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Numerical calculation and study of differential equations of muscle movement velocity based on martial articulation body ligament tension

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Abstract

The paper analyses the impact of ligament stretch and tension on the speed of movement in martial arts from the perspective of sports physiology. It establishes the numerical relationship between the peak impact value of the ligament speed and the differential equation of the flexibility of the joints in the initial stage of tension (impact peak). It was found that the differential equation of the ligament tension of the movement is formed after the movement is stable, which cannot reflect the flexibility of the ligament and the mastery of the movement. In this paper, a tension calculation model for ligament equilibrium is established by using a kinetic method of motion. Although it is a static equation, continuous use can obtain dynamic effects. The simulation proves that the initial tension change is more realistic.

Keywords: muscle tension, exercise speed balance, forward and backward slip, martial arts exercise, ligament tension.**AMS 2010 codes:** 12H99

1 Introduction

In college physical education, martial arts have attracted more and more college students because of its unique charm and exercise value. In martial arts, it is easy to cause ligament damage and meniscus injury and aging. After severe meniscus injury or aging degeneration, a total meniscectomy is required. In order to prevent the degeneration of the articular cartilage and subchondral bone in meniscectomy patients, students try their best to maintain the normal biomechanical function of the knee joint. Plate transplantation has gradually become

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a new treatment approach. In this meniscus transplantation, in addition to the type matching of the meniscus transplantation, the reasonable fixation of the meniscus transplantation is another key issue in the transplantation operation. Related studies have confirmed that insufficient fixation of the anterior and posterior angles of the meniscus transplantation will cause knee function degeneration after meniscus transplantation [1].

When a double meniscus is used to fix the meniscus, it is difficult to fix the shape (diameter or height) of the bone mass through the gap between the tibia and the femur. The deviation of the cooperation between the bone mass and the tunnel will also affect the surgical effect. Guidance, the transplantation of the meniscus through a flexible cable, the implantation operation is easy; but when drilling a tunnel, you need to plan the 3 tunnel positions and consider the correlation between the tunnels (such as the wall thickness between adjacent tunnels). Due to the lack of meniscus sources and difficulty in matching in the allogeneic meniscus transplantation technology, the mechanism of knee function after transplantation in this field is not fully discussed. The meniscus tear injury [2] and the effect tracking and failure rate analysis of the medial meniscus transplantation [3] all show the extremely important role of meniscus in knee function. The stress and tension characteristics of the posterior cruciate ligament are also closely related to the shape of the meniscus. Therefore, in this paper, the relationship between meniscus and knee ligaments in martial arts manoeuvres is established, and the differential equation of motion speed is established for impact on performance.

2 Analysis of related content of differential equations

Differential equations (groups) are one of the most used mathematical models in scientific research and engineering applications. For example, Newton's second law reveals the law of particle motion:

$$\begin{cases} m \frac{d^2x}{dt^2} = F(t) \\ x(t_0) = x_0 \quad x'(t_0) = x'_0 \end{cases} \quad (1)$$

Kirchhoff's circuit law describes the law of circuit current or voltage change, but there are only some simple and special ordinary differential equations and ordinary differential equation systems. The so-called 'analytic solution' or 'formula solution' such as the initial value problem of a first-order linear differential equation is given as follows:

$$\begin{cases} \frac{dy}{dt} = ay + f(t) \\ y(0) = y_0 \end{cases} \quad (2)$$

Find the solution as follows:

$$y(t) = e^{at}y_0 + \int_0^t e^{a(t-\tau)}f(\tau)d\tau \quad (3)$$

However, most of the ordinary differential equations and ordinary differential equation systems encountered in practice cannot obtain 'analytic solutions'. Therefore, based on the following facts, the following statements are made:

1. Most ordinary differential equations and ordinary differential equation systems cannot obtain (finite form) analytical solutions;
2. In practical applications, it is often only necessary to know the function value of the solution of the ordinary differential equation (group) at some points (which people are concerned about) (which can be an approximate value that meets certain accuracy requirements);

If you only need the function value of the solution of the ordinary differential equation (system) at some points, there is no need to find the solution of the formula and then calculate the function value. In fact, we can use the ordinary differential introduced below. The numerical solution of the initial value problem of the equation (system) can achieve this goal. The initial value problem of a general first-order ordinary differential equation (group) refers to the problem of determining the first-order ordinary differential equation (group) as

follows:

$$\begin{aligned} \frac{dy}{dt} &= F(t, y) \quad t_0 \leq t \leq t_f \\ y(t_0) &= y_0 \end{aligned} \quad (4)$$

