BIOMECHANICS OF GAMMA-IRRADIATED VERSUS NONIRRADIATED HUMAN TENDON

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BACKGROUND

Autograft tissue is considered the gold standard for anterior cruciate ligament (ACL) reconstruction. However, autograft harvest is not without associated morbidity. Postoperative patellofemoral pain has been reported to be as high as 80%. Crepitus and quadriceps/hamstring weakness are also reported. Surgeons frequently reconstruct the failed ACL with allograft. Allograft reconstructions avoid donor-site morbidity and provide greater utility for multiple reconstructions or revision surgeries. The use of allograft tissue has been criticized, primarily because the transplanted tissue could transmit hepatitis, bacterial or fungal infection, and the human immunodeficiency virus. Tissue banks have explored many sterilization techniques. At present, 2.5 Mrad gamma irradiation is the most universally used, but this may weaken the biomechanical properties of allograft. We investigated the biomechanics of human tendon irradiated with 2.5 Mrad gamma radiation.

METHODS

24 tendons of equal length were divided into groups A and B. Group A ($n = 12$) was not irradiated and Group B ($n = 12$) was irradiated with 2.5 Mrad gamma radiation. The grafts were then tensioned on a universal testing machine. The width, thickness, and cross-sectional area were calculated. Grafts were mounted on the apparatus, tensioned with 2.0 N of force, and measured with calipers.

RESULTS

The mean linear modulus of irradiated graft was 87.66% of the control ($t = 2.53$, $p < 0.05$). The maximum stress was 84.88% ($t = 2.91$, $p < 0.05$). The strain to failure was 85.82% ($t = 3.45$, $p < 0.05$). Structural mechanical index could ensure the tendon's ability of bear and transfer external force. The mean elongation to failure of the graft was 93.46% of the control ($t = 3.45$, $p < 0.05$). The stiffness was 95.27% ($t = 4.49$, $p < 0.05$). The mean maximum force was 96.72% ($t = 2.97$, $p < 0.05$). The mean energy to maximum force was 93.60% ($t = 3.34$, $p < 0.05$).

DISCUSSION/CONCLUSION

Although high levels of gamma irradiation sterilize allograft from bacterial and viral agents, they can also compromise the graft's mechanical properties. Our data indicate that the biomechanical indices were significantly lower than nonirradiated tendon. The current study confirmed that 4.0 Mrad caused 30% and 21% reductions in stiffness and maximum force, respectively. Our study revealed 4.73% and 15.12% reductions in stiffness and maximum force, respectively. Eventually, we will need to determine the irradiation threshold below which allografts are not degraded. Our data revealed that the graft strength dropped significantly during the process of remodeling and synthesis of new extracellular matrix in cruciate ligament reconstruction. Some scholars utilized computer simulation of ACL reconstruction and found that the early knee degeneration after reconstruction was closely related to graft stiffness. It is better to select the same structural mechanics of native graft to reconstruct the ACL in order to restore knee stability and protect knee cartilage.

We revealed that the allograft stiffness was reduced after irradiation. Therefore, additional studies are required to balance safety and structural mechanical properties. Some authors showed that the failure rate of 2.5 Mrad-irradiated allograft in ACL reconstruction was significantly higher than nonirradiated graft, but the underlying mechanisms are still unknown.

The commonly used method of 2.5 Mrad gamma irradiation sterilization can not eliminate all pathogenic micro-organisms. Furthermore, we confirmed that the structural and material mechanical parameters were reduced after irradiation and may translate into clinical failure.

In summary, gamma irradiation can inactivate infectious agents but may also affect allograft biomechanics.