

Biomechanical Properties of Synthetic Mesh Reconstructed Glenohumeral Joint Capsule

Tao Jin, Wei-Feng Liu, Hai-Rong Xu, Yuan Li, Xiao-Hui Niu

Department of Orthopaedic Oncology Surgery, Beijing Jishuitan Hospital, Peking University, Beijing 100035, China

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Synthetic mesh is often used in soft tissue reconstruction after artificial prosthesis replacement for patients with proximal humeral bone tumors. We carried out biomechanical and histological tests on two amputated extremities to test the stability of the joint and the biocompatibility of the synthetic meshes.

Two samples of amputated extremities were included in this study. Case 1 is a 31-year-old female who underwent artificial prosthesis replacement in treatment of Grade II chondrosarcoma in 2009. Parts of the starting point of deltoid muscle and the ending point of pectoralis major muscle were excised, and the brachial artery, median nerve, musculocutaneous nerve, axillary nerve, and radial nerve were remained. Then, a humeral prosthesis was implanted, a monofilament polypropylene fiber mesh (Bard® Mesh 26 cm × 36 cm) was fixed to the capsule, and four rivets were placed around the shoulder cup to reconstruct the soft tissue. Recurrence was observed in October 2013, forequarter amputation was performed, and the specimen was stored at -20°C.

Case 2 is a 54-year-old male patient with chondrosarcoma of the proximal humeral bone. The same resection and reconstruction surgery as case 1 was performed in 2013, except for the synthetic mesh was only covered the surface of the prosthesis but not fixed to the joint capsule. Recurrence was observed in March 2015, interscapular thoracic amputation was performed, and the specimen was stored at -20°C.

MTS858 Mini Bionix II (MTS Systems Corporation, USA) was used for the biomechanical studies; the load applied was 2–10 kN. The specimen was fixed on the equipment by a specifically designed clamper.

The methods of biomechanical test followed the instruction of Alexander cadaveric shoulder joint test.^[1] The scapula was

fixed and the load was exerted on the head of the humerus. Movement of the head of the humerus under a certain load on scapula was used as an index of shoulder joint stability. Stability of the reconstructed joint capsule was compared to the normal value.^[1]

Procedures of preparing and embedding the specimen followed the methods described by van de Sande *et al.*^[1] Then, the specimen was fixed to the test equipment using the specifically designed fixation system. To minimize the effect of soft tissue glutinosity to the test result, the humeral bone was placed 30° abduction position of scapular plane. The scapular bone was fixed, and the humerus was externally rotated 10 times with the force of 0.5 N·m.

Measurement of the stability: The scapula was fixed, and the humeral bone was adjusted by the equipment to two positions: (1) 0° abduction and neutral rotational position and (2) 30° abduction and neutral rotational position. A force of 1N–20N on upright, downright, forward, and backward directions was enforced, and the movement was measured to calculate the stability. The joint capsule was kept intact during the whole procedure.

The data are listed in Table 1. The stability of the reconstructed joint was close to that of normal control group which was reported in the literature^[1] in a different direction in case 1; however, the result in case 2 was not as good as case 1.

Address for correspondence: Prof. Xiao-Hui Niu,

Department of Orthopaedic Oncology Surgery, Beijing Jishuitan Hospital,
Peking University, Beijing 100035, China
E-Mail: niuxiaohui@263.net

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Table 1: Movement of the head of humeral bone with 20 N force compared with the value of normal control subjects in the literature

Direction of the force	Movement of humeral bone at neutral position (mm)			Movement of humeral bone at 30° abduction position (mm)		
	Case 1	Case 2	95% CI of normal control	Case 1	Case 2	95% CI of normal control
Upward	1.20	14.27	1.53–3.13	1.17	8.19	2.79–7.11
Downward	2.03	4.40	6.32–17.12	2.84	8.02	5.84–18.00
Forward	7.10	23.74	8.58–16.66	12.11	14.70	7.32–19.30
Backward	6.31	20.79	6.37–11.99	5.01	10.86	6.41–16.43

CI: Confidence interval.

Histopathologic observation: A piece of the synthetic mesh in case 1 was used for histological studies. Mature fibrous connective tissues were observed around the synthetic mesh. Scattered or a layer of multinucleated giant cells can be observed between the synthetic mesh and fibrous connective tissues, and the fibrous tissues have grown into the synthetic mesh, proving the fine biocompatibility of the synthetic mesh.

A stable shoulder joint is required when arms are performing necessary functions, and it improves patients' quality of life. Wittig *et al.*^[2] proposed that the aim of shoulder joint reconstruction is to gain stability but not function. The current research had focused on the stability of shoulder joint after reconstruction and obtained biomechanical and biocompatibility outcomes of monofilament polypropylene fiber mesh used in shoulder joint reconstruction surgery.

In case 1, stability of shoulder joint is not worse than normal controls, and the patient reported no pain due to instability of the joint after surgery. Stability of the joint in case 2 is not as good as case 1; this could be the result of the difference reconstruct methods. Moreover, the fact that patient in case 2 is older than that in case 1 may affect the stability of the reconstruction.^[3]

The synthetic mesh provides the prosthesis with instant stability, but to provide long-term stability, it should be integrated in the surrounding environment by scar tissue formation. A previous study^[4] found that Bard synthetic mesh could be integrated with the soft tissues when used in reconstructing ligamentum patellae. The result of case 1 is similar to the previous findings.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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