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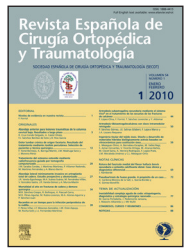

RESEARCH

Effect of radiofrequency on partial tears of the anterior cruciate ligament. *Ex vivo* experimental study in pigs

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KEYWORDS
ACL;
Partial tears;
Radiofrequency;
Ultimate failure

Abstract
Introduction: There is no consensus on the optimal treatment of partial tears in the anterior cruciate ligaments (ACL). Radiofrequency (RF) has been used to treat ACL partial tears. This treatment can be detrimental to ACL strength.
Objective: To evaluate the ultimate failure at maximum load (UFML) of porcine ACL with partial tears.
Methods: Two groups were evaluated, *N* = 40, A control and B treated with RF. Samples were placed in a PASCO® universal traction machine and axial continuous tension was applied until failure; documenting necessary strength in Newtons (N) to produce UFML.
Results: UFML for A: 1951,9 N (1144-2688) and B: 1457,1 N (1070-2025) (*P*≤.001).
Conclusion: RF use for single bundle ACL partial tears treatment compromises the UFML when compared to single bundle ACL parcial tears without RF.

PALABRAS CLAVE
LCA;
Roturas parciales;
Radiofrecuencia;
Punto de fallo

Efecto de la radiofrecuencia en roturas parciales del ligamento cruzado anterior: estudio experimental *ex vivo* en cerdos

Resumen
Introducción: En roturas parciales del ligamento cruzado anterior (LCA) no existe consenso en relación a la mejor opción de tratamiento. El uso de radiofrecuencia (RF) es una alternativa empleada actualmente. Este tratamiento puede alterar negativamente la resistencia del LCA.

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Objetivo: Evaluar punto de fallo a carga máxima (PFCM) de muestras de LCA porcinos con lesiones parciales tratados con RF en haz indemne.
Métodos: Se estudian dos grupos (N = 40); A control y B tratada con RF. Fijamos muestras en equipo de tracción universal PASCO® y aplicamos tracción axial continua hasta fallo, registrando fuerza en Newtons (N) necesaria para PFCM.
Resultados: PFCM fue A: 1951,9 N (1144-2688) y B: 1457,1 N (1070-2025) ($p \leq 0,001$).
Conclusión: El uso de RF de manera puntual en el haz indemne de secciones del fascículo PL del LCA porcino disminuye el PFCM en forma significativa respecto de las secciones del fascículo PL del LCA porcino sin tratamiento.

Introduction

Anterior cruciate ligament (ACL) tear is a very common diagnosis in clinical practice.[1,2]

Anatomically, the ACL has 2 bundles: the anteromedial (AM) and the posterolateral (PL). Both contribute to stabilizing the knee in the antero-posterior plane, and it has been postulated that they also play a secondary role in rotational stabilisation.[3]

There are 2 types of ACL tears: complete tears and partial tears, where only 1 ACL bundle is compromised. This type of tear represents 10% to 28% of all ACL tears.[4,5] The natural history of this lesion, with a progression toward complete tear in a great number of cases, has been documented in the literature.[4-6]

The use of radiofrequency (RF) to shrink partial lesions has had a place among the therapeutic alternatives for treating these lesions.[7-9] The physics principle behind the use of RF is that raising the temperature in the tissues, not above 65°-75°Celsius, shortens them, thereby improving joint stability.[4,5,7]

As described in therapeutic case series in the literature, results of this treatment are variable in terms of actual changes in the ligament, in both the resistance and the strength required to produce ultimate failure at maximum load (UFML).

The objective of this study was to evaluate the UFML in the ACL of pigs with systematically inflicted partial tears, separating them into 2 groups–with and without RF application–for the subsequent study and documentation in Newtons of the ultimate failure at maximum load (UFML).

Our hypothesis was that the UFML of an RF-treated partial ACL tear may be reduced in comparison with the UFML of a non-RF-treated partial ACL tear.

Materials and methods

Specimens

We worked with 40 knee specimens from pigs similar in age and sex characteristics. All specimens were obtained from fresh pigs, with 12 hours elapsing from the time the specimen was taken until it was utilised and subsequently measured (fig. 1).

