização da fixação interna estável FIE. Várias técnicas foram utilizadas, variando com a localização da fratura e energia do trauma. As fraturas de corpo, sínfise e parassínfise mandibular foram tratadas por meio dos princípios preconizados pela AO/ASIF, mediante a utilização de duas placas de fixação, sendo uma delas instalada na banda de tensão, com parafusos monocorticais, e a outra na banda de compressão, com parafusos bicorticais (32). As fraturas condilares em pacientes adultos foram tratadas também por FIE, principalmente em fraturas com deslocamento, envolvendo a região subcondilar. Segundo a literatura, a morbidade associada com a redução aberta neste tipo de fraturas é baixa e fornece resultados funcionais satisfatórios, sendo especialmente vantajosa em casos de fraturas condilares bilaterais (34).

A fixação ideal das fraturas de ângulo mandibular ainda é um tema bastante controverso. Diversas técnicas relacionadas à fixação dessas fraturas foram propostas, com os mais diversos resultados. Champy *et al*. (15) foram os primeiros a aplicar placas de menor rigidez no tratamento destas fraturas, preconizando a instalação de uma placa convencional, do sistema de 2,0mm, no bordo superior do ângulo mandibular. Estudos posteriores determinaram que o uso desta técnica é segura, mais fácil e rápida de se executar (6,17).

Embora com bons resultados, alguns autores mostraram que as fraturas de ângulo tratadas pela técnica de Champy eram particularmente vulneráveis às forças de torção. Para evitar estes inconvenientes, e obter maior estabilidade da fratura, foi recomendado o uso de duas placas (35,36).

Para outros autores, o uso de duas placas para osteossíntese de fraturas simples de ângulo mandibular sem deslocamento, não representam nenhuma

vantagem. Schierle *et al.* (16) e Danda (37) compararam, em estudos clínicos randomizados, o uso de duas técnicas de fixação para fraturas de ângulo de mandibular. Grupos de pacientes foram tratados com uma e duas placas do sistema de 2,0mm. Nenhuma diferença estatisticamente significante para alterações oclusais ou complicações do tipo sensorial foi encontrada entre esses métodos de osteossíntese. Os autores concluem afirmando que, em geral, duas placas de fixação podem não oferecer vantagens em relação à fixação com placa única.

Todos os pacientes nesse estudo foram tratados com materiais de fixação metálicos de titânio. Tendo em conta a biocompatibilidade do titânio, os materiais foram deixados na área, sem a necessidade de uma segunda cirurgia para remoção destes, a não ser que fosse evidenciada alguma alteração ou se tratasse de fraturas pediátricas.

O tratamento conservador embora tenha sido relacionado com resultados pouco favoráveis na redução e reparo das fraturas mandibulares (13,14), ainda pode ser considerado como um método de tratamento efetivo em situações especificas, como é o caso das fraturas de côndilo mandibular (38). Em nosso trabalho, o tratamento conservador foi empregado, apenas, em 10% dos casos, sendo todos eles de ocorrência em côndilos mandibulares que permitiram uma oclusão estável, sem deslocamento ou com deslocamento mínimo. Estes foram conduzidos por meio de restrição da dieta, eventual BMM, controle e guia da oclusão dentária e fisioterapia ativa, o mais precoce possível. Embora o tratamento destas fraturas seja ainda uma das maiores controvérsias na literatura maxilofacial, estudos multicêntricos têm reportado resultados satisfatórios nas condutas não-cirúrgicas de tratamento (39).

Complicações.

O número de complicações observadas em nosso estudo (30,2%) foi semelhante aos dados de outras publicações (4,40), sendo a grande maioria dos

casos complicações menores, sendo as mesmas resolvidas mediante tratamentos clínicos ambulatoriais.

Fatores anatômicos (mandíbulas atróficas) ou regiões mandibulares especificas (ângulo) podem estar relacionados a um maior índice de complicações (9). Mas também, fatores sociais como o abuso de drogas e a condição econômica dos pacientes (indigência, má-nutrição), assim como a não cooperação destes com o tratamento podem ter influência (40,41). Em concordância com estes autores, nós acreditamos que o alto índice de complicações em nosso estudo esteve relacionado com o tipo de população que recebeu tratamento, sendo muitos deles de baixa renda e/ou com baixo grau de instrução, o que dificultou a cooperação por parte do paciente. Consideramos que muitas destas complicações, principalmente as menores, poderiam ter sido evitadas se uma maior colaboração ocorresse, o que ocasionaria em maior cuidado quanto às instruções pós-operatórias. De outro lado, não foi encontrada relação entre o abuso de drogas e as taxas de complicações observadas.

