Etude en éléments finis analysant l’impact de la forme du PE sur les contraintes osseuses humérales des RSA

Geoffroy Nourissat MD PhD(1) Victor Housset (2)MD , Jean-Marie Daudet (3) Leo Fradet PhD Eng (4) Rohan-jean Bianco PhD (4) Uma Srikumaran (5)

(1) Groupe Maussins, Clinique Maussins Ramsay Santé, Paris, France. (2) Hopital Henri Mondor, UPEC, Créteil, France, (3) FX Solutions, 1663 Rue de Majornas, 01440 Viriat, France (4) Philomec Inc. 7687-9 Rue Saint-Denis, Montréal H2R 2E7 Canada
(5) Department of Orthopedic Surgery, Johns Hopkins University, Baltimore, Maryland,

CLINIQUE DE L’EPAULE

FX SOLUTIONS

Philomec

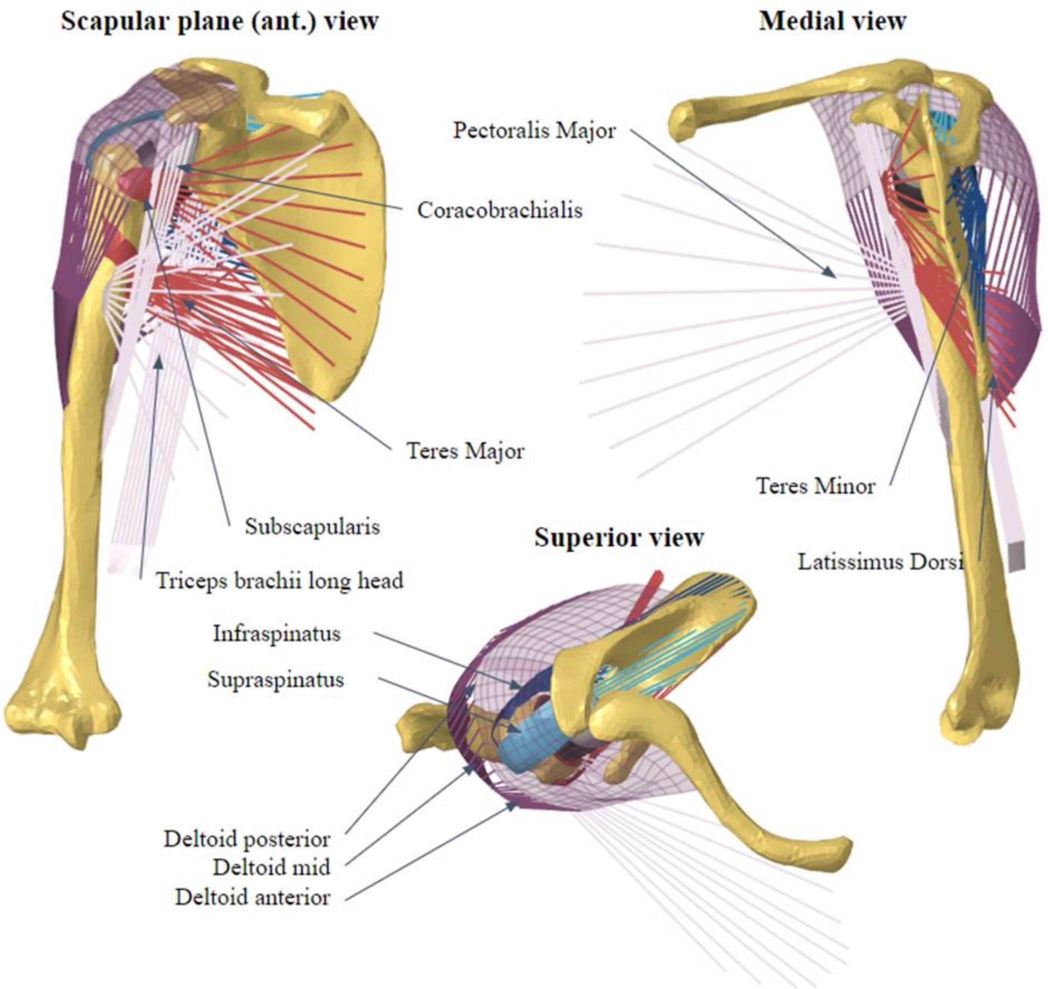
JOHNS HOPKINS SCHOOL of MEDICINE

Introduction

Humeral stress shielding is a major concern in short stem TSA and RSA as it can be responsible for critical metaphyseal bone loss or even fractures around the stem. Several elements have been reported to be involved in the causes of stress shielding, such as the size or the shape of the shaft, but currently no study has evaluated the influence of the shape of the polyethylene (PE) on the bone stress of around or in humeral stem.The main objective of this study was to explore the impact of PE shape on humeral stress distribution using a finite element (FE) model. The secondary objectives were to also know the influence of the use of different stem and PE sizes on the global biomechanics of the shoulder.