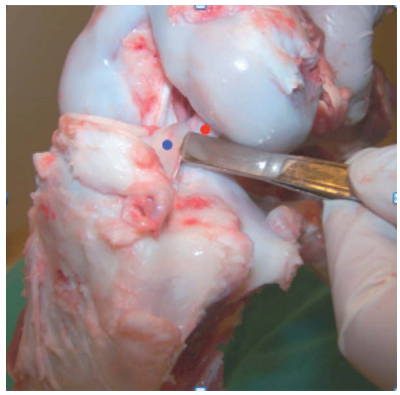

Figure 1 This shows the macroscopic features of the porcine knee specimens used. The blue dot shows the AM bundle of the ACL. The red dot shows the PL bundle of the AC.

The width of each ACL was documented, and a lesion equal to 50% of the area was made in the same anatomical region (middle third of the PL bundle) using a cold scalpel (fig. 2, A and B).

The specimens were randomly separated into 2 groups (N=20). Group A was used as a control. In group B, the undamaged bundle of the partial lesion was treated with Orthopedic Procedure Electrosurgical System monopolar RF (OPES, Arthrex®, Naples, Florida, USA), simulating arthroscopic conditions, to achieve ligament shrinkage. Medium coagulation was applied at a power of 1.373 μm (67°C and 40 W) for 3 seconds of contact (fig. 3).

Implementation

All specimens were attached to a machine consisting of a system of pulleys with a universal force transducer incorporated into it to measure and record the UFML. The proximal and distal ends of the knee were attached to a tube on the traction machine using cortical screws.

Once the specimen was attached at both ends, a steadily increasing axial force was applied until the UFML was reached. A PASCO® (Roseville, California, USA) electric transducer was used to record and document the curve of the tension applied until the UFML occurred, where a sharp inflection was noted in the graphed curve. The data was recorded by software especially designed for this transducer.

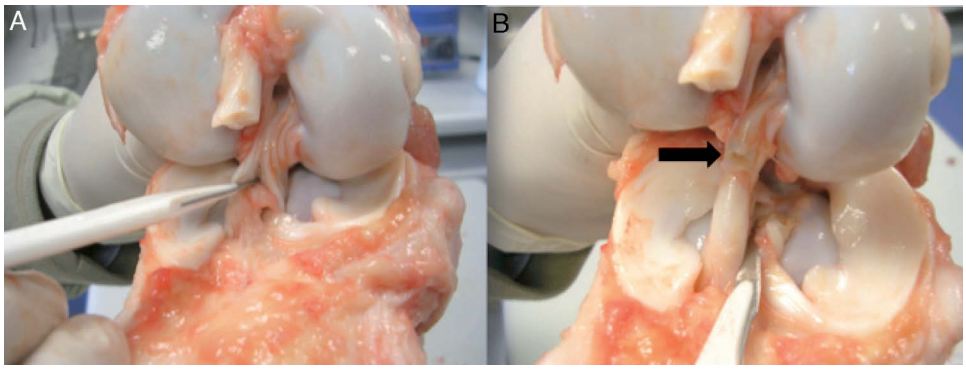

Figure 2 Shows 1 of the specimens as the partial ACL lesion is created with cold scalpel. The same lesion was inflicted on all specimens in both groups. B) The black arrow indicates the sectioned PL bundle resulting in the partial ACL lesion.

Figure 3 This shows RF being applied to the partial ACL tear, simulating arthroscopic conditions.

Statistical analysis

ANOVA tests were used to analyse the data obtained and confirm statistical differences in continuous variables. Statistical difference was established for a *P* value of <.005, for a 95% confidence interval and a statistical power of 90%. The SPSS program, version 15.0 for Windows, was used to do the analysis.

Table 1 Control group and group treated with radiofrequency

	Width (mm)	UFML (N)
GA (control)	9.9 (7-12)	1951.9 (1144-2688)
GB (RF)	9.92 (8-12)	1457.1 (1070-2025)
P	.96	.001

We documented no significant change between the 2 groups of specimens prior to treating group B with RF. In addition, following the use of RF and continuous traction up to the UFML, we documented that the RF-treated group had a statistically significant lower UFML.
GA: group A. GB: group B. mm: millimetres. N: Newtons. UFML: ultimate failure at maximum load.

Results

The results obtained in this study are shown in the table 1. Group A had a mean ACL diameter of 9.9±1.2 mm, while for group B it was 9.92±1.1 mm (*P*>.96); this indicates that all the specimens used had similar characteristics when subjected to the continuous load.

The mean UFML for group A was 1951.9±48 N (1144-2688), while for group B it was 1457.1±30 N (1070-2025), this being a significantly significant difference between the 2 groups (*P*<.001).

