Clinical Biomechanics 58 (2018) 1–6

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Lecture

Scaption kinematics of reverse shoulder arthroplasty do not change after the sixth postoperative month

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ARTICLE INFO

Keywords:
Kinematics
Shoulder
Reverse shoulder arthroplasty
Model-image registration techniques
Shoulder function
Time-course change

ABSTRACT

Background: Changes over time in shoulder kinematics and function after reverse shoulder arthroplasty have not been reported. The purpose of this study was to compare shoulder kinematics and function at 6 months and 1 year after reverse shoulder arthroplasty.
Methods: Twenty patients with a mean age of 74 years (range, 63–91 years) were enrolled in this study. Fluoroscopic images during scapular plane elevation were recorded at the mean of 6 months (range, 5–8 months) and 14 months (range, 11–21 months). CT-derived glenosphere models and computer-aided design humeral implant models were matched with the silhouette of the implants in the fluoroscopic images using model-image registration techniques. Glenosphere and humeral implant kinematics during scaption were compared between the two time points. Patients were also clinically examined with active range of motion and Constant score, and postoperative improvement in shoulder function were assessed.
Results: Active flexion and Constant score improved after surgery ($p < 0.001$ for both), but there was no significant improvement after six months. There was no significant improvement in active external rotation at either postoperative exam. There were no significant differences in glenosphere or humeral kinematics between six months and one year.
Interpretation: There was no significant additional improvement in either shoulder kinematics during scapular plane elevation or function between the sixth and twelfth postoperative months. We can assess kinematics at six months after reverse shoulder arthroplasty to determine how the shoulder will move. Clinically, treatment in the first six postoperative months should be emphasized to achieve better surgical outcomes.

1. Introduction

Reverse shoulder arthroplasty (RSA) is a preferred treatment option for the arthritic shoulder with rotator cuff dysfunction (Cuff et al., 2008; Nolan et al., 2011; Sirveaux et al., 2004). In RSA, the glenohumeral joint is converted into a reversed ball-and-socket articulation by implantation of a glenosphere on the glenoid and a stem with a concave polyethylene insert in the humerus (Grammont and Baulot, 1993). The altered anatomy provides several important changes in the biomechanical properties of the shoulder including an altered center of rotation, a stable and fixed fulcrum for elevation, and increased tension of the deltoid muscles, which partially compensate for the loss of rotator cuff function (Boileau et al., 2006). Grammont type RSA medializes the center of rotation on the glenoid face (Grammont and Baulot, 1993), but the medialized center of rotation has been associated with scapular notching, reduced range of motion, and loss of shoulder contour (Boileau et al., 2005; Boileau et al., 2006). To improve these shortcomings, newer design prostheses have employed the lateralized center of rotation (Chou et al., 2009; Gutierrez et al., 2008).

Researchers have been studying kinematic changes in the shoulder due to these biomechanical alterations after RSA (Alta et al., 2014; Alta et al., 2011; Chisholm and Poon, 2012; de Toledo et al., 2012; Kwon et al., 2012; Lee et al., 2016; Roren et al., 2017; Walker et al., 2015). Most studies evaluated shoulder kinematics > 1 year after surgery (Chisholm and Poon, 2012; de Toledo et al., 2012; Lee et al., 2016; Walker et al., 2015), while some studies included RSA shoulders at an earlier postoperative stage (Alta et al., 2014; Alta et al., 2011; Roren et al., 2017;). No published articles have assessed kinematic differences between different postoperative time points. Only one clinical study has examined changes of shoulder function from 0 to > 60 months after

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https://doi.org/10.1016/j.clinbiomech.2018.07.005
Received 19 October 2017; Accepted 4 July 2018

