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Comparing conventional and computer-assisted surgery baseplate and screw placement in reverse shoulder arthroplasty

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Background: Preoperative planning and intraoperative navigation technologies have each been shown separately to be beneficial for optimizing screw and baseplate positioning in reverse shoulder arthroplasty (RSA) but to date have not been combined. This study describes development of a system for performing computer-assisted RSA glenoid baseplate and screw placement, including preoperative planning, intraoperative navigation, and postoperative evaluation, and compares this system with a conventional approach.
Materials and methods: We used a custom-designed system allowing computed tomography (CT)–based preoperative planning, intraoperative navigation, and postoperative evaluation. Five orthopedic surgeons defined common preoperative plans on 3-dimensional CT reconstructed cadaveric shoulders. Each surgeon performed 3 computer-assisted and 3 conventional simulated procedures. The 3-dimensional CT reconstructed postoperative units were digitally matched to the preoperative model for evaluation of entry points, end points, and angulations of screws and baseplate. Values were used to find accuracy and precision of the 2 groups with respect to the defined placement. Statistical analysis was performed by *t* tests ($\alpha = .05$).
Results: Comparison of the groups revealed no difference in accuracy or precision of screws or baseplate entry points ($P > .05$). Accuracy and precision were improved with use of navigation for end points and angulations of 3 screws ($P < .05$). Accuracy of the inferior screw showed a trend of improvement with navigation ($P > .05$). Navigated baseplate end point precision was improved ($P < .05$), with a trend toward improved accuracy ($P > .05$).
Conclusion: We conclude that CT-based preoperative planning and intraoperative navigation allow improved accuracy and precision for screw placement and precision for baseplate positioning with respect to a predefined placement compared with conventional techniques in RSA.

Institutional Review Board approval was not required (Basic Science study).

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An important factor in the success of reverse shoulder arthroplasty (RSA) is the proper placement of the glenoid baseplate, and its secure anchoring in adequate-quality bone stock is thought to be important, regardless of the glenoid baseplate design.[1-3,5,8,17] Screw placement is also critical for long-term stability of the glenoid component.[16] Each screw contributes to the quality of the glenoid fixation.[2] However, the inferior screw is thought to be the one with the largest contribution because it is nearest to the point of loading of the humeral component.[2]

RSA glenoid baseplate fixation is improved by maximizing implanted screw length and minimizing bone perforation.[2,8,9] However, the morphology of the patients' scapulae is highly variable because of both the degrees of osteoarthritis changes and bone deformity/loss and the natural variability of scapula morphology.[7,15,16] Surgeons currently rely on experience and preoperative imaging both to position the implant accurately and to define the screw trajectories relative to the available bone stock.[9-11]

Bone ingrowth should be maximized to limit baseplate motion. Motion should be limited to less than 100 μm as motion >150 μm has been associated with fibrous tissue formation rather than bone.[16] Baseplate and screw placement in bone of poor quality may result in increased micromotion.[11,12,16]

The high and variable complication rate of this procedure may be attributable in part to a lack of reproducibility in RSA implant positioning or a lack of a consistent definition for complications.[3,13] Scapular notching, instability, and glenoid complication such as loosening have been reported to be the most common complications in RSA.[3,5,6] Each of these complications may be dependent, if indirectly, on prosthetic positioning and fixation.[5,6] Both preoperative and intraoperative computed tomography (CT) navigation and other computer-assisted surgery (CAS) technologies have been shown to be beneficial in identifying adequate bone stock for screw placement and improving baseplate positioning.[3,4,8,10,14,19] However, navigation technologies and preoperative planning have not yet been combined and evaluated in screw and baseplate positioning.

This study had two objectives. First, this work aimed to develop a system for performing computer-assisted RSA baseplate and screw placement, allowing preoperative planning, intraoperative guidance, and postoperative evaluation. Second, we evaluated this system in comparison to conventional techniques.

Materials and methods

Study design

This is a prospective accuracy study in a laboratory setting. Five orthopedic surgeons participated in this study; 3 were experienced board-certified shoulder surgeons and 2 were orthopedic clinical fellows. The surgeons defined a common optimal preoperative plan for the glenoid baseplate and its 4 fixation screws on 3-dimensional (3D) CT reconstructed scapulae, using a custom planning interface.

Each surgeon performed 6 RSA baseplate implantations, 3 conventional and 3 computer assisted, using a custom drilling platform and custom printed plastic scapula models (see specifications later). The implantation phase in this study is defined as registration (if applicable), drilling, reaming, baseplate placement, and screw fixation. Surgical exposure, humeral implantation, and closure and many other elements are not included in this study. Surgeons were instructed that they would be performing 1 trial for each of the 3 different cadaveric scapulae used in this experiment. In an attempt to control internal validity of the experiment, the same scapula, drilling platform, and preoperative planning were used each time.

For the conventional group, surgeons were asked to replicate the predefined plan and could visualize the preoperative 2-dimensional CT images before and during the procedure, as is typical in a conventional surgery; but they were not able to see the preoperative plan while performing the procedure. For the computer-assisted group, surgeons had to first register the anatomy of the drilling platform to its virtual analogue of the CAS interface. Points were collected on the anatomy of the drilling platform and registered to points collected on its virtual analogue. Then, surgeons performed glenoid baseplate and screw placement using a tracked drill guide to replicate the preoperative plan. In both groups, each trial was timed, and models were CT scanned and reconstructed in 3D for comparison of glenoid baseplate and screw positioning with respect to the preoperative plan.

Specimens

Three cadaveric ex vivo shoulders were CT scanned at a slice thickness of 0.625 mm with the General Electric LightSpeed + XCR 16-slice CT scanner (GE Healthcare, Milwaukee, WI, USA). Each 3D CT scan data set was imported into the commercially available Mimics software (Materialise, Leuven, Belgium), and the 3 scapulae were systematically segmented into 3D CT reconstructed models.

This study used a Delta Xtend glenoid baseplate (DePuy Synthes, Warsaw, IN, USA). This glenoid implant has been laser scanned and digitalized, with a resolution of 140 μm, by a 3D