Material

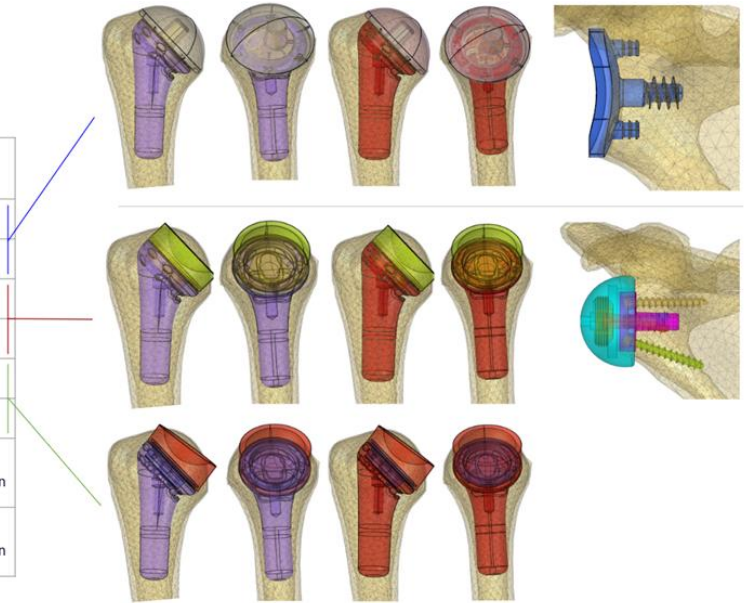
We have developed a shoulder specific finite element model to analyze the bone, capsulo-ligamentous and muscular tissues of the glenohumeral joint, including the rotator cuff and the deltoid. A defined set of muscle forces was applied through active stimuli to simulate abduction movement. An intact rotator cuff state and a superior/posterior-superior deficient rotator cuff state were modeled.



Method

We used the FX V135 stem (FX Solutions) in several conditions: anatomic total shoulder arthroplasty, reverse shoulder arthroplasty with symmetrical PE and asymmetrical PE.For each condition we measured biomechanical markers related to bone stress at the humerus and glenoid for different implant sizes. The joint kinematics and the mechanical behavior of the implant were also compared.

Sim #	Config	Stem size
1	Anatomical	14
2		16
3	Reverse 135° *(Failed SSP)*	14
4		16
5	Reverse 145° *(Failed SSP)*	14
6		16
7	Healthy	No instrumentation
8	Pseudo-paralytic *(Inactive SSP)*	No instrumentation



FX V135 anatomic.

