DOI: http://dx.doi.org/10.1590/1413-785220223001e246613

HOW USEFUL IS ELASTOGRAPHY IN THE FOLLOW-UP OF ACHILLES TENDON REPAIR?

QUÃO ÚTIL É A ELASTOGRAFIA NO ACOMPANHAMENTO DO REPARO DO TENDÃO DO CALCÂNEO?

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ABSTRACT

Introduction: In addition to conservative modalities in the treatment of Achilles tendon injuries, open, percutaneous and minimally invasive semi-open techniques, as well as biological open surgical repair methods are used as surgical options. Compression elastography is one of the methods used for the follow-up of treatment in Achilles tendon injuries. Methods: 23 patients were included in our study between July 2013 and June 2014, as long as they had at least 4 years of follow-up. In the final control, the intact side and the operated side were both examined and compared. The variables were the American Orthopedic Foot and Ankle Score (AOFAS) which is measured as a functional score considering plantar flexion and dorsiflexion; calf circumference; Achilles tendon anteroposterior (AP) diameter; and elastographic examination. Results: The strain ratio value and AP diameter of the patients was significantly higher on the operated side than on the non-operated side ($p < 0.001$). There was no significant difference between the plantar flexion and dorsiflexion degrees on the operated side of the patients ($p > 0.05$). No correlation was observed between strain ratio and AOFAS (p: 0,995). Conclusion: Elastography is not a useful technique to evaluate functional results on long-term tendon healing. ***Level of Evidence III; Retrospective comparative study.***

Keywords: Achilles tendon. Tendon Injuries. Elasticity Imaging Techniques.

RESUMO

Introdução: Além de métodos mais conservadores de terapia, utilizam-se, como opções cirúrgicas para o tratamento das lesões do tendão do calcâneo, técnicas abertas, percutâneas e semiabertas minimamente invasivas, bem como métodos cirúrgicos de reparo aberto. A elastografia por compressão é um dos métodos utilizados para o acompanhamento do tratamento das lesões do tendão do calcâneo. Métodos: Entre julho de 2013 e junho de 2014, 23 pacientes com pelo menos 4 anos de seguimento foram incluídos em nosso estudo. No controle final, o lado intacto e o lado operado foram examinados e comparados. As variáveis foram o American Orthopaedic Foot and Ankle Score, que foi medido como pontuação funcional por meio da flexão plantar e dorsiflexão; a circunferência da panturrilha; o diâmetro anteroposterior (AP) do tendão do calcâneo; e exame elastográfico. Resultados: O índice de tensão e o diâmetro AP dos pacientes foram significativamente maiores no lado operado do paciente que no lado não operado. Não houve diferença significativa entre os graus de flexão plantar e dorsiflexão dos pacientes no lado operado ($p > 0,05$). Não foi observada correlação entre strain ratio e AOFAS(p: 0,995). Conclusão: Acreditamos que a elastografia não seja uma técnica útil para avaliar os resultados funcionais na cicatrização do tendão em longo prazo. ***Nível de evidência III; Estudo comparativo retrospectivo.***

Descritores: *Tendão do Calcâneo. Traumatismos dos Tendões. Técnicas de imagem por elasticidade.*

Citation: Çetin MÜ, Sökmen BK, Fidan F, Mutlu H, Sarı A, Dinçel YM, Kazdal C. How useful is elastography in the follow-up of achilles tendon repair? Acta Ortop Bras. [online]. 2022;30(1)Esp.: Page 1 of 4. Available from URL: http://www.scielo.br/aob.

INTRODUCTION

Achilles tendon is one of the most frequently injured tendons in the human body.[1] The tendon is mainly formed by parallel structured type 1 collagen. The amount of type 3 collagen fibers increases during the healing period and the tendon becomes a heterogeneous structure.[2] As a result of this fibrosis, the tendon becomes stiffer and has reduced elasticity.[3] In addition to conservative modalities in the treatment of Achilles tendon injuries; open, percutaneous, minimally invasive semi-open techniques and biological open surgical repair method defined by Arslan et al. are available as surgical options.[4] Ultrasound-dependent methods used in the follow-up of the treatment are preferred because they are easily accessible,

All authors declare no potential conflict of interest related to this article.

The study was conducted at Gaziosmanpaşa Training and Research Hospital, Istanbul, Turkey.
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Article received on 12/15/2020, approved in 05/12/2021.

quick and low cost methods.[5] There are two main techniques in the elastographic method, which are compression elastography and shear-wave elastography.[6] Compression elastography (Figure 1) is a qualitative or semiquantitative method based on the application of compression waves to the tissue.[7] The practitioner performs rhythmic and regular compressions to obtain an axial tension in the relevant area. When a certain amount of stress is applied, flexible tissues undergo more deformation, resulting in more tension than hard tissues.

