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Odontoid plate fixation without C1–C2 arthrodesis: Biomechanical testing of a novel surgical technique and comparison to the conventional screw fixation procedure

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ABSTRACT

Background: Odontoid plate fixation without C1–C2 arthrodesis appears to be a practicable option for the management of odontoid fractures that are not amenable for conventional screw fixation. The purpose of this study was to measure the mechanical stability of odontoid plate fixation using a specially designed plate construct, and to compare the results to those after conventional screw fixation.
Methods: The second cervical vertebra was removed from twenty fresh human spinal columns. Stiffness and failure load of the intact odontoid were measured, and type II odontoid fractures were created. Afterward, the specimens were randomly assigned to one of the following four groups: Group I: plate-fixation; Group II: 2-AO-screw-fixation; Group III: 1-AO-screw-fixation; Group IV: Herbert-screw-fixation. In a second series, stiffness and failure load of the stabilized odontoid fractures were assessed for comparison and statistical analysis.
Findings: Group I showed a significantly higher mean failure load than the other groups. The mean failure load of Group I after fixation of the odontoid fracture was 86% of the mean failure load of the intact odontoid. Comparing Groups II, III and IV, there was no significant difference regarding the failure load. In these three groups the mean failure load after odontoid fixation was approximately 50% of the mean failure load of the intact odontoid.
Interpretation: Odontoid plate fixation as an alternative procedure in certain fracture patterns provided a significantly higher biomechanical stability than the technique of odontoid screw fixation. Using a specially designed plate construct, 86% of the original stability of the intact odontoid was restored.

1. Introduction

Anterior screw fixation has become an important and accomplished treatment option for surgical stabilization of odontoid fractures (Böhler, 1982; Maak and Grauer, 2006; Nakanishi et al., 1982; Ochoa, 2005; Platzer et al., 2007). Contrary to the various procedures of posterior cervical arthrodesis, it provides a number of benefits, like immediate stabilization of the fracture without compromising the movement at the upper cervical spine level, as well as no need for harvesting autologous bone grafts (Böhler, 1982; Maak and Grauer, 2006; McCullen and Garfin, 2000; Ochoa, 2005; Platzer, et al., 2007).

However, there are certain fracture types that are not amenable for the technique of anterior screw fixation (Böhler et al., 1990; Grosse et al., 1991; Hadley et al., 1988; McCullen and Garfin, 2000; Vichard et al., 1996). Especially type II odontoid fractures with an anterior oblique fracture line, comminuted fractures or pathological fractures of the odontoid do not allow fragment compression by conventional odontoid screws (Böhler, 1982; Böhler et al., 1990; Grosse et al., 1991; Hadley et al., 1988; McCullen and Garfin, 2000; Platzer et al., 2009; Vichard et al., 1996). In these fractures, the traditional techniques of atlanto-axial arthrodesis (posterior wiring and bone grafting according to Gallie or Brooks et al., as well as posterior transarticular screw fixation according to Magerl et al.) have been usually reserved as preferred treatment options for stabilization of these fractures (Brooks and Jenkins, 1974; Gallie, 1939; Magerl and Seeman, 1986; McCullen and Garfin, 2000; Neurosurgery, 2002; Platzer et al., 2009).

In contrast to the procedures of posterior cervical arthrodesis, anterior plate fixation appears to be a practicable method for the management of odontoid fractures that are not amenable for conventional screw fixation (Platzer et al., 2009; Vichard et al., 1996). As this technique spares the rigid fixation of the atlanto-axial joint, axial rotation can be maintained without relevant restrictions (Böhler, 1982; Böhler et al., 1990; Grosse et al., 1991; Platzer et al., 2009). We performed this method in a clinical series of nine patients with odontoid fractures that needed additional support of the fracture site and were able to obtain promising clinical and radiographic results (Platzer et al., 2009). Now we were interested in biomechanical testing of the plate construct by performing a cadaver study.

The aim of this study was to assess the mechanical stability of odontoid plate fixation with a specially designed, 'clover-shaped'

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looking plate construct, and to compare the results to those after conventional screw fixation procedures.

2. Methods

The second cervical vertebra was harvested from twenty fresh human cadaveric spinal columns. Human cadaver ages ranged from 68 to 89 years, with an average age of 78. Before being tested the specimens were cleaned and freed of all muscular tissue. An image intensifier was used to exclude pathologic lesions or abnormalities of the harvested vertebrae and to assess the correct placement of the implants.

