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Mechanical and photoelastic analysis of four different fixation methods for mandibular body fractures

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A B S T R A C T

Objective: The aim of the present study was to compare four methods of fixation in mandibular body fractures.

Study design: Mechanical and photoelastic tests were performed using polyurethane and photoelastic resin mandibles, respectively. The study groups contained the following: (I), two miniplates of 2.0 mm; (II) one 2.0 mm plate and an Erich arch bar; (III) one 2.4 mm plate and an Erich arch bar, and (IV) one 2.0 mm plate and one 2.4 mm plate. The differences between the mean values were analyzed using Tukey's test, the Mann–Whitney test and the Bonferroni correction.

Results: Group II recorded the lowest resistance, followed by groups I, IV and III. The photoelastic test confirmed the increase of tension in group II.

Conclusion: The 2.4 mm system board in linear mandibular body fractures provided more resistance and the use of only one 2.0 mm plate in the central area of the mandible created higher tension.

1. Introduction

Mandibular fractures are very common and correspond to almost two thirds of facial fractures due to the jaw's prominent position in the facial skeleton. Different categories of fracture exist, depending on the etiology, type and anatomical location (Dingman and Natvig, 1964; Thaller, 1994). The basic principles in treating mandibular fractures include reducing the fracture, restoring dental occlusion and controlling complications or post-operative infections (Joss et al., 1999). Two standard treatment types are used to repair this type of fracture: closed reduction, which involves maxillomandibular fixation; and open reduction, which involves the direct exposure, reduction and fixation of fragments through the use of steel wires and a system of plates and screws (Peterson et al., 2005; Andreasen et al., 2008; Miloro et al., 2008).

The ideal fixation method depends on the region and characteristics of the fracture. While some fractures can be fixed adequately with a simple miniplate, others may require a reconstruction plate. In addition, the selection of the fixation method depends on the experience and judgment of the surgeon. It is necessary to estimate the magnitude and duration of the load for each specific situation (Assael and Ueeck, 2012). The clinical effectiveness of plates and screws for stable internal fixation in mandibular trauma and reconstructive surgery has been well documented. Experimental investigations are frequently performed to attain a better understanding of the biomechanics of mandibular fixation, fixation techniques and fixation materials. They also quantify and assess functionality in an in vitro environment (Asprino et al., 2006).

Fixation methods can be empirically assessed by mechanical tests (Vieira e Oliveira and Passeri, 2011). Thus, it is possible to observe the in vitro evolution and behavior of the fixation method when it is exposed to load, although this only serves as an auxiliary method to determine the potential of the systems for use in vivo (Oliveira et al., 2012; Falci et al., 2014).

Another method used to validate the different methods of osteosynthesis used in the treatment of fractures is photoelasticity (Rudman et al., 1997; Sato et al., 2010; Lima et al., 2011; Christopoulos et al., 2012). The photoelastic test is an

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experimental technique that enables rapid qualitative analysis of the stress within the photoelastic model by observing the optical effects in models (Ueda et al., 2004). Therefore, the aim of the present study was to compare four methods of fixation in mandibular body fractures using linear load testing and photoelastic analysis.

2. Materials and methods

This study did not require ethics committee approval as it was an in vitro study, which did not involve human or animal participants.

Sixty hemimandibles (Nacional Ossos, Franceschi & Costa e Silva Ltda, Jaú, São Paulo, Brazil) with teeth of rigid polyurethane (ASTM F 1839; density of 200/L) were used for the mechanical test (Falci et al., 2014). They were submitted to sectioning, simulating a fracture of the mandibular body (between the second lower premolar and the first lower molar). This was done by designing a colorless, chemically activated, acrylic resin guide (Dental Vipi Ltda. Pirassununga, São Paulo, Brazil) to standardize the section.

The design of the models for photoelastic analysis was based on a rigid polyurethane hemimandible built from birefringent photoelastic resin (Araldite GY 279 and Aradur HY 2963) standardized by Nacional Ossos (Franceschi & Costa e Silva Ltda. – Jaú, São Paulo – Brazil), sectioned in two segments that were identical to those used in the mechanical tests (Falci et al., 2014). The segments were then sent to Nacional Ossos to design the four hemimandibles in photoelastic resin. A full hemimandible was used as a control in the photoelastic test.

The fixation materials included in the mechanical and photoelastic tests were the following: 16 straight plates with four holes (system 2.4); 16 straight plates with six holes (system 2.4); 64 straight plates with four holes (system 2.0); 256 monocortical screws (system 2.0) of 5 mm in length; 160 bicortical screws (system 2.4) of 10 mm in length and Erich arch bars. The plates were made of commercial titanium (Grade II – ASTM F67) and the screws of alloy-6 aluminum-4 vanadium (Ti-6Al-4V ASTM F136) (Tóride, Mogi-Mirim, São Paulo, Brazil).

