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Deterministic Adjustable Bone Plate Design

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1 Background

Fracture of the mandible is a common injury associated with facial trauma. Close to 50% of patients admitted to the hospital require surgery to restore normal anatomy and function, often with a period of jaw immobilization to allow formation of a bony union between the fracture halves [1]. Occlusion, or proper alignment of teeth, is necessary for patient comfort and also determines the success of a surgical repair. Misalignment of the fracture halves can be difficult for a physician to objectively assess, but is easily noticed by the patient, leaving little room for error during surgery. Misalignment, called malocclusion, is observed in close to 18% of patients after mandibular fracture repair [2].

Metal bone plates are commonly used to immobilize fracture alignment during the healing process. Bone plate designs used for mandibular fracture repair must be tailored to the geometry and loading conditions of the mandible. Average bite force following a mandibular fracture repair is 150 N [3]. This force is often applied to the superior surface of the mandible, resulting in an applied moment such that the axis is perpendicular to the lateral surface of the bone. Mandibular geometry is shaped to withstand these loading conditions; during the healing process, a mandibular bone plate must provide sufficient bending stiffness to allow for healing.

Several plate designs and applications are described in the literature, each tailored for specific fracture locations and conditions [4]. A concept for an adjustable bone plate that provides surgeons with direct control of the fracture alignment after the plate has been affixed has been introduced as a method to reduce misalignment errors [5]. The present work describes the design process used to synthesize an adjustable bone plate that is substantially equivalent to current technology, and also to develop testing methods which accurately simulate fracture dynamics to adequately test the new plate design.

2 Methods

An adjustable bone plate concept (Fig 1a) with a central deformable region allows control of the occlusal alignment after the plate has been affixed with screws. Figure 1b shows an updated model that is being used for further experimentation. The geometry of the adjustable section was selected such that the cross-sectional second area moment of inertia is equivalent to that of standard plate designs. The new design is has been scaled to the dimensions of standard plates and can be affixed using 2mm screws.

The concept in Figure 1a was shown to have comparable strength to traditional bone plate designs through analytical, numerical, and experimental methods [5]. Preliminary evaluation of the current model was conducted using these methods. A fixed-fixed simple beam model was used to predict the force-to-yield. The solid model of the plate, using the material properties of 304SS, was analyzed in SolidWorks™ Simulation™ (Dassault Systemes, Lowell, MA). 304SS is more cost-effective for prototyping than Titanium, and allows for accurate scaling of results using a ratio of the materials' elastic moduli.

3 Results

A closed-form model with a fixed-fixed boundary condition indicates that a force of 292N is needed to deform the present plate adaptation. Numerical modeling results suggest a required force of 375N. Previous studies have shown that these methods correlate well with experimental results [5]. The results for a titanium bone plate are 1100N and 1675N using the same analytical and numerical methods, respectively.

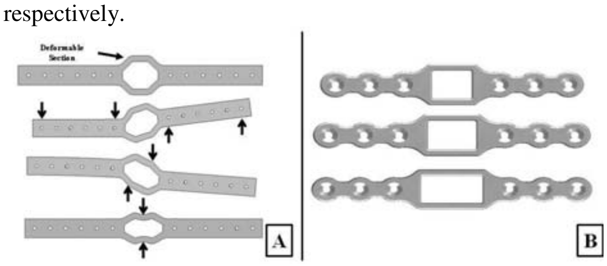

Figure 1: (A) Concept for an adjustable bone plate showing various deformation modes; (B) prototype plates for testing on synthetic and human mandibles.

4 Interpretation

Analytical and numerical modeling of the new plate design suggests the mechanical strength is substantially equivalent to existing mandibular bone plates. Imaging studies and further mechanical testing of the updated plate shown in Figure 1b will be presented to evaluate the adjustment capabilities of the bone plate design.

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