Especificamente, as fraturas de ângulo mandibular têm sido frequentemente relacionadas a altos índices de complicações pós-operatórias (10,11). Da mesma forma, 27% das complicações presentes em nossa amostra estiveram relacionados às fraturas de ângulo mandibular. Isso pode ser explicado devido ao menor contato ósseo na linha de fratura e, por consequência, diminuição da vascularização na área.

Alguns autores tentaram estabelecer relação entre as complicações e o tipo de fixação utilizada nas fraturas de ângulo mandibular. Levy *et al*. (20) reportaram índices de complicações correspondentes a 50% em grupos de pacientes tratados com a técnica de Champy, associada ou não a BMM. Autores como Ellis & Walker (22) e Ellis, (6), reportaram que o uso de duas placas para fixação de fraturas de angulo parecem estar relacionadas a um maior índice de complicações pós-operatórias, como infecção, má oclusão ou presença de cicatrizes. No entanto, não foi possível estabelecer uma relação entre as complicações e o tipo de fixação

utilizada em nosso estudo. Isso devido ao pequeno número de casos envolvidos em nossa amostra.

Estudos mecânicos

A grande variedade de opiniões sobre qual seria a técnica de fixação ideal para fraturas mandibulares resultou em um crescente interesse pelos estudos biomecânicos. Estes tipos de estudos procuram demonstrar, laboratorialmente, quais são as melhores técnicas de fixação, quanto ao seu potencial de resistir às cargas que podem desestabilizar a união entre os segmentos fraturados (42).

Atualmente, mesmo com a desvantagem de não simular o comportamento complexo da mandíbula e sua interação com estruturas correlatas, como ossos, músculos e ligamentos (43), os estudos mecânicos são considerados como ferramentas altamente confiáveis para se avaliar a resistência dos materiais e dos diferentes métodos de fixação. A partir da interpretação sistemática de seus resultados, estes testes podem orientar os cirurgiões quanto às qualidades de cada sistema em suportar as forças mastigatórias imediatamente após a cirurgia, e extrapolar informações para as aplicações clínicas destes materiais (44).

Cordey (45) classificou em três tipos as forças que são exercidas sobre os segmentos fixados com dispositivos de osteossíntese: cargas axiais, flexão e torque. A flexão é um dos mais importantes tipos de carga em biomecânica sendo caracterizada pelo efeito da força aplicada perpendicularmente ao longo eixo do modelo testado. A forma mais intuitiva é a flexão em cantilever. Este foi o padrão de força utilizado neste trabalho.

Quanto ao registro da carga suportada por um sistema de fixação, Kohn *et al.* (46) padronizaram um deslocamento máximo de 3 mm para registro ao final do teste, considerando que movimentos acima de um determinado deslocamento não seriam compatíveis com as condições fisiológicas. Esses registros foram tomados a partir do início do deslocamento da ponta de aplicação de carga.

Trivellato (47) padronizou o deslocamento de 10 mm, ou quando houvesse a falha do sistema. Autores como Vieira e Oliveira & Passeri, (28) estabeleceram o limite de 10 mm de deslocamento na avaliação de métodos de fixação em fraturas de sínfise mandibular. Diferente desta, Alkan *et al.* (36) determinaram um deslocamento máximo de 1.75 mm correspondente à distância entre os segmentos osteotomizados, o qual corresponderia à falha da fixação. No entanto, ao invés de definir um limite de deslocamento para finalização do teste, outros autores preconizaram o deslocamento até o momento em que ocorre a falha do sistema. Dessa forma, obtêm-se quatro medidas: carga e deslocamento de pico; carga e deslocamento finais (48).

Kohn *et al.* (46) enumeraram algumas vantagens em se limitar o deslocamento, tais como racionalizar o tempo dispensado para a realização dos testes e representar mais fielmente um modelo clínico em humanos, uma vez que deslocamentos superiores a 10mm não seriam compatíveis com situações clinicas em cirurgia maxilofacial.

