Original Article

Photoelastic evaluation of two different sagittal split ramus osteotomies in advancement surgery

Valdir Cabral Andrade1, Sergio Olate2,3, Leandro Pozzer1, Lucas Cavalieri-Pereira1, Márcio de Moraes1, José Ricardo de Albergaria-Barbosa1

1Division of Oral and Maxillofacial Surgery, Piracicaba Dental School, Campinas State University, Brazil; 2Division of Oral and Maxillofacial Surgery, Universidad de La Frontera, Chile; 3Center for Biomedical Research, Universidad Autónoma de Chile, Chile

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Abstract: The aim of this study was to establish the influence of the design of the sagittal split ramus osteotomy (SSRO) on stress distribution on the osteosynthesis in a photoelastic resin model. Two polyurethane hemimandibles were used to perform the osteotomies, tilted in the lateral sector of the first/second molar (group I) and the other descending downwards and laterally from the first molar (group II), with no higher angle. Six replicas of each were made in photoelastic resin and stabilized with a plate and 5 mm monocortical screws in a standardized way. Stabilization was done in the SSRO without advancement, with 3 mm advancement and with 7 mm advancement. Compressive loads were applied at the level of the lower first molar in an Instron machine (model 4411) with a speed of 1 mm/min until reaching 3 mm of displacement, at which point the data was recorded with a camera to identify the stress distribution bands. The results showed stress distribution in different places: for group I it was observed mainly in the screws of the proximal segment, being more intense closer to the osteotomy; in group II it was observed mainly in the screws of the proximal segment furthest from the osteotomy, also being distributed towards the upper area of the plate. It may be concluded that under standard osteosynthesis conditions, modifications to the SSRO produce changes in the location and distribution of stress.

Keywords: Mandibular osteotomy, orthognathic surgery, photoelastic model

Introduction

The sagittal split ramus osteotomy (SSRO) is a technique with a long history and broad application [1]. Its evolution has involved various modifications and the application of different stabilization methods, using wires, screws, plates and different devices in all of these [2].

It has been reported that the stability of the SSRO is one of the determinants of the success of orthognathic surgery [3], making it efficient in the long term. Modifications to the layout and application of the osteosynthesis imply different capacities for stress distribution and absorption; in vitro studies have established that osteosynthesis with bicortical screws can resist higher levels of force than plates and monocortical screws [4].

In these studies, little value has been afforded to the type of SSRO. The guarantees provided by the use of the SSRO proposed by Epker [5] have been widely recognized; however, it is possible to think that variations in the type or the angulation of the SSRO can also produce changes in the absorption of force.

The aim of this study was to determine the impact of the SSRO on the stress distribution in monocortical screws using a system of analysis with photoelastic resin.

Materials and methods

Analysis groups

The osteosynthesis systems used in this study were 2.0 system 4-hole straight plates with titanium alloy screws (Grade 2 titanium, ASTM F136 - Engimplan®, Rio Claro SP, Brazil), spaced at 7 mm with a 1 mm profile; all the screws were 5 mm long. For the osteotomies, 2 polyurethane hemimandibles were used (Nacional
Ossos®, Jáu - SP - Brazil) and 2 analysis groups were established according to the type of osteotomy

Group I: An osteotomy was performed from the upper sector the lingula (5 mm above it), moving the saw downwards to 14 mm. Then, sagittal through the lateral area of the second molar and between the two molars, the osteotomy descended perpendicularly to the basilar area, including the medial area of the mandible.

Group 2: An osteotomy was performed from the upper sector of the lingula (5 mm above it), moving the saw downwards to 14 mm. The movement was then made sagittal to the distal edge of the second molar and then descended straight towards the anterior, following the oblique line (lateral to the first molar), arriving at the basilar area of the mandible, with no angles created between the osteotomies.

Each group had a master model with the described osteotomy created in a polyurethane mandible; and from this 6 standardized models of each were replicated, created in photoelastic resin. Then, each specimen was placed in a sub-group defined according to the degree of advancement of the osteotomy: A: No mandibular advancement, B: Mandibular advancement of 3 mm, C: Mandibular advancement of 7 mm.

**Photoelastic model**

The replica was made in photoelastic resin from the master hemimandible in each group. To do this, each hemimandible was covered by transparent liquid enamel to eliminate surface irregularities. Silicon was installed in each plas-
Figure 5. Load in group IIA (no advancement), showing the load distribution mainly on screw 4 and stress distribution upwards.

Figure 6. Load in group IIB (3 mm advancement), showing the load distribution mainly on screws 3 and 4 and stress distribution upwards.

