Development of FE models of clavicular ligaments: quasi-static tensile test and FE simulation

Sarah Doerfel[1], Ketuo Zhou[1], Girish Sharma[2], Christian Mayer[3], Steffen Peldschus[4]

I. INTRODUCTION

This study is the continuation of previous work of Gupta et al. [1] who developed and validated a finite element model of the human shoulder in order to understand the complex dynamics of the shoulder under various side and frontal loading conditions in automotive accidents. Therefore, this part of the study reports on the adaption of FE models for clavicular ligaments playing an important role in the mentioned loading cases.

II. METHODS

In the first step quasi-static tensile tests with acromioclavicular (ac), sternoclavicular (sc), costoclavicular (cc) and interclavicular (ic) ligaments were performed. The results of the experiments were used to develop FE models of these ligaments which are able to describe the global ligament's behavior for this loading case.

Experimental Testing

Twelve human bone-ligament-bone specimens (three of each ligament type) were tested in a quasi-static tensile test. The bony parts were fixed in a Zwick Z010 universal testing machine (shown in Figure 1) and the specimen was loaded until failure. Load and displacement were recorded during each test. Based on these data stress and strain were calculated as described in [2].

Computational Modeling

Geometry of the Daimler shoulder model was basis for the simulation of the quasi-static tensile tests but geometrical data obtained from measurements were implemented (length, width, cross-sectional area and circumference of the ligaments, example shown in Figure 1). Material type 24 (material piecewise linear plasticity) in the LSDyna code was selected for describing the ligaments and the experimental data were used as validation input.

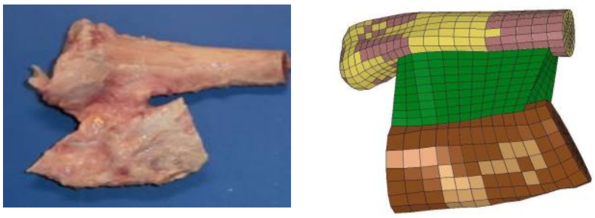

Figure 1: Specimen and finite element model of the costoclavicular ligament

III. RESULTS

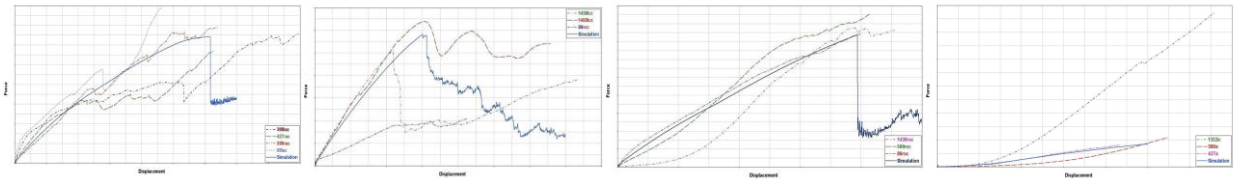

Figure 2: Force-displacement curves of experiment (dotted lines) and simulation (blue line) (seen from left to the right: ac, cc, sc and ic ligament)

IV. DISCUSSION AND CONCLUSION

The results of this study show that it is possible to model the global behavior of bone-ligament-bone specimen in a quasi-static tensile test with a common material model of the LSDyna code. The limitation of this study is the complex geometry of the whole ligament. Therefore, a stress and strain calculation within the ligament is not possible without further imaging processes.

V. REFERENCES

[1] Gupta A et al, Ircobi Conference, 2011.
[2] Koh S et al, Stapp Car Crash Journal, 2004.

1. Sarah Doerfel is doctoral student in the Biomechanics Group at the Institute of Legal Medicine of Ludwigs-Maximilians-University in Munich (phone: +49 89 2180 73365, fax: +49 89 2180 73009, email: sarah.doerfel@med.uni-muenchen.de), Ketuo Zhou is doctoral student in the Biomechanics Group at the Institute of Legal Medicine of Ludwigs-Maximilians-University in Munich. 2. Girish Sharma is responsible for human body models at Mercedes-Benz Research and Development India, Bangalore, India.3. Christian Mayer is senior expert in Vehicle Safety Concepts at Daimler in Sindelfingen, Germany.4. Steffen Peldschus is Professor of Applied Mechanics in the Faculty of Industrial Technologies at Campus Tuttlingen of Hochschule Furthwangen University.