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Finite element analysis of the stability of transverse acetabular fractures in standing and sitting positions by different fixation options

Ahmet Ozgur Yildirim [a,*], Kadir Bahadir Alemdaroglu [b], Halil Yalcin Yuksel [c], Özdamar Fuad Öken [a], Ahmet Ucaner [a]

[a] Ankara Numune Training and Research Hospital, Orthopaedics and Traumatology Clinics, Ankara, Turkey
[b] Ankara Training and Research Hospital, Orthopaedics and Traumatology Clinics, Ankara, Turkey
[c] Antalya Training and Research Hospital, Antalya, Turkey

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ABSTRACT

Background: Treatment of a transverse acetabular fracture type is possible from an anterior approach, a posterior approach or both. Different fixation methods have been described but whether one is superior to the other is still under debate. The aim of the current study was to test the different fixation alternatives of stabilization of transverse acetabular fractures under two basic physiological loading conditions: standing and sitting utilizing a finite element model.

Material and methods: A transtectal transverse fracture model was fixed in five different alternatives: an anterior column plate; a posterior column plate; an anterior column plate combined with a posterior column screw; a posterior column plate combined with an anterior column screw; and a posterior column plate and an anterior column plate. In these models, a load of 400 N was applied at standing and sitting positions and the displacements were analyzed by using three-dimensional finite element stress analysis method.

Results: In the model simulating standing human position, overall motion at the posterior column was minimum when two columns were plated (0.071 mm). The second best fixation was posterior column plate with an anterior column screw (0.077 mm). Overall motion at the anterior column was minimum by posterior column plate with an anterior column screw (0.0326 mm). The plating of two columns was associated with motion of (0.0333 mm).

In the model that simulates sitting position, the motion at the posterior column was minimum when two columns were plated (0.0478 mm), and (0.0517 mm) when a posterior column plate with an anterior column screw was used. Overall motion in the anterior column was minimum when posterior column plate with an anterior column screw (0.0198 mm) was used, whereas the motion was (0.0203 mm) when plating of both columns was examined.

Conclusion: Posterior column plating combined with an anterior column screw has quite comparable results to a both column plating in transverse fractures, suggesting that two column fixations might be unnecessary. This method is also very superior to anterior column plating combined with a posterior column screw in that type of fractures.

Introduction

Surgical treatment of acetabular fractures continues to be one of the most challenging conditions to the orthopaedic trauma surgeons [1–3]. Anatomical reconstruction of the articular surface combined with rigid internal fixation followed by early postoperative mobilization of the affected joint remains the standard treatment of these injuries [4]. Transverse type fractures constitute approximately 30% of acetabular fractures. These fractures comprise both the anterior and the posterior columns of the acetabulum with a single fracture line, by mostly sagittally crossing the weight-bearing acetabular dome [5]. Treatment of this specific fracture type is achievable from an anterior approach, a posterior approach or both [6–8]. However, it is under debate which approach should be selected as reduction can often be managed from any of these approaches and both permit adequate plate and screw fixation.

In the literature comparison of different methods of fixation has been investigated. Although most of the studies suggest that fixation should be carried out of both columns by at least

* Corresponding author. Tel.: +90 532 4738511; fax: +90 312 3114340.
E-mail address: aoyildirimmd@yahoo.com (A.O. Yildirim).

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supplementing the opposite column by screw fixation [9], some authors have suggested that fixation of a single column might be sufficient [10,11]. In a cadaveric model used by Shazar et al. [12] posterior column plating with an anterior column screw fixation was found as the most stable construct. In another cadaveric study on fixation alternatives of transverse acetabular fractures, Sawaguchi et al. found, no significant difference of rigidity between both column plating and posterior column plating combined with an anterior column screw [9]. However, the biomechanical conditions in these studies did not completely comply with the basic daily activities (e.g. standing, sitting) of a living human. These earlier studies have been based on loading the bone and implant model until failure occurs [12]. However, in finite element analysis, it is possible to test the stability of the bone implant construct under physiological loads. Recently, a finite element model for acetabular fractures with a synthetic pelvis has been described by Shim et al. [13].