Mechanical study design

A metallic iron alloy support was constructed, composed of a rectangular base and a vertical horn, giving the mandible rigidity and stabilization at three points of the posterior sector of the condylar neck, mandibular ramus and mandibular angle, avoiding the clockwise rotation of the system during the load.

For the load test, a universal testing machine was used (Instron model 4411 -Instron Corp, Norwood, MA). The hemimandible was subjected to a linear and constant force of 1 mm/min in the central fossa region of the first molar with application of a progressive load until reaching 3 mm of displacement. A camera (Fuji Model 9000 - Fuji Corporation, Japan) and plane polariscope (Eikonal Instrumentos Ópticos Comércio e Serviço Ltda., São Paulo - SP, Brazil) were connected to the system.

The force was applied in the central fossa of the first molar and used in the same way as the aforementioned technique. After application of the compressive force, the models that had
already been manipulated were transferred to a furnace at 55°C where they remained for 5 minutes to eliminate residual stresses. The photographic recording was done with the camera and the test was recorded with a Sony Handycam (DCR-SR300 6.1 MP) to confirm the stress distribution dynamics. The stresses caused by the insertion of screws were recorded with this methodology, making it possible to compare with the stresses present after the test. The data analysis was descriptive, comparing the location, distribution and number of bands observed in the different screws and osteotomy area. The data were analyzed descriptively using the band distribution as the evaluation method.

Results

The results are described next according to the analysis group:

Group IA: After compression, it was observed that a good part of the stress was on screw 3, presenting a limited load on screw 4 and practically no stress on screws 1 and 2 (Figure 2).

Group IB: Screw 3 presented less stress than screw 4; the screws in the distal segment presented a minimum amount of stress. Screw 3 presented less stress than in group IA (Figure 3).

Group IC: Screw 4 presented a high stress level, with distribution towards the base and distal areas; screw 3 had less tension than screw 4, but more than in groups IA and IB (Figure 4).

Group IIA: Screws 3 and 4 accumulated stress with greater intensity than in group IA; the stress was directed mainly upwards with greater participation by screw 4. Screws 1 and 2 presented minimum involvement in the distribution of forces (Figure 5).

Group IIB: Greater stress dissipation was observed upwards and downwards in screws 3 and 4; there was greater participation of screw 1 in the dissipation of forces (Figure 6).

Group IIC: A uniform stress distribution was observed in the distal and proximal segments. The stress was concentrated close to the screws and no significant distribution was observed towards the neighboring bone segments (Figure 7).

Discussion

The photoelastic model has been applied by other researchers [6], who described and qualified photoelasticity as an analytical method that enables the joint visualization of stress in bodies of analysis, which very useful in the examination of complex anatomical regions such as the mandible.

Osteosynthesis is very important in the SSRO. Ellis [3] showed that the loss of stability of the osteosynthesis creates increased occlusal complications as well as the need for new surgeries. In this sense, the value of the osteotomy in the scheme of osteosynthesis has not really been considered.

The photoelastic images clearly show differences in the absorption of stress when different osteotomies with the same system of osteosynthesis are compared. The different degrees of advancement revealed differences in the stress distribution and different phenomena were also observed in both types of SSRO; group I presented greater stress distribution in screws 3 and 4, whereas group II presented greater stress distribution towards the upper sector of the proximal segment (with the exception of group IIC).

The rigid or semi-rigid internal fixation requires a clear interaction between the bone, screws and plates, with the stability depending on the three components [7]. As a result, differences in the osteotomy design can produce differences in the mechanical behavior of the entire system.

There is limited research with analyses similar to those discussed here. Sato [6] used a similar osteotomy model to that observed in our group II, and they determined that in the 3 mm advancement all 4 screws presented some degree of involvement in the absorption of forces, with the greatest being in screw 4 and then 1 and 2; these data partially differ from ours since we demonstrated minimal stress on the screws of the distal segment, which may be associated with the direction in which the load is applied. Another study conducted in finite analysis [8] determined that in a SSRO similar to that of our group I with 5 mm advancement, there was resolution of forces mainly in screw 3, but the stress distribution was not shown at bone level.
The paucity of information in the current literature limits the discussion of our results; however, we can conclude that differences in the SSRO design produce differences in the behavior of the stress distribution in the osteosynthesis applied.

Disclosure of conflict of interest

The authors declare that they have no competing financial interests.

Address correspondence to: Dr. Sergio Olate, Facultad de Odontología, Universidad de La Frontera, Claro Solar 115, 4 Piso, Oficina 20, Temuco, Chile. E-mail: sergio.olate@ufrontera.cl

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