Neste trabalho, a opção foi pela realização dos testes em deslocamentos de 1mm, 3mm, 5mm e até o momento em que o sistema atingisse a sua máxima resistência. Desta forma, teríamos mais dados referenciais para a comparação entre as diversas formas de fixação. Caso o deslocamento tivesse sido definido somente em 10 mm, nenhum grupo teria atingido a máxima resistência em carga oclusal. Entretanto, se essa definição fosse de 1mm, os resultados não permitiriam estabelecer diferenças estatísticas entre os grupos avaliados.

Quanto à escolha do substrato para os testes mecânicos, a utilização de mandíbulas frescas congeladas de humanos ou animais foram por um bom tempo a melhor indicação para esses estudos. Entretanto, a escolha destes materiais implica em outro problema, como a dificuldade ou impossibilidade de formar um grupo amostral homogêneo, devido a grande variabilidade anatômica. Além disso, substratos de origem biológicas supõem limitações do tipo ético ou legal, que podem, até mesmo, impedir seu uso.

Com o intuito de determinar o substrato ideal para uso em estudos mecânicos, Bredbenner & Haug (49) analisaram o torque necessário para inserir e remover parafusos de titânio, usados em fixação interna, em 7 substratos diferentes: osso humano, costela bovina, costela suína, epóxi fotoelástico, carvalho vermelho e 2 tipos de mandíbulas sintéticas. Como resultado, as mandíbulas de poliuretano mostraram torques similares ao osso humano, sendo considerado pelos autores o material de escolha para estudos in vitro.

Existem fatores adicionais que colocam as mandíbulas de poliuretano como a primeira escolha para este tipo de estudo. Estas mandíbulas são confeccionadas para combinar com as dimensões, proporções e anatomia humanas. Elas têm uma densa camada exterior, que representa o osso cortical, e uma camada interna porosa que imita o osso esponjoso, sendo capazes de fornecer amostragem mais uniforme (44). Além disso, apesar de serem apenas semelhantes ao osso humano em seu módulo de elasticidade, estas réplicas são capazes de identificar tendências no comportamento mecânico dos materiais, sendo por isso utilizada em diversas pesquisas biomecânicas (25,44).

Os métodos de fixação analisados foram escolhidos com base nas técnicas mais utilizadas para o tratamento de fraturas de ângulo mandibular: Champy e duas placas dispostas paralelamente, e em novas propostas de fixação, 2 tipos de placas grade.

Choi *et al*. (35) realizaram um estudo comparando o uso de uma e duas miniplacas para a fixação de fraturas de ângulo, demonstrando que a colocação de uma segunda placa no bordo inferior da mandíbula poderia estabilizar a fratura de maneira mais adequada, facilitando a mobilidade precoce da mandíbula. Da mesma maneira, Alkan *et al.* (36) observaram que a fixação com duas miniplacas apresentou um comportamento biomecânico superior, quando comparada com fixações por uma miniplaca.

A importância da localização das placas é comprovada em um estudo simulando fraturas em costelas bovinas de Trivellato & Passeri (50). Os autores

encontraram melhor resistência nas simulações fixadas com placas de titânio do sistema 2,0mm, quando dispostas paralelamente, de tal forma que uma delas ocupasse a zona de tração e outra a zona de compressão. 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.

Em concordância com esses estudos verificou-se melhores resultados no grupo com duas placas dispostas paralelamente. Altos valores de resistência foram obtidos por este grupo quando da aplicação de carga incisal, mostrando diferença estatística em comparação com todos os outros grupos para movimentos 3 e 5 mm. Da mesma forma, em carga molar este grupo também apresentou os melhores resultados, com valores de resistência superiores e estatisticamente significantes.

Embora exista um consenso entre os diversos estudos biomecânicos sobre as vantagens da fixação com duas miniplacas nas fraturas de ângulo, clinicamente este tipo de fixação tem sido relacionado com maiores índices de complicações pós-operatórias. A possibilidade de contaminação bacteriana, edema, hematoma e lesões nervosas são mais elevados devido ao maior trauma e tempo cirúrgico necessário para a instalação de uma segunda miniplaca no bordo inferior mandibular (6). Diante desse dilema, os novos sistemas de fixação com miniplacas grade têm sido sugeridos como alternativa de tratamento.