Among them,

$$y(t) = \begin{pmatrix} y_1(t) \\ y_2(t) \\ \vdots \\ y_n(t) \end{pmatrix} \quad F(t, y) = \begin{pmatrix} f_1(t, y) \\ f_2(t, y) \\ \vdots \\ f_n(t, y) \end{pmatrix} \quad (5)$$

The initial value problem of ordinary differential equations (systems) is usually a description of the evolution law of a dynamic process (dynamic system). Solving the initial value problems of ordinary differential equations (systems) is to understand and master the evolution law of dynamic processes.

2.1 Introduction to numerical solution of Cauchy problems of ordinary differential equations

Assume that the (approximate) value of the solution $y = y(t, t_0, y_0)$ of the initial value problem (6) is required at point (time) $t_k, k = 1, 2, \dots, n$. If the value $y(t_k)$ at time t_k or its approximate value y_k (such as the value $y(t_0)$ at time t_0) has been obtained, then both ends of Eq. (6) are integrated over the interval:

$$\int_{t_k}^{t_{k+1}} \frac{dy}{dt} dt = y(t_{k+1}) - y(t_k) = \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \quad (6)$$

Available

$$y(t_{k+1}) = y(t_k) + \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \quad (7)$$

Or

$$y(t_{k+1}) \approx y_{k+1} = y_k + \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \quad (8)$$

However, in order to use Eqs. (7) or (8) to obtain the exact value of $y(t_{k+1})$ (approximate value y_{k+1}), the integral at the right end must be calculated. This is the key and difficult point of the problem. As mentioned earlier, the exact formula is generally not available. Therefore, it is necessary to use the numerical integration method to find its approximate solution. It can be said that different formula-valued integration methods will give different numerical solutions to the Cauchy problem.

2.2 The simplest numerical solution-Euler's method

Suppose an approximate value of the solution $y = y(t)$ of the initial value problem (6) is required at the point (time) $t_k = t_0 + kh, h = \frac{t_f - t_0}{n}, k = 1, 2, \dots, n$. First integrate both ends of Eq. (6) to get the following equation:

$$\int_{t_k}^{t_{k+1}} \frac{dy}{dt} dt = y(t_{k+1}) - y(t_k) = \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \quad (9)$$

For the right side of Eq. (9), if the integrand is replaced by the function value $f(t_k, y(t_k))$ at the integral lower limit $t = t_k$ (from a geometric point of view, a rectangular area is used instead of a curved side trapezoidal area), then the following equation is obtained:

$$y(t_{k+1}) - y(t_k) = \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \approx hf[t_k, y(t_k)] \quad (10)$$

Then, the recursive algorithm given by the following formula-Euler method is obtained:

$$\begin{aligned} y_{k+1} &= y_k + hf(t_k, y_k) \quad k = 1, 2, \dots, n \\ y(t_0) &= y_0 \end{aligned} \quad (11)$$

Example 1: Use Euler's method to solve the following initial value problem and take $h = 0.3$,

$$\begin{aligned} \frac{dy}{dt} &= y - 2y^3 \sin t \quad 0 \leq t \leq 3 \\ y(0) &= 1 \end{aligned} \quad (12)$$

The results are as follows.

Fig. 1 Numerical solution based on the Euler method.

If $h = 0.1$ is taken, the result is shown in the following figure:

Fig. 2 Numerical solution based on the improved Euler method.

2.3 Improved Euler method

For the right side of Eq (11), if the integrand is replaced by the arithmetic mean of the function values at the integration limits $t = t_k$ and $t = t_{k+1}$ (geometrically, trapezoidal area is replaced by trapezoidal area), then the following equation is obtained:

$$y(t_{k+1}) - y(t_k) = \int_{t_k}^{t_{k+1}} f(t, y(t)) dt \approx \frac{h}{2} [f(t_k, y(t_k)) + f(t_{k+1}, y(t_{k+1}))] \quad (13)$$

Then, the recursive algorithm is given as follows:

$$y_{k+1} = y_k + \frac{h}{2} [f(t_k, y_k) + f(t_{k+1}, y_{k+1})] \quad k = 1, 2, \dots, n$$

$$y(t_0) = y_0 \quad (14)$$

Generally, the algorithm (13) is more accurate than the Euler method (12), but the (nonlinear) equations (groups) must be solved when y_{k+1} is calculated according to the algorithm (13). This is the aspect of the algorithm (13) that is inferior to the Euler method. It is possible to keep the advantage of the high accuracy of the algorithm (13); use the Euler method to calculate the simple advantages as much as possible; people have adopted the following compromise solution called the improved Euler method.

