INTRODUCTION

The menisci are integral to normal knee joint function and play an important role in joint load distribution, lubrication, joint stability, and proprioception. Radial meniscal tear is a common disease in young patients, especially in the group of athletes. It often occurs at the junction of the body and the posterior horn of the medial meniscus. The treatment of radial meniscal tear is directed at the prevention of future degenerative disease. It has been reported that radial tear (RT) extending to the periphery has been believed to result in the reduction of meniscal hoop strength and has been described as functionally equivalent to a total meniscectomy. While the literature has clearly indicated the deleterious effects of total meniscectomy, there is no definitive understanding of the effect of meniscal tear on knee joint mechanics.

In this study, a systematically experimental evaluated concurrent finite element (FE) musculoskeletal (MS) lower limber model was developed and used to predict the variation of contact mechanics of the knee as a function of the percentage of the meniscus involved by the RT.

METHODS

A subject-specific finite element-musculoskeletal (FE-MS) lower limber model was created to analyse the impact of medial meniscus RT on joint kinematics and contact mechanics during the gait cycle, as shown in Fig.1. The accuracy of the FE-MS model was firstly evaluated on a subject with instrumented knee prosthesis from Ground Challenge Database and a good consistent was found on knee joint contact force (RMSE=0.28, $R^2=0.86$) [1]. The intact knee model was created based on Open Knee project on Simtk.org, including bone, cartilage, meniscus, and patellar tendon. All the ligaments (LCL, MCL, PCL, and ACL) were simplified as 1D nonlinear spring with followed a nonlinear piecewise force–displacement relationship [2]. The soft tissue related to patellofemoral joint including the patellar tendon and quadriceps muscle were modelled as 2D fiber reinforced membrane (M3D4R) and non-linear spring elements (CONN3D2). The horns of meniscus were represented as bundles (40) of no-compression springs with the elasticity of 40 N/mm, while the anterior and posterior meniscofemoral ligament were set as 4 springs with the elasticity of 12.25 N/mm. The articular cartilage was modelled as nonlinear Neo-Hookean hyperelastic isotropic material [3]. Medial and lateral meniscus were considered as transversely hyperplastic isotropic materials, which were implemented using the Holzapfel-Gasser-Ogden (HGO) model [4]. Five kinds of knee joint models with meniscus tear (0% RT, 30% RT, 45% RT, 60% RT and 90% RT) were modelled and investigated in the study, as shown in Fig.1.

The FE knee model was coupled to preoperative MS bone model based on iterative closest point algorithm. A gait from a healthy male subject (BW-65 Kg, Height-183cm) was applied to demonstrate the kinematics and contact mechanics on knee joint with meniscal damage.

RESULTS AND DISCUSSION

The peak tibial contact pressure on medial cartilage in the intact knee are 7.2MPa and 10.6MPa at the 14% and 45% of gait cycle, respectively. The magnitude and location of peak contact pressure are little affect (within 0.5MPa) by the RT involving up to 45% of the meniscal rim width, as shown in Fig.2. The RT involving 90% results in a poster central shift in peak-pressure location and the magnitude is 2.4MPa larger than the intact knee. A similar trend can be found in in-vitro experimental results from Bedi et al’s research [5]. Thus, the method provides a high accuracy and
comprehensive analysis of the impact of meniscus tear on knee joint mechanics, as shown in Fig.3. A higher peak contact pressure is observed in the study compared to the in-vitro experimental results based on ISO 14243 because of the structural limitations of pressure film sensor which will smooth pressure changes.

A sudden decrease of contact area is found after radial tear larger than 45% of meniscus width. It also can be found that kinematics of tibiofemoral (TF) joint is changed from the simulation results. The main reason is that the radial meniscus tear will change the laxity on TF joint. The main limitation of the study is that we hypothesized the change of ground reaction force caused by the meniscal damage could be neglected.

**CONCLUSIONS**

In this study, a subject-specific FE-MS lower limber model provided a high accuracy and a comprehensive analysis of the impact of meniscus tear on knee joint mechanics. What’s more, an optimized meniscectomy surgery (stitching method and resection area, etc.) could be expected using the proposed simulator.

**REFERENCES**