I.S.Mu.L.T. Achilles Tendon Ruptures Guidelines

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Original article

I.S.Mu.L.T. Achilles tendon ruptures guidelines

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Summary

This work provides easily accessible guidelines for the diagnosis, treatment and rehabilitation of Achilles tendon ruptures. These guidelines could be considered as recommendations for good clinical practice developed through a process of systematic review of the literature and expert opinion, to improve the quality of care for the individual patient and rationalize the use of resources. This work is divided into two sessions: 1) questions about hot topics; 2) answers to the questions following Evidence Based Medicine principles. Despite the frequency of the pathology and the high level of satisfaction achieved in treatment of Achilles tendon ruptures, a global consensus is lacking. In fact, there is not a uniform treatment and rehabilitation protocol used for Achilles tendon ruptures.

KEY WORDS: Achilles tendon ruptures, guidelines.

Introduction

Achilles tendon rupture is the most frequent tendon rupture in the human body[1,2]. In 85% of patients, the rupture is 2-7 cm proximal to its calcaneal insertion[3].
Acute ruptures of the Achilles tendon are most frequent in men[4], 30-40 years old, in particular in weekend atlethes who play football, basketball, tennis and squash[5]. Chronic ruptures are defined as an untreated tendon rupture persisting more than 4 weeks[3]. The incidence changes in the different countries.
Re-rupture of the Achilles tendon is failure of its treatment[6], conservative (12%) or surgical (4%)[7].
The etiology of the Achilles tendon rupture is multifactorial, including intrinsic and extrinsic factors, but the specific role and weight of each of these factors remains unclear (Tab. I).

Methodology

These guidelines are recommendations developed through a process of systematic review of the literature and expert opinion. The recommendations are based on the scientific evidence and clinical experience and can be used to improve the quality of care for individual patients.
The Authors were divided into four groups:
- *Coordinator:* conceived and organized the work with the group of experts.
- *Overseeing group:* controlled the development of the work and discussed the recommendations.
- *Group of experts:* individually received a question and developed the topic according to the rules of Evidence Based Medicine (EBM), when it was possible.
- *Group of preparation and evaluation of literature:* drew up the text and assisted the group of experts in evaluating the literature.

Methods and criteria study selection

For the research were consulted the following databases:
- PubMed;
- Embase;
- Web of Science;
- CINAHL;
- Scopus;
- Google Scholar;
- Cochrane Library.

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, randomized controlled trials (RTCs) and systematic reviews were included; to follow if missing the first two, the other levels of evidence. Date of publications: 1987-November 2017.

Level of evidence

De Vries JG, Berlet GC. *Understanding levels of evidence for scientific communication.* Foot and Ankle Spec. 2010;3(4):205-9 (Tab. II).

Question n. 1: Animal models

The study of the animal models is consequent to the necessity of regenerate the tendon, identify optimal surgical techniques and rehabilitative protocol, accelerate return to work and return to sport.
The main animal models for Achilles tendon studies are mouse, rat and rabbit. The choice of animal model should be based on the type of study: rupture, tendinopathy, healing physiopathology.

Key points
- Animal models allow to study molecular and cellu-

Table I. Extrinsic and intrinsic factors involved in the etiology of Achilles tendon rupture.

Theory	Author	Year
	Extrinsic factors	
Mechanical factors	Hunt KJ, et al.[8]	2014
	Józsa L, et al.[9]	1989
	Kannus P, et al.[10]	1997
Drugs	Laseter JT, et al.[11]	1991
	Khaliq Y, et al.[12]	2003
	Parmar C, et al.[13]	2007
Footwear, ground and type of training	Wertz J, et al.[14]	2012
	Intrinsic factors	
Age	Magnusson SP, et al.[15]	2002
	McCarthy MM, et al.[16]	2014
Gender	Claessen FMAP, et al.[17]	2014
	Hunt KJ, et al.[8]	2014
	Smith FB, et al.[18]	2002
	Frizziero A, et al.[19]	2014
	Lemoine JK, et al.[20]	2009
	Cook JL, et al.[21]	2000
Genetic factors (group ABO)	Józsa L, et al.[22]	1989
	Kujala UM, et al.[23]	1992
Hormonal factors	Oliva F, et al.[24]	2016
Obesity	Battery L, et al.[25]	2011
Hypercholesterolemia	Hast MW, et al.[26]	2014

lar characteristics and healing physiopathology through quantitative and qualitative analysis, not possible on human.
- Because of the heterogeneity of models and of studies, it is not possible to establish the best suture technique, the best suture material and whether adjuvant therapies ameliorate tendon healing after suture.
- Most animal models do not mimic rupture, but are simple transition models, and are therefore not relevant to the matter at hand.

Level of recommendation: D.

KEY WORDS: Achilles tendon, clinical trials, animal models, surgery, surgical sutures, tendon sutures.

Question n. 2: Clinical diagnosis

The clinical diagnosis is based on history (sudden and severe pain, audible snap), clinical exam in action (swelling, ecchymosis, tendon discontinuity) and clinical tests. The main clinical tests used are: Calf squeeze sign (Simmond-Thompson test), Single leg heel rise test, Matles test, Copeland test, O'Brien test.

Key points

- Signs and clinical tests recommended are:
- tendon discontinuity;
- calf squeeze sign;
- simmond triad (Matles test, Calf squeeze test, palpable gap).

Level of recommendation: C.

KEY WORDS: clinical test, physical examination, diagnosis, Achilles tendon rupture.

Question n. 3: Ultrasound diagnosis

Ultrasound is used to identify or to confirm Achilles tendon ruptures (both partial and total) and to identify Achilles tendon alterations. Ultrasound is able to identity silent mechanical and structural tendon

Table II. Level of evidence and criteria for analysis.

Level of evidence	Criteria for analysis and inclusion
I	Meta-analyzes and systematic reviews of randomized controlled trials (RCTs) of high quality, or RCTs with minimum or low risk of bias. Systematic reviews of high quality relative to cohort studies or case-control.
II	Cohort studies or randomized case-control high quality, with minimal risk of confounding or bias and with high or discrete probability of causation.
III	Case-control studies and retrospective comparison of well-conducted with reasonable probability of causation.
IV	Non-analytic studies as case series or individual cases

Level of recommendation	Criteria for analysis
A	Supported by at least two studies of level Ib or from a review level Ia (" It was shown")
B	Supported by at least two independent studies of level II or extrapolations from studies of level I (“it is possible")
C	Not supported by adequate studies of level I or II ("indications")
D	Indications of experts ("there is no evidence")

changes which led to rupture. Ultrasound is also used to identify complications after rupture (deep venous thrombosis) and to prevent complications after surgery (identifying sural nerve). It is necessary focused on: patient position, probe position, acoustic window utilized.

Key points

- Ultrasound is useful to diagnose Achilles tendon ruptures, but also to study Achilles tendon characteristics (length, biomechanics, degenerative features) and results after surgery.

Level of recommendation: C.

- Ultrasound is useful to guide to the best choice of treatment.

Level of recommendation: C.

- Ultrasound allows dynamic study. Dynamic study is more sensible than static study to recognize Achilles tendon diseases.

Level of recommendation: B.

- Ultrasound is helpful to recognized degenerative changes in Achilles tendon of asymptomatic athletes and to identify athletes with higher risk of Achilles tendon rupture.

Level of recommendation: C.

KEY WORDS: Achilles tendon, tear, injury, rupture, ultrasonography, ultrasound, sonography, sonoelastograhy.

Question n. 4: Magnetic resonance diagnosis

Preoperative magnetic resonance (MR) imaging is useful to distinguish partial from complete ruptures and to assess the site and the extent of the tear.

In acute ruptures, the tendon gap demonstrates intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images. These findings are consistent with oedema and haemorrhage. In chronic ruptures, scar or fat may replace the tendon.

Key points

- MR is a valid alternative or complementary diagnostic technique.
- MR is recommended to identify or confirm Achilles tendon ruptures and to distinguish acute or chronic ruptures and partial or complete ruptures.

Level of recommendation: C.

KEY WORDS: Achilles tendon, rupture, tear, diagnosis, magnetic resonance, imagine.

Question n. 5: Conservative treatment

The aim of both conservative and surgical treatment is restoring tendon length and tension to optimize force and function. In the last 10 years, the use of conservative treatment has increased in Europe. Modern rehabilitative protocols after conservative treatment are based on early weight bearing concession and early mobilization. However, it is not possible to establish which is the better treatment because of lack of high quality clinically applicable randomized studies.

Key points

- The choice between surgery and conservative treatment should be based on individual factors (age, comorbidities, functional necessity, physical activity, patient preference).

Level of recommendation: A.

- Conservative treatment is recommended if adequate functional rehabilitation is permitted (early mobilization and weight-bearing).

Level of recommendation: B.

- PRP infiltrations and rehabilitation after conservative treatment do not add benefits.

Level of recommendation: C.

KEY WORDS: Achilles tendon, rupture, conservative, non surgical, non operative, rehabilitation.

Question n. 6: Sutures and materials

The suture must restore tendon continuity and resistance, allowing tendon glide and preventing adherences. In addition, the aim of suture is to support mechanical load during rehabilitation, preventing complications and recurrences.

There is lack of randomized clinical trials comparing the different types of sutures and the various techniques. Some studies are discordant on the recommendation of the most adequate technique.

Key points

- The use of absorbable sutures (Vycril, Polydioxanone) is safe because of strength and because of low rate of complications (granuloma, infections).

Level of recommendation: B.

- The choice of the suture technique (es. Bunnell, Kessler, Dresden, Krackow) depends on the experience and on the preference of the surgeon, because of lack of adequate studies.

Level of recommendation: A.

KEY WORDS: suture, material, Achilles tendon, repair, technique, tendon rupture.

Question n. 7: Use of autologous derived

The use of platelet-rich plasma (PRP) is started to aid tendon healing. PRP is rich of platelets and of their products such as vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), fibroblast growth factor (FGF), platelet-derived growth factor (PDGF), transforming growth factor beta (TGFb) and epidermal growth (EGF). These agents aid regeneration and tissue healing. The biological action of PRP is clear but it is unknow the best application protocol.

There is no consensus in literature above the use of PRP in the Achilles tendon ruptures. The existing studies use different protocols, different kinds of PRP, different surgical techniques and different rehabilitation protocols.

Key points

- PRP regenerative capacity is demonstrated.
- Which is the best type of PRP? PRP or PRF (platelet-rich fibrin)? Which is the best application protocol? Is it necessary to associate surgery? Which is the best surgery technique to associate? Which is the best rehabilitation protocol?
- High level of evidence studies are necessary.

Level of recommendation: A.

KEY WORDS: Achilles tendon, Achilles tendon rupture, mesenchymal stem cells, MSC, PRP, platelet rich plasma, platelet gel, platelet derived growth factors, platelet concentrate, PRGF, platelet lysate, platelet rich fibrin, platelet rich membrane.

Question n. 8: Open surgery

The open surgical technique allows to directly see the tendon stumps but it mostly damages paratenon and tendon vascularization. The open technique requires less days of hospitalization compared with both conservative treatment and mini-open surgery. Different suture configurations can be utilized in open technique; the most frequently used are Bunnel, Kessler and Krackow. There are contrasting results on ROM, tropism, return to work, and to sport.

It is impossible to define the gold standard treatment of Achilles tendon acute ruptures and the better open suture technique because of lack of high level literature.

Key points

- There are no differences in clinical results after open or percutaneous surgery.
- Open surgery reduces the risk of re-ruptures.
- Open tenorrhaphy requires a longer surgery time and leads to a major rate of complications during wound healing.
- Open surgery is associated with a greater rate of complications, especially infections.
- The treatment choice should be individualised.

Level of recommendation: B.

KEY WORDS: Achilles tendon acute rupture, open tenorrhaphy, recurrence, complications.

Question n. 9: Minimally invasive surgery

The complications of the open treatment (infections, adherences, paresthesia, incision delayed healing)

led to development of mini-invasive and percutaneous techniques. The main mini-invasive techniques studied are mini-open techniques, mini-open Dresden technique, mini-open Kakiuchi technique, Achillon device. The results are satisfactory (rate of complications, return to previous activities, objective and subjective questionnaires, imaging).
The literature does not offer high level studies. Adequate studies are necessary.

Key points

- Mini-invasive surgery techniques, used to treat the acute subcutaneous Achilles tendon ruptures, lead to optimal results and clinical recovery rate is at least 85%.
- Absorbable sutures and the post-surgery weight-bearing reduce the risk of complications.
- The use of PRP in the acute ruptures does not significantly ameliorate clinical and functional outcomes.

Level of recommendation: C.

KEY WORDS: Achilles tendon, rupture, mini-open, repair.

Question n. 10: Percutaneous surgery

Percutaneous techniques consist in no exposition of tendon stumps with intact skin. In this way, the two stumps are approached but not sutured. The first percutaneous technique was described by Ma and Griffith (1977). Subsequently, many modifications were introduced and different instruments used.

Key points

- Percutaneous surgery reduces surgery time and wound complications.

Level of recommendation: A.

- There are no statistically significant difference in clinical outcome between percutaneous and open surgery.

Level of recommendation: A.

- Earlier return to daily activities and to sport.

Level of recommendation: C.

- Higher rate of re-ruptures.

Level of recommendation: C.

- Percutaneous technique leads to a higher rate of sural nerve's lesions than open surgery.

Level of recommendation: A

- Lower rate of infective complications.

Level of recommendation: C.

KEY WORDS: Achilles tendon, tendon rupture, Achilles tendon repair, tendon suture, open repair, percutaneous suture.