The aim of the study is to evaluate the long-term results of Achilles tendon rupture cases operated with biological open surgical repair in terms of functional and elastographic aspects and to examine the correlation between them.

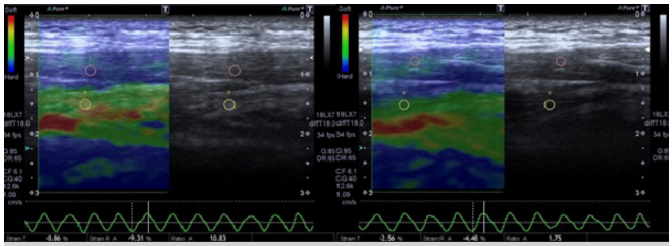

Figure 1. Comparative elastographic examination of the patients' intact and operated sides.

MATERIAL AND METHODS

This study was conducted in accordance with the 'Declaration of Helsinki and approved by the ethics committee of authors' previous affiliated institution. Approval number: 16.9.15.30

Patients between 18-50 years old who underwent biological open surgicalrepair for traumatic Achilles tendon rupture between July 2013 and June 2014 with at least 4 years offollow-up were included in our study. Patients with previous ankle fracture or ankle arthrosis, diabetes mellitus and rheumatoid arthritis, as well as any Achilles tendinopathy, collagen tissue disease or infection in the postoperative period and those who did not come to the final control were excluded. Finally, 23 patients between 28-46 years old were included in the study.

The same surgical method was applied to all patients by the same surgeon. Short leg circular cast in 25º-30º plantar flexion was applied to all the patients postoperatively and was kept in place until the sutures were removed. The daily wound care was performed through the plaster window opened from the incision line.

The plaster was removed at the second week and the same position was maintained with range of motion (ROM)walker without weightbearing. Starting from the third week, partial weightbearing was initiated. In full active plantar flexion, dorsiflexion was increased by 10º degrees weekly and normal ankle ROM was achieved after eight weeks. After the eight week, full weightbearing and active Achilles stretching exercises were started.

In the last control, while the patients were lying in the prone position with their feet hanging over the edge of the examination (Table 1), ROM of both ankles were measured with goniometry. In the standing weightbearing position, the calf circumference was measured on both sides from the widest part of the calf by placing the tape measure parallel to the ankle joint. Patients were evaluated functionally according to the AOFAS.

Imaging

The operated patients underwent ultrasonographic examination with a real-time sonoelastographic scanner (Aplio 500; Toshiba, Tokyo, Japan) at a frequency rangeof 7–18 MHz.

The Achilles tendon was examined ultrasonographically while the patient was lying in the prone position with the foot hanging over the edge of the examination (Table 1) in a fixed neutral dorsiflexion position. The tendons were evaluated axially and longitudinally by a radiologist.[8] Apart from this, measurements were made with the help of a probe holder to prevent differences in the probe's grip. In this procedure, thecalculation of tissue elasticity distribution was performed in real-time and the examination results were represented on acolor map superimposed on the B-mode image. The colorpresented the relative stiffness of the tissues within the region of interest and ranged from blue (stiff) to red (soft) inthe spectrum. Green and yellow indicated medium stiffness.

The Achilles tendon was compressed with the same pressure. Real-time sonoelastographic scans were repeated by compression and relaxation of the scan area for at least four cycles so that findings could be verified as reproducible. The Achilles tendons with elastographic image evaluation were divided into the following thirds: proximal (musculotendinous junction), middle (2–6 cm above insertion at the calcaneus), and distal (insertion at the calcaneus).[9] Central part of the Achilles tendon in the 2-6 cm proximal of calcaneal insertion point were selected for review and evaluated in the longitudinal plane. Localized Kager fat plan posterior to the tendon was selected for strain ratio. The operative tendon and intact tendon of each patient were measured.

Table 1. Comparison of measurements between the operated side and the intact side.

	Average	Standart Deviation	Median	Percentile 25	Percentile 75	P
AP Diameter (O)	11,08	11,07	6,80	5,50	14,10	<0,001†
AP Diameter (NO)	3,97	0,98	3,50	3,20	4,60	
StrainRatio(O)	8,83	5,20	7,88	5,80	10,19	<0,001†
StrainRatio(NO)	1,81	1,06	1,51	1,03	2,52	
PF(O)	35,02	5,22	34,75	30,00	39,00	0,534*
PF(NO)	35,04	5,31	35,00	30,00	40,00	
DF(O)	26,96	3,96	27,00	24,00	29,00	0,521*
DF(NO)	26,26	4,67	7,00	24,00	28,00	
Calf Circumference (O)	36,98	2,97	36,50	35,00	40,00	0,039*
Calf Circumference (NO)	37,59	2,89	38,00	35,00	40,00	

O: Operated Side, NO: Nonoperated Side†Wilcoxon Test *Paired Sample T test.

