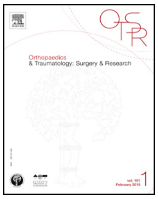
Orthopaedics & Traumatology: Surgery & Research 102 (2016) 575–581

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en



Original article

Improved accuracy of K-wire positioning into the glenoid vault by intraoperative 3D image intensifier-based navigation for the glenoid component in shoulder arthroplasty

J. Theopold[a,*], P. Pieroh[a,b], M.L. Scharge[a], B. Marquaß[a], T. Hohmann[b], C. Josten[a], P. Hepp[a]

[a] Department of Orthopedics, Trauma and Plastic Surgery, University of Leipzig, Liebigstrasse 20, 04103 Leipzig, Germany
[b] Institute of Anatomy and Cell Biology, Martin Luther University Halle-Wittenberg, Grosse Steinstrasse 52, 06097 Halle (Saale), Germany

ARTICLE INFO

Article history:
Received 8 October 2015
Accepted 21 March 2016

Keywords:
Computer-assisted surgery
Shoulder arthroplasty
Glenoid centerline

ABSTRACT

Introduction: This article aimed to show that navigation, based on an intraoperative mobile 3D image intensifier, can improve the accuracy of central K-wire placement into the glenoid vault for glenoid component.
Hypothesis: The navigated k-wire placement is more accurate and shows a smaller deviation angle to the standard centerline compared to the classical “free hand technic”.
Methods: In 34 fresh frozen sheep scapulae, 17 K-wire placements using the navigation (group 1) were compared with 17 using standard “face plane technique” (group 2). The relation to glenoid standard and alternative centerlines (CL) and the position within the glenoid vault were analyzed.
Results: In groups 1 and 2 the angle between the K-wire and standard CL was 2.2° and 4.7°, respectively ($P = 0.01$). The angle between the K-wire and alternative CL was 14.4° for group 1 and 17.2° for group 2 ($P = 0.02$). More navigated K-wire positions were identified within a 5 mm corridor along the glenoid vault CL (52 vs. 39; $P = 0.004$).
Discussion: Intraoperative 3D image intensifier-based navigation was more accurate and precise than standard K-wire placement.
Type of study and level of proof: Basic science study, evidence level III.

1. Introduction

The durability of implants in total shoulder arthroplasty depends largely on the stability of the glenoid component [1–3]. Exact implant placement is one of the most important elements for improving stability [4]. Implantation is technically challenging: the soft tissue and the complex geometry of the surgical site impede accurate implant placement [5–7]. Without navigation, implantation is only indirectly possible by the use of methods such as the ‘face plane’ and the ‘neutralization’ technique that offer only partial accuracy [8–10]. Recently, a method for finding a position and orientation of optimal containment of the central peg within the normal glenoid vault has been introduced with use of computer optimization [8]. Navigated implantation of shoulder arthroplasty has thus an increasing role [4,8,11,12] and may help to improve positioning of the glenoid component [4,11,13,14]. Recently, the accuracy was enhanced by the development of patient-specific systems. In these studies, inclination and version were mainly used for investigating the accuracy of the procedures [15–18]. However, there is a time frame after the first examination to produce these guides. Hence, a real-time intraoperative application is impossible.

The introduction of 3D-fluoroscopy enabled intraoperative multiplanar imaging. 3D-fluoroscopy has become an established method in navigated spine surgery [19] and pelvic surgery [20]. Thus far, however, only one feasibility study has been done on using this method for navigation at the glenoid component [21]. Therefore, the purpose of this controlled laboratory study was to

---

* Corresponding author. Tel.: +49 341 9717300; fax: +49 341 9717309.
E-mail addresses: jan.theopold@medizin.uni-leipzig.de (J. Theopold), Philipp.Pieroh@medizin.uni-leipzig.de (P. Pieroh), MariaLuisa.Scharge@medizin.uni-leipzig.de (M.L. Scharge), Bastian.Marquass@medizin.uni-leipzig.de (B. Marquaß), Tim.Hohmann@medizin.uni-halle.de (T. Hohmann), Christoph.Josten@medizin.uni-leipzig.de (C. Josten), Pierre.Hepp@medizin.uni-leipzig.de (P. Hepp).