Prediction:

$$y_{k+1}^0 = y_k + hf(t_k, y_k) \quad (15)$$

Amend

$$y_{k+1} = y_k + \frac{h}{2} [f(t_k, y_k) + f(t_{k+1}, y_{k+1}^0)] \quad k = 1, 2, \dots, n$$

$$y(t_0) = y_0 \quad (16)$$

Example 2: Comparison of the Euler method with the improved Euler method. The following figure is the comparison result when: $h = 0.3$

Fig. 3 Comparison of the Euler method and modified Euler method.

3 Introduction to sports physiology related to wushu

Flexibility is one of the special qualities of martial arts; it is the physiological basis for correctly grasping the martial arts sports mode; it is an indispensable important factor to achieve the purpose of martial arts exercise, and it is also the basic link to reduce and avoid sports injuries. Therefore, in college martial arts teaching, we must attach great importance to improving students' physical flexibility.

3.1 From the way of martial arts

Martial arts are different from acrobatic, gymnastics, dance and other sports performances and have unique requirements for physical flexibility. In martial arts, the various leg methods, waist turning, sacral arms and equipment use have a large range of motion. Good martial arts practitioners must not only show the beauty of speed, strength and charm that are unique to martial arts but also show offensive and defensive consciousness and tactics unique to martial arts. Therefore, in the practice of movements and body styles, we must achieve

wide opening and closing, throughput expansion and contraction, ups and downs, flashing and moving and folding back and forth, which fully reflect the yin, yin, yang, huh, huh, huh and huh. The dialectical unification of the next and the last. This puts very high demands on the flexibility of shoulders, waists, hips, knees and ankles, which is also determined by the martial arts nature of martial arts, and is different from the inherent characteristics of other aesthetic processes. Therefore, in teaching students to correctly grasp the methods and methods of martial arts to achieve standard movements, physical fitness and energy coordination and reflect agility, all of these must be based on good flexibility. Therefore, boxing proverbs say: 'practice boxing first and tendons,' 'fist boxing without slipping your legs, you will be daredevil' and 'do not practice your waist, you will never be good at it.'

3.2 From the purpose of martial arts exercise

The motivation of college students for martial arts generally has two aspects: one is to strengthen their body and fitness and the other is to improve their combat skills through martial arts practice. Physiological research has already proposed that human development generally reaches the peak of various physiological indicators from the age of 25 to 30 years. After that, various indicators will gradually decline, including the decline of the physiological elasticity of muscles, joints and ligaments and limited extension. The external reaction is not sensitive, and ageing occurs over time. For college students around the age of 20 years, although there is still some distance from the physiological peak but starting from strengthening martial arts training, focussing on the flexibility of the exercise system will help improve the stretchability of muscles, joints and ligaments, increase flexibility and reduce blockage sex to achieve the purpose of physical fitness. For students who want to improve their combat skills, it is more important to strengthen the flexibility of the whole body and improve the flexibility.

Flexibility refers to the softness and toughness of the bone in nature. Flexibility exercises are the ability of the human body to perform large-scale movements. Martial arts sports must show both softness (motion range) and strength (speed and strength). Softness serves strength, and strength is set against softness. Flexibility exercises not only reflect the softness of the limbs and joints of the martial arts practitioners during the exercise but also reflect the strength of each fist, knee, elbow, shoulder and hip during exercise. Therefore, comprehensively improving the flexibility of each joint ligament cannot increase the initial length before muscle contraction, increase the range of motion, improve synergy and quality of movement and extend the life of the exercise. Moreover, it has a positive effect on improving the speed of movement and increasing muscle strength. This is because with the increase in flexibility, the viscosity of muscle joints and ligaments decreases, reducing the resistance of the conduction of power in the body, coordinating the strength, reaching the dry season and shortening the work time, which is conducive to increasing the need for technical fighting professional power and instant explosive power.

