INTRODUCTION

Recently, several clinical reports have dealt with effects of the thermal shrinkage using radiofrequency (RF) energy to the chronically relaxed anterior cruciate ligament (ACL) [1, 2, 3]. However, there has been much controversy on the clinical utility of RF energy in the ACL. Therefore, we should increase the database on this treatment. Recently, a few studies that mimic the clinical shrinkage treatment have shown that RF energy deteriorates structural properties of the whole ACL into 60-76% of the normal properties [4, 5, 6]. The degrees of the deterioration are significant but not extremely great. Then, we should recognize that, in these studies, the cross-section of the treated ACL includes both the RF-treated lesion and the non-treated lesion, because the clinical RF treatment is applied to the ACL only from the anterior surface so that the posterior portion of the ACL substance often remains intact. Thus, no studies have clarified the effect of RF energy on the material properties of collagen fascicles in the ACL, eliminating the influence caused by existence of intact fascicles. The purpose of this study is to clarify the acute effect of RF energy on the material properties of collagen fascicles in the ACL.

MATERIALS AND METHODS

**Study 1:** 50 fresh femur-ACL-tibia complexes harvested from fully matured LWD pigs were used in this study. In each specimen, the posterolateral (PL) bundle of the ACL was resected, the anterior and posterior portions of the anteromedial (AM) bundle were resected along the longitudinal axis so that the central one-third of AM bundle remained intact. The femur-bundle-tibia complex specimens were randomly divided into 5 groups of 10 specimens each. In each group, RF energy set at non-ablative levels was applied to the bundle with a bipolar RF generator (Arthrocare, Sunnyvale, CA). In Groups I and II, the shrinkage treatment was applied for 30 seconds, using 28-Watt (W) and 45-W power, respectively. In Groups III and IV, the shrinkage treatment was applied for 60 seconds, using 28-W and 45-W power, respectively. In Group V, no treatment was applied in order to obtain the normal control data. During the RF treatment, each specimen was hung from a testing jig in physiological saline solution of 37 degrees Celsius, applying a constant load of 1N. In each group, 8 out of the 10 specimens were used for biomechanical evaluation, and the remaining 2 were used for histological observation with light and polarized light microscopy. The cross-sectional area (CSA) and the length changes of the ACL were measured with a non-contact optical method using a video dimension analyzer before and after the treatment. The material properties of collagen fascicles were determined in tensile testing at a cross-head speed of 50 mm/min. Statistical analyses were performed using the ANOVA with the Fisher’s PLSD test for post-hoc multiple comparisons.

**Study 2:** Another 50 specimens of the fresh femur-ACL-tibia complexes were used. In each specimen, only the PL bundle of the ACL was resected. The femur-bundle-tibia complex specimens were randomly divided into 5 groups of 10 specimens each. In Group A, B, C, D, and E, the same shrinkage treatment as performed in Group I, II, III, IV, and V of Study 1, respectively, was applied to the AM bundle with a clinical technique by an orthopaedic surgeon. The same tensile testing, histological evaluation, and statistical analyses as performed in Study 1 were made.

RESULTS

**Study 1:** The length of the ACL fibers was significantly reduced by 13%, 17%, 18% and 24% of the original length in Groups I, II, III, and IV, respectively (p<0.0001). The ANOVA demonstrated a significant difference in the tensile strength (Fig 1) among the groups (p<0.0001). Groups I, II, III, and IV were significantly lower than Group V, respectively (p<0.0001). Groups IV were significantly lower than Group I and II, respectively (p<0.0205). Concerning the tensile modulus (Fig 2), the ANOVA showed a significant difference among the groups (p<0.0001). Group IV was significantly lower than Groups I, II, and III (p<0.0298). Histological examination showed diffuse collagenous denaturation and pyknotic nuclear changes in fibroblasts at the whole mid-substance of the bundle (Fig 5-a, b).

**Study 2:** The length of the AM bundle was significantly reduced by 7%, 14%, 20% and 27% of the original length in Groups A, B, C, and D, respectively (p<0.0001). In tensile testing, all specimens were avulsed from the insertion in Group E, while 1, 3, 4, and 8 out of the 8 specimens failed at the treated portion within the bundle in Groups A, B, C, and D, respectively. Concerning the maximum load (Fig 3), the ANOVA showed a significant difference among the groups (p=0.0176). Group D was significantly lower than Group E (p=0.0014). Regarding the stiffness (Fig 4), the ANOVA demonstrated a significant difference among the groups (p=0.0012). Groups A, B, C, and D were significantly lower than Group E, respectively (p<0.0176). Histological examination showed that the cross-section includes both the intact lesion and the lesion with the collagenous denaturation and pyknotic nuclear changes (Fig 5-c).

DISCUSSION

This study demonstrated that the application of RF energy dramatically reduces the material properties of collagen fascicles of the ACL into only 20-32% of the original value, dependent of its magnitude. In the treatment condition in Study 2, however, the reduction of the structural properties of the whole AM bundle of the ACL by the RF treatment was 57-76% of the original value. These results showed that the previously reported data on the deterioration of the structural properties of the whole ACL (Fig 4) do not precisely indicate the degree of the deterioration in the material properties of the RF-treated lesion in the ACL. Although loads were evenly distributed to all fibers of the ACL in tensile testing, loads are unevenly distributed to them in daily activities [8]. Therefore, the RF-treated lesion having the extremely low material properties in the ACL is threatened with rupture in daily activities. Therefore, this study warned against too optimistic clinical application of RF energy to the ACL shrinkage.

**REFERENCES**