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Does lag screw fixation of condylar fractures result in adequate stability? A finite element analysis

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ABSTRACT

The great incidence and controversies related to the diagnosis, treatment, surgical accesses, and type of osteosynthesis materials confer an outstanding role to condylar fractures among facial fractures. Plate configurations, with diverse formats and sizes, may be used to surgically resolve condylar fractures. With the purpose of improving the advantages and minimizing the disadvantages of fixation techniques, the neck screw was developed aiming at the needed stabilization to render a correct fixation through a system of dynamic compression. This is achieved by increasing the contact between the fractured bone stumps, as well as assisting at the time of fracture reduction. The present paper aims at comparing the fixation and stability of mandibular condylar fractures using the neck screw and an overlaid "L"-shaped-4-hole-2 mm plate on the one hand, with a system in which the neck screw and the "L"-shaped plate form a single structure, having been joined by a welded point, on the other hand. The results with the neck screw are satisfactory, and, thus, it is an alternative for the reduction and fixation of fractures of the mandibular condyle, whether or not a plate is joined to the structure, provided it is correctly prescribed and with adequate surgical sequence and technique.

1. Introduction

Mandibular condylar fractures correspond to 11%–16% of facial fractures and to 30%–40% of all mandibular fractures (Yang and Patil, 2012; Chrcanovic, 2015).

When a surgical treatment is chosen, a method consisting of fracture reduction and stable internal fixation by means of titanium plates and screws affords good function for patients during bone restoration (Yang and Patil, 2012; Sugiura et al., 2001; Asprino et al., 2006; Tominaga et al., 2006).

Many techniques have been developed over time for fixation of mandibular condyle fractures, aiming to improve the quality of life of the patient (Krenkel, 1992; Eckelt, 1999; Reuter, 1999).

Krenkel developed a surgical technique for the management of mandibular condylar neck fractures. A new axial/oblique-axial lag screw (anchor screw) with biconcave washers (anchor washer) makes it possible to carry out standardized osteosynthesis in the region of the thin neck mandibular condyle (Krenkel, 1992; Reuter, 1999).

The neck screw is prescribed for condylar fractures, regardless of the degree and type of displacement, as described by Conci et al. (2014). The neck screw is fitted within the bone medulla in the fractured proximal portion of the mandibular condyle, and a groove is cut into the distal portion to accommodate the screw. A plate is then installed, which may be straight or preferably in an "L" shape (since it is easier to install), perpendicularly overlying the screw so as to prevent its movement, taking into account the round shape of the screw head, thereby conferring satisfactory stability when reducing the fracture.

Finite element analysis (FEA) is an efficient method to evaluate and compare various forms of treatment of mandibular condylar fractures, so as to improve fixation materials and thereby provide

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greater fracture stability and more comfort to patients (Wagner et al., 2002; Mesnard et al., 2011; Christopoulos et al., 2012; Aquilina et al., 2012, 2013).

2. Materials and methods

A mandible was built from a mandibular DICOM file taken from a database at CTI (*Centro de Tecnologia da Informação*—the Center for Information Technology of the former Renato Archer Research Center of the Ministry of Science and Technology, in Campinas, SP, Brazil). The data were obtained from a mandible that was submitted to 1-mm -thick helical computed tomography (CT). The computer models of the titanium plates and screws were based on physical samples from Tóride (Tóride Ind. e Com. Ltda., Mogi Mirim, SP, Brazil), the same as those used in the work by Sato et al. (2012) and by Conci et al. (2015), who used the comparison of the results obtained with FEA.

The neck screw models were based those described in the papers by Conci et al. (2014) and Conci et al. (2015).

The neck screw consists of a 26-mm screw 2 mm in diameter, its head being 3.15 mm. The tip of the screw is sharp, with a 1-mm screw-thread step. The central part of the screw (neck) is smooth, and the posterior region (near the head) has more threads.

The three-dimensional geometry of all three structures, namely, mandible, miniplates and screws, was created with the 5.0 Rhinoceros software (McNeel-North America, Seattle, WA, USA).

The geometry was imported to the Ansys Workbench V.16.2 software (Ansys Inc., Canonsburg, PA, USA) for the pre-processing of the FEA modeling development. All materials were regarded as homogeneous, isotropic, and of linear elasticity.