FX V135 Symetric PE

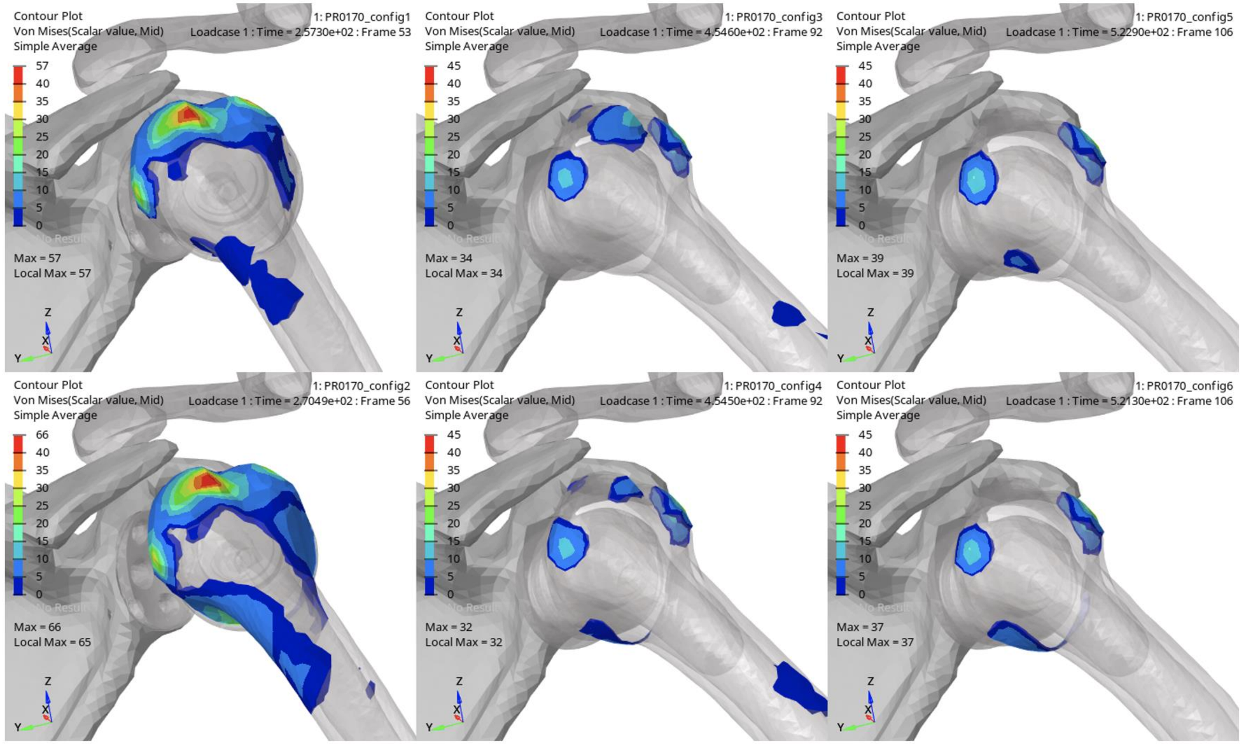
FX V 135 asymetric PE

Results 1

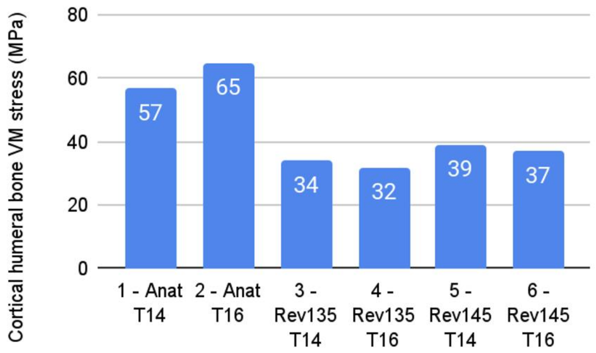
Cortical humeral bone stress analysis

Anatomical | **Reverse 135°** | **Reverse 145°**

Stem 14 / **Stem 16**



*Cortical areas where Von Mises stress is superior to 4 MPa are highlighted in color.



- All cortical bone stresses were below the material limit (175 MPa)
- Most high stress were located at muscle and ligaments insertion areas
- The anatomical configurations lead to more stressed volume higher maximal measured stress compared to the reverse configurations due to an active SSP muscle. Visible stress in cortical bone below the stem keel
- No high stress were measured around the stem or due to stem movement
- In the reverse configurations, the larger (T16) stems lead to slightly lower cortical maximal stress