Question n. 11: Tendon transfers for chronic tears

Surgery treatment is necessary for the chronic Achilles tendon ruptures because of the retraction of tendon stumps. Tendon transfers are used for the treatment of inveterate Achilles tendon ruptures. There are different tendon transfer techniques: autograft, allograft, xenograft (based on the source of donor) and flexor hallucis longus, peroneus brevis, gastrocnemius-soleus, fascia lata, semitendinosus, gracilis (based on the donor site). The results are good but randomized controlled clinical trials are necessary.

Key points

- Autograft transfer to treat chronic Achilles tendon ruptures with tendon loss > 50%.

Level of recommendation: A.

- Allograft or xenograft transfer to treat inveterate Achilles tendon ruptures.

Level of recommendation: D.

- Lower rate of return to sport at the same level.

Level of recommendation: A.

- Higher post-surgery outcomes (AOFAS score, calf circumference) after tendon autograft.

Level of recommendation: D.

- Re-ruptures incidence after tendon autograft not statistically significant.

Level of recommendation: D.

- Infection (deep and superficial) incidence of the surgical wound not statistically significant.

Level of recommendation: D.

KEY WORDS: Achilles tendon and transfer, neglected Achilles tendon rupture, chronic Achilles tendon rupture, tendon transfer, Achilles tendon and flexor hallucis longus transfer, Achilles tendon and peroneus brevis tendon transfer.

Question n. 12: Imaging post-surgery

Imaging post-surgery allows to study the intrinsic characteristics of tendon fibers. Follow-up of an operated tendon is clinical. Post-surgery examination can include magnetic resonance imaging (MRI) or Ultrasound (US). Imaging examination may give important information regarding general morphology, tendon structure, grade of vascularisation and tissue mobility. In particular, US plays a crucial role in the follow-up of operated tendons because of the dynamic nature of this technique and the contribution of colour-doppler tool and MRI has shown to be a useful method to evaluate the healing process of surgically treated Achilles tendon. In addition, the use of elastosonography and diffusion tensor imaging (DTI) is increased. Elastosonography and DTI represent innovative and effective quantitative tools that might be able to provide microstructural abnormalities not appreciable using conventional radiological techniques. In last years, the use of DTI in musculoskeletal field keeps on growing in clinical practice. After surgical procedures the use of DTI may ascertain the microstructural properties and integrity restoration of the ruptured tendon during the healing process, even if DTI technique needs more studies on musculoskeletal structures. However, imaging post-surgery appearance of Achilles tendon repair is dependent on the surgical technique used.

Key points
- Imaging post-surgery does not offer clinical and functional benefits.
- Use of DTI allows to have quantitative informations on tendon structure.
- Using Elastonography, healing tendons are shown to be softer than healthy tendons.

Level of recommendation: D.

KEY WORDS: imaging, follow-up, post-surgery, Achilles tendon, rupture, magnetic resonance, ultrasonography.

Question n. 13: Rehabilitation protocol after acute ruptures

Recently, the rehabilitation regimen after Achilles tendon ruptures has become more active. Immobilization and weight bearing prohibition for 6 weeks has been replaced by functional rehabilitation, characterized by partial or full weight bearing in the first 2 weeks after surgery, and active controlled mobilizations in the first few days after surgery. Functional rehabilitation can include early mobilization or early weight bearing, or both early mobilization and early weight bearing.

Key points
- Functional rehabilitation after surgery is safe and more advantageous than conventional immobilization.

Level of recommendation: A.
- There are no scientific evidences among the best rehabilitation protocol.

Level of recommendation: A.

KEY WORDS: Achilles, ruptur, surg*, operat*, mobili*, immobili*, cast*, weight bearing, rehab*, comparison.*

Question n. 14: Rehabilitation protocol after chronic ruptures

The rehabilitation protocol after chronic Achilles tendon ruptures proposed by these guidelines is as follows.

WEEKS 1-4
Cast/Boot (30° plantar flexion), weight-bearing after 3 weeks, cautious mobilizations.
WEEKS 4-8
Complete weight-bearing with cast (5-6 weeks), progressive mobilizations.
WEEKS 8-12
Free deambulation, mobilizations against resistance, cyclette and swimming.
MONTHS 3-6
Sport specific exercises (closed chain), muscular strengthening.
6° MONTH
Jogging, running, jumping and eccentric exercises.
8°-9° MONTH
Return to sport if possible.

Key points
- There are no scientific evidences among the best rehabilitation protocol.

Level of recommendation: A.

KEY WORDS: Achilles tendon, rehabilitation, program, chronic rupture.

Question n. 15: Nutraceuticals

The word nutraceutical derived from “nutrition + pharmaceutical”. Nutraceuticals are food supplements: L-arginine-α-ketoglutarate, methylsulfonylmethane, type I collagen, bromelain, polyphenols, vitamins (C, A, B6, E), minerals (selenium, zinc), essential fatty acids (omega-3, omega-6). Nutraceuticals can help the normal functions of human body. They have different mechanisms of action: antinflammatory, analgesic, antioxidant, collagen synthesis promotion, immunomodulation, free radicals scavenging.

Key points
- There are only studies on animal models (studies on human are necessary).
- The use of nutraceuticals, in different combinations, can be helpful to tendon healing and to Achilles tendon rupture prevention, with or without the addition of other strategies.

Level of recommendation: D.

KEY WORDS: supplement, nutraceutical*, phytochemicals, extract*, plant, herbal, herbals, glucosamine, glycosaminoglycans, mucopolysaccharides, mucopolisaccharides, glycosaminoglycan polysulphate, glycosaminoglycan polysulfate, chondroitin sulphate, chondroitin sulfate, vitamin C, ascorbate, ascorbic acid, type I collagen, arginine, curcumin, boswellic acid, Boswellia, methylsulfonylmethane, bromelain, tendon*, tendinopathy, tendonitis, Achilles, peritendinitis, tendinitis, tendinosis.*

Question n. 16: Return to sport

Achilles tendon rupture is frequent during sport activities, only 50% of patients return to sport after 1 year. Return to sport is on average 6 months after rupture. 4 of 5 patients return to play after Achilles tendon rupture. Different methods to evaluate function are utilized: AOFAS (American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score), ARPS (Achilles Rupture Performance Score), ATRS (Achilles Tendon Total Rupture Score), FAAM (Foot and Ankle Ability Measure), FAOS (Foot and Ankle Outcome Score—Ankle and Hindfoot), PAS (Physical Activity Scale), PER (Player Efficiency Rating). Therefore, it is not possible to compare the results of scientific researches.

Key points
- 80% of patients return to sport after Achilles tendon rupture.
- The literature is heterogeneous.
- Scientific evidence about return to play is needed to establish recovery time.

Level of recommendation: D.

KEY WORDS: Achilles tendon and injury, Achilles tendon and rupture, recovery of function or performance outcome, athletic performance, return to play, return to sport, treatment outcome.

Question n. 17: Outcome evaluation devices

There are different types of outcome evaluation devices:

- non invasive laboratory techniques to estimate *in vivo* Achilles tendon force during deambulation;
- movement analysis through methodological and technological instruments: planar trajectories measurement of selected anatomic landmarks, constrain force returned by ground, inertial parameters and muscular geometries evaluation to calculate tendon force through reverse dynamic.

Key points

- AT force during terrestrial human locomotion can be estimated non-invasively through inverse dynamics by means of motion analysis techniques and musculoskeletal modeling.
- Such an approach, although clinical-friendly, presents several limitations due to the reliability of the collected experimental data and to the specificity of musculoskeletal models.
- State-of-the-art high-resolution imaging techniques are being used to record subject-specific musculoskeletal geometries to fit to motion data collected into the laboratory to improve the accuracy in estimating muscle force through inverse dynamics.

Level of recommendation: D.

KEY WORDS: joint kinematics, inverse dynamics, gait analysis, Achilles tendon force, musculoskeletal model.

Question n. 18: Acute ruptures in the childhood

Acute Achilles tendon ruptures in the childhood are rare. The rupture can be initially partial and can become total after few weeks because of a new trauma.

Key points

- In patients under 10 years old treatment can be conservative, with good results.

Level of recommendation: C.

- Chronic ruptures usually require open surgical treatment; if there is a wide gap, autografts can be used to bridge such gap.

Level of recommendation: C.

- Acute ruptures in skeletally mature patients can be treated both surgically (percutaneous technique) or conservative.

Level of recommendation: C.

KEY WORDS: pediatric Achilles tendon tear, pediatric Achilles tendon repair, pediatric Achilles tendon injury.

Answer n. 1: Animal models in Table III.

Answer n. 2: Clinical diagnosis in Table IV.

Answer n. 3: Ultrasound as diagnostic tool in Table V. Ultrasound as outcome measurement to establish treatment validity in Table VI.

Answer n. 4: Magnetic resonance diagnosis

Preoperative MR imaging is useful for distinguishing partial from complete rupture and assessing the site and extent of the tear[93,94]. At MR, partial tendon tears can be defined on MR images in the sagittal and axial planes demonstrating heterogeneous signal intensity and thickening of the tendon without complete interruption[95]. Longitudinal splits in chronic Achilles tendinopathy that are low to intermediate in signal intensity on long-TR/TE images may be seen in association with a superimposed acute partial tear. Linear or focal regions of increased signal and thickening of fibers without a tendinous gap are characteristic[95].

Differentiation between partial tear and severe chronic Achilles tendinosis may be difficult apart from clinical history. In general, acute partial tears are often associated with subcutaneous edema, haemorrhage within the Kager fat pad and intratendinous haemorrhage at MR imaging, whereas chronic tendinosis does not usually demonstrate increased subcutaneous or intratendinous signal intensity on T2-weighted images[96,97].

Complete Achilles tendon rupture manifests as discontinuity with fraying and retraction of the torn edges of the tendon. In acute rupture, the tendon gap demonstrates intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images, findings that are consistent with edema and haemorrhage, whereas in chronic ruptures, scar or fat may replace the tendon[97].

Key MRI findings include: a fluid-filled gap with or without interposed fat at the tear site in complete tendinous disruptions with discontinuity; fraying or corkscrewing of the tendon edges associated with proximal tendon retraction; in the absence of overlapping tendon edges, no tendon fibers can be seen at the tear site on axial images; tendon disruption with discontinuity and a wavy retracted tendon; associated haemorrhage or edema in intratendinous or peritendinous soft tissues on axial or sagittal images; effacement of Kager's triangle[95].

The main differential features between partial and complete tears include the following: partial tears demonstrate hyperintense signal with incomplete anterior-to-posterior or posterior-to-anterior extension on fat sat FSE PD images; complete tears demonstrate a hyperintense fluid-filled tendinous gap; tendon rupture usually occurs 2 to 6 cm superior to the os calcis; the size of the rupture varies, based on the degree of tendon retraction; ruptures demonstrate dif-

Table III. Answer n. 1: Animal models.

Authors	Year	Animal	Type of lesion	Type of suture +/- additional techniques
Dogan A, et al.[27]	2009	36 Sprague-Dawley rats	Z-plasty	Group 1: suture with 5-0 Ethibond; Group 2: no suture
Lusardi DA, Cain J E[28]	1994	24 New Zealand rabbits	Longitudinal	Group 1: 4-0 prolene "horizontal mattress" suture; Group 2: fibrin sealant
Jielile J, et al.[29]	2016	135 New Zealand rabbits	Unilateral tenotomy 1.6 cm by calcaneal insertion	Yurt-bone suture method Group 1: suture + cast Group 2: suture + mobilization; Group 3: control
Aydın BK, et al.[30]	2015	12 Wistar albino rats	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 4/0 polypropylene Group 1: suture + topic hemostatic agent Group 2: suture only
Dabak TK, et al.[31]	2015	72 Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 5/0 absorbable. Group 1: single phospholipids injection post-surgery; Group 2: multiple phospholipids injections post-surgery; Group 3: hyaluronic acid injection post-surgery Control group: physiological solution injection
Aliodoust M, et al.[32]	2014	88 Wistar rats with and without diabetes - streptozotocin induced	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 4.0 nylon. Group 1: non diabetics, suture + low-level laser therapy; Group 2: non diabetics, suture; Group 3: diabetics+ suture+ low-level laser therapy; Group 4: diabetics + suture
Gereli A, et al.[33]	2014	21 albino Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 5/0 monofilament polypropylene. Group 1: suture + 0.01 ml solution with organic silicone; Group 2: suture + 0.01 ml physiological solution
Liang JJ, et al.[34]	2014	120 Sprague-Dawley rats	Cross sectional, in the half tendon	Modified Bunnell technique with 4-0; Nylon. Group 1: suture + 0,2 ml hyaluronic acid + tenocytes; Group 2: suture + 0,2 ml hyaluronic acid; Group 3: suture + physiological solution
Selek O, et al.[35]	2014	40 albino Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 3-0 Ethibond. Group 1: suture + mesenchymal cells; Group 2: suture + physiological solution
Zeytin K, et al.[36]	2014	16 albino diabetic Sprague-Dawley rats	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 5-0 monofilament polypropylene. Group 1: suture + perichondral autologous graft with suture 6-0 monofilament polypropylene; Group 2: suture
Hapa O, et al.[37]	2013	32 samples of bovine Achilles tendon	Cross sectional, 5 mm by calcaneal insertion	Krackow technique. Group 1: 2 sutures with 2 sutures and 2 locked loops; Group 2: 2 sutures with 2 strands and 4 locked loops; Group 3: 2 sutures with 2 strands and 4 locked loops; Group 4: 2-0 suture with 4 strands and 2 loops

