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Comparison of compressive strength between three different plates for mandibular angle fractures fixation

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ABSTRACT

The present study aims to compare three types of internal fixation for fractures of the mandibular angle. Mechanical testing was performed on replicas of polyurethane hemimandibles sectioned at the angle region to simulate a fracture and fixed with three different hardwares. Fixation devices enrolled on this survey included the grid plates with and without an intermediate bar and the method described by Champy and colleagues in 1978 and the sample consisted of 10 hemimandibles for each group. Vertical loadings were applied on each hemimandible and recorded after a vertical displacement of 3 and 5 mm. Statistical analysis was made by means of the variance analysis (ANOVA) and the Duncan test with a significance level of 5%.

The Champy technique showed a statistically significant increased resistance when compared to the grid plates after vertical displacements of 3 and 5 mm. The results of this survey suggest that the Champy technique, when compared to the grid plate positioned at the middle of the mandibular bone (placement site selected for this study), is more resistant than the grid plate and that the inclusion or not of an intermediate bar to the grid plates does not improve its resistance after linear vertical loadings.

1. Introduction

Several papers describe the mandibular angle as the site of higher incidence for mandibular fractures (Ogundare et al., 2003; Paza et al., 2008; Sauerbier et al., 2010; Höfer et al., 2012). Moreover, fractures on this location present the highest complication rates amongst all mandibular fractures, despite all the advancements on internal fixation (Passeri et al., 1993; Ellis and Sinn, 1993; Ellis, 1993, 1999; Ellis and Walker, 1994, 1996; Schierle et al., 2013; Feller et al., 2003; Vineeth et al., 2013). Although there are obvious differences related to surgical access, size and type of fixation devices, the basic goals for all fixation techniques are the same: early return to function and enough stability for adequate osseous repair (Wittenberg et al., 1997).

In order to minimize the extent of surgery and failure of the monocortical systems, as well as to avoid extra-oral approaches, the grid plates have been developed for the application on maxillofacial trauma and orthognathic surgery. Those plates can be easily applied for fractures of the mandibular angle through an intra-oral approach and percutaneous screw positioning or with the aid of the 90° screwdriver (Guimond et al., 2005; Hochuli-Vieira et al., 2011).

Some studies have reported a low incidence of complications with the use of the grid plates on the mandibular angle fractures (Hochuli-Vieira et al., 2011). They have become an alternative to conventional internal fixation with the advantage of simultaneous adaptation of the inferior and superior borders of the mandible providing increased stability (Feledy et al., 2004; Guimond et al., 2005; Zix et al., 2007).

2. Material and methods

Morphologically standardized replicas of a human dentate mandible made of rigid polyurethane (SYNBONE 8311- Malans – Switzerland) were sectioned in the midline and the left side was chosen for this assay. An oblique cut at the mandibular angle region was performed from the retromolar region, 3 mm posteriorly to the distal border of the second molar, to the gonial region of the inferior border of the mandibular angle, simulating the fracture. An acrylic splint (Dental Vipi Ltda., Pirassununga-SP, Brazil) was built based

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on the first sectioned model reproducing the same site of fracture for all the other samples.

Three different systems of fixation were tested (Bucoplan – Engimplam Indústria e Comércio de Materiais Dentários, Rio Claro-SP, Brazil):

- Group I: 10 straight 4-hole titanium bone plates (1 mm × 25 mm × 5.5 mm) and 40 monocortical titanium screws (6.0 mm); system 2.0
- Group II: 10 grid 4-hole titanium bone plates (1 mm × 20 mm × 11.5 mm) and 40 monocortical titanium screws (6.0 mm); system 2.0
- Group III: 10 grid 4-hole titanium bone plates with an intermediate vertical reinforcement bar (1 mm × 20 mm × 11.5 mm) and 40 monocortical titanium screws (6.0 mm); system 2.0

All fractured replicas were reduced anatomically and another acrylic splint was fabricated to customize plate positioning according to the methodology described by Asprino et al. (2006).

For group I, the plates were positioned at the external oblique line according to the technique described by Champy et al. (Fig. 1A). For groups II and III (Fig. 1B and C, respectively), the plates were positioned at the intermediary portion of the angle, 10 mm above the basal portion of the synthetic mandible, approximately at the neutral zone of the mandibular angle, following the manufacturer placement suggestion. The horizontal long axe of the grid plate was placed perpendicular to the fracture line.