As miniplacas grade, constituídas por unidades quadradas ou retangulares, tem sido indicadas para o tratamento em fraturas de ângulo, devido à sua geometria favorável à redução e estabilização da fratura em três dimensões. As miniplacas grade são maleáveis, de baixo perfil, possuem alta resistência contra torque e menor custo. A literatura cita a baixa taxa de complicações e inúmeras vantagens sobre as miniplacas convencionais, como a fácil adaptação ao osso, simultânea fixação das bordas superior e inferior, sem deslocamento da fratura (24,25).

O desempenho clínico das miniplacas grade foi avaliado por Feledy *et al*. (23). Neste estudo, as miniplacas grade demonstraram maior estabilidade e resistência quando comparadas à sistemas convencionais de fixação com duas placas do sistema 2,0mm. Aliás, foram de fácil instalação no trans-cirúrgico e nenhuma complicação pós-operatória foi reportada.

Posteriormente, Guimond *et al.* (24) realizaram uma avaliação retrospectiva clínica do tratamento de fraturas não cominutas de ângulo mandibular, reduzidas mediante acessos intraorais e fixadas com placas grade. A taxa de infecção reportada foi de 5,4%. Outras complicações, como déficit sensorial devido à cirurgia, tiveram recuperação completa. Os autores concluíram que a fixação de fraturas, não cominutas, de ângulo mandibular com placas grade é um procedimento altamente previsível.

Hochuli-Vieira *et al.* (51) verificaram, em 45 pacientes tratados com placas grade de 4 furos, uma incidência de complicações de 11,1%. Dentre estes, 4 pacientes apresentaram complicações menores e apenas um necessitou de troca do material de fixação. Os autores concluíram que as placas grade de 4 furos representam uma opção clínica viável para o tratamento das fraturas de ângulo quanto apresentarem suficiente contato interfragmentário.

Apesar dos relatos clínicos reportarem um ótimo comportamento das miniplacas grade, os estudos *in vitro* encontram-se divididos, inclusive apresentando resultados bastante discretos quanto à resistência destes sistemas. Alkan *et al*. (36) demonstraram, mediante testes em mandíbulas de carneiro, que as miniplacas grade de 08 furos apresentavam grande resistência às forças de compressão quando comparadas à técnica de Champy. Não entanto, não foram encontradas diferenças estatísticas significantes no comportamento biomecânico quando comparadas às técnicas de fixação convencionais com duas placas.

Kalfarentzos *et al*. (25) avaliaram, mediante testes em mandíbula de poliuretano, miniplacas grade de 4 e 8 furos, e as compararam com os métodos de fixação convencionais usando uma ou duas placas. A miniplacas grade de 4 furos

foi contornada de forma a se adaptar passivamente entre a linha obliqua e o bordo superior mandibular. Os autores reportaram uma ótima conduta mecânica das placas grade submetidos à forças de flexão e torção. O desempenho das placas grade de 4 furos foi superior e estatisticamente significante, quando comparado com a placas grade de 8 furos e com os métodos de fixação convencionais.

No entanto, apenas 6% dos cirurgiões preferem o uso de placas grade (18), afirmando entre outras razões, que estes sistemas têm excesso de material e que não oferecem benefícios reais para seu uso na fixação de fraturas (52). Os resultados do nosso estudo parecem confirmar essa percepção, demonstrando que, embora a fixação de fraturas de ângulo com placas grade de quatro furos foram mais resistentes às forças de carregamento vertical que a fixação com uma miniplaca, esta superioridade não foi estatisticamente significativa.

Quando comparada com o grupo de duas placas, as placas grade apresentaram os menores valores de resistência, tanto para carga molar, como para a incisal. Além disso, os resultados ainda demonstraram que placas grade de 8 furos não aumentaram a resistência do sistema. O menor perfil (0.8mm) pode ter influenciado no comportamento mecânico inferior destas placas.