Cortical bone properties with a Young's elasticity modulus were 18,600 MPa for the cortical bone, 1,860 MPa for medullar bones, and 103,000 MPa for the titanium alloy, with Poisson ratios of 0.34 for the medullar and cortical bones and the titanium alloy.

Identical subcondylar fractures were simulated for both groups, with forces simulating mouth opening and muscular action.

A supporting tool was used to restrict the upper movement, simulating a mandible that is articulated to the basis of the cranium. Mandibular condyles were restricted superiorly so that the mandible did not "turn" virtually when inferior forces were applied. Next, 39,059 N was exerted simultaneously in the region of the molar and incisive teeth, and 4.9773 N bilaterally in the direction that simulates the action of lateral pterygoid muscles.

The fractures were fixed by means of two techniques: the first had a neck screw type of screw associated with an overlaid 2.0-mm, "L"-shaped, 4-hole miniplate with 6.0-mm-long screws, as described by Conci et al. (2015) (G1), in addition to a group with a new structure, formed by the union, by a virtual welded point, of the neck screw associated with an "L"-shaped, 4-hole miniplate and 6.0-mm screws (G2) (Fig. 1).

Plates and screws were "virtually" folded so that they would passively adjust to the surface and morphology of the mandible, in simulation of clinical situations, and according to protocols detailed by Parr et al. (2012).

After each model was completed, the movement regarding the proximal and distal fragments was calculated. The stability of a three-dimensional stress state was assessed through the hypothesis of main minimal and maximum tensions, which measures pure traction and compression tensions. All tension values are provided in MPa (N/mm^2) and are reproduced in a color scale, to quantitatively evaluate distribution.

Quantitative analysis was carried out taking into account the load held by the model in the recommended displacement.

3. Results

The value found for fracture displacement when forces were exerted was 0.011678 mm for G1 and 0.014047 mm for G2. The conventional and united neck screw systems showed no significant differences when compared in isolation (Fig. 2).

The Von Mises tension values for G1 were higher on the interface between the screw and the overlaid "L"-shaped plate, whereas for G2, the highest value was that found in the welded point region. A comparison between the two groups using the neck screws shows that the result for G1 was 170 MPa, whereas for G2 it was 350 MPa, probably owing to the fact that the welded area is very small and thus accumulates a lot of tension (Fig. 3).

The neck screw, in both techniques studied, showed results that were similar to those found in the one-plate configuration, according to the FEA results described by Conci et al. (2015).

When compared to the fixation system with two miniplates, the results found in our research corroborate previous literature, which shows that the system with two miniplates is considered ideal, according to the FEA results described by Conci et al. (2015).

When the screws were "removed" for assessment, the results were identical, that is, greater tension in the same points of the synthesis materials that were found with the presence of the screws.

The values of the main maximum tension and main minimum tension were also similar for both configurations (Figs. 4 and 5).

4. Discussion

Dynamic biomechanical trials have made it possible to better understand the tension that occurs in the condylar process and in osteosynthesis materials used, and provide information that may be applied to other kinds of analyses as well as in clinical prescriptions, aiming at improvement of patients' well-being and the ideal resolution of fracture cases (Meyer et al., 2002, 2007; Bujtár et al., 2010; Kanno et al., 2014).

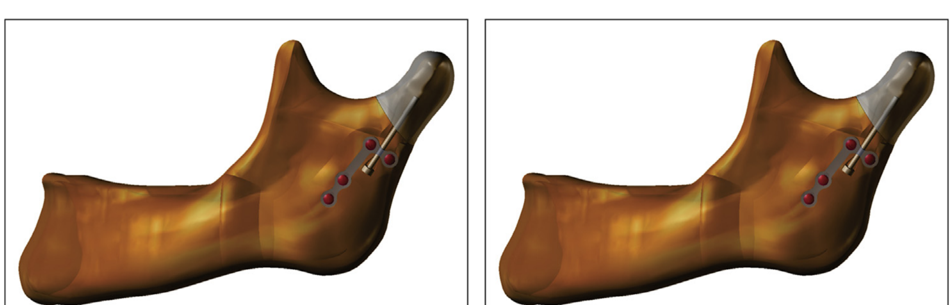

Fig. 1. The two study groups. Group 1 (G1) has a neck screw with an overlaid plate; group 2 (G2) has a neck screw and a plate with a virtual welded point.