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A novel electromagnetic navigation tool for acetabular surgery

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KEYWORDS

Acetabulum
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ABSTRACT

Background: Acetabular fracture surgery is demanding and screw placement along narrow bony corridors remains challenging. It necessitates x-ray radiation for fluoroscopically assisted screw insertion. The purpose of this cadaver study was to evaluate the feasibility, accuracy and operation time of a novel electromagnetic navigation system for screw insertion along predefined acetabular corridors.
Methods: A controlled laboratory study with a total of 24 electromagnetically navigated screw insertions was performed on 8 cadaveric acetabula. 3 peri-acetabular bony corridors (QSS, Quadrilateral Surface Screw; IAS, Infra-Acetabular Screw; PCS, Posterior Column Screw) were defined and screws were placed in a defined order without fluoroscopy. Operation time was documented. Postoperative CT scans were performed to analyse accuracy of screw placement.
Results: Mean cadaver age was 70.4 ± 11.7. Successful screw placement was accomplished in 22 out of 24 (91.7%) cases. The overall mean time for all 3 acetabular screws was 576.6 ± 75.9s. All 3 complications occurred during the placement of the IAS due to an impassable narrow bony corridor. QSS mean length was 50 ± 5mm, IAS mean length was 85 ± 10mm and PCS mean length was 120 ± 5mm.
Conclusion: In this cadaver study the novel electromagnetic navigation system was feasible to allow accurate screw placement without fluoroscopy in defined narrow peri-acetabular bony corridors.

Introduction

Due to the complex three-dimensional configuration, acetabular fracture surgery is demanding and screw placement along narrow bony corridors remains challenging and necessitates x-ray radiation for fluoroscopically assisted screw insertion [1]. With the population increasing in age, rising numbers of osteoporosis related fractures involving the anterior column of the acetabulum are expected [2]. To provide sufficient biomechanical stability screws along bony corridors require maximum lengths [3]. Furthermore different fracture entities such as transverse and two column fractures require long screws down the posterior column or along the quadrilateral surface [1].

Three screw configurations around the acetabulum remain especially challenging: The Quadrilateral Surface Screw (QSS), starting at the iliopectinal rim aiming for the ischial spine running parallel to the quadrilateral surface being referenced in most standard works to prevent a medial subluxation of the quadrilateral fracture component [4]. The Posterior Column Screw (PCS) is inserted for transfixation of the posterior column as a single screw fixation or integrated into plate fixation to augment stability. This technically demanding screw starts from the first ilioinguinal window from the ilium extending deep into the ischial spine or toward the ischial tuberosity. This screw usually requires lengths between 100 and 140mm. Additionally a third, the Infra-Acetabular Screw (IAS) can close the incomplete periacetabular fixation “frame”.

Conventional fluoroscopy for peri-acetabular screw placement requires acquisition of multiple images in different projections to determine the correct entry point and screw direction [5,6] leading to prolonged surgical and radiation times [5]. Navigation in acetabular surgery has become an important tool to simplify the handling and to increase precision in placing these screws [7,8]. As of today only 2D and 3D opto-electrical navigation systems for pelvic navigation procedures are available necessitating direct visualization of each component [5].

The purpose of this cadaver study was to evaluate the feasibility, accuracy and operation time of a novel electromagnetic navigation system (ENS) for screw insertion along predefined acetabular corridors.

Materials and Methods

A standard modified Stoppa approach (anterior intrapelvic approach) in combination with exposure of the first ilioinguinal window [9,10] was performed bilaterally on 4 human cadavers to expose 8 acetabula.

The electromagnetic navigation system (NaviDrill™, Arthrex, Naples, Florida, USA) used in this study was designed to be an

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intraoperative image-guided navigation tool providing spatiotemporal real-time information to the surgeon without the need for a stationary patient tracker and without relevant setup and calibration times. The core system consists of 3 major parts: a sensor-equipped probe hook which is placed at the desired endpoint of the drilling, an electromagnetic field generator and a centrally slotted hand piece, to be placed at the desired starting point of the drilling (Fig. 1). A monitor provides real-time intraoperative electromagnetic tracking data of surgical instrument placement to the surgeon. Distance information in millimeters between the tip of the probe hook and the tip of the drill is provided on the monitor (Fig. 1). Continuous visual real-time feedback of spatiotemporal drill position ensures correct direction and angle for the drilling. The x-ray radiation free system is calibrated once during the manufacturing (factory assembling) process and does not require further preoperative or intraoperative calibrations as well as no need for a stationary patient tracker.

3 screws in defined corridors were placed in each acetabulum (24 screws in total). The order of screw insertion was standardized starting with the screw parallel to the quadrilateral surface (QSS) followed by the infraacetabular (IAS) and, finally, the posterior column screw (PCS) using the first ilioinguinal window for the latter (Fig. 2). Electromagnetic navigated oscillated drilling prior screw insertion was performed using a standard 2.5mm drill bit. Screws were inserted subsequently without navigation. No fluoroscopy was used for drilling and screw insertion.

After standardized preparation of anatomical landmarks, the cannulated handpiece was placed at the desired starting point for the QSS directly on the iliopectineal rim anterior to the acetabulum in line to the ischial spine. The probe hook was consecutively placed at the endpoint of the drilling and hooked into the lesser sciatic notch (Fig. 2).