Os diferentes locais de instalação de placas grade, a variedade de tamanhos e formas disponíveis comercialmente, impedem uma comparação efetiva entre os diversos estudos. A continuidade de investigações poderá demonstrar a eficácia de cada desenho das placas grade na prática clínica e se estas apresentam vantagens em relação às placas convencionais.

5. CONCLUSÔES.

- As principais etiologias das fraturas de mandíbula foram os acidentes de trânsito e as agressões físicas. As regiões mandibulares mais afetadas foram a parassínfise e o ângulo mandibular.

- O ângulo foi a principal região mandibular afetada por complicações pós-operatórias.

Nas condições experimentais dos trabalhos incluídos nesta tese, podemos concluir que:

- Nos testes de carregamento, duas miniplacas paralelas oferecem maior resistência a cargas de compressão, do que a técnica de fixação Champy e as placas grade.

- Não houve diferença estatisticamente significativa entre a fixação pela técnica de Champy e a placa grade de 4 furos. As placas grade de oito furos apresentaram os menores valores de resistência mecânica.

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7. ANEXOS

- **Carta de aceite para publicação do artigo I.**

De: em.scs.0.3c7a20.12f0c600@editorialmanager.com en nombre de Journal of Craniofacial Surgery (no-reply@editorialmanager.com)
Enviado: martes, 15 de julio de 2014 10:34:36 p.m.
Para: Jose Luis Munante-Cardenas (vonpaulus9@hotmail.com)
CC: mbhabal@verizon.net

Jul 15, 2014

RE: SCS-14-175R1, entitled "ETIOLOGY, TREATMENT AND COMPLICATIONS OF MANDIBULAR FRACTURES: A SIX-YEAR RETROSPECTIVE STUDY"

Dear Mr Munante-Cardenas,
I am pleased to inform you that your work has now been accepted for publication in Journal of Craniofacial Surgery. All manuscript materials will be forwarded immediately to the production staff for placement in an upcoming issue.

Thank you for submitting your interesting and important work to the journal.

With Kind Regards,

Mutaz B. Habal, M.D.
Editor-in-Chief
Journal of Craniofacial Surgery
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- **Submissão do artigo II para publicação.**

De: em.omfs.0.35de63.48dcb21f@editorialmanager.com en nombre de Oral and Maxillofacial Surgery (noel.ampong@springer.com)
Enviado: miércoles, 18 de septiembre de 2013 04:28:59 a.m.
Para: Jose Luis Munante-Cardenas (vonpaulus9@hotmail.com)
Dear Mr Munante-Cardenas,

Your submission entitled "EPIDEMIOLOGY AND TREATMENT OF MANDIBULAR ANGLE FRACTURES IN A BRAZILIAN POPULATION" has been assigned the following manuscript number: OMFS-D-13-00168.

You will be able to check on the progress of your paper by logging on to Editorial Manager as an author.
The URL is http://omfs.edmgr.com/.

Thank you for submitting your work to this journal.

Kind regards,

Editorial Office
Oral and Maxillofacial Surgery

- **Carta de aceite para publicação do artigo III.**

De: onbehalfof+pmanson+jhmi.edu@manuscriptcentral.com,en nombre de pmanson@jhmi.edu
Enviado: lunes, 21 de abril de 2014 09:48:49 a.m.
Para: vonpaulus9@hotmail.com
21-Apr-2014

Dear Mr. Munante-Cardenas,

It is a pleasure to accept your manuscript entitled "A BIOMECHANICAL COMPARISON OF FOUR MANDIBULAR ANGLE FRACTURE FIXATION TECHNIQUES / Unable to Display Letter Tag (##DOCUMENT_RUNNING_HEAD##)" in its revised form for publication in Craniomaxillofacial Trauma and Reconstruction. The comments of the reviewers who reviewed your revision are included at the end of this letter.
You find your manuscript as well as this decision letter in your Author Centre under Manuscripts with Decisions.
Your manuscript will be forwarded to Georg Thieme Publishers. They will prepare your manuscript for printing. Thieme will contact you in the next weeks for further details.
Thank you for your contribution. Also on behalf of the reviewers of Craniomaxillofacial Trauma and Reconstruction, we look forward to your continued cooperation to the journal.
Sincerely,
Dr. Paul Manson
Editor-in-Chief
Craniomaxillofacial Trauma and Reconstruction
pmanson@jhmi.edu