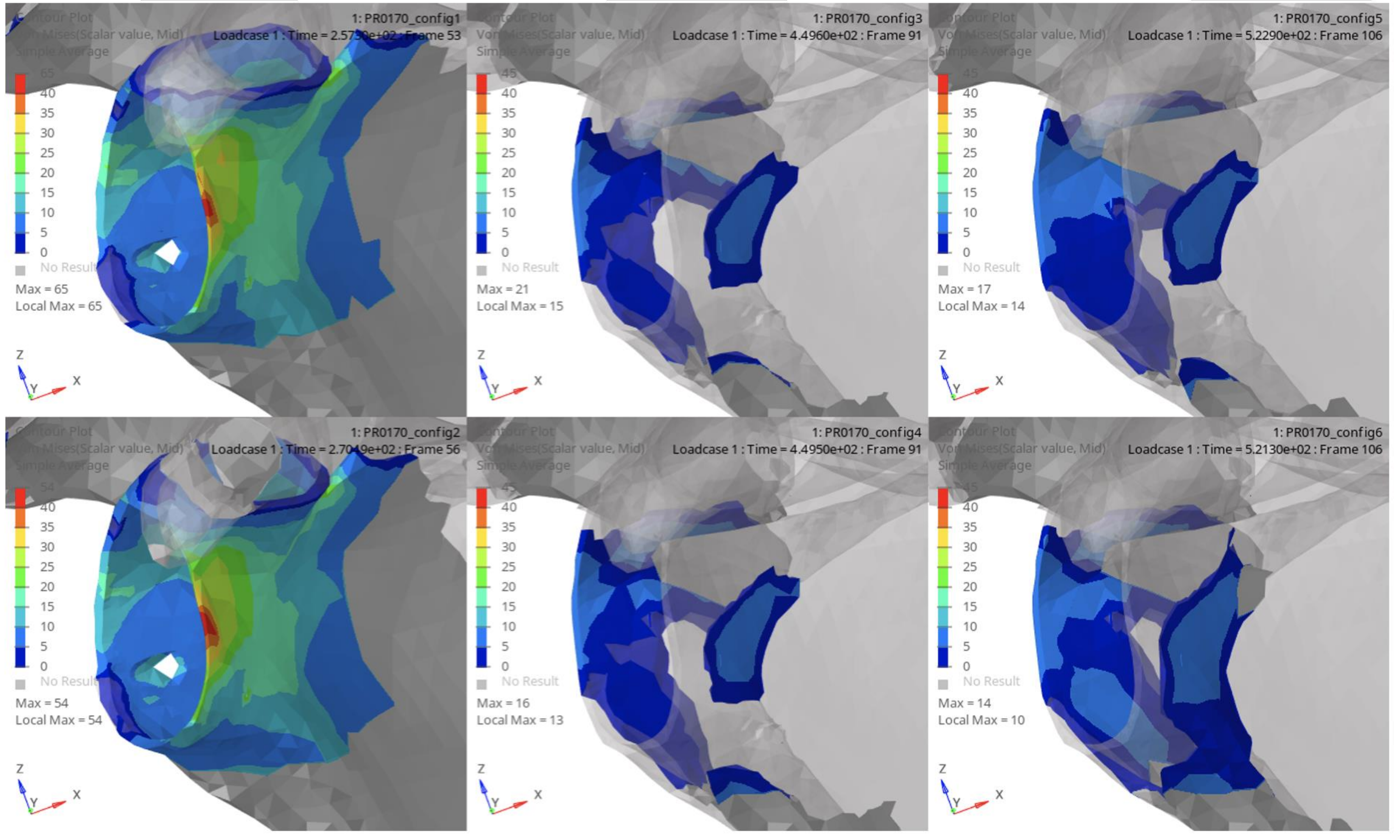
Results 2

Cortical scapular bone stress analysis

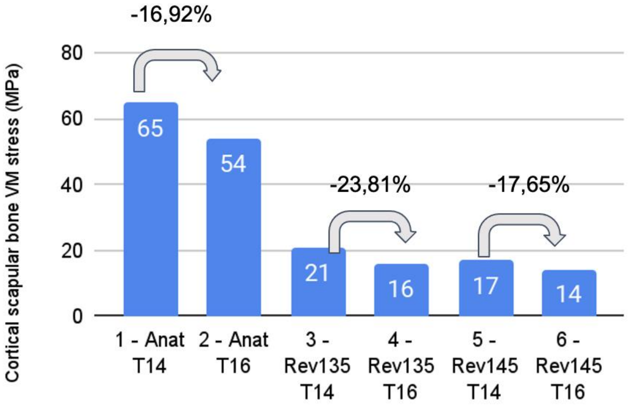
Anatomical | Reverse 135° | Reverse 145°

Stem 14

Stem 16



*Cortical areas where Von Mises stress is superior to 4 MPa are highlighted in color.