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Continued from **Table III**

Huri G, et al.[38]	2013	27 Merino Wether sheeps	Cross sectional, 2 cm by calcaneal insertion	Group 1: Modified Bunnell technique Endobutton-assisted; Group 2: Krackow technique; Group 3: native tendon
Nouruzian M, et al.[39]	2013	33 diabetic streptozotocin-induced Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Kessler technique with 4.0 nylon. Group 1: non diabetics + suture + low-level laser therapy 2.9 J/cm; Group 2: non diabetics+ suture + low-level laser therapy 11.5 J/cm; Group 3: diabetics + suture + low-level laser therapy 2.9 J/cm; Group 4: diabetics + suture+ low-level laser therapy a 11.5 J/cm
Leek BT, et al.[40]	2012	84 New Zealand rabbits	Cross sectional, partial (50%)	Krackow technique. Group 1: 0-ultrabraide suture impregnated with butyric acid; Group 2: non impregnated
Ni T, et al.[41]	2012	64 adult New Zealand white rabbits	Cross sectional, 1-2 cm by calcaneal insertion	Kessler technique. Group 1: 5-0 vicryl coated + epitendinous suture; Gruppo 2: 5-0 vicryl + 1 cm by section electrospun silk (ES) bounded to tendinous surface + lambda 532 nm and 0.3 W/cm² irradiated for 6 minutes
Ishiyama N, et al.[42]	2011	18 Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Kessler technique with 6-0 braided polyestere + cast. Group 1: suture + injected 2- metha cryloyloxyethyl phosphorylcholine (MPC) polymer 2,5%; Group 2: suture + injected 2-metha cryloyloxyethyl phosphorylcholine (MPC) polymer 5.0; Group 3: suture + physiological solution
Ishiyama N, et al.[43]	2010	12 Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Kessler technique with 6-0 braided polyestere + cast. Group 1: suture + injected 2-metha cryloyloxyethyl phosphorylcholine (MPC) polymer 2,5%; Group 2: suture + injected 2- metha cryloyloxyethyl phosphorylcholine (MPC) polymer 5.0; Group 3: suture + physiological solution
Lyras DN, et al.[44]	2011	48 New Zealand white rabbits	Cross sectional, 2 cm by calcaneal insertion	Paratenon with continuous suture 4-0 nylon. Group1: suture + injected 0.5 ml of PRP distal and proximal tendon insertions; Group 2: suture
Saygi B, et al.[45]	2008	45 Sprague-Dawley rats	Cross sectional, 5 mm by calcaneal insertion	Kessler technique 3/0 Ethibond. Group 1: suture; Group 2: direct exposition to air + irrigation with 3 drops physiological solution each 5 minutes for 60 minutes + suture; Group 3: exposition to air for 60 minutes + suture
Chong AK, et al.[46]	2007	57 New Zealand white rabbits	Cross sectional, in the half tendon	Modified Kessler technique with prolene 4-0. Group 1: suture + mesenchymal bone marrow cells in a fibrin carrier; Group 2: suture + fibrin carrier
Gilbert TW, et al.[47]	2007	12 mongrel dogs	Segmental excision, 1.5 cm in the half tendon	Graft marked with carbonio14 2x3 cm extracellular matrix of intestinal submucosa and suture 4-0 prolene

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Continued from **Table III**

Duygulu F, et al.[48]	2006	22 New Zealand rabbits	Cross sectional, in the half tendon	Modified Kessler technique with 4/0 PDS + cast. Group 1: suture + nicotine subcutaneous injection 3 mg/kg/die; Group 2: suture + physiological solution infusion
Strauch B, et al.[49]	2006	40 Sprague-Dawley rats	Cross sectional	Modified Kessler technique with 6-0 nylon. Active group: suture + PMF (pulsed-magnetic-field) 2 sessions (30 minutes/die) for 3 weeks; Control group: suture
Bolt P, et al.[50]	2007	90 Sprague-Dawley rats	Cross sectional, in the half tendon	Horizontal mattress with 6-0 Ticron. Group 1: suture + transfection with adenovirus expressing green fluorescent protein gene (AdGFP); Group 2: suture + transfection with adenovirus expressing humane BMP-14 gene and AdBMP-14; Group 3: suture
Zantop T, et al.[51]	2006	40 chimerical rats expressing fluorescent green protein in all mesenchimal cells	Step 1: placing 7-0 prolene suture loops 2 cm apart in the midsubstance of the tendon. Step 2: the tendon was cut within the suture loops to hold the explanted tendon in place. Step 3: the sutures were finally performer to secure the autologous tendon graft	Two 7-0 Vicryl sutures were placed proximal and distal in the Achilles tendon. A single layer of lyophilized porcine small intestinal sub mucosa (SIS) was secured to the cut ends of the tendon with 7-0 prolene suture. Finally, the graft and the graft was hydrated with saline. Group 1: SIS graft; Group 2: autologus tendon repair
Chan BP, et al.[52]	2005	48 Sprague-Dawley adult rats	Cross sectional, 6 mm by calcaneal insertion	Modified Kessler technique + cast + injected Rosa bengala (RB) solution (0.1%) at the extremities lesions. Group 1: suture; Group 2: laser Group 3: RB only; Group 4: photochemical tissue bonding (PTB) treatment (RB + laser)
Kashiwagi K, et al.[53]	2004	90 Wistar rats	Cross sectional, 5 mm by calcaneal insertion	Tsuge technique with 5/0 nylon. Control group: suture + local injection of physiological solution; Group 1: suture + local injection of TGF-beta1 10 ng; Group 2: suture + local injection of TGF-beta1 100 ng
Orhan Z, et al.[54]	2004	48 Wistar albino rats	Cross sectional	Modified Kessler technique. Group 1: suture + shock waves (ESWT) post-surgery; Group 2: suture Group 3: suture + 500 15 KV shock waves in 2nd day post-surgery
Kazimoğlu C, et al.[55]	2003	75 Sprague-Dawley rats	3 cm lesion	Group 1: only cutaneous incision; Group 2: lesion 1 cm by calcaneal insertion + cast; Group 3: modified Kessler technique; Group 4: plasty with biodegradable film PCL (poly-e-caprolactone); Group 5: lesion 1 cm distal by half tendon

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Continued from **Table III**

Palmes D, et al.[56]	2002	114 Balh-C mice	Cross sectional, 5 mm by calcaneal insertion	Modified Kirchmayr-Kessler technique. Group 1: equine cast; Group 2: passive mobilization; Group 3: controlateral Achilles tendons
Thermann H, et al.[57]	2002	105 rabbits	5 longitudinal lesion, 1 cm by calcaneal insertion	Group 1: continuous fascia suture; Group 2: suture with 5/0 plantar flexion; Group 3: 1 mm of fibrin glue
Rickert M, et al.[58]	2001	80 Sprague-Dawley rats	Cross sectional, 5 mm by calcaneal insertion	Suture with 3 points. Group 1: suture impregnated with growth and differentiation factor-5 (GDF-5); Group 2: suture
Pneumaticos SG, et al.[59]	2000	24 New Zealand rabbits	Cross sectional, 1-1.5 cm by calcaneal insertion	Krackow technique + immobilization at 90° with Kirschner wire Group 1: 35 days of immobilization; Group 2: 14 days + active mobilization
Owoeye I, et al.[60]	1987	60 Sprangue-Dawley rats	Cross sectional	Suture with 5-0 black silk + glue for K wire fixation. Group 1: suture + anodic electrical stimuli (15 minutes for 2 weeks 75 microA and 10/sec frequency); Group 2: suture + catodic electrical stimuli; Control group: no suture, no electricity
Petrou CG, et al.[61]	2009	42 New Zealand white rabbits	Tenotomy, 3 cm by calcaneal insertion	Absorbable epitenon suture. Group 1: calcitonin 21 IU /kg intramuscularly; Group 2: physiological solution
Fukawa T, et al.[62]	2015	24 New Zealand white rabbits	Cross sectional, 2 cm by calcaneal insertion	Paratenon suture with standard technique 4-0 nylon. Group 1: 1.0 ml di PRP application; Group 2: 1.0 ml physiological solution application
Adams SB, et al.[63]	2014	54 Sprague Dawley rats	2 Cross sectional lesions, 3 mm by muscle-tendon origin muscolo tendine with 3mm segmental tendon excision	Suture type 8. Group 1: suture only; Group 2: suture + mesenchymal cells injection
Irkören S, et al.[64]	2012	8 New Zealand white rabbits	Cross sectional, 5 mm by calcaneal insertion	Modified Kessler technique with 5/0 monofilament polypropylene. Group 1: suture + perichondral autologous graft by right ear and continuous suture with 6-0 monofilament polypropylene; Group 2: suture only
Meimandi-Parizi A, et al.[65]	2013	75 White New Zealand rabbits	Longitudinal	Kessler technique with monofilament absorbable 4-0 polydioxanon. Group 1: suture + collagen implant; Group 2: suture only
Oryan A, et al.[66]	2013	40 white New Zealand rabbits	2 Cross sectional lesions, 5 mm by muscle-tendon origin with 5 mm segmental tendon excision	Kessler technique. Group 1: suture + collagen 3-D structure between tendon stumps; Group 2: suture only
Godbout C, et al.[67]	2009	12 males C57BL/6 mice	Cross sectional	Technique type 8 with VICRYL 6-0. Group 1: suture + suture impregnated with antibodieswhich induce thrombocytopenia; Group 2: suture + placebo

Table IV. Answer n. 2: Clinical diagnosis.

Sign/Test	Action	Significance	Sensitivity	Specificity
Tendon discontinuity[68-70]	Palpation of the tendon in prone position	Positive if palpable gap is felt	0.73	0.89
Calf squeeze sign[69-70] (Thompson's test)	Compression of the triceps muscle in a prone patient	Positive if the manoeuvre cannot elicit foot plantarflexion	0.96	0.93
Matles's test[71-73]	Active knee flexion in the prone position	Positive if knee flexion leads to progressive foot dorsiflexion	0.88	0.85
Simmonds triad[74,69]	Association of tendon discontinuity, Thompson's test and Matles test	Positive if all three signs are present	1	

fuse convexity of the anterior margin and enlarged tendon ends at the tear site[97].

We point out, however, that even advanced imaging techniques should be interpreted in the light of clinical findings. In case of diagnostic doubts, the fallback position should be more accurate clinical examination, not just this imaging.

Answer n. 5: Conservative treatment in Tables VII-VIII.

Answer n. 6: Sutures and materials in Table IX.

Answer n. 7: Use of autologous derived blood products in Table X.

Answer n. 8: Open surgery in Table XI.

Answer n. 9: Minimally invasive surgery in Table XII.

Answer n. 10 : Percutaneous surgery in Table XIII.

Answer n. 11: Tendon transfers in Table XIV.

Answer n. 12: Imaging post-surgery

Despite follow-up of an operated tendon is primarily clinical, postoperative examination has been improved by the recent technological progress either on MRI or on ultrasound that allow better representation of tendon structural specimens. Postoperative imaging appearance of Achilles tendon repair is dependent on the surgical technique used. Imaging examination allows to obtain information regarding: general morphology, tendon structure, grade of vascularity, tissue mobility.

Ultrasound

Ultrasound (US) can be used to follow-up operated tendons[219] because of the dynamic nature of this technique and the contribution of colour-doppler tool[220-221].

Both scans are essential for the correct examination of the treated area and for correct measurement of tendon's dimension. The operated tendon is thicker and wider than a normal ones; its mean thickness is about 10 mm (ranged from 7 to 16 mm) whereas the average diameter of a healthy tendon is 5.4 mm (ranged from 4.0 to 7.9 mm)[222]. This progressive increase in size occurs during the first 3-6 months after surgery and gradually decrease in thickness 1 year after surgery[223,224].

Fluid collections are suggestive of a poor prognosis if greater than 50% of the affected tendon, and extensive intratendinous calcifications should be considered pathological[225]. The contours of the tendon may be irregular with hypoechoic peritendinous area, which may persist for up to 3 months[226], and small hypoechoic areas may surround the stitches into 6-24 months after surgical treatment[220,224].

The microvascularity assessment with colour-doppler tool shows newer vessels with higher flow rates during the healing process[227-228]; the vascular response may indicate tendon healing with initial high flow vas-

Table V. Answer n. 3: Ultrasound as diagnostic tool.