Another group of intact hemimandibles (group IV – control) was also tested to evaluate the force needed to fracture the sample as well as to ascertain correct positioning of the specimen on the loading device.

The compressive loading tests were executed on the electromechanical testing machine EMIC DL 2000 (São José dos Pinhais-PR, Brazil) at 1.0 mm/min and a load cell of 5.0 kN.

After correct adaptation and fixation on the testing machine, the samples were subjected to a vertical compressive loading, simulating bite forces at the region of the cuspid and first bicuspids. By means of the progressive application of force over the specimens, the compressive strength (N) and the displacement (mm) imposed by the testing machine were obtained.

Two distinct moments of loading support were measured and recorded. The first after 3.0 mm and the second after 5.0 mm of vertical displacement. The end of the assessment was established at the 5.0 mm dislocation even in cases where the system failed before this end-point.

The statistical analysis was employed to compare quantitatively the groups studied regarding the means of compressive strength (N) at the two previously described vertical displacement points. The one-way (ANOVA) variance analysis was used to compare the groups with a significance level of 5.0%. After verification of statistically significant differences, Duncan test ($\alpha = 0.05$) was used for the pairwise comparison among the experimental groups.

Table 1
Statistical analysis and results (ANOVA) among the groups at the 3 mm point of vertical displacement.

Group	Mean	Standard deviation	*p*-value
Group I	149.10	48.86	0.05
Group II	23.77	2.96	
Group III	30.50	6.33	
Group IV	364.22	101.82	

Table 2
Final results according to the Duncan test (3 mm point). Sig = significance.

Group	*N*	Homogenous	Subgroups	Averages
		1	2	3
I	10		149.10	
II	10	23.77		
III	10	30.50		
IV	10			364.22
Sig.	-	0.792	1.000	1.000

3. Results

For the 3 mm loading point, the ANOVA analysis showed statistically significant difference among the studied groups (Table 1) with a higher compressive strength registered for group I (Table 2). Therefore, the presence of the intermediate vertical bar did not increase the compressive strength of the grid plates.

The mean values and standard deviations of loading at the 5 mm point indicated the same statistical results as for the 3 mm point (Tables 3 and 4). Likewise, the reinforcement bar of the grid plates on group III showed no increase on compressive strength.

4. Discussion

The concepts of stable internal fixation and non-rigid fixation have been widely discussed. The increased application of the load-sharing principles for the treatment of mandibular fractures has motivated the development of new types of fixation systems with plates and screws that are able to provide increased stability with a smaller size and number of implants. The three dimensional systems, which are basically two plates linked by a vertical bar, are considered stable and resistant to masticatory loads and, therefore, they exempt the patient from the intermaxillary fixation period (Wittenberg et al., 1997; Guimond et al., 2005).

The combination of monocortical screws with the cuboidal or rectangular design of the plates deliver the three dimensional stability to the system, while the reconstruction and compression systems rely on the plate thickness for their stability. Biomechanical studies have already shown the stability of the three dimensional bone plates, however only a few clinical studies have been reported regarding its use on fractures of the mandibular angle

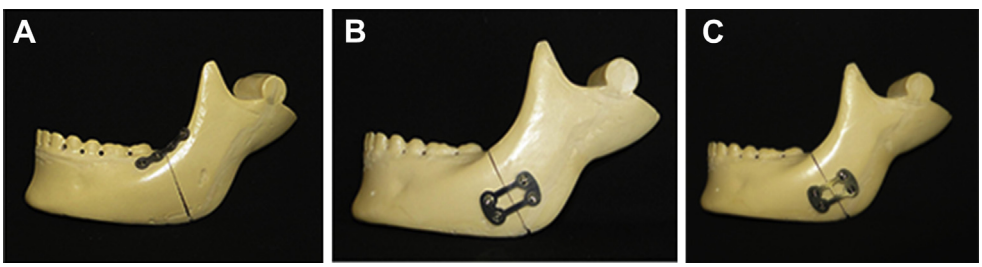

Fig. 1. A: The Champy fixation technique representing group I. B: The 4-hole grid plate representing group II. C: The 4-hole grid plate with the middle reinforcement vertical bar representing group III.