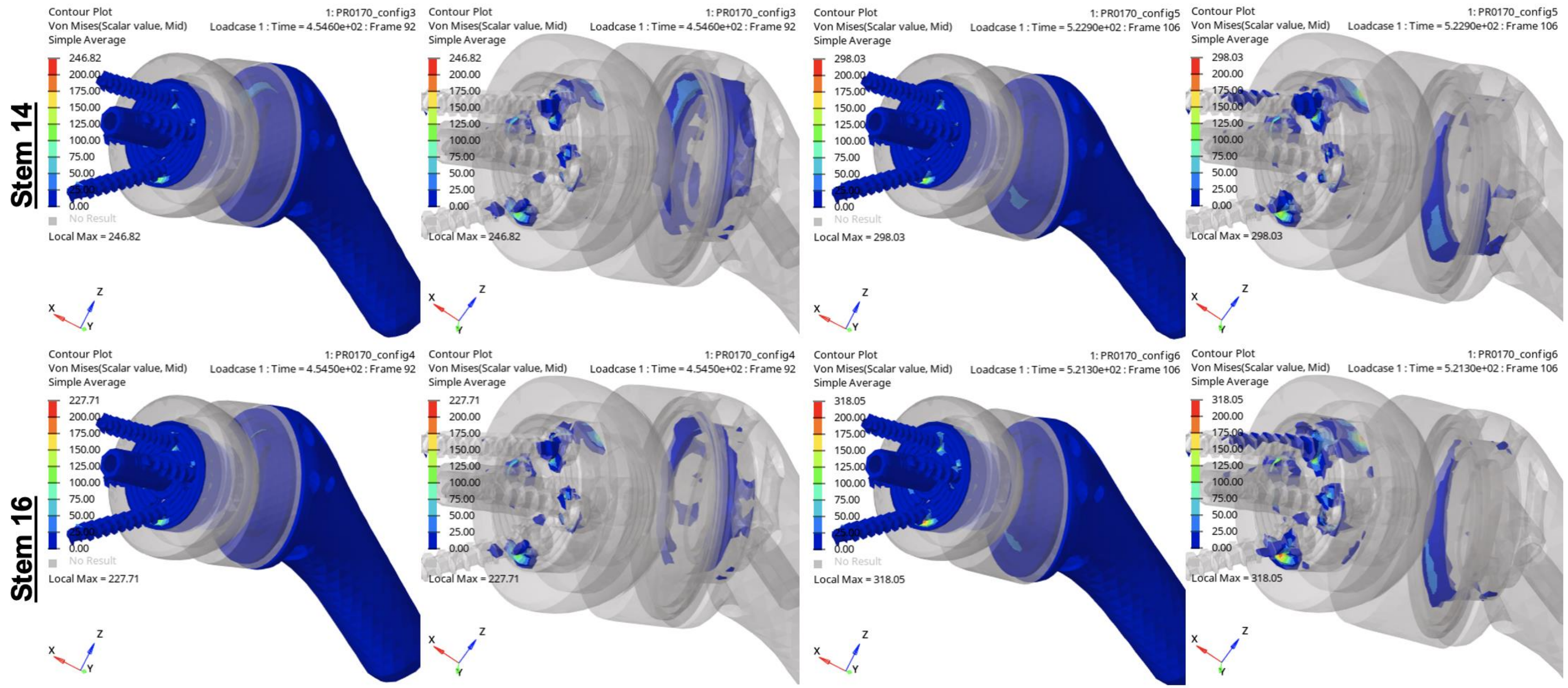


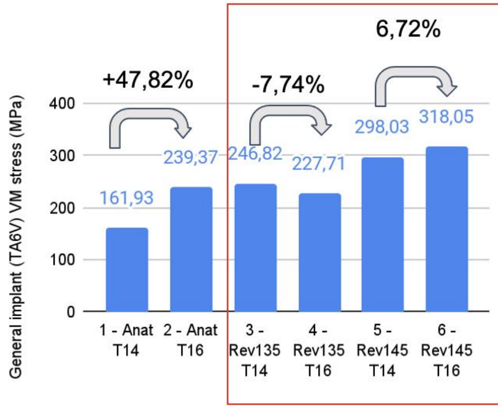
- All cortical bone stresses were below the material limit (175 MPa)
- The anatomical configurations lead to more stressed volume higher maximal measured stress compared to the reverse configurations due to an active SSP muscle