http://dx.doi.org/10.1016/j.otsr.2016.03.013
1877-0568/

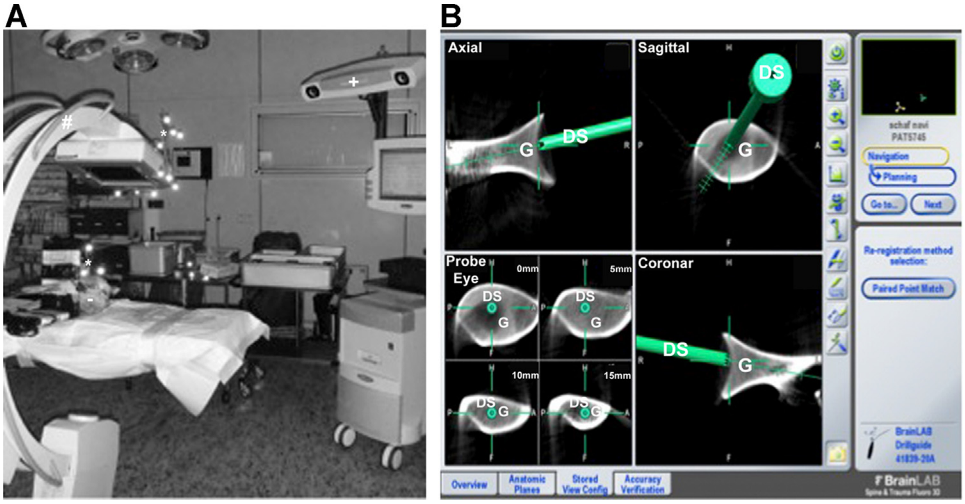


Fig. 1. Experimental setup with navigation. A. The shoulder is mounted in the upright position, perpendicular to the carbon table. The navigation clamp is attached to the scapula (*). Navigation machine with cameras (+), C-arch of the 3D image converter (#). B. Screenshot of the navigation (Fa. Brainlab, Feldkirchen, Germany). The luminous dots are the fluorescent markers of the navigation. Grey: drill sleeve; dotted line: direction of drill wire; Probe Eye view: drill depth at 0, 5, 10 and 15 mm.

evaluate the accuracy of intraoperative 3D image intensifier-based navigated placement of the central K-wire into the glenoid vault by comparing this method to conventional placement. We hypothesized that the navigated k-wire placement is more accurate and shows a smaller deviation angle to the standard centerline compared to the classical "free hand technique".

2. Materials and methods

2.1. Specimen

Thirty-four pairs of fresh female sheep scapulae ($< -20\,^{\circ}$Celcius) with the adjacent soft tissue and muscle were used for this study. The bony humerus of all specimens was removed before testing. The shoulders were divided into left and right shoulder pairs in order to prevent a side-bias. Then, the shoulders were divided into the navigated group (group 1) and the non-navigated group (group 2).

2.2. Navigated placement of K-wires

First, the shoulders from group 1 were mounted onto the operating table in the upright position (Fig. 1). A small incision was made in the area of the scapular spine and a carbon-clamp with three tracking points was fixed. The anatomical landmarks used in this study are reliable and have previously been described [7,8]. After this, a preoperative scan was performed with Ziehm Vision FD Vario 3D© (Ziehm Imaging GmbH, Nürnberg, Germany). The middle of the scanner was placed at the central point of the glenoid. The scan performed consisted of 110 single images with a radius of 136° within 110 seconds. The DICOM-format raw data were consequently transferred from the 3D image converter to the VectorVision© navigation system (Brainlab AG, Feldkirchen, Germany).

In the navigation system, the data record was used as a CT data record. After creating a 3D image, the data was verified by comparing the image and the anatomy. This control was performed at three defined points (proximal glenoid, central glenoid and the distal glenoid).

The instruments were calibrated using the instrument calibration matrix (Fa. Brainlab, Feldkirchen, Germany). A 1.8-mm navigable drill sleeve was used (Fa. Brainlab, Feldkirchen, Germany). By using the navigation screen, (1B), the wire was placed as centrally as possible. Subsequently, a K-wire was positioned and shortened to fit into the glenoid.

2.3. Conventional wire positioning

In group 2, the shoulders were stabilized in the upright position on the operating table. In contrast to group 1, the central point of the glenoid vault was determined visually using electrocauterization. Subsequently, drilling was also performed with the same navigable 1.8 mm sleeve in a perpendicular direction to the glenoid face plane and marked with a K-wire. Thus, accordingly to the description of this technique by Lewis et al. [8], the sCL should be aimed.

2.4. CT analysis

A CT scan with reconstructions comprising of 1 mm layers was performed in multiple planes to measure the canal position. A 64-row multidetector CT was used in all specimens (Brilliance, Philips Medical Systems, Cleveland, USA).

The DICOM data generated by the CT was imported into Mimics® Software (Version 16: Materialise, Leuven, Belgium). The 'threshold' and 'region growing' segmentation functions for bony CT scans were used to calculate the 3D models of the cortical bone. Seven fixed anatomical points were defined, as described elsewhere [7,8,12] (Fig. 2). To allow for better comparison, the measurement was completed by three independent and blinded investigators.

2.5. Anatomic measurements

Quantitative measurements of glenoid version were made on each scapula [22,23].

Two different centerlines were defined [23] (Fig. 3):

- the standard centerline (sCL) was perpendicular (by definition) to the articular surface and exited on the anterior scapular neck [24];
- the alternative centerline (aCL) was set along the scapular spine and was not necessarily perpendicular to the glenoid surface.