RESULTS

The average age of the patients was 34.35 ± 6.47 years and the mean follow-up period was 61.74 ± 5.72 months. The operation side is on the right side in 13 patients (56.5%) (Table 2).

The measurements between operated side of the patients and the measurements on the intact side were evaluated as dependent groups. The AP diameter value (median: 6.80) of the patients on the operated side was significantly higher than the non-operated side (median: 3.50) ($p < 0.001$) (Figure 2). The strain ratio value (median: 7.88) of the patients on the operated side was significantly higher than the non-operated side (median: 1.51) ($p < 0.001$) (Figure 3). There was no significant difference between the plantar flexion and dorsiflexion values of the patients ($p > 0.05$). However, the calf circumference (mean: 36.98 ± 2.97) on the operated side was significantly lower than the non-operated side (mean: 37.59 ± 2.89) (p: 0.039) (Figure 4). When the correlation between the age, follow-up time, AOFAS, AP diameter difference and strain ratio difference was examined; there was a moderate negative correlation between age and follow-up period (r: -0.431, p: 0.040). Most importantly, no correlation was observed between strain ratio and AOFAS in patients (r: -0,001 p: 0,995) (Table 3).

Table 2. Demographic data of patients.

		Mean s.s	Median (Min-Max)
Age (year)		34,35 ± 6,47	34,00 (25.00-46.00)
Follow-up time (month)		61,74 ± 5,72	60,00 (56.00-76.00)
Operated side*	Right	13	56,5
	Left	10	43,5

*n is used instead of mean standard deviation while % is used instead of median.

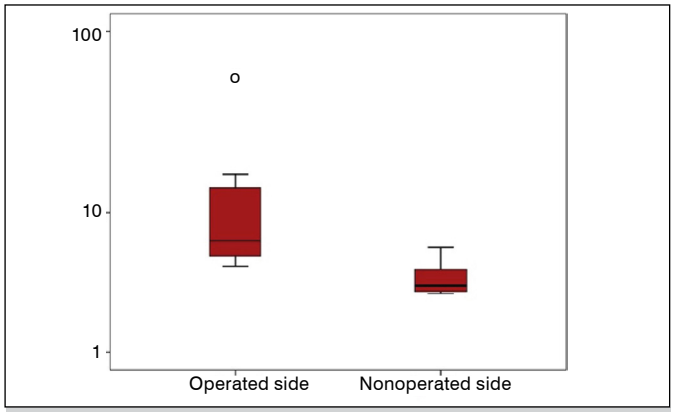

Figure 2. AP Diameters of Operated and Non-operated sides.

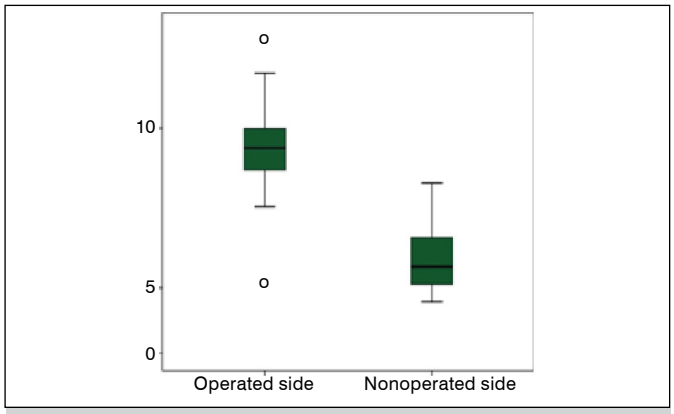

Figure 3. Strain Ratio Values of Operated and Non-operated Sides.

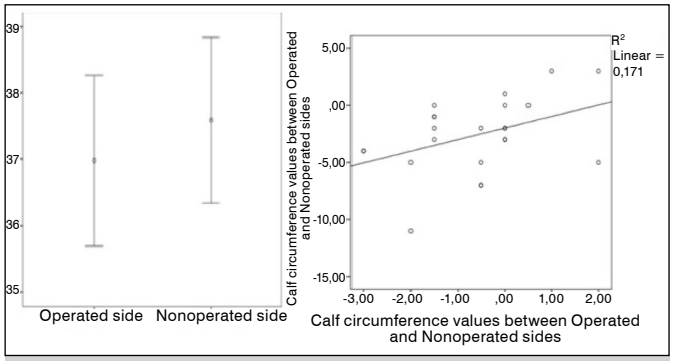

Figure 4. Calf Circumference values of Operated and Non-operated Sides.