On post-failure macroscopic analysis of the specimens, we noted a complete ACL tear in both group A and group B. All failures occurred in the injured band in the RF-treated area; no tears were noted at other levels.

Discussion

In this study, the UFML was analysed in *in vitro* porcine specimens with partial ACL lesions repaired using RF to shrink the undamaged bundle and compared with another group having the same characteristics but not treated with RF. All specimens were subjected to continuous loads until the UFML was reached. The purpose of our study was to test the biomechanical resistance level and the differences between the porcine specimen group with RF-treated partial ACL lesions and the control group with non-RF-treated partial lesions.

Macroscopically, the results showed that the failure was similar in both groups. No differences between the specimens were found in terms of the shape, direction, or length of the failure at the resistance level. The RF-treated group had a UFML significantly lower than the control group (table 1).

With regard to the limitations of our study, it is worth pointing out that the UFML was analysed continuously until failure occurred. We do not know how these specimens would behave if subjected to cyclical loads, where it might be possible to find differences in terms of force, as in macroscopic behaviour. Due to technical limitations during performance of the experiments, we also did not succeed in determining changes in ligament length following RF treatment.

The appropriate management of partial ACL lesions is currently a matter of controversy because no standardised management is described in the literature, nor are clearly established protocols presented. A wide range of treatment alternatives for these lesions is reflected, among which the use of monopolar RF in combination with arthroscopic repair is prominent, the ultimate objective being to shrink the deficient ligament, thereby restoring the stability lost due to the partial lesion.[7-9]

Studies on the use of RF in managing partial ACL tears are limited to clinical series, and arthrometric testing to measure stability is what is most commonly reported in the literature.[6-9]

The evidence levels found in the literature on the use of RF in management are not consistent enough to recommend or establish it as a therapeutic tool in partial lesions.

Derek et al[9] analysed a clinical series of 64 patients with ACL instability due to partial lesions who had not had previous ligament reconstruction. These patients received treatment with monopolar RF set at 40 W and 65°C with the objective of achieving a 20% contraction of the ligament. The results at follow-up 2 years after the intervention did not commend the use of RF: 49.2% of patients had a satisfactory result, but 50.8% of patients presented with joint failure, as documented on a KT1000 arthrometric assessment. This is an evidence level IV study, and they concluded that RF treatment is not a recommended therapeutic alternative.

In terms of experimental studies designed to analyse RF treatment of this pathology, there is a wide variety of biomechanical models.[10-15] Those most used in the literature are the *ex vivo* human models and the *in vitro* sheep and pig joint models, the latter being the most similar to human anatomy and, therefore, widely used.[10]

López and Markel et al[11] evaluated the effects of RF on normal ACLs in a canine model, where 18 females without pre-existing joint injury underwent treatment of the ACL with monopolar RF at an intensity of 25 W and 70°C. The subjects' gait was evaluated using force plates prior to the surgery and at 4, 8, 12, 16, 26, and 36 weeks after the surgery. The results obtained documented a tear in all the ligaments treated an average of 55 days after the surgery.

On the other hand, a study by Lamar et al[15] evaluated 12 patients with arthroscopy-confirmed partial ACL tear. They were treated with thermal modification (Oratec Interventions®, Menlo Park, CA, USA) and then evaluated at 6 weeks and 3, 6, 12, and 24 months after surgery. Their results documented 10 patients, with an average of 23 months of evaluation, with Lachman sign and pivot shift negative, and 2 patients with complications who were referred for ACL reconstruction. The conclusion was that thermal modification may be a treatment alternative in a subgroup of well-selected patients.

The results reported showed weakness of the tissues in RF-treated specimens, compared to the control group, when subjected to a constant load to the point of UFML or tissue rupture.

Conclusion

Application of RF targeting the undamaged bundle of PL fasciculus sections of porcine ACL reduces the UFML significantly in comparison with untreated PL fasciculus sections of porcine ACL.

Evidence level

Evidence level II.

Protection of human and animal subjects

The authors will declare that the procedures followed were in accordance with the regulations of the responsible Clinical Research Ethics Committee and in accordance with those of the World Medical Association and the Helsinki Declaration.

Confidentiality of data

The authors declare that no patient data appears in this article.

Right to privacy and informed consent

The authors declare that no patient data appears in this article.

Conflict of interest

The authors have no conflict of interest to declare.

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