2.1. Mechanical test

For the mechanical test, the polyurethane mandibles were divided into four fixation groups as follows: **Group I:** 15 hemimandibles of polyurethane fixed with two miniplates, four titanium holes of 2.0 mm and screws inserted and linearly arranged with an angulation of 90° in relation to the hemimandible. The first plate was fixed 20 mm up from the lower border of the mandibular body (in the tension zone) with 2.0 mm × 5 mm screws. The second plate was fixed 8 mm up from the lower border of the mandible body (in the compression zone) with 2.0 mm × 5 mm screws (Fig. 1A). **Group II:** 15 polyurethane hemimandibles fixed with an Erich arch bar in the dental area and a titanium miniplate with four 2.0 mm holes (fixed 17 mm up from the lower border of the mandibular body) and 2.0 mm × 5 mm screws, linearly arranged and inserted at an angle of 90° in relation to the hemimandible (Fig. 1B). **Group III:** 15 polyurethane hemimandibles fixed with an Erich arch bar in the dental area and a titanium plate (2.4 mm) with six holes in the compression zone of the mandible (8 mm up from the lower border of the mandibular body), fixed with 2.4 mm × 10 mm screws, linearly arranged and inserted at an angle of 90° in relation to the hemimandible (Fig. 1C). **Group IV:** 15 polyurethane hemimandibles fixed with titanium miniplates (2.0 mm) in the tension zone of the mandible (20 mm up from the lower border of the mandibular body) using 2.0 mm × 5 mm screws, a titanium plate with four holes and a 2.4 mm system in the compression zone of the mandible (8 mm up from the lower border

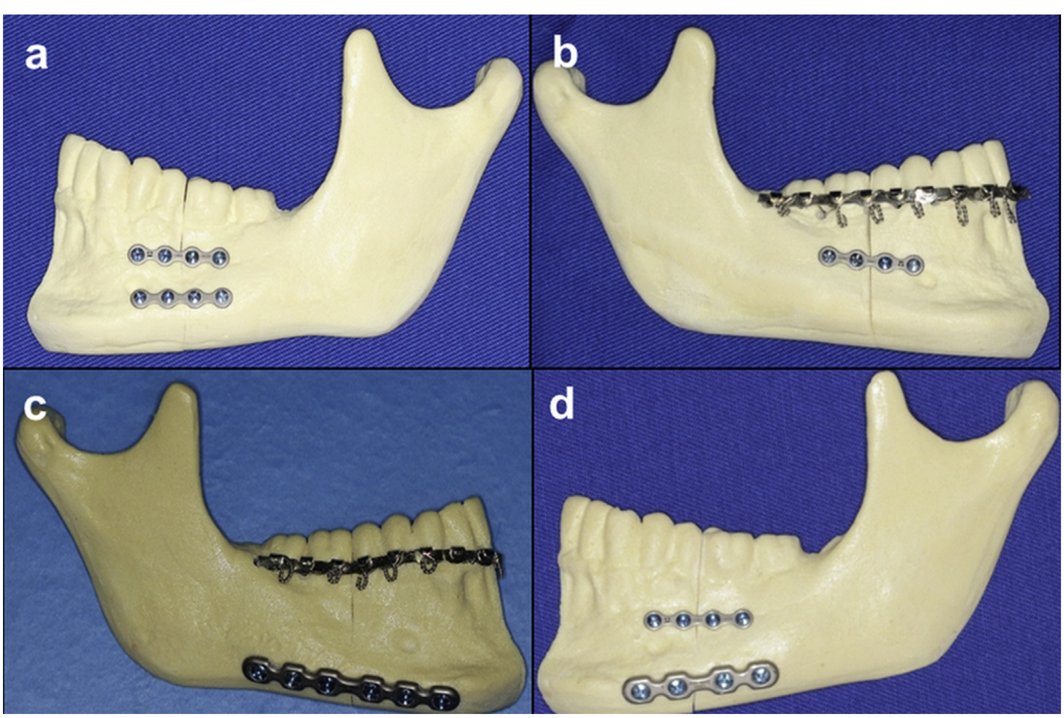

Fig. 1. Methods of fixation in the study groups: (a) Hemimandible of group I, fixed with two plates of 2.0 mm, one in the tension zone and the other in the compression zone; (b) Hemimandible of group II, fixed with a 2.0 mm plate in the central zone of the mandible and an Erich arch bar in the dental area; (c) Hemimandible of group III, fixed with a 2.4 mm plate in the compression zone and an Erich arch bar in the dental zone; (d) Hemimandible of group IV, fixed with a 2.0 mm plate in the tension zone and a 2.4 mm pate in the compression zone.