  - High stress in the cortical bone was measured due to contact of the glenoid in the anterior face
- The larger (T16) stems lead to slightly lower cortical maximal stress

Results 3

Stem, taper, metaglenoid and screws stress analysis (TA6V ELI)

Reverse 135° **Reverse 145°**



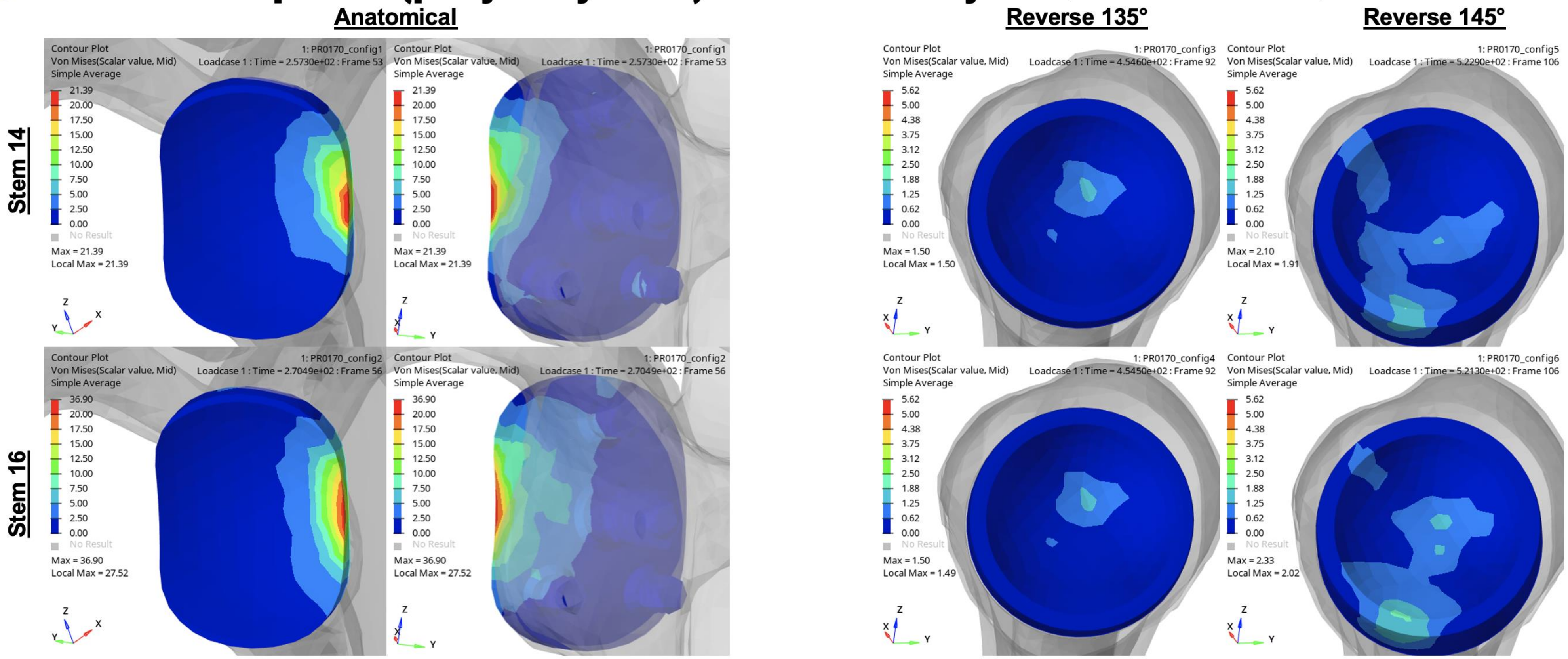


*TA6V ELI areas where Von Mises stress is superior to 15 MPa are highlighted in color.