3.3 From the need to reduce and avoid sports injuries

At present, college students are generally enthusiastic in training martial arts and have strong excitement. A few students have the characteristics of blind impulse, but most of these students have not received martial arts training before entering school, and their martial arts special qualities, including flexibility, are generally poor. Therefore, in self-practice outside of teaching time, different levels of ligament tears, joint sprains and other phenomena are prone to not only affect their further study of martial arts but also have a negative psychological impact, so many people regret it. Yu went to the other extreme, thinking that "I shouldn't be so reckless, I will never practice the flexibility of my legs again, punching and pushing the palm can also strengthen myself." Yes, punching and pushing the palm can also strengthen myself, but you lose your leg punch advantage. Martial arts athletes have a high injury rate and a wide range of complications. It is pointed out that in addition to the special technical characteristics and excessive local load, the cause of the injury has a greater relationship with the inflexibility of flexible qualities. Taking the waist injury as an example, the text says "Waist injury accounts for 38.8% of the surveyed people." Because martial arts routines have high requirements on the waist, requiring changes in body rotation, extension, contraction, folding, bending, bending and elevation, and the

waist must be flexible and stiff, some athletes in order to increase the range of movement and body changes in the process of exercise often exceed their training level and exceed physiological limits. Especially, in the equipment exercise, increasing the distance to increase the strength of the equipment is also easy to cause waist injury. Comprehensively, strengthening flexibility training is of great significance to master martial arts movements and techniques and improve the quality of training.

4 Building a three-dimensional calculus model of ligament tension

The three-dimensional solid model of the tibiofemoral joint is imported into the general finite element software ANSYS11.0 to establish a finite element model. The specific process includes mesh division, definition of material properties of each tissue, definition of boundary conditions and setting of loads.

4.1 Grid division and definition of material properties of each organisation

SOLID187 element and 3-mm mesh size are selected to mesh the model so that the number of nodes in the posterior cruciate ligament mesh unit of the smallest organisation is above 1000, which meets the calculation accuracy of the finite element model. In order to compare the calculation results, the model is transplanted into the model. The meshing is the same as the normal model. The hardness of the tibia, femur and fibula is much greater than that of the surrounding cartilage and meniscus. The bone can be regarded as an isotropic linear elastic material. The femoral cartilage and tibial cartilage have a viscoelastic time constant of 1500s. Therefore, during an experimental loading time of 1s, the cartilage can be regarded as an isotropic linear elastic material. According to reference [4], the elastic modulus E and Poisson's ratio ν of the bones are 17GPa and 0.3, respectively. The material properties of the cartilage are set to $E = 5\text{MPa}$ and $\nu = 0.46$. Considering that the matrix collagen fibres are arranged differently in different parts of the meniscus, the meniscus can be regarded as a linear elastic transverse isotropic material (there is an isotropic surface). Reference [5] refers to the material parameters, which are set as follows: the elastic modulus in the radial and axial directions is taken as 20 MPa, the elastic modulus in the circumferential direction is taken as 150 MPa and the Poisson ratio in an isotropic plane perpendicular to the circumference is taken as 0.2 and 0.3 out of the plane. The materials of the ligaments are relatively special and complex. The free energy function (Eq. (1)) proposed by [6] is used to fit the stress-strain curves of each ligament.

$$\begin{cases} \lambda \Psi_\lambda = 0 & \lambda = 1 \\ \lambda \Psi_\lambda = C_3 (e^{C_4(\lambda-1)} - 1) & \lambda > \lambda^* \\ \lambda \Psi_\lambda = C_5 \lambda + C_6 & \lambda < \lambda^* \end{cases} \quad (17)$$

where λ is the ratio of the length of the ligament after deformation to the standard length and Ψ_λ is the strain energy. The values of the parameters C_3 , C_4 , C_5 , C_6 , λ^* and the inverse of the bulk elastic modulus [7] involving anterior cruciate ligament (ACL), PCL, MCL and LCL are shown in Table 1.

In the double tunnel fixed model, the same material as the normal meniscus is still selected at the base of the meniscus. The material properties of the bones are set to those of the bones in the normal model. The tissue material settings in the three-tunnel fixed model are the same as those in the normal model.

Table 1 Material properties of each ligament (/MPa)

Ligament	Parameter				
	C3	C4	C5	C6	λ^*
MCL/LCL	0.57	48.0	467.1	-485.37	1.063
ACL	0.0139	116.22	535.039	-556.75	1.046
PCL	0.1196	87.178	431.063	-443.74	1.035

ACL, anterior cruciate ligament.