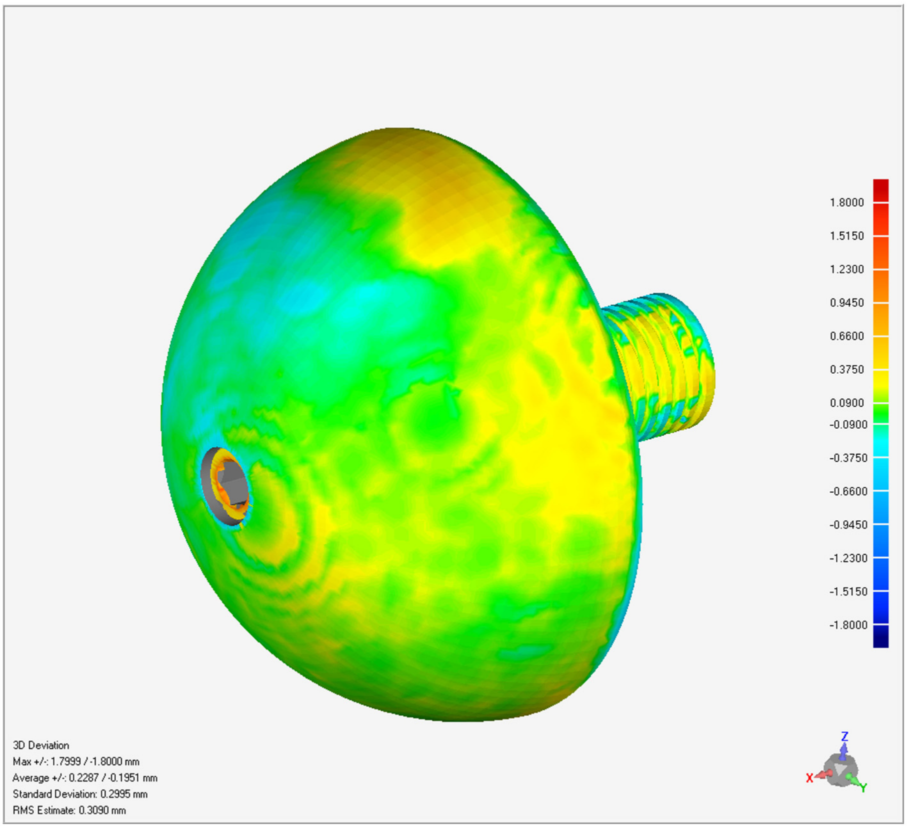

Fig. 1. Deviation analysis of CT-derived glenosphere models. Deviations of CT-derived glenosphere models were three-dimensionally tested using the manufacture-provided computer-aided design model as a reference with use of commercial software (Geomagic Studio, 3D Systems, SC, USA). Mean RMS surface deviations were 0.4 mm, roughly the voxel size of the CT scan image.

RSA and reported that most of functional improvement was noted in the first 6 months (Simovitch et al., 2015). Through our clinical experience, we also observe that shoulder function does not change dramatically after the sixth postoperative month. The postoperative period of kinematic change likely represents the most dynamic phase of shoulder healing and functional gain after RSA, and so may delineate the period where physical therapy and exercise may be most effective in restoring function and range of motion. Similarly, patients who fail to achieve satisfactory outcomes in this period might be expected to continue with poor function and require further treatment.

The purpose of this study was to compare shoulder kinematics and function at 6 months and 1 year after RSA. Based upon previous reports (Simovitch et al., 2015) and our clinical experience, we hypothesized there would be no significant differences in kinematics and function between the two time points.

2. Methods

2.1. Patients

Twenty shoulders (20 patients) that underwent RSA were enrolled in this study. The patients consisted of 13 males and 7 females with a mean age of 74 years (range, 63–91 years). There were 13 right and 7 left shoulders, and all patients were right-handed. Indications for RSA were cuff tear arthropathy or irreparable massive cuff tear in 16 shoulders, osteoarthritis/rheumatoid arthritis in 2 shoulders, fracture sequelae in 1 shoulder, and revision after hemiarthroplasty in 1 shoulder. Aequalis Reversed (Tornier, Saint Martin, France) was used in all patients. The 36 mm diameter glenosphere was used in all shoulders, and no shoulders used the eccentric or tilted glenosphere. The standard tray was used in all cases, and the depth of polyethylene insert was 6 mm in 15 shoulders, 9 mm in 3 shoulders, and 12 mm in 2 shoulders. Our Institutional Review Board approved the protocol of this study, and all subjects provided informed consent to participate.

2.2. Image acquisition

Fluoroscopic images of scapular plane abduction were recorded at the mean of 6 months (range, 5–8 months) and at 14 months (range, 11–21 months) in each subject (Plessart ZERO, Toshiba, Tochigi, Japan; 7.5 frames/s, 310 × 310 mm field of view, 1024 × 1024 pixel, 8-bit images). The mean time between the two follow-ups was 8 months (range, 5–16 months). The subject stood with their torso at approximately 30° to the plane of the image intensifier, so that the plane of the scapula was perpendicular to the x-ray beam (Matsuki et al., 2012). On average, the angle between the plane of the glenosphere base and the x-ray beam in the axial plane was 21° ± 18° at the starting position. Elevation in the scapular plane was performed from the arm at side to maximum elevation, at approximately five seconds per cycle, with the elbow fully extended and the arm externally rotated (thumb-up position). Subjects' bodies were not constrained to allow them to naturally move their arm, and the speed of motion was not strictly controlled. The subjects practiced the activity until they felt comfortable, and then two cycles of the activity were recorded. The mean number of recorded images was 33 ± 9 per cycle. CT scans of the shoulders were also acquired with a 0.3 mm slice pitch (Alexion, Toshiba, Tochigi, Japan; image matrix, 512 × 512 pixels; pixel size, 0.468 × 0.468 mm; slice pitch, 0.3 mm). To minimize metal artifact, CT scans were performed using iterative reconstruction techniques.

2.3. Three-dimensional models of implants

Computer-aided design (CAD) models of humeral implants were provided by the manufacturer (Tornier). Three-dimensional surface models of glenospheres with a baseplate and screws were created by segmenting the CT images using ITK-snap software (Penn Image Computing and Science Laboratory, Philadelphia, PA, USA) (Yushkevich et al., 2006). These patient-specific models are required for 3-D model-image registration because of the glenosphere's rotational