- Maximal measured Von Mises stress were below material yield strength (795 MPa)
- Highest Von Mises Stress were mainly measured at the screw and metaglenoid. The superior and inferior screws were the most stressed under abduction conditions. High VM stress were also measured at the taper and stem connection, similarly to the anatomic configurations.
- Higher Von Mises stress were measured with the reverse V145 configuration

Results 4

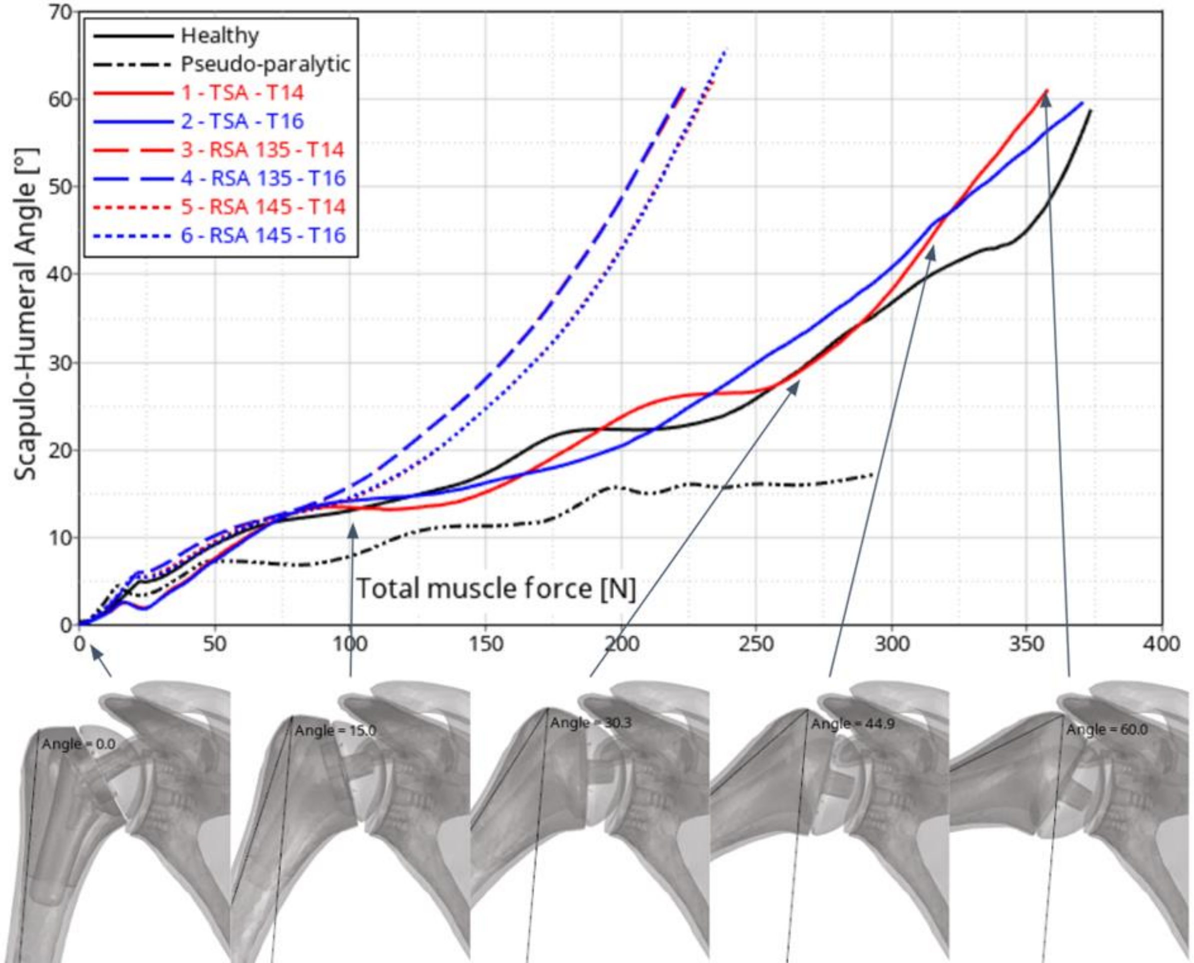
Female implant (polyethylene) stress analysis (at maximal humeral elevation)