The specimens were mounted to the experimental apparatus, with the load cell at the articular surface of the odontoid process (see Fig. 1). To secure the harvested vertebrae at the experimental apparatus, modified clamps were used to allow insertion and removal without damage. The specimens were loaded using a displacement controlled hydraulic actuator (Instron® biomechanical, Instron, Pfungstadt, Germany) moving at 5 mm/s. Actuator motion and reaction force under the specimen were recorded with a microcomputer-based data acquisition system, calculating (1) the failure load and (2) the stiffness. The failure load was presented as the maximum of the load compressive curve, whereas the stiffness was determined as the slope of the most linear portion of the load displacement curve (see Fig. 2). We did not perform any rotational testing, as the experimental apparatus did not allow to load torques.

Initially, low-load tests were performed to measure the stiffness of the intact odontoid in flexion, extension, and lateral bending. Afterwards, type II odontoid fractures were created by 45° oblique extension loading at the articular surface of the odontoid process. This technique has already been described to be successful and reliable in creating reproducible type II odontoid fractures for biomechanical testing (Sasso et al., 1993). Fractures were assessed by inspection and by using an image intensifier.

After the fracture had been produced, the vertebrae were removed from the experimental apparatus and directly reduced and stabilized using either a plate device or cortical screws. Therefore, the specimens were randomly assigned to one of the following four groups: In Group I ($n=5$) the fractures were stabilized using a specially designed plate construct, which is precisely described below (see 'description of plate device'), in Group II ($n=5$) the fractures were fixed using two regular 3.5 mm cortical screws (AO screws), in Group III ($n=5$) we used one regular 4.5 mm cortical screw (AO screw), and in Group IV ($n=5$) we used a 4.5 mm double-thread screw (Herbert).

Fig. 1. Set up showing the bone being loaded.

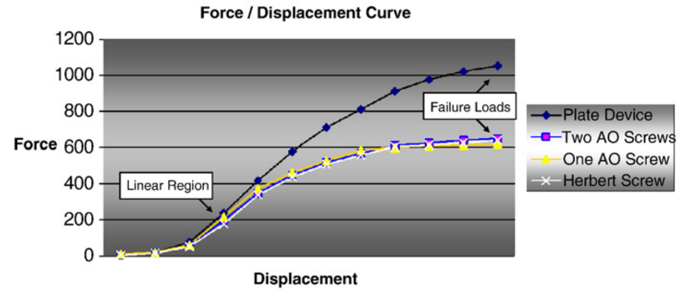

Fig. 2. 'Force versus Displacement' curve.

After correct fixation of the fractures, the specimens were remounted to the experimental apparatus for a second testing. Firstly, low load test were performed to assess the stiffness of the fixed odontoid process in flexion, extension, as well as in lateral bending. Then, each specimen was loaded to failure in 45° oblique extension load, as described before. Failure was defined as force at which a reduction in load with increasing deflection of the fixed odontoid due to bending or cut-out of the implant that was observed.

For statistical analysis, we performed the Student's *t* test. Statistical significance was defined as $P<0.01$. Logistic regression analysis was additionally performed between study groups that did not show any statistically significant differences by using the Student's *t* test.

2.1. Description of the plate device

In clinical practice the plate device is inserted at the anterior site of the second cervical vertebra through an anterior approach to the upper cervical spine level. To determine the correct position of the plate, the odontoid base and the body of the axis must be identified. After preparing a small space between the anterior ring of the atlas and the odontoid process using a chisel, the plate construct is inserted by moving the upper tip of the plate between the ring of the atlas and the odontoid process (see Fig. 3). To maintain the reduced position of the odontoid during fixation, a K-wire is temporarily inserted into the odontoid process. The plate device is finally fixed by two (or three) 4.0 mm cancellous screws into the body of C2. A 3.5 mm cortical screw is additionally used for fixation of the odontoid process (see Fig. 4). Optionally, the 'clover-leaf' shaped design of the implant would allow placing additional screws into the body of C2 in the median and on

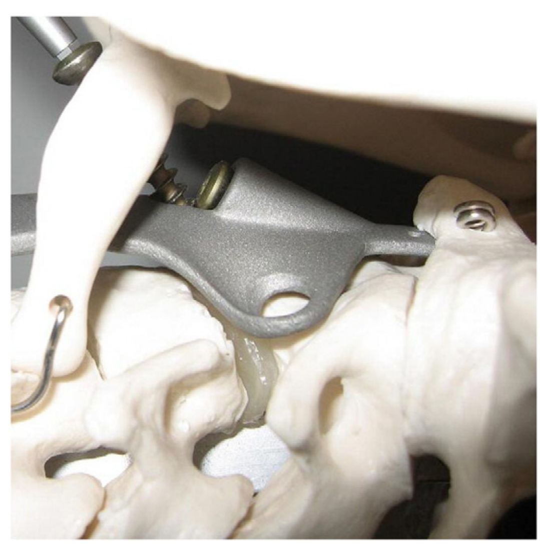

Fig. 3. Plastic skull-neck model featuring insertion of the plate device at the anterior site of the odontoid.