4.2 Definition of boundary conditions and loads

Refer to the anatomical structure of the joint and related literature to define the interaction of the tissues in the tibiofemoral joint: there is no relative movement between the bone and cartilage, and the initial connection point between the bone and ligament should be kept unchanged and set to consolidation (complete binding, no friction and no sliding) (phase effect); there is relative sliding between the articular cartilage, cartilage and meniscus, and it is set to have no friction (no friction and sliding) (phase effect). In addition, the anterior and posterior angles of the meniscus are connected to the tibial plateau with the ligament bundle of approximately 50 mm². The anterior angle of the medial and lateral menisci is connected by transrectal ligaments. Due to the lack of literature on the material properties of these two types of ligaments, reference [8], a one-dimensional linear spring was used to simulate the finite element model. The spring stiffness coefficients were 2 kN/mm and 900 N/mm, respectively. The results are shown in Table 2.

Table 2 Selection results

Ligament	Buckling angle			
	0°	25°	60°	80°
ACL	35	10	25	30
PCL	0	0	25	30
MCL	25	10	10	5
LCL	35	20	25	30

ACL, anterior cruciate ligament.

For the double tunnel fixation model, the bone mass and the bone canal were set to act as a consolidation phase to simulate the fixation between the medial meniscus anteroposterior angle and the tibial plateau. In the three-tunnel fixed model, the front and rear angles of the medial meniscus and the outer 1/3 of the rear meniscus are connected to the corresponding bone channels by wire springs. The stiffness coefficient should be less than that of the spring at the front and rear corners of the meniscus in the normal model, which is taken as 1 kN/mm. In addition, no ligament constraint connecting the medial and lateral meniscus anterior horns was added in the transplant model. For comparative analysis, the remaining constraints in the transplanted model are the same as those in the normal model [9].

Knee joints are subject to more complex forces when subjected to compression, bending and torsion or the combined effects of compression, bending and torsion. However, torsional moment is one of the main factors inducing meniscus tearing or injury. In order to simplify the problem, this paper uses the tibiofemoral joint extension, flexion of internal rotation and external rotation torque as the load for simulation analysis. During loading, the tibia and distal fibula are fixed, and two sets of loads are set according to the internal rotation/external rotation of the tibia during flexion/extension of the knee joint: internal rotation torque of 10 N/m and external rotation torque of 10 N/m both are applied to the distal surface of the femur, and the torque vector is selected along the direction of the femoral shaft. The external rotation torque applied to the femur corresponds to the flexion of the joint, while the internal rotation torque corresponds to the extension of the joint. From the simulation results under two groups of loads, the maximum equivalent tensile stress of the ligament, the tension in the ligament and the maximum equivalent deformation of the ligament were extracted. The maximum equivalent stress of the femur and tibia was used as the characteristic values. The model and the corresponding values of the medial meniscus were compared to analyse the effects of different fixation methods of the medial meniscus on the mechanical properties of ligaments and bones.

5 Simulation results

5.1 Maximum tensile stress of the ligament

From the simulation results, extract the cloud map of the maximum principal stress on each ligament at each of the four buckling angles and obtain the maximum positive value of the maximum principal stress from the cloud, which corresponds to the maximum tensile stress on the ligament, so as to obtain each ligament. The change in the maximum tensile stress is shown in Figure 4. After the medial meniscus is removed, the maximum tensile stress on the ligament rises. The two fixation methods of the medial meniscus transplantation can suppress the rising trend of stress on the ligament to a certain extent, but the effects on the 4 ligaments are different [10, 11].

Fig. 4 Maximum tensile stress on PCL surface.

For ACL, whether it is under internal or external torque, it corresponds to the extension and flexion of the joint.

During the process, the maximum tensile stress on the ligament was increased by resection of the medial meniscus, and the increase was obvious at 25° flexion angle, which exceeded 30%. The two methods of medial meniscus transplantation reduced the maximum tensile stress on the ligament. Under the action of internal rotation torque, the double tunnel fixing caused the maximum tensile stress to decrease by more than 20% at 0° and 25°; while under the external rotation torque, the double tunnel fixing caused the maximum tensile stress at 25° and 80° to decrease. The rate of change has exceeded 30%. The three-tunnel fixing only reduces the maximum tensile stress on the ACL by 45% at 25° under the effect of external rotation torque. Combining the effects of the two loads, three-tunnel fixing is more suitable for stress recovery on ACL than double-tunnel fixing.