The aim of the current study was to test the different fixation alternatives of stabilization of transverse acetabular fractures under two basic physiological loading conditions: standing and sitting utilizing a finite element model. The fixation alternatives used in this study was (1) anterior column plating alone, (2) anterior column plating combined with a posterior column screw, (3) both anterior and posterior column plating, (4) posterior column plating combined with a anterior column screw, (5) posterior column plating alone.

Materials and methods

This investigation was undertaken by Ay Tasarım Ltd. Şti. at Ankara University. Investigation was done by utilizing three-dimension finite element stress analysis by using isotropic materials and static linear analysis.

A transverse fracture model was fixed in five different alternatives: an anterior column plate; a posterior column plate; an anterior column plate combined with a posterior column screw; a posterior column plate combined with an anterior column screw; and a posterior column plate and an anterior column plate (Figs. 1–5). In these models, a load of 400 N was applied at standing and sitting positions and the displacements were analyzed by using three-dimensional finite element stress analysis method (Fig. 6).

A computer with Intel Xeon® R CPU 3.30 GHz operator, 500 GB hard disk, 14 GB RAM and Windows 7 Ultimate Version Service Pack 1 operating system, Activity 880 optic scanner (smartopticsSensortechnikGmbH, Sinterstrasse 8, D-44795 Bochum, Germany) and Rhinoceros 4.0 3-D modeling software (3670 Woodland Park AveN, Seattle, WA 98103, USA), and VRMesh Studio (Virtual Grid Inc., Bellevue City, WA, USA) and Algor Fempro analysis software (ALGOR, Inc. 150 Beta Drive Pittsburgh, PA 15238-2932, USA), in order to edit and optimize three dimensional surface mesh models, solid meshing performing finite element analysis.

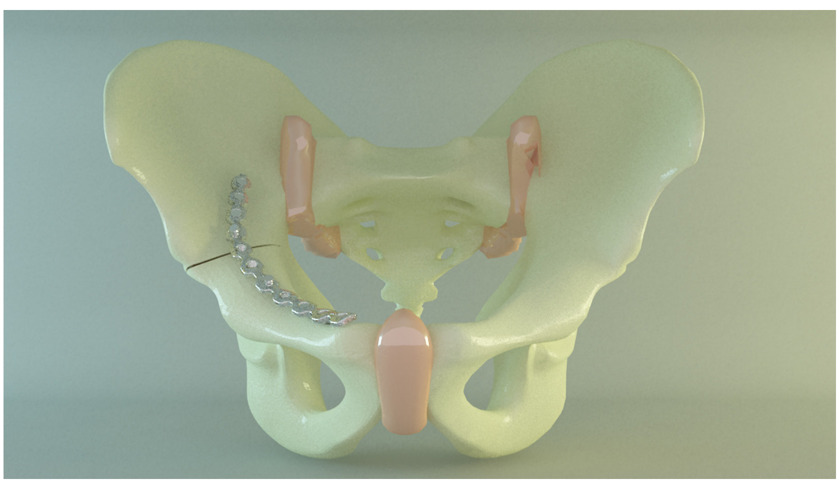

Fig. 1. The model of anterior column plate fixation.

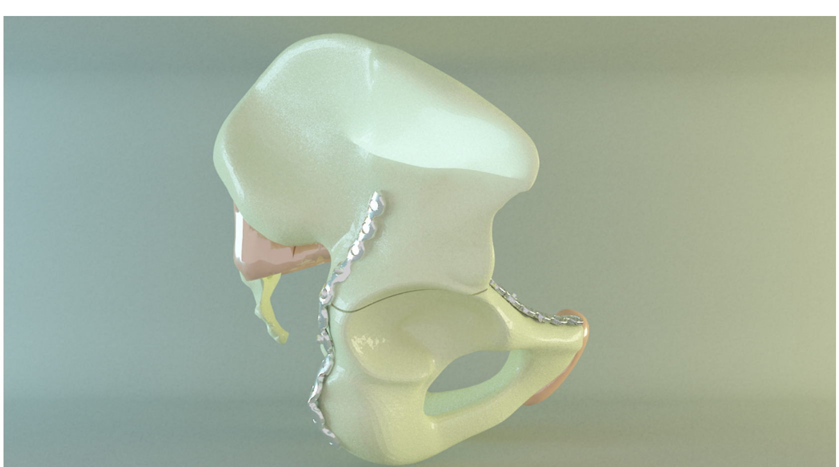

Fig. 2. The model of both column plate fixation.