Author	Type of study	Patients	Type of surgery	Outcome assessment	Results	Conclusions	Level of evidence
Lang TR, et al., 2017[75]	Systematic revision	26 articles (20 case studies, 5 case series e 1 prospective not controlled study), 61 participants. 53 patients (88%, 53 of 61 cases): calcaneal tendon involved	Different databases (Medline, CINAHL, Biological Abstracts, AMED, Web of Knowledge, SCOPUS, SportDiscus e EMBASE) utilising words MeSH and free text, combined with the boolean operators (AND, OR). Imaging utilised: MRI, ultrasound B-mode and CT	Not applicable	Complete rupture in 25% of subjects. In the article, qualitative description of tendon thickening (25%), partial or incomplete ruptures (11%), signal intensity (10%), tendon thinning (7%), inflammation and hypoechogenicity	Despite the strong clinical indication for fluoroquinolones, data are not sufficient to define specific structural changes that lead to adverse reactions in the tendon	I
Barford KW, et al., 2015[76]	Cross sectional study	19 patients (8 men, 11 women, mean age: 43.4 years old, range of age: 26-63 years old) without previous problems of Achilles tendon	Achilles tendons (both 2 sides) of all patients (dominant side: dx) examined with MRI and ultrasound. Two phases of measurement: idendification of anatomical references and measurement of the skin distance with a centimeter. Repeated ultrasound measurements compared with MRI measurements	Not applicable	Intra-operator reliability with ultrasound do not have significantly differences between prove days: ICC 0.96, SEM 4 mm and MDC 10 mm. Inter-operator reliability has a systematic difference between ultrasounds: 2-5 mm (p = 0.001-0.036); ICC 0.97, SEM 3 mm e MDC 9 mm. MRI measurement is mean 4 mm longer than ultrasound (p = 0,001)	Ultrasound has a good reliability and precision. Comparing groups of healthy people it is possible to identify differences of more than 4 mm. With repeated evaluations it is possible identify differences of more than 10 mm	III

To be continued

Continued from **Table V.**

Pedersen M, et al., 2012[77]	Systematic revision	8 articles about miotendineous elastosonography *in vivo* (4 AT)	PubMed e EMBASE were utilised with a free text research	Not applicable	Elastosonography (SEL) results correlate with conventional ultrasound results and with MRI clinical exam. In few articles, elastosonography is more sensible than traditional ultrasound. For muscles, it is founded an important correlation between SEL, ultrasound and MRI, but only an article exists. Sonoelastography discerns between healthy muscles and lesioned and is probably more sensible than ultrasound and MRI to identify early dystrophic changes	Elastosonography is utilised to identify tendon alterations, like ultrasound and RMI. Elastosonography can identify subclinical alterations of the tendon, not visible with conventional ultrasound. Elastosonography could be a supplementar imaging technique to evaluate muscle-skeletal alterations, virtually superior to ultrasound and MRI. Currently it must be considered an experimental exam	I
Fredberg U, et al., 2008[78]	Randomized trial	209 danish professional men footballer (Achilles tendon and patellar tendon)	Experimental group (mean age 25 years old; range of age: 18-37): eccentric prevention and streching of patellar and Achilles tendons Control group (mean age 25 years old; range of age: 18-38)	Follow-up with ultrasound more than 12 months and accidents registration	Eccentric training and stretching do not reduce the risk of lesions and this risk is higher during season in player with abnormal patellar tendon at the start of the study. Training programme reduces ultrasound abnormalities in patellar tendon, but not in Achilles tendon	With ultrasound, changes of footballer tendons could be diagnosed before coming symptomatic. Eccentric prevention and stretching reduce the risk of ultrasound alterations in patellar tendon, but there is not the reduction of risk of lesions. On the contrary, in asymptomatic footballer with patellar tendons alterated at ultrasound ultrasonographically, eccentric prevention and stretching increase the risk of lesions	I
Flavin R, et al., 2007[79]	Cross sectional study	10 healthy men (range of age: 25-30)	All patients analised with ultrasound	Ultrasound evaluation	Average distance between geographical mapping and clinical points is 2,5 mm (range 0-20 mm)	Good correlation between clinical and ultrasound evaluation	III

To be continued

Continued from **Table V.**

Ofer N, et al., 2004[80]	Cross sectional study	Patients with Achilles tendon rupture	Group A (range of age: 31-57): patients with Achilles tendon rupture; Group B (range of age 31-56): control healthy people	Ultrasound: automatic test for evaluation of symmetrical proprieties of tendon movement	Result better in post-surgery tendons than in healthy controlateral tendon in the same subjects. In case of traumatic rupture, there is not this effect. So, negative asimmetry of tendon movement can be associated to degenerative or pre-degenerative processes	Objective method, low cost, non invasive and maybe more sensible of non invasive technique	III
Bleakney RR, et al., 2002[81]	Cross sectional study	72 patients (58 men, 14 women; average age 49.3 years old; range of age 30-82 years old) with clinical diagnosis of Achilles tendon rupture	All patients analised with ultrasound + 70 control healthy people (same age and gender)	Ultrasound (diameter, echogenicity, presence of calcifications)	Average maximum AP diameter of ruptured tendon is 11,7 mm (SD = 2,10); the normal tendons is on average 5,4 mm (SD = 0,9) and it is on average 4,9 mm (SD = 0,5) (p <0,0001) in the controls. No differences in maximum AP diameter of ruptured tendon depending of the treatment method (conservative, open reparation, percutaneous reparation). 17 patients have hypoechoic areas in the ruptured tendon, 2 patients have hypoechoic areas in their healthy controlateral tendon, 10 patients have calcifications in their ruptured tendon	AP diameter of ruptured tendon is significantly greatest of healthy controlateral tendon. However, if compared with control group, controlateral tendons have a significantly maximum AP diameter and a higher prevalence of intratendinous alterations. This difference can signified a subclinical tendinopathy that can lead to rupture	III

To be continued

Continued from **Table V.**

Cunndne G, et al., 1996[82]	Cross sectional study	19 patients (10 men, 9 women; average age 42 years old; range of age: 18-72) with tallodinia in associated with chronic inflammatory arthritis	All patients analised with ultrasound	Ultrasound	8 patients (2 had previous blinded failed injections) had 11 injections of corticosteroids ultrasound-guided to treat retrocalcanear bursitis (n=6), plantar fascitis (n=3) and tibial posterior tenosynovitis (n=2). Ultrasound showed Achilles tendon rupture (n=2), Achilles tendinitis (n=8), tibial posterior tenosynovitis (n=6), peroneus longus tenosynovitis (n=2), retrocalcanear bursitis (n=13) and plantar fascitis (n=4). Lost of bone profile (n = 13) is related to osseous erosions on radiographs in all patients, except one. 10 of 11 guided injections lead to complete resolution of tallodinia	The different causes of allodinia were identify and the ultrasound capacity to provide useful informations to clinical management is confirmed. Ultrasound guided injection of corticosteroids is advantageous, mostly after failure of blinded injection	III

Table VI. Answer n. 3: Ultrasound as outcome measurement to establish treatment validity.

Author	Type of study	Patients	Type of surgery	Outcome assessment	Results	Conclusions	Level of evidence
Eliasson P, et al., 2016[83]	Cross sectional study	23 patients (19 men, 4 women; average age ± SD: 38±2.1 years old) with Achilles tendon rupture during sport, surgery	Open surgery and cast (6 weeks)	PET, ultrasound with power doppler (PDUS), evaluation questionnaires (ATRS, VISA-A)	Glucose supply is more elevated in repaired tendon than in intact tendons at all follow-up times (6, 3 and 1,6 time more elevated rispectively at 3, 6 and 12 months, p<0,001) and it is also more elevated in the central part of the tendon than at extremities at 3 and 6 months (p≤ 0,02), but lower at 12 months (p = 0,06). Relative glucose absorption is negatively correlated to ATRS at 6 months after reparation (r = -0.89, p<0.01). Flow activity at PDUS is more elevated in repaired tendon than in intact tendon at 3 and 6 months (both p<0,05), but it is normalized at 12 months	Healing process based on metabolic activity and on vascularization, continues for 6 months after lesion when heavy loads on the tendon are allowed. In fact, metabolic activity was high for more than 1 year after lesion despite vascularization normalization	III

To be continued

Continued from **Table VI.**

Jielile J, et al., 2016[84]	RCT	57 patients with misunderstood Achilles tendon rupture	2 groups: 25 patients (21 men, 4 women; mean age: 31-47) early rehabilitation post-surgery (group EPR) and 32 patients (27 men, 5 women; range of age 29-45) immobilization post-surgery with cast (group PCI)	Leppilahti Score (LSS), ultrasound, computed tomography multislice spiral (TCmS), electromyography	Ultrasound and msTC do not revealed presence of tendon elongation or adhesion. Group PCI have higher post-surgery LSS score, but recovery is slower. Post-surgery complications, such as ankle ankylosis and osteoporosis, are present only in PCI group. In both the groups, cross sectional section of ruptured tendon is wider than section of healthy controlateral tendon. However, comparing cross sectional section of ruptured tendon in the different groups, the section in EPR group is significantly wider than in PCI group (p<0.01)	Compared to immobilization with a cast, early post-surgery rehabilitation leads to a better clinical result and a faster global regeneration of tendon with an ignored tendon lesion	II

To be continued

Continued from **Table VI.**

Busilacchi A, et al., 2016[85]	Perspective study	25 patients (22 men, 3 women) spontaneous subcutaneous Achilles tendon rupture	Percutaneous tenorrhaphy using terephtalate polyethylene. Control group: 30 healthy volunteers (25 men, 5 women) compared for ultrasound and elastonography results	Evaluation questionnaire (ATRS) correlated with ultrasound	Strain index (SI) in the treated tendons shows progressive stiffness, mostly at myotendinous junction and a sutured site, with stiffness significantly higher in both the controlateral tendons and in healthy volunteers. Maximum thickness of treated tendons is at 6 months, with a reduction after 1 year, without return to physiological normality. The better remodelling is at lesion site. Contralateral tendon has a significantly thickness at myotendinous and osteotendinous junctions. Strain index of controlateral tendon is more rigid than physiological values in the control group. ATRS score is better between 6 months and 1 year, negatively related to SI (p<0,001)	Elastosonography demostrated that Achilles tendon become progressively thicker after surgery during follow-up, while ATRS score is better. Basing on biomechanical evaluation, 1 year after surgery Achilles tendons do not have a "restitutio ad integrum". Elastosonography provides to major qualitative and quantitative information for diagnosis and follow-up in Achilles tendon pathologies and evaluating post-surgery evolution of repaired tissue	II

To be continued

Continued from **Table VI.**

Chiu CH, et al., 2013[86]	Retrospective study	19 patients (18 men, 1 woman; average age 38.7 years old, range of age: 20-50) with acute Achilles tendon lesion related to sport	Diagnosis: anamnesis, objective exam, ultrasound. Percutaneous reparation endoscopic assisted, post-surgery rehabilitation	Physical exam, ultrasound and magnetic resonance (MRI)	Tendon healing in all patients. All patients were evacuate with ultrasound and 16 patients with MRI to evaluate the level of healing. Final dorsiflexion was 16° and plantar flexion 26°. 95% of patients (18/19) returned to sport at previous level	Percutaneous Achilles tendon reparation, endoscopy assisted, allowed tendon treatment and return to sport after 6 months	III
Jielile J, et al., 2012[87]	Retrospective study	107 patients (84 women, 23 women; average age 36.2 years old) with acute Achilles tendon rupture	Surgery: new technique "Pa-bone". Early rehabilitation post-surgery	Achilles tendon rupture score (ATRS), bilateral ultrasound	At ultrasound, cross sectional areas of ruptured tendon are significantly major than in the controlateral tendon	Early post-surgery kinesitherapy after "Pa-bone" surgery technique leads to excellent clinical results and it is useful to Achilles tendon reconstruction	III
Gigante A, et al., 2008[88]	RCT	40 patients (36 men, 4 women; average age 40.7 years old; range of age: 20-60) with acute Achilles tendon rupture related to indirect trauma	Open reparation (group A) or percutaneous reparation (group B) (randomization with Casio Scientific Calculator fix-88). Same rehabilitation protocol with minimal differences in immobilization time	Evaluation questionnaire (SF-121), bilateral ultrasound, isocinetic test	Not significantly differences in clinical evaluation, except ankle circumference, that significantly wider in group B. Not significantly differences between the groups in SF-121 questionnaire, ultrasound and isokinetic test	Open and percutaneous techniques are safe and effective for repair of calcanear tendon ruptures. Both the techniques lead to the same clinical, ultrasonography and isokinetic results	II

To be continued

Continued from **Table VI.**

Maffulli N, et al., 2003[89]	RCT	45 patients with subcutaneous Achilles tendon rupture diagnosed with clinical evaluation and confirmed with surgery	Group 1 (21 men, 4 women; average age 44 years old; range of age: 31-69): immobilization with ankle in physiological position (equine) for 2 weeks and in neutral position for 4 weeks. Weight bearing if comfortable and progressive increase; Group 2 (24 men, 4 women; average age 43.8 years old; range of age: 30-67): immobilization with ankle in equine for 2 weeks and in neutral position for 2 weeks. Plantar flexion between 4 and 6 weeks after surgery. Weight bearing when ankle is immobilizer in neutral position	Anthropometric evaluation, sural triceps isometric force, evaluation questionnaire, ultrasound	Group 1: few out patients visits, crutches for 2.5 weeks after surgery (group 2: on average 5,7 weeks after surgery) more patients satisfied of surgery. On ultrasound average repaired tendon thickness is 12,1 mm (SD=2), without differences in ruptured tendon thickness, regardless of post-surgery protocol. Not significantly differences between the two groups in isometric resistance	Early weight bearing with plantigrade load is not dangerous to result of reparation after Achilles tendon rupture	II

To be continued

Continued from **Table VI.**

Costa ML, et al., 2003[90]	RCT	28 patients (24 men, 4 women; average age: 41 years old) unilateral Achilles tendon rupture diagnosed with clinical evaluation	Group A: immediate weight bearing with cast; Group B: weight bearing with traditional plaster	Return to sport, flexion deficit; force deficit, ultrasound	Ultrasound evaluation of tenodesis: not negative effects of early weight bearing. Not significantly wider tendon diameter in group with cast. In group with immediate weight bearing: clinical anthropometric and functional improvements	Ultrasound evaluation confirms absence of deleterious effects on tenodesis	II
Maffulli N, et al., 2003[91]	RCT	53 patients subcutaneous Achilles tendon rupture diagnoses with clinical evaluation and confirmed with surgery	Group 1: post-surgery immobilization with ankle in equine, early weight bearing cast changed after 2 weeks with ankle in plantar flexion; Group 2: immobilization with ankle in equine, cast changed after 2 weeks, ankle in intermediate position after 4 weeks with weight bearing	Anthropometric evaluation; isometric force of sural triceps, ultrasound evaluation with high temporal resolution and at real time, evaluation questionnaire	Group 1: few outpatients visits, crutches for 2,5 weeks, satisfied of surgery. On ultrasound, average repaired tendon thickness is 12,1 mm, no differences in thickness of ruptured tendon regardless of post-surgery protocol. Not significantly differences between the two groups in isometric resistance	Early weight bearing with plantar flexion do not influence the results of reparation after Achilles tendon acute rupture and reduces time necessary to rehabilitation. However, force deficit and muscular atrophy are not prevented	II

To be continued

Continued from **Table VI.**

Möller M, et al., 2002[92]	RCT	65 patients (55 men, 10 women; average age 38.6 ± 8.3 years old) with Achilles tendon ruptured	Group A (35 patients): surgery; Group B (30 patients) no surgery	Ultrasound and magnetic resonance	Peritendineous reactions, oedema and deficit only in few patients. Not significantly differences between the two groups, except tendon elongation function, that significantly lower in no surgery group. No correlation between radiological and clinical results, such as muscular force, resistance and range of movement	The role of ultrasound and MRI during healing process after Achilles tendon ruptures is limited, because of a weak correlation with clinical results	II

cularity within and around repaired tendons and the total blood flow amount consistently and predictably decrease with time[229]. The increased vascularity showed by Power Doppler indicated a possible healing progress of repaired Achilles tendon and it persisted until avascular scar formation.