The IAS corridor extends from the upper pubic ramus 1cm caudal of the iliopectineal eminence in the mid-width of the pubic ramus direct before the obturator foramen down to the ischial tuberosity. The cannulated handpiece was placed at the desired starting point for the IAS and the probe hook consecutively placed at the endpoint of the drilling at the ischial tuberosity (Fig. 2).

Finally, for placement of the PCS the cannulated handpiece was placed at the desired starting point using the first window of the ilioinguinal approach 2cm medial to the anterior superior iliac spine in the ilium. Again, the probe hook was then placed at the endpoint of the drilling at the tip of the ischial tuberosity (Fig. 2).

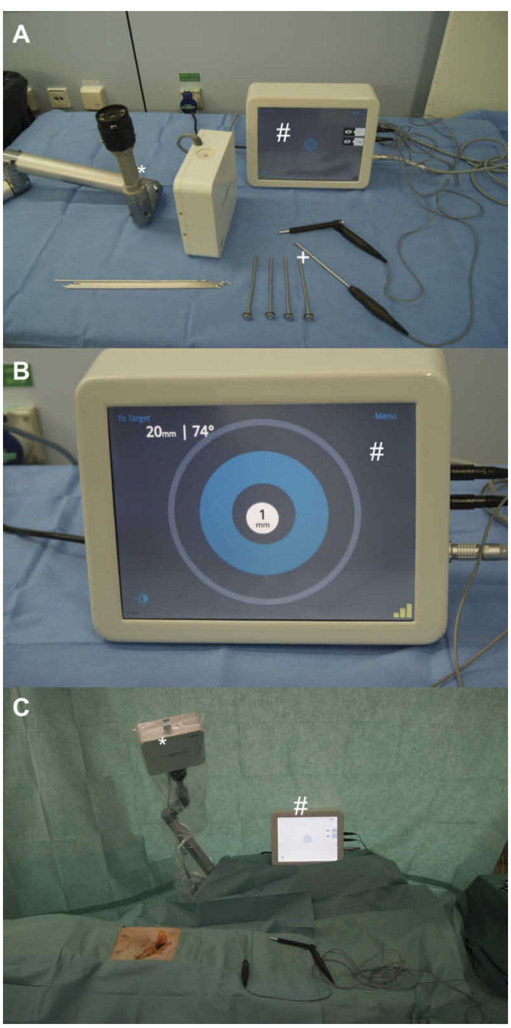

Fig. 1. The NaviDrill system and Study Set-Up. A, Electromagnetic Navigation System (ENS), * Electromagnetic field generator incl. mounting, # Navigation monitor, + Probe hook and cannulated drill piece, drills and reduction sleeves; B, Navigation monitor providing real time spatiotemporal information indication distance between the tip of the drill bit and the tip of the probe hook, angulation, misguiding distance and electromagnetic field quality; C, Cadaver setup with mounted field generator, monitor and Stoppa approach.

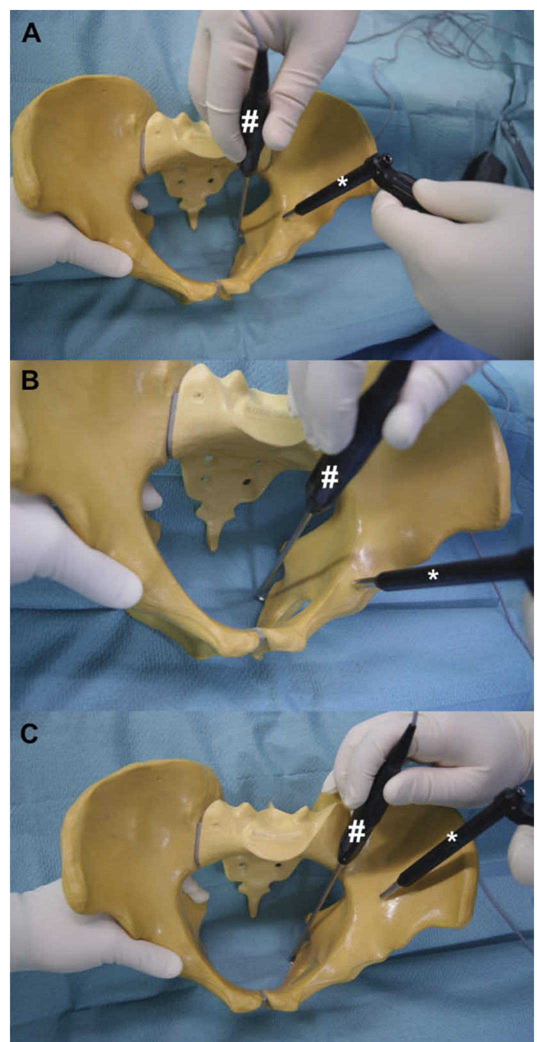

Fig. 2. Sawbone demonstration of navigated screw placement. A, Placement of the Quadrilateral Surface Screw (QSS); B, Placement of the Infra-Articular-Screw (IAS); C, Placement of the Posterior Column Screw (PCS). #, Probe Hook positioned at the endpoint of the drilling; * Cannulated Drill Sleave positioned at the startpoint of the drilling.