DISCUSSION

Achilles tendon is the strongest and the most frequently injured tendon of the body. As a result of injury, the mechanical properties of the tendon and lower extremity functions may vary. Surgical repair and rehabilitation is accepted to be the standard treatment for providing the original mechanical properties of the tendon.[10]

Table 3. Correlation between patients' age, follow-up time, AOFAS, AP diameter difference, Strain ratio difference.

		Age	Follow-up time	AOFAS	AP diameter difference
Follow-up time	r	-0,431*			
	p	0,040			
AOFAS	r	-0,186	0,368		
	p	0,395	0,084		
AP diameter difference	r	0,284	-0,199	-0,178	
	p	0,189	0,362	0,417	
Strain ratio difference	r	0,150	0,199	-0,001	-0,063
	p	0,496	0,363	0,995	0,776

There are open, minimally invasive and percutaneous techniques described for the surgical treatment. In the literature; there are articles stating that the open technique is better,[11] as well as articles reporting that percutaneous technique is superior.[12] Also some authors indicated that there was no difference between the two techniques.[13]

Arslan et al. have described the biological open technique by protecting the paratenone and tendon blood flow, and reported that theyachieved near-perfect results in terms of AOFAS, range of motion and proprioception with this method.[4] In the presented series the same technique desribed by Arslan et al. was used, however no correlation between the long term functional scores and elastographic results was detected.

Although we obtained good functional results similar to the authors, a significant difference was observed in favor of the intact tendon in elastographic measurements. This might be due to the fibrosis occurring while the tendon heals and the increased amount of collagen type 3. This is also supported with the difference between the AP diameter of the repaired tendon and the intact tendon.

As we know the tendon elasticity varies with age but this will not affect the results of the presented series. Because we had a relatively young patient population and the comparison was made with the patients' own intact tendons. This was also confirmed by that the age did not have a correlation with other parameters in our study.

Compression elastography depends on the depth of the affected tissue, the probe position, and the person who performed it.[14] In our study, after measuring the neutral dorsiflexion angle while thepatient was lying in the prone position, measurements were made perpendicular to the tendon with the probe holder by the same radiologist. Thus, differences that may occur depending on the practitioner have been removed.

Karatekin et al. conducted a study including patients with at least 4 years of follow-up examining two different suture methods, and stated that regardless of the suture technique, all operated Achilles tendons showed lower elasticity compared to the intact side.[15]

Zhang et al. reported that different phases of tendon healing correlated with elastographyand this was correlated with the AOFAS score.[10] Yamamoto et al. in their experimental study on rabbit Achilles tendon, showed a marked increase in strain ratio and found that the tendon was more stiff. In addition, they found a correlation between the histological and mechanical properties of the tendon that healed with strain ratio.[16] In our study, while the functional results of the patients who were followed up for a long period were quite satisfactory, significant differences were observed between the elastographic results. It was observed that high or low difference between elastography results did not correlate with tendon's functional results. Even similar functional results were detected in the patient with 26-times strain ratio variation and the case with 2.5-times strain ratio variation.

Some authors argue that the elastic properties of the tendon correlate with the clinical situation and find this method to be useful in the follow-up of the treatment.[10,17] In this study no correlation was

detected between strain ratio and AOFAS score. For this reason we don't agree that elastography is efficient in determining the effectiveness of the treatment in patients who have finally completed recovery and who have a long-term follow-up.

Although the blood-supply of the tissue was preserved as much as possible by protecting the paratenone, we would like to point out that the repaired tendon tissue was found to be significantly weak when compared with the intact tendon in terms of elasticity. The strengths of this study are that the measurements were made by a single radiologist, all patients were operated by a single surgeon with the same suture material and the same surgical technique, the same rehabilitation method was applied and there is a long period of follow-up. The weaknesses include the absence of a control group and a relatively low number of patients.

CONCLUSION

Even after a long follow-up period of approximately 5 years, there was no correlation between the functional results of the tendon and elastography. In this context, we think that elastography is not a useful technique to evaluate functional results on long-term tendon healing.

ACKNOWLEDGEMENTS

Thanks to Prof. Dr. Ebru Yeşildağ for consultation of study planning

AUTHORS' CONTRIBUTION: Each individual author contributed individually and significantly to the development of this work. MUC: wrote and reviewed the and performed the surgeries; FF and CK: performed the surgeries, analyzed the data analysis and wrote the articles; HM: performed statistical analysis, participated at the surgeries and reviewed the article AS and YMD drafted and reviewed the article and contributed to the intellectual concept of the study; BKS: performed the radiologic measurements.

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