In the last years ultrasound elastosonography increased its diagnostic utility with the introduction of shear wave method (SWE), a non-invasive ultrasonographic imaging technique introduced in 2002 which has the advantage of being operator-independent, reproducible, and quantitative[230].

Healthy Achilles tendons have a hard elastographic pattern, whereas pathologic ones show a reduction in stiffness. After surgical treatment of a complete tear, tendon stiffness pattern gradually increases at 12, 24, and 48 weeks as the wound-healing process continues[230,231].

If an Achilles tendon re-rupture is suspected, sonographic diagnosis is more difficult due to the structural characteristics of the tendon, particularly if large fluid collections are present; a dynamic evaluation during ankle flexion and extension is helpful in revealing the gap of tendon discontinuity[224].

Magnetic resonance imaging

MR imaging can be useful to evaluate the healing process of a surgically treated Achilles tendon.

In almost all surgically repaired Achilles tendons, high signal intensity areas (on fluid sensitive sequences) at the rejoined tendon ends was identified. This finding was clearly seen between 6 weeks and 3 months postoperatively; 6 months after, this area had reduced greatly in size. The high-signal intensity findings on MR images seems to be correlate with the healing response and with the actual tendon tissue composition with respect to morphology and biochemistry[232].

Fujikawa, et al. explored the MRI features of normal healing of the expected residual gap in the Achilles tendon after surgical repair. MRI images showed visible gap on MR imaging on 4 weeks after surgery on T1-WI and T2-WI images, both after percutaneous repair and after open surgery. At 8 weeks a gap was visible on T1-weighted MR images in 80% after percutaneous repair and in 10% after open surgical repair; T2-weighted MR images showed a tendon gap in 63% but in none of the tendons in the open surgical repair group. After 12 weeks, neither T1-weighted nor T2-weighted images showed a tendon gap in both the two tendon's group[233].

Karjalainen, et al. analysed 21 surgically repaired Achilles tendon ruptures with imaging at 3 and 6 weeks, and at 3 and 6 months after surgery and found intratendinous area of high-intensity signal in almost all surgically repaired Achilles tendons (19/21) at 3 months after surgery on PD (proton density) and T2-WI[234].

Hahn, et al. demonstrated the postoperative MR course after flexor hallucis longus tendon transfer and described that full tendon integration can be expected only in half the patients and fatty muscle degeneration in

Table VII. Answer n. 5: Conservative treatment.

Author	Type of study	Protocol	Follow-up (months)	Outcome assessment	Results	Level of evidence
Neumayer F, et al.[98] 2010	Prospective not randomized	Dynamic cast and early mobilization	60	Leppilahti ankle score, isokinetic strenght	Good functional results	III
Metz R, et al.[99] 2008	RCT	Surgery *vs* conservative treatment	6	Isokinetic strenght, ROM	Not significant differences between the two groups	II
Willits K, et al.[100] 2010	RCT	Surgery *vs* conservative treatment	24	Re-ruptures, isokinetic strenght, ROM, Leppilahti score, calf circumference	Less complications with conservative treatment, similar functional results	I
Nillson-Helander K, et al.[7] 2010	RCT	Surgery *vs* conservative treatment	12	ATRS, functional tests	Not significant differences between the two groups	I
Soroceanu A, et al.[101] 2012	Meta-analysis of RCT	Surgery *vs* conservative treatment	-	Complications, strenght, calf circumference, functional tests	Less complications and similar functional results with early functional rehabilitation	I
Wilkins R, et al.[102] 2012	Meta-analysis of RCT	Open surgery *vs* conservative treatment	-	Re-ruptures and other complications	Less re-ruptures but major complications with surgery	I
Olsson N, et al.[103] 2013	RCT	Surgery + early rehabilitation *vs* conservative treatment	12	ATRS, functional tests, quality of life	Not significant differences between the two groups	I
Kaniki N, et al.[104] 2014	Comparative retrospective	Functional rehabilitation + PRP *vs* functional rehabilitation	24	Isokinetic strenght, ROM, calf circumference, Leppilahti score	Not significant differences between the two groups	III
Mark-Christensen T, et al.[105] 2014	Meta-analysis of RCT	Functional rehabilitation *vs* immobilization	-	Complications, strenght, ROM, return to work and to sport	Better results with the functional rehabilitation	II
Young SW, et al.[106] 2014	RCT	Early weight bearing *vs* not weight bearing for 8 weeks	24	Re-ruptures, return to work and to sport, pain, stiffness	Not significant differences between the two groups	I
Zhang H, et al.[107] 2015	Review of meta-analysis	Surgery *vs* conservative treatment	-	Complications, ROM, calf circumference, functional tests	Different complications for major re-ruptures with surgery, not other significant differences between the two groups	II
Lantto I, et al.[108] 2015	RCT	Surgery *vs* conservative treatment	18	Leppilahti score, isokinetic strenght	Similar functional results, but force, ROM and quality of life better with surgery	I

Table VIII. Answer n. 5: Conservative treatment.

Author	Type of study	N° of studies/patients	Topic	Results	Level of evidence
Khan RJ, et al.[109] 2010	Meta-analysis (RCTs)	12	• Conservative treatment *vs* surgery • Different techniques of tenorrhaphy	Surgery: less risk of recurrence and major risk of complications, in particular with open technique	I
Gigante A, et al.[88] 2008	RCT	40	Open *vs* percutaneous technique	Less complications and recovery time with percutaneous technique	II
Aviña Valencia JA, et al.[110] 2009	RCT	56	Open *vs* mini-invasive technique	Less complications and recovery time with mini-invasive technique	II
Kou J,[111] 2010	Guidelines	8	Open surgery - all outcomes	Attention at diabetic patients, smokers, >65 years old, sedentary, obese (BMI >30), neuropathic and with local or systemic dermatologic pathologies	IV
Wilkins R, et al.[102] 2012	Review of randomized studies	7	Conservative treatment *vs* surgery	Less incidence of recurrence with surgery	I
Jiang N, et al.[112] 2012	Review of randomized studies	10	Conservative treatment *vs* surgery	Surgery: major complications risk but early functional recovery and less risk of recurrence	I
Jones MP, et al.[113] 2012	Review of randomized studies or almost randomized	8 4	• Conservative treatment *vs* surgery • Open *vs* percutaneous technique	Less complications risk. Not differences in recurrence. Major infection risk with open technique. Not differences in sural nerve lesions, TVP and hematomas.	I
Wu Y, et al.[114] 2016	Review of meta-analysis	9	Conservative treatment *vs* surgery	Less risk of recurrence and major risk of complications with surgery	I

To be continued

Continued from **Table VIII.**

Miyamoto W, et al.[115] 2017	Retrospective	44	Double locked suture	Correct tendon tension, good functional results, early recovery	IV
Yang B, et al.[116] 2017	Meta-analysis of RCT and retrospective studies	12	Open *vs* percutaneous technique	• Open technique: major risk of deep infections • Percutaneous technique: major risk of sural nerve lesions, less surgery time, better AOFAS score • No significantly differences in recurrence incidence, in thrombotic risk, in ankle ROM, in sural triceps tropism	II
Del Buono A, et al.[117] 2014	Meta-analysis of RCT and retrospective studies	12	Open *vs* mini-invasive technique	Less complications and major ROM with mini-invasive technique	I
Li CG, et al.[118] 2017	Retrospective	24	Single bundle termino-terminal suture	After 1 year: mean AOFAS score: 92.4 ± 5.9. Not differences in dorsiflexion, plantar flexion and muscular tropism with contralateral limb	IV
Lewis N, et al.[119] 2003	Controlled on cadaver	/	Reparation with Teno Fix anchor	Good stumps approach, less risk of gap formation	III
Manent A, et al.[120] 2017	Controlled on cadaver	/	Differents techniques of tenorrhaphy	Bunnel technique: less risk of lengthening	III
Aktas S, et al.[121] 2007	Perspective	30	Termino-terminal suture *vs* augmentation	Less complications with termino-terminal suture	III
Oze Mr, et al.[122] 2016	Retrospective	23	Gastrocnemius rotation flap, associated with crural fascia incision	Mean AOFAS score: 98.2 ± 2.3 (range 93-100)	IV

Table IX. Answer n. 6: Sutures and materials.

Author	Type of study	Protocol	Follow-up (months)	Outcome assessment	Results	Level of evidence
Kocaoglu B, et al.[123] 2015	Perspective not randomized	Absorbable *vs* not absorbable suture	-	AOFAS hindfoot clinical outcome scores, return to work, complications	Less risk of complications with absorbable suture	II
Kara A, et al.[124] 2014	Case report	-	12	Post-surgery complications	Granuloma formation with non absorbable suture	V
Ollivere BJ, et al.[125] 2014	Case report	-	8	Post -surgery complications	Granuloma formation with FiberWire suture (silicone and polyethylene)	V
Baig MN, et al.[126] 2017	Perspective not randomized	Absorbable *vs* not absorbable suture	6	Complications (infections), Boyden score	Major risk of complications and worse Boyden score with absorbable suture	II
Sadoghi P, et al.[127] 2012	Systematic review	Different suture techniques evaluation (Kessler, Bunnell, Krackow, Achillon, Ma-Griffith, giftbox)	-	Resistance to rupture	Impossible to define better technique	II
Manent A, et al.[120] 2017	Perspective not randomized	Different suture techniques evaluation (double Kessler, double Bunnell, Krackow, Ma-Griffith)	-	Resistance to rupture•	• Double Bunnel: major resistance, less risk of tendon lengthening • Krackow technique: same resistance, major lengthening	III
Herbort M, et al.[128] 2008	Perspective not randomized	Bunnell *vs* Kessler on cavader	-	Resistance to cyclic loads	Similar biomechanical properties	II
McCoy BW, et al.[129] 2010	Perspective not randomized	Different suture techniques evaluation (double Kessler, double Bunnell, double Krackow)	-	Resistance to rupture	No differences in resistance	III

the gastrocnemius muscle and soleus muscle is commonly seen after this technique.[235]
The analysis of gadolinium contrast agent enhancement (Gd-CME) images shows larger high signal intensity alterations than on T1-WI before CME or on T2-WI; this finding slowly decreased with time and, at the 2-year MR follow-up, there was no significant intratendinous signal enhancement. This supports the hypothesis that the Gd-contrast agent interacts with the pathological intratendinous tendon healing process[232].
One year after surgery, adhesions between the tendon and the skin may be reported in as many as 40% of the patients[236]. The surgical wound scar may be clearly detected on MR images; there was no high signal intensity subcutaneous fat tissue on images and the tendon seemed to be attached to the skin at the site of the scar, thereby preventing the correct range of motion of the tendon[237].

Advanced MRI application
The use of diffusion tensor imaging (DTI) in musculoskeletal field keeps on growing not only in experimental settings but also in clinical practice, reflecting the information about the architectural organization of tissue. After surgical procedures the use of DTI may ascertain the microstructural properties and integrity restoration of the ruptured tendon during the healing process[238].

Table X. Answer n. 7: Use of autologous derived blood products.

Author	Year	Type of study	Level of evidence	N. of patients	Follow-up (months)	Technical notes
Sánchez M, et al.[130]	2007	Retrospective (S *vs* S+PRP)	III	12 (6 *vs* 6)	-	Intraoperative injection
Shepull T, et al.[131]	2011	RCT (S *vs* S+PRP)	II	30 (14 S *vs* 16 S+PRP)	12	Intraoperative injection
Kaniki N, et al.[104]	2014	Retrospective (S *vs* PRP)	III	145 (72 *vs* 73 PRP)	24	No surgery
De Carli A, et al.[132]	2016	Comparative (S *vs* S+PRP)	IV	30 (15 S *vs* 15 S+PRP)	6	Intraoperative injection and after 14 days
Alvitti F, et al.[133]	2017	Retrospective (S *vs* S+PRF *vs* control group)	IV	28 (9 S *vs* 11 S+PRF vs 8 control group)	6	PRF application
Zou J, et al.[134]	2017	RCT (S *vs* S+PRP)	II	36 (20 S *vs* 16 S+PRP)	24	Intraoperative injection

S, Surgery (tenorrhaphy); PRP, platelet-rich plasma; PRF, platelet-rich fibrin.