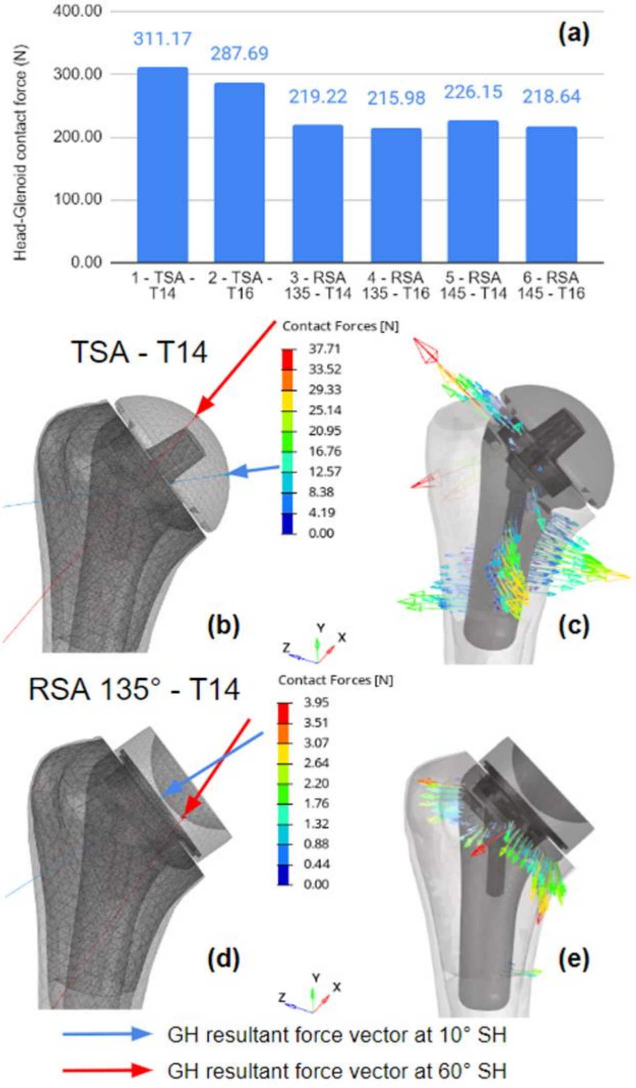


- Highest HDPE stress was observed for anatomical configurations, due to the lower congruence between humeral head and glenoid components
- Stress were higher than (standard) material limits (22 MPa) for the anatomical stem 16 configuration
    - Premature wear might occur.
- No visible trend for stem size

Most important findings

Our model reveals that rupture of the supraspinatus and infraspinatus produces a functionally limited shoulder as expected clinically. The placement of an anatomic TSA with intact rotator cuff allows full restoration of function with a range of motion similar to that of a healthy preoperative model. The reverse TSA in the rotator cuff deficient shoulder restores function regardless of the stem size and PE tested.





Our study demonstrates that the stress around the stem differs between RSA and TSA conditions. First important point our study reveals is that the main difference in biomechanics between TSA and RSA is due to glenohumeral contact force vector

Conclusion

Our finite element study demonstrates that the main difference in biomechanics between TSA and RSA is due to glenohumeral contact force vector. TSA results in more loading around the stem shaft, and RSA results in more loading around the calcar. Smaller stems seem more appropriate than larger stems for overall bone stress of the stem. Smaller stems seem more appropriate in TSA, larger stems seem more appropriate in RSA, mostly because of the interference of the stress induced by the intact cuff in case of TSA. PE shape on the same stem does not increase humeral stresses, but results in different ranges of motion and abduction stresses in the metal structures of the implant in our finite element model.