In summary, the resection of the medial meniscus will significantly change the stress distribution on the ligament, especially the stress distribution on the MCL. The three-tunnel-fixed medial meniscus transplantation can improve the increase of the maximum tensile stress on the ligament and stress from the ligament surface from the perspective of the distribution returning to the normal state, and it is better than the double tunnel fixing.

5.2 Tension in the ligament

For the normal model, when internal rotation torque is applied to the femoral end, the internal tension of ACL and MCL is large, and the internal tension of PCL and LCL is small. When external rotation torque is applied to the femoral end, the internal tension of MCL and LCL is large, and the internal tension of ACL and PCL is small.

After resection of the medial meniscus, the tension in each ligament changed significantly, and the order of the 4 ligaments bearing load changed when the internal rotation torque was applied at a 25° flexion angle, as shown in Figure 5. Synthesising 4 flexion angles, the double-tunnel-fixed medial meniscus transplantation makes the order of the load of each ligament close to the normal joint. Compared with the medial meniscus resection, the change in tension in each ligament is also smaller, only at 25°. This changes the order in which the ligaments bear the load. For a three-tunnel-fixed medial meniscus transplantation, the flexion angles do not change the order in which the ligaments bear the load under both loads. Compared with double-tunnel fixation, the change in tension in the ligaments is smaller and closer to normal joints, as shown in Figure 5.

Fig. 5 Intensity of each ligament at 60° flexion angle.

5.3 Deformation of the ligaments

Obtain the deformation cloud map of each ligament under the influence of internal and external rotation torque from the simulation results and then extract each ligament from the cloud map from the maximum amount of deformation at 4 flexion angles. The values extracted from the medial meniscus resection, double tunnel fixation and triple tunnel fixation are compared with the corresponding values in the normal model. The average value P of the percentage of the amount at 4 flexion angles is used to measure the changes of the ligament deformation of the two fixation methods, as shown in Table 3. The calculation of P value is based on the following formula: In t

$$P = 1/4 \sum \frac{D^i - D}{D}, I = 0^\circ, 25^\circ, 60^\circ, 80^\circ \quad (18)$$

he formula, D is the maximum deformation on the ligament of the normal joint; D_i is the corresponding value obtained by medial meniscectomy, double tunnel fixation and triple tunnel fixation.

The maximum deformation of PCL and MCL was significantly changed when the medial meniscus was removed. The increase of the maximum deformation of PCL reached the maximum at 25° buckling angle, exceeding 60%. The increase of the maximum deformation of MCL also reached the maximum at 25° buckling angle, nearly 35%, and the average value at 4 buckling angles exceeded 20%. The maximum deformation of ACL and LCL that changed by resection of the medial meniscus is relatively small, and the percentage change is not more than 10%. Double tunnel fixed medial meniscus transplantation made the average rate of maximum ligament deformation less than 5%, which is closer to that of normal joints, but still increased the maximum deformation of PCL by more than 40% at 25° flexion angle. When the medial meniscus transplantation was fixed with three tunnels, the maximum deformation of ACL changed relatively, and the deformation of the remaining ligaments returned to the level of normal joints.

Table 3. Average change percentage of maximum deformation of each ligament

Meniscus transplantation fixation	ACL/(%)		PCL/(%)		MCL/(%)
	Pronation	External rotation	Pronation	External rotation	Pronation
Medial meniscus resection	-6.1	-3	26.9	25.3	20.4
Double tunnel fixing	1.5	1.1	2.4	-3.9	1.8
Three tunnels fixing	7.2	8	-0.1	-4.3	-4.2

ACL, anterior cruciate ligament.

Fig. 6 Maximum equivalent stress of the femur.

6 Conclusion

In order to analyse the ligament tension in martial arts movements, using the fractional differential equations, this paper reconstructs a finite element model of the human normal tibiofemoral joint at 4 flexion angles ($0^\circ/25^\circ/60^\circ/80^\circ$) and is based on the established two models of medial meniscus transplantation: double tunnel fixation and triple tunnel fixation. Two types of loads were applied to each group of models to compare the ligaments and bones (femur/tibia) in the transplant model, normal model and meniscectomy model. According to the evaluation of the mechanical behaviour of joint ligaments and the femur/tibia after meniscus implantation, it provides a characteristic index for the evaluation of the advantages and disadvantages of meniscus transplantation in two fixation methods.

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