Sarman, et al. analysed pre and postoperative DTI imaging of the Achilles tendon of 16 patients with median duration of follow-up of 21 (range 6 to 80) months; the tendon fractional anisotropy values of the ruptured Achilles tendon were statistically significantly lower than those of the normal side (p=.001)[238].

Answer n. 13: Rehabilitation protocol after acute ruptures (Tabs. XV, XVI)

Answer n. 14: Rehabilitation protocol after chronic ruptures

Regardless of treatment, timing does not change, depending on biological healing[249-264].

Rate of recurrence

The American Academy of Orthopaedic Surgeons (AAOS) guidelines[265,111] published in. 2010, underline the necessity of a cast in the first phases after accident. A meta-analysis of 2012[266] reports a significantly rate of post-surgery re-rupture after plaster (3.5%) and after utilised of functional cast (5%). In other studies[267-269], the rate of recurrence is 3.3% after an accelerated rehabilitative protocol with functional cast and 11.4% with post-surgery plaster.

Rehabilitation protocol

An evidence based optimal protocol does not exist. In 2008, the Swansea Morriston Achilles Rupture Treatment (SMART) Programme was proposed[270]. Usually, it is recommended a cast at 30° of plantar flexion for 2 weeks with progressive weight bearing until 8°-9° weeks[240-271]. Other Authors recommend the use of a cast at 20° of equinism for the first weeks after tenorrhaphy until start of rehabilitative programme[272]. Full ankle and limb motion is recommended after 8-9 weeks and return to sport is allowed after 6-9 months[240-271]. There is no standard protocol but only some guidance according to biological healing time considering the better synthesis of collagene and the improvement of tendon viscoelastic properties after the first weeks. Physical therapy is a part of protocol reducing inflammatory processes and pain during physiotherapy[273].

Instrumental physiotherapy

Instrumental physiotherapy has therapeutic effects: analgesia, activation of local metabolism, relaxing or muscle tonification. Therefore, instrumental physiotherapy can be utilised in most of therapeutic and rehabilitative programmes in association with other methods[273].

Answer n. 15: Nutraceuticals (Tabs. XVII, XVIII)

Answer n. 16: Return to sport in Table XIX

Table XI. Answer n. 8: Open surgery.

Author	Year	Type of study	Level of evidence	N. of patients (P *vs* O *vs* C)	Follow-up	Surgery technique
Nilsson-Helander K, et al.[7]	2010	RCT	I	97 (49 *vs* 48)	1 y	O *vs* C
Keating JF, et al.[135]	2011	CT	II	80 (41 *vs* 39)	1 y	O *vs* C
Nistor L[136]	1981	RCT	II	105 (45 *vs* 60)	2.5 y	O *vs* C
Cetti R, et al.[137]	1993	RCT	II	111 (65 *vs* 55)	1 y	O *vs* C
Möller M, et al.[138]	2001	RCT	II	112 (59 *vs* 53)	2 y	Modified Kessler *vs* C
Twaddle BC, et al.[139]	2007	RCT	II	50 (25 *vs* 25)	1 y	O vc C
Willits K, et al.[100]	2010	RCT	II	144 (72 *vs* 72)	2 y	O *vs* C
Kołodziej L, et al.[140]	2013	RCT	II	47 (22 *vs* 25)	3-24 m	Achillon *vs* Krackow
Gigante A, et al.[88]	2008	RCT	II	40 (20 *vs* 20)	1 y	Tenolig *vs* Kessler
Cretnik A, et al.[141]	2005	CT	II	237 (132 *vs* 105)	2 y	P *vs* O
Aktas S, et al.[142]	2009	RCT	II	40 (20 *vs* 20)	10-48 m	Achillon *vs* Krakow
Karabinas PK[143]	2014	RCT	II	34 (19 *vs* 15)	9-24 m	Ma and Griffit *vs* Krackow
Lim J, et al.[144]	2001	RCT	II	66 (33 *vs* 33)	NA	Ma-Griffit *vs* Krackow
Aviña Valencia JA, et al.[110]	2009	RCT	II	56 (28 *vs* 28)	4 m	Achillon *vs* Linn
Henriquez H, et al.[145]	2012	Retrospective	III	32 (17 *vs* 15)	6-48 m	Dresden *vs* Kessler
Carmont MR, et al.[146]	2013	Retrospective	III	84 (49 *vs* 35)	18-70 m	P *vs* Kessler
Miller D, et al.[147]	2005	Retrospective	III	140 (54 *vs* 86)	3-12 m	Ma-Griffit *vs* Kessler
Chan AP, et al.[148]	2011	Retrospective	III	19 (10 *vs* 9)	2-12 m	Achillon *vs* Krackow
Goren D, et al.[149]	2005	Retrospective	III	20 (10 *vs* 10)	6-39 m	P (Ma-Griffit) *vs* O (Krackow)
Daghino W, et al.[150]	2016	Retrospective	III	140	6 m	M (Achillon) *vs* O
Haji A, et al.[151]	2004	Retrospective	III	108 (38 *vs* 70)	NA	Ma and Griffith *vs* Bunnell
Lewis N, et al.[119]	2003	Comparative on cadaver	III	10	NA	Teno Fix *vs* two-strand modified Kessler repair
Zhao HM, et al.[152]	2011	Case series	IV	6	2 y	Bundle to bundle suture
Li CG, et al.[118]	2017	Case series	IV	24	1 y	Tendon-bundle technique
Ozer H, et al.[122]	2016	Case series	IV	23	1 y	Tenorrhaphy + gastrocnemius flap
Miyamoto W, et al.[115]	2017	Case series	IV	44	2 y	Double side-locking loop suture

P, percutanous tenorrhaphy; M, mini-invasive tenorrhaphy; O, open surgery; C, conservative treatment; NA, no application.

Table XII. Answer n. 9: Minimally invasive surgery.

Author	N. of patients	Follow-up (months)	Variable evaluated	Results	Complications	Level of evidendce	Return to sport	Type of surgery
Rebeccato A, et al.[153] (2001)	22	21	Objective and subjective evaluation, RMN	Objective and subjective improvement, RMN improvement	1 re-rupture; 1 incision healing delayed	III	Not evaluated	Open *vs* mini-open *vs* percutaneous
De Carl A, et al.[154] (2009)	20	52	Objective and subjective evaluation, functional tests (Ergo-jump Bosco System)	Objective and subjective improvement, dynamic scores improvement	4 incision adherences	III	85%	Mini-open
Ng ES, et al.[155] (2006)	25	65,5	Surgery complications	Less complications in mini-open group, similar clinical results	3 minor complications (1 hypertrophic scar, 2 superficial infections)	III	96%	Open *vs* mini-open (double-ended needle)
Bhattacharyya M, et al.[156] (2009)	25	14	Objective and subjective evaluation	Objective and subjective improvement, cost reduction	No complications	III	Not evaluated	Mini-open (Achillon system) *vs* open
Mukundan C, et al.[157] (2010)	21	12	Functional scores (Leppilahti score, AOFAS)	Functional scores improvement (Leppilahti score, AOFAS)	No complications	III	95%	Mini-open (Achillon system)
Aktas S, et al.[142] (2009)	20	22,4	Objective and subjective evaluation, functional scores (AOFAS) and complications	No significantly difference in AOFAS, less complications rate	1 insertional tendinopathy	I	89%	Mini-open (Achillon system) *vs* open
Vadalà A, et al.[158] (2012)	80	58	Functional scores (Hannover score, VISA-A), ultrasound	Functional scores improvement (Hannover score, VISA-A), ultrasound improvement	12 minor complications (1 hypertrophic scar, 9 incision adherences, 2 incision healing delayed)	III	84%	Combined mini-open and percutaneous
Vadalà A, et al.[159] (2014)	36	28	Functional scores (Hannover score, VISA-A), ultrasound	Functional score improvement (Hannover score, VISA-A), ultrasound improvement	6 minor complications (2 incision adherences, 1 hypertrophic scar, 3 superficial infections).	III	91%	Combined mini-open and percutaneous

To be continued

Continued from **Table XII.**

Keller A, et al.[160] (2014)	100	42.1	Objective and subjective evaluation, AOFAS and complications Isokinetic test (21 patients)	Objective and subjective improvement, isokinetic evaluation: full recovery of gastrocnemius and soleus function	2 re-ruptures; 5 TVP;	IV	85%	Dresden mini-open
Klein EE, et al.[161] (2012)	18	12-108	Objective and subjective evaluation, VISA-A score and complications	Objective and subjective improvement	1 re-rupture; 1 complications incision	III	Not evaluated	Mini-open (Achillon system) *vs* open
Barte AF, et al.[162] (2014)	253	19,2	Complications	Incidence of complications acceptable, in relation to the other surgery techniques	Re-ruptures 8; incision complications: 5; sural nerve lesions: 3; infections: 2; suture irritation: 3	Systematic review	Not evaluated	-
De Carli A, et al.[132] (2016)	30	28	Functional scores (VAS, FAOS, VISA-A), ultrasound and RMN	Functional scores improvement (VAS, FAOS, VISA-A), ultrasound and RMN improvement	5 minor complications (3 incision healing delayed, 2 incision adherences)	IV	100%	Mini-open
Daghino W, et al.[150] (2016)	68	6-53	Objective evaluation and complications	Objective improvement, quality of life improvement	2 major complications (2 re-ruptures); 2 minor complications (2 incision adherences)	III	87,50%	Mini-open (Achillon system) *vs* Open
Taștan E, et al.[163] (2016)	20	58,5	Functional scores (AOFAS)	Functional scores improvements (AOFAS)	No complications	III	100%	Mini-open (Achillon system)

Table XIII. Answer n. 10: Percutaneus surgery.

Author	Year	Type of study	Level of evidence	N. of patients (P *vs* O)	Follow-up (months)	Type of surgery
Karabinas PK, et al.[143]	2014	RCT (P *vs* O)	I	34 (19 *vs* 15)	22	Ma and Griffith
Gigante A, et al.[88]	2008	RCT (P *vs* O)	I	40 (20 *vs* 20)	24	Tenolig®
Lim J, et al.[144]	2001	RCT (P *vs* O)	I	66 (33 *vs* 33)	6	Ma and Griffith
Jallageas R, et al.[164]	2013	Comparative (P *vs* O)	II	31 (16 *vs* 15)	15	Tenolig®
Cretnik A, et al.[141]	2005	Comparative (P *vs* O)	II	237 (132 *vs* 105)	24	Ma and Griffith
Zayni R, et al.[165]	2017	Retrospective (P *vs* O)	III	29 (16 *vs* 13)	46	Tenolig®
Henriquez H, et al.[145]	2012	Retrospective (P *vs* O)	III	32 (17 *vs* 15)	18	Tenolig®
Taglialavoro G, et al.[166]	2011	Retrospective (P *vs* P)	III	60 (30 *vs* 30)	24	Ma and Griffith *vs* Tenolig®
Haji A, et al.[151]	2004	Retrospective (P *vs* O)	III	108 (38 *vs* 70)	Not reported	Ma and Griffith
Bradley JP, et al.[167]	1990	Comparative (P *vs* O)	III	27 (12 *vs* 15)	Not reported	Ma and Griffith
Tenenbaum S, et al.[168]	2010	Case series	IV	29	32	Ma and Griffith
Maes R, et al.[169]	2006	Case series	IV	124	23	Tenolig®
Lacoste S, et al.[170]	2014	Case series	IV	75	21	Tenolig®

P, percutaneous tenorrhaphy; O, open surgery.

Answer n. 17: Outcome evaluation devices (Indirect determination of Achilles tendon force during locomotion by motion analysis techniques)

The position of selected anatomical landmarks of the lower limb and the foot-to-ground reaction force, as collected during terrestrial locomotion, represent the experimental data that are sufficient to solve the inverse dynamic problem and estimate the so-called "intersegmental couple" (IC) at the ankle[359]. IC can be considered as a muscle-equivalent representation of the angular actuator responsible for the motion of the foot about the ankle joint center in the sagittal plane during the ground-contact phase. IC results from the contributions of the moments due to: the ground reaction force acting on the foot; the segment's weight; the acceleration force of the segment's center of mass; the segment's angular acceleration[360]. All these quantities can be easily gathered in a motion analysis laboratory. When the sign of IC is negative[361]. The tensile force of the Achilles tendon (AT) can be computed as the ratio between IC and the AT lever arm with respect to the ankle joint center[362]. In fact, as the main plantar-flexor muscles of the ankle converge in the AT and no optimization may be needed as no plantar-flexor muscles redundancy occurs[363]. The AT lever arm is typically estimated from scaled generic musculoskeletal models[364]. A high level of association and a low bias were found between the AT force estimated through inverse dynamics and that measured *in vivo* with an implanted force transducer[365].

Several are, however, the limitations of such approach. First, the assumption that IC can be uniquely addressed to the plantar-flexors muscles (hence, excluding co-contraction of antagonist muscles[362] and neglecting the contribution of passive forces exerted by ligaments[366]). Second, the accuracy of the estimated AT force strongly depends on the reliability of the collected experimental data (anatomical landmarks identification and skin artefact in the first place[367-369]) and on the chosen musculoskeletal model (inertial parameters and musculoskeletal geometries are based on generic models scaled on the subject's proportions)[370]. For this latter reason, the scientific community has been recently focusing on the availability of imaging techniques to assess subject-specific musculoskeletal geometries simultaneously to motion data collection to estimate ankle dynamics[371-373].

