Fractographic Analysis of 2.0-mm Plates With a Screw Locking System in Simulated Fractures of the Mandibular Body

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Purpose: The purpose of the present study was to analyze the fractured plates from 2 brands of 2.0-mm locking fixation systems submitted to axial linear load testing.

Materials and Methods: Four aluminum hemimandibles with linear sectioning to simulate a mandibular body fracture were used as a substrate and fixed with 2 fixation techniques from 2 national brands: Tóride and Traumec. The techniques were as follows: one 4-hole plate, with four 6-mm screws in the tension zone, and one 4-hole plate, with four 10-mm screws in the compression zone; and one 4-hole plate, with four 6-mm holes in the neutral zone. The hemimandibles were submitted to vertical linear load tests using an Instron 4411 mechanical test machine. The system was submitted to the test until complete failure had occurred. Next, a topographic analysis of the surface of the plates was performed using a stereomicroscope and an electronic scanning microscope. The samples were evaluated using different magnifications, and images were obtained.

Results: The surface of the fracture analyzed in scanning electron microscopy demonstrated a ductile-type fracture, usually found in the traction test bodies of ductile materials, such as titanium. No evidence of failure was observed in any fracture surface from a change in the structure or composition of the material.

Conclusions: The plates were fractured by a ductile rupture mechanism, as expected, suggesting that the manufacturing of the national brand name plates used in the present study has been under adequate quality control, with no structural changes produced by the manufacturing process that could compromise their function.

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The rigid internal fixation systems with miniplates that were developed by Michelet et al[1] and Champy et al[2] have become the standard treatment for mandibular fractures.[3,4] Because of their high success index, surgeons and patients have been encouraged to use this technology to treat certain afflictions.[5] However, knowing the properties of each material, the functions performed, and the conditions of the location that will

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receive the implant is fundamental to choosing the correct material. This has become a determining factor for the success of the surgical intervention.[6]

In the context of oral and maxillofacial surgery, several fixation systems with plates and screws have been applied to treat facial fractures or for orthognathic and reconstructive surgery. Thus, these fixation systems must be able to meet all the necessary criteria for adequate function and minimizing the risk of osteosynthesis failure.[4,7] However, fractures on miniplates and reconstructive plates have been previously reported[8-12] for both dentate patients, with mandibular defects after tumor resection, and edentulous patients, for which the masticatory force is reduced. In such cases, analyzing the failures would be an important tool to discover or confirm the actual failure process of the material, even when the forces to which they were submitted were known, offering improvements to the material during its manufacturing, design, and finishing process.

The fracture surface records the history of the failure. It contains information on the environmental effects, the quality of the material, and the loads to which the part has been submitted. Thus, fractography has been the main technique used to determine how a material has fractured.[13]

However, information is lacking regarding the cause of failure of the fixation plates and screws used on mandibular fractures, mainly in relation to the fractures of 2.0-mm plates with a screw locking system. These are important considerations, because their use has increased with time, and newer and more advanced manufacturing techniques have been developed. However, failures still occur, with fixation failures due to fracture of the material. In the present study, we performed fractographic analysis using scanning electron microscopy of plates from 2 national brands of a 2.0-mm fixation system with a screw locking system in aluminum hemimandibles with simulated fractures of the mandibular body.

Materials and Methods

HEMIMANDIBLES

The hemimandibles were manufactured of 5052-F aluminum (ASTM B- 209-M-AA) by Tóride (Tóride Indústria e Comércio, Mogi Mirim, São Paulo, Brazil). Their composition was 0.01% copper, 2.35% magnesium, 2.35% manganese, 0.17% chrome, 0.3% iron, and 0.1% zinc, with titanium, boron, zinc, calcium, silicon, tin, vanadium, and lead constituting approximately 0.2%.

The hemimandibles were submitted to sectioning, simulating a mandibular body fracture at the lower premolar and first molar region. They were also perforated according to group and the outer diameter and thread pitch of the screws from each brand. For group I, the hemimandibles had 4 perforations in the tension zone, with 2 holes on each side of the fracture, according to the design of the plate, and 4 perforations in the compression zone, similar to the tension zone. For group II, 4 perforations were made in the neutral zone, similar to the specifications for the tension zone in group I. All perforations completely crossed the body of the substrate. Figure 1 shows the measurements of the hemimandible.

SAMPLES

The samples were divided into 2 groups. In group I, 2 aluminum hemimandibles received a rigid internal fixation system from Tóride (Tóride Indústria e Comércio) and Traumec (Traumec, Tecnologia e Implantes Ortopédicos Imp e Exp, Rio Claro, SP, Brazil). The hemimandible was fixed with a 4-hole straight plate with a screw locking system, no intermediate space in the tension zone, with four 2.0- × 6-mm titanium screws, and another plate in the compression zone, with four 2.0- × 10-mm titanium screws. Five samples from each brand were used. In group II, 2 aluminum hemimandibles with a rigid internal fixation system were used from the same manufacturers. The hemimandible was fixated in the neutral zone with a 4-hole straight plate and a screw locking system, no intermediate space, with four 2.0- × 6-mm titanium holes. Five samples from each brand were used.

According to the specifications from the manufacturers, the plates were composed of grade II commercially pure titanium, and the screws were a titanium-aluminum-vanadium alloy.

BIOMECHANICAL TESTS

The mechanical test was performed using the Instron model 4411 universal mechanical testing machine (Instron, Norwood, MA). A support device for the hemimandibles was manufactured with the equipment to perform the test.

The noncyclical linear load test was performed at a 1-mm/minute speed to apply a progressive load to the system, thus obtaining the load resistance, in Newtons, and the displacement imposed by the test, in millimeters. The load was applied to a fixed point in the distal segment in a region similar to the canine. The machine was calibrated at the initial displacement resistance point imposed by the system. Thus, the 5,000-N load cell was manually leaned against the load application force up to a limit at which the console showed the first load values against displacement in a decimal scale. The system was submitted to the test up to its complete failure, when it lost resistance, and the machine ended the test (Fig 2).