FACULDADE DE CIENCIAS MEDICAS - UNICAMP (CAMPUS CAMPINAS)

PROJETO DE PESQUISA

Título: ESTUDO RETROSPECTIVO DOS CASOS DE FRATURA DE MANDÍBULA TRATADOS PELA ÁREA DE CIRURGIA PLÁSTICA FCM-UNICAMP, NO PERÍODO DE JANEIRO DE 2006 A DEZEMBRO DE 2011

Área Temática: Versão: 1

CAAE: 05774512.6.0000.5404

Pesquisador: Jose Luis Munante Cardenas

Instituição: Hospital de Clínicas da UNICAMP

PARECER CONSUBSTANCIADO DO CEP

Número do Parecer: 83897

Data da Relatoria: 28/08/2012

Apresentação do Projeto:

Lesões na região maxilofacial são comuns em vítimas de trauma e estão freqüentemente associadas a outras lesões, como as crânio-encefálicas, espinhais e dos membros superiores e inferiores. Diversos estudos identificaram à mandíbula como um dos ossos faciais mais afetados por fraturas.

Embora exista consenso sobre a necessidade de redução aberta e fixação interna estável destas fraturas, ainda existe controvérsia sobre o melhor sistema de fixação ou a técnica que deve ser utilizada. Assim, diferentes modelos de fixação têm sido descritos e extensamente reportados na literatura, apresentando resultados amplamente variáveis e controversos. O objetivo dos autores neste estudo será analisar a prevalência, as formas de tratamento e os índices de complicações dos casos de fratura de mandíbula, associadas ou não a outras fraturas faciais, tratados pela Área de Cirurgia Plástica da Faculdade de Ciências

Médica, no Hospital de Clínicas da Unicamp, no período de Janeiro de 2006 a dezembro de 2011.

Serão analisados os prontuáriosde todos os pacientes vítimas de fratura de mandíbula. Os dados coletados serão: gênero, idade, raça, etiologia, uso de dispositivos de segurança, consumo de substâncias nocivas, local anatômico da fratura, acesso cirúrgico utilizado, material de fixação e sua disposição, e complicações pós operatórias. Os resultados obtidos serão analisados através de estatística descritiva; a comparação entre os dados será realizada usando o teste de Qui-quadrado e teste exato de Fisher, quando indicado. Será utilizado o software Bioestat 5.0. Espera se estabelecer os principais fatores etiológicos, a efetividade das formas de tratamento instituídas e as complicações presentes nas fraturas mandibulares tratadas em nosso Serviço. Todos estes dados permitirão uma interpretação mais realista e consistente da melhor maneira como nossos pacientes devem ser conduzidos.

Objetivo da Pesquisa:

O objetivo deste estudo será avaliar retrospectivamente a epidemiologia, as formas de tratamento e os índices de complicações dos pacientes vítimas de fraturas de mandíbula tratados pela Área de Cirurgia Plástica da Faculdade de Ciências Médicas, no Hospital de Clínicas da Unicamp, no período de Janeiro de 2006 a Dezembro de 2011.

Avaliação dos Riscos e Benefícios:

Por ser uma pesquisa de caráter retrospectivo, não apresenta riscos aos sujeitos.

Os benefícios serão para os futuros pacientes e para pacientes que sofrerem complicações após a realização do tratamento, uma vez que o estudo servirá como embasamento e fundamentação teórica para a melhora dos procedimentos cirúrgicos, baseados nos conhecimentos relacionados à epidemiologia e opções terapêuticas utilizadas.

Comentários e Considerações sobre a Pesquisa:

O projeto está conciso e adequadamente delineado.

Considerações sobre os Termos de apresentação obrigatória:

O pesquisador solicita dispensa do TCLE, uma vez que a pesquisa é retrospectiva e não foi possível contactar os sujeitos.

Recomendações: Não há.

Conclusões ou Pendências e Lista de Inadequações:

Não há pendências.

Situação do Parecer: APROVADO

Necessita Apreciação da CONEP: Não

Considerações Finais a critério do CEP: Aprovado em reunião do colegiado aos 28/08/2012.

CAMPINAS, 28 de Agosto de 2012

Assinado por:

Carlos Eduardo Steiner