Computed Tomography–Based 3-Dimensional Finite Element Analyses of Various Types of Plates Placed for a Virtually Reduced Unilateral Condylar Fracture of the Mandible of a Patient

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Purpose: This study was performed to evaluate stresses in various types of plates placed for a virtually reduced unilateral condylar fracture of the mandible using computed tomography–based 3-dimensional finite element (FE) models of a patient to select the optimal plate system.

Materials and Methods: A computed tomography–based FE model of the mandible of a patient with a unilateral condylar fracture was constructed. The fracture was virtually reduced and fixed with 1 straight titanium plate; 2 straight titanium plates; 2 straight poly-L-lactic acid plates; and 4-hole (box), 5-hole (strut), and 7-hole (lambda) condylar plates. Stresses developing in these plates were analyzed by applying 478.1 N of bite force at the first molar of the contralateral side of the mandible.

Results: The magnitudes of tensile stress were within the tensile strength in all types of plates. However, the magnitudes of compressive stress in 1 straight titanium plate and 2 straight poly-L-lactic acid plates were beyond the compressive strength. The tensile and compressive stresses of the 5-hole (strut) plate were the smallest among the 3 types of condylar plates.

Conclusions: Fixation by 2 straight titanium plates or any type of condylar plate was biomechanically indicated for the condylar fracture of this patient. Among these plates, the 5-hole (strut) plate was considered optimal. FE analysis is useful in selecting the optimal fixation method in the individual patient.

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Mandibular condylar process fractures are the most common fractures of the mandible.[1,2] However, the choice between closed and open treatment remains controversial.[3] When condylar fractures cause mandibular dysfunction, surgical intervention may be needed for better occlusion because reduction and rigid fixation allow good anatomic repositioning and immediate function.[4,5] The essential problem in surgical treatment is the choice of internal fixation devices. At present, the most frequent procedure is the application of miniplates fixed with screws.[6] There is evidence that 1 plate is not sufficiently stable;

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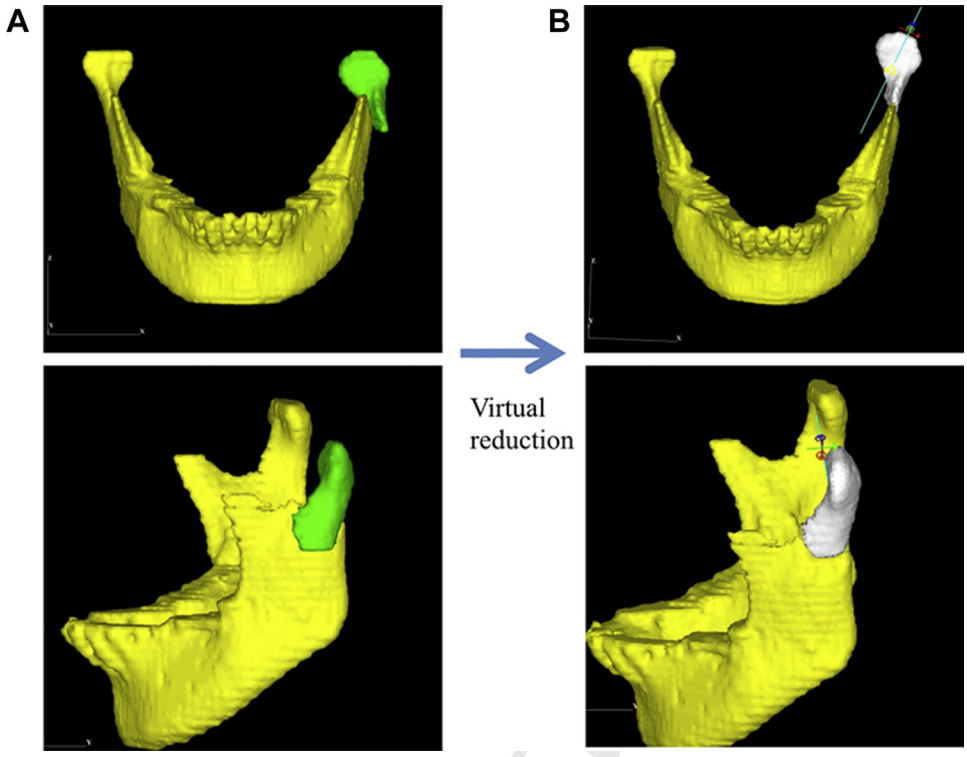

FIGURE 1. *A*, Original computed tomography (CT)–based finite element models of mandible with condylar fracture. *B*, The condylar process was virtually reduced in the anatomically correct position.

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therefore, 2 plates are needed to achieve stable fixation.[7] Open treatment of mandibular condylar fractures has become more favorable since a variety of osteosynthesis materials have been developed over the past few decades.[8,9] Recently, frame-like plates (square, trapezoid) were introduced and found to provide better stability than 2 straight plates.[7] The biomechanical behavior of these plates was analyzed by photoelastic analysis. A trapezoidal plate, a square plate, an A-shaped plate, and a triangular plate were analyzed by the finite element (FE) method.[10-12] Other plates such as poly-L-lactic acid (PLLA) plates and specific condylar plates have not been compared. Therefore, the best selection of the plates for a specific condylar fracture needs to be determined by the FE method.

To analyze the complex biomechanical behavior of the mandible in living persons, mathematical methods such as FE analysis have been used. This is a technique by which the displacement, stresses, and strains of an inhomogeneous solid body can be determined if the complex material properties and loading conditions are known. In addition, a computed tomography (CT)–based FE model, in which information on 3-dimensional (3D) architecture and bone density distribution is incorporated, can allow the precise assessment of the strength of the mandible by newly developed software.[13,14]

The purpose of this study is to evaluate different plate materials and designs when applied along ideal osteosynthesis lines for a virtually reduced condylar fracture of the mandible using a CT-based FE model, as well as to explore an effective method of plate application before surgery.

Materials and Methods

PATIENT

A 63-year-old female patient scheduled to undergo surgery for a left condylar fracture was the subject of the study. CT x-ray photographs showed that the fracture was located in the subcondylar region according to the classification of Lindahl[15] with the type of dislocation in the classification of MacLennan.[16] CT data Q3 with a slice thickness of 0.5 mm from the submental region to the supraorbital rim were obtained.

This study was conducted based on the principles outlined in the Declaration of Helsinki and was approved by the Hattori Memorial Hospital human subjects' protection committee. The patient was informed of the purposes of the study and signed a consent form before participating.