Table XIV. Answer n. 11: Tendon transfer.

Author	Year	Type of study	Level of evidence	N. of patients	Follow-up (months)	Type of surgery
Maffulli N, et al.[171]	2005	Cohort study	III	21	24	Free autologous gracilis tendon graft
El Shewy MT, et al.[172]	2009	Case series	IV	11	90	Intratendinosus flaps from gastrocnemius-soleus complex
Maffulli N, et al.[173]	2010	Case series	IV	32	72	Peroneus brevis tendon transfer
Us AK, et al.[174]	1997	Case series	IV	6	16	V-Y gastrocnemius recession, end to end anastomosis and gastrocnemius aponeurotic flap
Kissel CG, et al.[175]	1994	Case series	IV	4	38	V-Y gastrocnemius recession, end to end anastomosis and plantaris tendon weaving
Esenyel CZ, et al.[176]	2014	Case series	IV	10	43,2	Turndown gastocnemius-soleus fascial flap
Guclu B, et al.[177]	2016	Retrospective comparative study	III	17	195	V-Y tendon plasty with fascia turndown
Rush JH, et al.[178]	1980	Case series	IV	5	18-24	Gastrocnemius-soleus aponeurotic flap turndown
Wapner KL, et al. [179]	1993	Case series	IV	7	17	Flexor hallucis longus tendon transfer
Pintore E, et al.[180]	2001	Comparative (A *vs* C)	II	59	53	Peroneus brevis tendon transfer
Ademoglu Y, et al.[181]	2001	Case series	IV	4	39,2	Peroneus brevis tendon transfer
Wong MW, et al.[182]	2005	Case series	IV	5	28,8	Flexor hallucis longus tendon transfer
Elias I, et al.[183]	2007	Case series	IV	15	26,5	V-Y leghtening and flexor hallucis longus tendon transfer
Mahajan RH, et al.[184]	2009	Case series	IV	36	12	Flexor hallucis longus tendon transfer
Maffulli N, et al.[185]	2012	Case series	IV	16	185	Peroneus brevis tendon transfer
Rahm S, et al.[186]	2013	Retrospective comparative series (tt *vs* to)	III	40	73-35	Flexor hallucis longus tendon transfer
Dumbre Patil SSD, et al.[187]	2014	Case series	IV	35	30,7	Semitendinosus tendon autograft
Singh A, et al.[188]	2014	Case series	IV	22	12	Peroneus brevis tendon augumentation
Khiami F, et al.[189]	2013	Retrospective	IV	23	24,5	Free sural triceps aponeurosis transfer
Maffulli N, et al.[190]	2015	Case series	IV	17	54	Peroneus brevis tendon transfer
Ahmad J, et al.[191]	2016	Case series	IV	32	62,3	Flexor hallucis longus tendon transfer
Gedam PN, et al.[192]	2016	Retrospective comparative	III	14	30,1	Central turndown flap with free semitendinosus tendon graft
Maffulli N, et al.[193]	2013	Case series	IV	26	31,4	Free semitendinosus tendon graft

To be continued

Continued from **Table XIV.**

Author	**Year**	**Type of study**	**Level of evidence**	**N. of patients**	**Follow-up (months)**	**Type of surgery**
Mann RA, et al. [194]	1991	Case series	IV	7	39	Flexor digitorum longus tendon graft
Elgohary HEA, et al.[195]	2016	Case series	IV	19	29	Flexor hallucis longus tendon transfer
Miao X, et al.[196]	2016	Case series	IV	32	32,2	Flexor hallucis longus tendon transfer
Maffulli N, et al.[197]	2015	Cohort study	III	21	54	Peroneus brevis tendon transfer
Yeoman TF, et al.[198]	2012	Case series	IV	11	6	Flexor hallucis longus tendon transfer
Park YS, et al.[199]	2012	Retrospective (VY *vs* G *vs* FHL)	III	12	36,2	V-Y advancement, gastrocnemius fascial turndown flap, FHL tendon transfer
Sarzaeem MM, et al.[200]	2012	Case series	IV	11	25	Free semitendinosus tendon graft
Zheng L, et al.[201]	2011	Case series	IV	10	8-48	Peroneus brevis tendon transfer
Wegrzyn J, et al.[202]	2010	Case series	IV	11	79	Flexor hallucis longus tendon transfer
Lee KB, et al.[203]	2009	Case series	IV	3	18-24	Flexor hallucis longus tendon transfer
Fotiadis E, et al.[204]	2008	Case series	IV	9	44	Plantaris tendon transfer and Duthie's biological repair
Lui TH, et al.[205]	2007	Case series	IV	3	15	Flexor hallucis longus tendon transfer
Miskulin M, et al.[206]	2005	Case series	IV	5	12	Peroneus brevis tendon transfer and plantaris tendon Augumentation
Dalal RB, et al. [207]	2003	Case series	IV	2	Not reported	Flexor hallucis longus tendon transfer
Seker A, et al.[208]	2016	Case series	IV	21	145,3	Gastrocnemius fascial flap
Lapidus LJ, et al.[209]	2012	Case series	IV	9	60	Achilles tendon island flap
Takao M, et al.[210]	2003	Case series	IV	10	26-192	Gastrocnemius fascial flap
Ozan F, et al.[211]	2017	Comparative (V *vs* L)	II	15	19.6	Lindholm and Vulpius tecnique
Sanada T, et al.[212]	2017	Case series	IV	56	6	Free gastrocnemius aponeurotic flap
Maffulli N, et al.[213]	2014	Case series	IV	28	24	Semitendinosus tendon autograft
El Shazly O, et al.[214]	2014	Case series	IV	15	27	Free hamstring tendon autograft
Tay D, et al.[215]	2010	Case series	IV	6	24	Turndown tendon flaps
Nilsson-Helander K, et al.[216]	2008	Case series	IV	28	29	Free gastrocnemius aponeurotic flap
Tawari AA, et al.[217]	2013	Case series	IV	20	18	Peroneus brevis tendon transfer
Oksanen MM, et al.[218]	2014	Case series	IV	7	27	Flexor hallucis longus tendon transfer

A, acute rupture; C, chronic rupture; tt, transtendineous technique; to, transosseus technique; VY, V-Y plasty; G, gastrocnemius fascial flap; "FHL", flexor hallucis longus tendon transfer; V, Vulpius tecnique; L, Lindholm tecnique.

Table XV. Answer n. 13: Rehabilitation protocol after acute ruptures. Open Surgery.

Author	Year	Type of study	Level of evidence	N. of patients (P *vs* O)	Follow-up (months)	Treatment groups
Valkering KP, et al.[239]	2017	RCT	II	56 (27 *vs* 29)	12	• Mobilized and FWB group • Immobilized and NWB group
Lantto I, et al.[240]	2015	RCT	I	50 (25 *vs* 25)	132	• Early mobilization group • Immobilization in tension group
Suchak AA, et al.[241]	2008	RCT	I	110 (55 *vs* 55)	6	• Weight-Bearing as tolerated Group • NBW group
Costa ML, et al.[242]	2006	RCT	II	48 (23 *vs* 25)	12	• Treatment Group • Control Group
Maffulli N, et al.[91]	2003	Case-control study	III	53 (26 *vs* 27)	4.5	• Group 1 • Group 2
Kangas J, et al.[243]	2003	RCT	II	50 (25 *vs* 25)	15	• Group I • Group II
Kerkhoffs GM, et al.[244]	2002	RCT	II	39 (23 *vs* 16)	80	• Cast group • Wrap group
Mortensen HM, et al.[245]	1999	RCT	II	61 (31 *vs* 30)	24	• Early Motion group • Cast group

FBW, complete weight bearing; NBW, no weight bearing.

Table XVI. Answer n. 13: Rehabilitation protocol after acute ruptures. Minimally invasive or percutaneous surgery.

Author	Year	Type of study	Level of evidence	N. of patients (P *vs* O)	Follow-up (months)	Treatment Groups
De la Fuente C, et al.[246]	2016	RCT	II	38 (19 *vs* 19)	3	• Conventional group • Aggressive group
Groetelaers RP, et al.[247]	2014	RCT	II	60 (32 *vs* 28)	12	• Functional group • Immobilization group
Majewski M, et al.[248]	2008	Case-control study	III	28 (14 *vs* 14)	12	• Cast group • Shoe group

Prediction of AT force during terrestrial locomotion: difference with respect to methods, to the computational approach and to the adopted musculoskeletal model in Table XX.

Answer n. 18: Acute ruptures in the childhood in Table XXI.

Project management
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Table XVII Answer n. 15: Nutracenticals. Clinical studies about the characteristics in the use of nutraceuticals for therapy of tendinopathies.

Author/Year	Pathology	Type of nutraceutical and composition	Type of study/N. of patients	Groups compared
Notarnicola A, et al. 2012 [274]	Insertional Achilles tendinopathy	Tenosan® (L-arginine-α-ketoglutarate, methylsulfonylmethane, type I hydrolazate collagen, Vinitrox™, bromelain, vitamin C)	RCT (placebo) g-t: 32 g-c: 32>26	g-t: ESWT + Tenosan® g-c: EWTS + placebo Dosage: 2 bags/day for 60 days before main meal
Balius R, et al. 2016[275]	Non-insertional painful Achilles tendinopathy	Tendoactive® (mucopolysaccharids, type I collagen, vitamin C)	RCT (no placebo) g-t 1: 19>17 g-t 2:. 20 g-c: 19->18	-t 1: EC + Tendoactive® g-t 2: PS + Tendoactive® g-c: EC Dosage: 3 capsules/day for 12 weeks
Hai-Binh B, et al. 2014 [276]	Various tendinopathies (Achilles tendon, sopraspinatus, lateral epicondyle, plantar fascitis)	Tendoactive® (mucopolysaccharids, type I collagen, vitamin C)	RCT (placebo) g-t: 30 g-c: 30	g-t: Tendoactive® g-c: placebo Dosage: 2 capsules/day for 90 days
Nadal F, et al. 2009[277]	Various tendinopathies (Achilles tendon, sopraspinatus, lateral epicondyle, plantar fascitis)	Tendoactive® (mucopolysaccharids, type I collagen, vitamin C)	RCT (no placebo) g-t: 10 g-c: 10	g-t: rehabilitation + Tendoactive® g-c: rehabilitation Dosage: 2.16 g/day for 3 months
Arquer A, et al. 2014[278]	Various tendinopathies (Achilles tendon n=32, patellat tendon n=32, lateral epicondyle n=34)	Tendoactive® (mucopolysaccharids, type I collagen, vitamin C)	Perspective not controlled explorative study of phase IV n=98->70	Dosage: 3 capsules/day for 90 days
Mavrogenis S, et al. 2004 [279]	Chronic tendon disorders*	Bio-Sport® Essential fatty acids (EPA, DHA, GLA) + antioxidants (selenium, zinc, vitamin A, vitamin B6, vitamin C, vitamin E)	RCT (placebo, double blinded) on athletes g-t:. 20->17 g-c:. 20->14	g-t: ultrasounds + supplements c-g: ultrasounds + placebo Dosage: 8 capsules/day essential fatty acids + 1 antioxidants for 32 days

EC, eccentric exercise; PS, passive stretching; g-t, treated group; g-c, control group; ESWT, Extracorporeal shock wave therapy; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; GLA, gamma-linolenic acid; *Chronic tendon disorders.
NB: Balius - Hai-Bin - Arquer - Nadal: same supplement (Tendoactive®).

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Table XVIII. Answer n. 15: Nutracenticals. Clinical studies about the use of nutraceuticals for therapy of tendinopathies.

