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Rocking-horse phenomenon of the glenoid component: the importance of inclination

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Background: Abnormal glenoid version positioning has been recognized as a cause of glenoid component failure caused by the rocking horse phenomenon. In contrast, the importance of the glenoid inclination has not been investigated.
Materials and methods: The computed tomography scans of 152 healthy shoulders were evaluated. A virtual glenoid component was positioned in 2 different planes: the maximum circular plane (MCP) and the inferior circle plane (ICP). The MCP was defined by the best fitting circle of the most superior point of the glenoid and 2 points at the lower glenoid rim. The ICP was defined by the best fitting circle on the rim of the inferior quadrants. The inclination of both planes was measured as the intersection with the scapular plane. We defined the force vector of the rotator force couple and calculated the magnitude of the shear force vector on a virtual glenoid component in both planes during glenohumeral abduction.
Results: The inclination of the component positioned in the MCP averaged 95° (range, 84°-108°) and for the ICP averaged 111° (range, 94°-126°). A significant reduction in shear forces was calculated for the glenoid component in the ICP vs the MCP: 98% reduction in 60° of abduction to 49% reduction in 90° of abduction.
Conclusion: Shear forces are significantly higher when the glenoid component is positioned in the MCP compared with the ICP, and this is more pronounced in early abduction. Positioning the glenoid component in the inferior circle might reduce the risk of a rocking horse phenomenon.
Level of evidence: Basic Science, Computer Modeling.

Keywords: Rotator cuff; force couple; glenoid plane; inclination; retroversion; rocking horse

The most frequent complication of total shoulder arthroplasty remains loosening of the glenoid component. Radiologic loosening is regarded as radiolucent lines progressing in size or as actual implant migration. This can progress to clinical loosening, which is associated with increased pain and decreased function of the shoulder, with revision surgery as the end point. According to literature, the occurrence of loosening is time dependent, with

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The local Ethics Committee approved this study (EC/2011-069).

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asymptomatic radiolucent lines seen at a rate of 7.3% per year after a primary shoulder replacement. Symptomatic glenoid loosening is seen at a rate of 1.2% per year, and surgical revision at 0.8% per year.[17] The risk ratio for revision of radiolucent lines amounts 0.27, with a higher risk for keeled than for pegged components.[23] Moreover, metal-backed prostheses have a higher rate of failure than all-polyethylene components.[16]

Besides the features of the prosthetic material, the positioning of the glenoid component also is a determining factor in the occurrence of loosening.[26] The position of the glenoid component relative to the scapular plane seems to be important in the transversal plane of the body (type B2 and C glenoids according to Walch) and in the scapular plane of the body (type A1 and A2).[7,17] This can partially be explained by the role of the rotator cuff muscles in compressing the humeral head into the glenoid socket.[18] An equal distribution of the rotator cuff forces in the transversal plane is required to obtain active centering, since a change in retroversion resulted in a posterior displacement of the humeral head and eccentric loading of the glenoid component causing glenoid loosening (rocking horse phenomenon). Surprisingly, this rocking horse phenomenon at the glenoid has not yet been studied for the inclination of the glenoid plane. The aim of this study was to analyze the magnitude of the eccentric loading (shear force), as part of the total joint force, exerted by the transversal force couple of the rotator cuff on a virtual glenoid component positioned in two differently orientated planes.

Materials and methods

This is a computed tomography (CT) scan simulation study determining forces on a virtual glenoid component in different positions.

Methodology

We measured 152 CT scans of healthy shoulders from patients who were scanned for pathology at the contralateral side. Since 2007, we have included in a radiologic database the Digital Imaging and Communications in Medicine (DICOM) information of both shoulders of all patients who have had a CT arthrogram in our shoulder unit for pathology of 1 shoulder. Because it is not possible to position only the diseased shoulder centrally in the CT gantry, both shoulders are scanned simultaneously; however, patients do not receive supplementary irradiation.

Exclusion of pathology of the shoulder to be studied was done by history taking, physical examination, and CT scan evaluation. The senior author (L.F.D.W.) inspected all CT scans for structural bony lesions (eg, cysts and visible bony deformations of the clavicle, scapula, and humerus, and the sternoclavicular, acromioclavicular, and glenohumeral joints) and soft tissue lesions (eg, integrity of the rotator cuff tendons, atrophy or muscular fatty degeneration of the rotator cuff or deltoid muscles, or both). If such lesions were present, the data were excluded.

The selected group of 152 patients had different pathologies from the contralateral shoulder, including rotator cuff tears in 35 (5 partial and 30 full-thickness tears), acromioclavicular-joint osteoarthritis in 33, instability lesions in 30, subacromial impingement in 17, calcifying tendinitis in 12, tendinitis of the long head of biceps brachii in 12, frozen shoulder in 8, and fractures of the proximal humerus in 5.

A standardized method was used to position all patients in the CT gantry, as detailed in a previous study.[5] The patient is placed in dorsal recumbence, with a cushion on the belly and a strap around the body and this cushion. The upper arms are positioned at the side of the body with the elbows flexed to 90° and the hands holding the cushion. This keeps both arms adducted in the coronal plane and the forearm flexed in the sagittal plane of the body.

A Somatom Volume Zoom–Siemens CT (Siemens, Erlangen, Germany) with a matrix set to 512 × 512, kV at 140/eff, and mAs at 350 was used with a field of view adapted to each patient. This resulted in a maximum of 500 mm for both shoulders and 180 mm for 1 shoulder with a pixel size of no more than 0.97 or 0.35 mm, respectively. The glenohumeral joint was scanned with maximum 1.5-mm interval slices. To create 3-dimensional images of the shoulder joint, the DICOM CT images are imported into medical imaging computer software (Mimics 14.0 for Intel X86 Platform V14.0.0.90 1992–2010; Materialise NV, Leuven, Belgium). This software permits virtual separation of both bones of the joint so that the determination of the bony reference points or best-fitting shapes for measurement purposes can be done digitally. Three investigators independently performed the measurements.

Determination of planes

A virtual glenoid component was positioned in 2 different planes: the maximum circular plane (MCP) and the inferior circular plane (ICP). We defined the MCP as the best fitting circle (maximum circle [MC]) constructed by the most superior point of the glenoid and 2 points at the lower third glenoid rim (Fig. 1, *A*). The MCP was chosen because it is the most commonly used plane in osteoarthritis.[20] The ICP was defined as the best fitting circle (inferior circle [IC]) of the rim of the inferior quadrants (Fig. 1, *B*). We chose the ICP because it is important for glenohumeral stability and has the least variability in orientation.[1,8,13,24,25] The radius (r) of the MC (rMC) and IC (rIC) was calculated.

To obtain a reproducible Cartesian coordinate system, we defined the scapular plane. This was constructed by the most medial point (Smed) and most inferior point (Sinf) of the scapula and the center of each circle. The center the MC (cMC) and center of the IC (cIC) was also the origin of a Cartesian coordinate system, with the x-axis positioned in parallel to the MCP or ICP, and the y-axis defined as the intersection of the scapular plane and the MCP (Fig. 2, *A*) or ICP (Fig. 2, *B*).

Parameters

The inclination of the glenoid component was measured as the angle between the perpendicular to the scapular plane (different related to different center of each circle) and the 2 different glenoid planes (Fig. 3, *A* shows this for the ICP). The version was measured as the angle between the perpendicular to the scapular plane and the x-axes of the two different glenoid planes (Fig. 3, *B* shows this for the ICP). The position of the center of rotation (cR)