Author/Year	Outcome assessments	Follow-up	Results
Notarnicola A, et al. 2012[274]	Tenosan® efficacy combined with shock waves in insertional Achilles tendinopathy management Primary endpoints (clinical and functional effects) VAS score[a] Ankle-Hindfoot Scale[b] (pain, function, alignment) Roles and Maudsley score (subjective improvement perception)[c] Secondary endpoint (neoangiogenesis) Tissue oximetry	2 and 6 months	VAS score significantly lower in both groups during the study. At 6 months, VAS score significantly lower in the group with combined treatment (average score: 2.0 *vs* 2.9, $p=0.04$), although difference <2 points (threshold clinically significantly) Ankle-Hindfoot Scale significantly improved scores only in the group with combined treatment during the study. At 2 and 6 months, improved scores in the group with combined treatment (average at 6 months: 92.4 *vs* 76.5, $p=0.0002$) At 2 and 6 months, improved scores (lower) in Roles and Maudsley score in the group with combined treatment (average at 6 months: 1.5 *vs* 2.3, $p<0.0001$) Significantly lower scores at oximetry in both groups due during the study; only at 6 months significantly difference between the two groups in favor of the group with combined treatment (average 60.2 *vs* 66.0, $p=0.007$)
Balius R, et al. 2016 [275]	Tendoactive® efficacy combined with eccentric physical exercise to improve non-insertional painful Achilles tendinopathy symptoms Primary endpoint VISA-A questionnaire score[d] (function and pain) Secondary endpoints VAS score for pain[a] at rest and during activity Tendon thickness (ultrasound)	6 and 12 weeks	At 12 weeks, VISA-A score significantly improved (higher) in the 3 groups. No significantly difference between the groups at VISA-A score At 12 weeks, VAS score at rest and during activity significantly reduced in the 3 groups. Significantly difference in reduction of VAS score at rest in the Tendoactive® + PS group compared with EC (-3.7 *vs* -2.7, $p<0.005$); borderline difference at VAS during activity (-4.4 Tendoactive® + PS *vs* -3.5 EC, $p=0.074$). At 12 weeks, no significantly difference in tendon thickness between the 3 groups; significantly reduction from baseline to 12 weeks only in Tendoactive® +PS group (-0.63 mm). In analysis stratified on pathology stage (reactive/degenerative tendinopathy): no significantly differences between the treated groups in both stages; VAS score at rest significantly lower in Tendoactive® + PS group than in EC (-3.82 *vs* -2.80, $p<0.005$) in patients with reactive tendinopathy; VAS score at rest and during activity similar between the groups in patients with degenerative tendinopathy; significantly reduction of tendon thickness from baseline only in Tendoactive® + PS group in patients with degenerative tendinopathy
Hai-Binh B, et al. 2014 [276]	Tendoactive® efficacy and safety in management of different tendinopathies Swelling, heat, redness (clinical evaluation) VAS score for pain[a] Tendinopathy (ultrasound)	Monthly during the study (90 days)	Progressively reduction of presence of swelling, heat, redness in both groups; lower in the experimental group at every monthly control VAS score significantly reduced in both groups during the study. At 90 days, VAS score significantly lower in the experimental group (average: 2.5 *vs* 3.2, $p<0.05$) At 90 days, no patient in the experimental group has diagnosis of tendinopathy (% placebo group not reported by Authors)

To be continued

Continued from **Table XVIII.**

Author/Year	Outcome assessments	Follow-up	Results
Nadal F, et al. 2009 [277]	Tendoactive® efficacy in treatment of different tendinopathies Pain SF36 (Quality of life) Functional evaluation by physiotherapist	1, 2 and 3 months	Significantly reduction of pain in the experimental group for every pathology, except for epicondylitis Improved of SF36 in every group of pathology At 3 months significantly improvement of function for every tendinopathies. (Results of placebo group not reported by Authors)
Arquer A, et al. 2014 [278]	Tendoactive® efficacy and safety in treatment of different tendinopathies VAS score for pain[a] at rest and during activity Function (VISA-A score for Achilles tendon, VISA-P for patellar tendon, PRTEE for elbow) Ultrasound structural parameters (tendon thickness, effacement of the paratenon, eteroechogenicity and hypoechogenicity levels, neovascularization)	30, 60, 90 days	3 groups based on pathology: Achilles tendinopathy (AQ), patellar tendinopathy (RO), lateral epicondylitis (EPI) Significantly reduction of VAS score at rest and during activity in the 3 groups at 30, 60 and 90 days. At 90 days, compared to baseline, the pain at rest is reduced of 80% in AQ, of 71% in RO and of 91% in EPI; pain during activity reduced of 82% in AQ, 73% in RO and 81% in EPI Significantly improvement of VISA-A, VISA-P and PRTEE at 30, 60 and 90 days. At 90 days, compared to baseline, improvement of 38%, 46% and 77% in AQ, RO, and EPI Significantly reduction in tendon thickness in the 3 groups (at 90 days: 12% in AQ, 10% in RO and 20% in EPI). In EPI group reduction during all period; in AQ and RO groups reduction at 60 days, after stable at 90 Improved of all structural parameters in the 3 groups. Paratenon blurred and levels of heteroechogenicity and hypoechogenicity significantly improved in AQ and EPI; level of hypoechogenicity not significantly improbe in RO group (*p*=0.07); neovascularization significantly improbe only in EPI group
Mavrogenis S, et al. 2004[279]	Efficacy of suppluement combined with phyisiotherapy in treatment of chronic tendinopathies in athletes Primary endpoints VAS score for pain[a] VAS score for pain[a] after isometric test Secondary endpoints Physical activity	8, 16, 24 and 32 days	VAS score lower duraing the study in both groups. At 32 days, statistically significantly difference between the groups in favor of experimental group ($p<0.001$) (VAS score reduced 99% in experimental group and 31% in control group). Similar results of VAS score after isometric test: at 32 days, score significantly lower ($p<0.001$) in experimental group (VAS score reduced 99% in experimental group and 37% control group) At 32 days, improved sport activity compared to basal (53% in experimental group and 11% control group No adverse events in both groups

EC, eccentric exercise; PRTEE, Patient-Rated Tennis Elbow Evaluation; PS, passive stretching; SF, short-form; VAS, visual analog scale; VISA-A, Victorian Institute of Sports Assessment-Achilles; VISA-P, Victorian Institute of Sports Assessment-Patella.

[a] VAS: range 0-10 (10=severe pain; 0=no pain).

[b] Ankle-Hindfoot Scale: range 0-100 (100=no pain, no limitations, good alignment; 0=severe pain, severe limitations, severe misalignment).

[c] Roles and Maudsley score: range 1-4 (4=no satisfaction or low satisfaction of the treatment, 1=good satisfaction of the treatment).

[d] VISA-A questionnaire: range 0-100 (higher scores for better functionality and lower pain).

Table XIX. Answer n. 16: Return to sport.

Author	N. of patients	Groups	% return to sport	Variables analyzed
Ahmad J, et al.[280]	30	1	NR	FAAM Sports Subscale
Aktas S, et al.[142]	40	1	87	AOFAS
Aktas S, et al.[121]	30	1	86.9	AOFAS
Al-Mouazzen L, et al.[281]	30	1	NR	ATRS
Amin NH, et al.[282]	18	1	61	NBA Player Efficiency Rating
Amlang MH, et al.[283]	39	1	51	AOFAS
Ateschrang A, et al.[284]	104	1	64.4	Thermann Score
Barfod KW, et al.[271]	56	1	18.6	ATRS
Bassi JL, et al.[285]	11	2	100	
Bevoni R, et al.[286]	66	2	98.5	AOFAS, Leppilahti
Bostick GP, et al.[287]	84	2	84	
Boyden EM, et al.[288]	10	2	80	Boyden Scale
Carmont MR, et al.[289]	26	1	61	Tegner Score
Ceccarelli F, et al.[290]	24	1	91.7	AOFAS
Chandrakant V, et al.[291]	52	1	90	AOFAS
Chen Z, et al.[292]	76	1	100	
Chiu CH, et al.[86]	19	1	94.7	Tegner Score, AOFAS
Coutts A, et al.[293]	25	1	80	
Cretnik A, et al.[141]	237	1	72.1	AOFAS
Cretnik A, et al.[294]	116	1	96	AOFAS
Cretnik A, et al.[295]	13	2	100	AOFAS
De Carli A, et al.[154]	20	1	70.5	
Demirel M, et al.[296]	78	1	77.1	
Doral MN,[297]	32	1	100	FAOS, ATRS
Eames MHA, et al.[298]	32	1	63	
Feldbrin Z, et al.[299]	14	1	100	AOFAS
Fernández-Fairén M, et al.[300])	29	2	96.6	AOFAS
Fortis AP, et al.[301]	20	1	100	
Garabito A, et al.[302]	49	1	89.8	AOFAS

To be continued

Continued from **Table XIX.**

Garrido IM, et al.[303]	18	2	72.2	AOFAS
Goren D, et al. [149]	20	1	55	
Gorschewsky O, et al.[304]	20	2	100	
Gorschewsky O, et al.[305]	66	2	100	
Groetelaers RP, et al.[247]	55	1	39	ARPS
Guillo S, et al.[306]	23	1	80	ATRS, Boyden Scale
Halasi T, et al.[307]	144	1	60.7	
Hohendorff B, et al.[308]	42	1	88.6	Thermann score
Hufner TM, et al.[309]	125	2	75.2	
Jaakkola JI, et al.[310]	55	2	90.9	AOFAS
Jacob KM, et al.[311]	46	1	88.9	
Jallageas R, et al.[164]	31	1	77.5	AOFAS
Jennings AG, et al.[312]	30	1	63.6	Tennier
Josey RA, et al.[313]	39	1	66.7	AOFAS, Thermann score
Jung HG, et al.[314]	30	2	90	
Kakiuchi M, et al.[315]	22	1	45.5	
Karabinas PR, et al.[143]	34	2	NR	AOFAS
Karkhanis S, et al.[316]	107	2	77	ATRS
Keating JF, et al.[135]	80	1	66.9	
Kelle A, et al.[160]	100	1	80	
Klein EE, et al.[161]	34	2	100	VISA-A
Knobe M, et al.[317]	64	1	36.6	
Kolodziej L, et al.[140]	47	1	46	
Korkmaz M, et al.[318]	47	1	NR	PASS
Kraus R, et al.[319]	36	1	53	
Labib SA, et al.[320]	44	1	65.71	
Lacoste S, et al.[170]	75	1	63.6	ATRS, AOFAS
Lansdaal JR, et al.[321]	163	1	59.5	Leppilahti Score
Lee DK,[322]	11	2	NR	
Leppilahti J, et al.[323]	101	1	85.7	Boyden Scale
Macquet AJ, et al.[324]	87	1	68.1	

To be continued

Continued from **Table XIX.**

Maffulli N, et al.[91]	53	1	92.5	Modified VISA-A
Maffulli N, et al.[325]	17	2	94	ATRS
Maffulli N, et al.[326]	27	2	50	ATRS
Majewski M, et al.[327]	84	1	100	Hannover Achilles tendon score
Majewski M, et al.[248]	28	1	65.2	Hannover Achilles tendon score
Mandelbaum BR, et al.[328]	29	1	100	
Maniscalco P, et al.[329]	7	1	100	Mandelbaum and Pavanini evaluation
Martinelli B, et al.[330]	30	1	100	
McComis GP, et al.[331]	15	1	66	
Metz R, et al.[99]	83	1	72.8	Leppilahti score
Metz R, et al.[332]	210	1	50	ATRS
Miller D, et al.[147]	111	1	88	
Möller M, et al.[138]	112	1	54	Functional index of lower limbs
Mortensen HN, et al.[333]	57	1	70	
Mortensen HN, et al.[245]	61	1	54.1	
Motta P, et al.[334]	71	1	28	
Mukundan C, et al.[157]	21	1	95.2	AOFAS, Leppilahti
Nestorson J, et al.[335]	25	1	36	
Nilsson-Helander R, et al.[7]	97	1	NR	PAS, ATRS
Olsson N, et al.[103]	100	1	NR	PAS, ATRS, FAOS
Orr J, et al.[336]	15	2	100	AOFAS
Ozsoy M, et al.[337]	13	1	92	AOFAS
Pajala A, et al.[338]	60	1	100	Leppilahti score
Parekh SG, et al.[339]	31	1	64.3	Power rating (pre-surgery and during match)
Park HG, et al.[340]	14	2	NR	
Rajasekar K, et al.[341]	35	1	50	Accidents questionnaire
Rebeccato A, et al.[153]	59	1	98.4	
Rettig AC, et al.[342]	89	1	100	
Richardson LC, et al.[343]	30	1	77	AOFAS
Sánchez M, et al.[130]	12	1	58	Functional Cincinnati Scale (modified)
Schepull T, et al.[344]	10	1	40	Thermann score

To be continued

Continued from **Table XIX.**

Silbernagel KG, et al.[345]	8	1	NR	ATRS, FAOS
Soldatis J, et al.[346]	30	1	61	
Solveborn S, et al.[347]	17	1	94	Amer-Lindon Scale
Sorrenti S, et al.[348]	52	2	100	
Speck M, et al.[349]	20	1	100	
Stein BE, et al.[350]	27	1	92	
Strauss E, et al.[351]	54	1	74	Boyden Score, AOFAS
Suchak AA, et al.[241]	98	2	65	
Talbot J, et al.[352]	15	1	66.7	AOFAS
Tenenbaum S, et al.[168]	29	1	90	AOFAS, Boyden score (modified)
Troop RL, et al.[353]	13	1	94	
Uchiyama E, et al.[354]	100	1	100	
Valente M, et al.[355]	35	2	100	AOFAS
Wagnon R, et al.[356]	57	1	40	
Wallace RGH, et al.[357]	945	1	100	
Wallace RGH, et al.[358]	140	1	37	
Young SW, et al.[106]	84	1	NR	Leppilahti score, halasi score

NR, not reported; AOFAS, American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score; ARPS, Achilles Rupture Performance Score; ATRS, Achilles Tendon Total Rupture Score; FAAM, Foot and Ankle Ability Measure; FAOS, Foot and Ankle Outcome Score-Ankle and Hindfoot; PAS, Physical Activity Scale; PER, Player Efficiency Rating.

Table XX. Prediction of AT force during terrestrial locomotion: difference with respect to methods, to the computational approach and to the adopted musculoskeletal model.

Authors	Protocol	Task	Results
Fukashiro S, et al.[365] 1993	Inverse dynamics *vs* direct measure	Hopping	diff = 8% r = 0.99
Kernozek T, et al.[362]. 2017	Conventional *vs* optimized inverse dynamics	Running	diff = 4.7% (p = 0.054)
Gerus P, et al.[372]. 2012	Subject-specific *vs* generic musculoskeletal models	Hopping/running	diff = 17%

Table XXI. Answer n. 18: Acute ruptures in the childhood.

Author	Year	Type of study	Level of evidence	N. of patients	Follow-up (months)	Type of treatment
Ralston EL, et al.[374]	1971	Case series	IV	1	12	Surgery
Eidelman M, et al.[375]	2004	Case series	IV	1	12	Conservative
Tudisco C t al.[376]	2012	Case series	IV	1	36	Surgery - Bunnell open
Vasileff WK, et al.[377]	2014	Case series	IV	1	8	Surgery -Bunnell open

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Ethics

The Authors declare that this research was conducted following basic ethical aspects and international standards as required by the journal and recently update in[378].

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