Overview of Tendinopathy

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NJSIAA SPRING EVENT 2020

IMPACT OF TENDINOPATHY

Tennis/golfer's elbow: 7 million/year

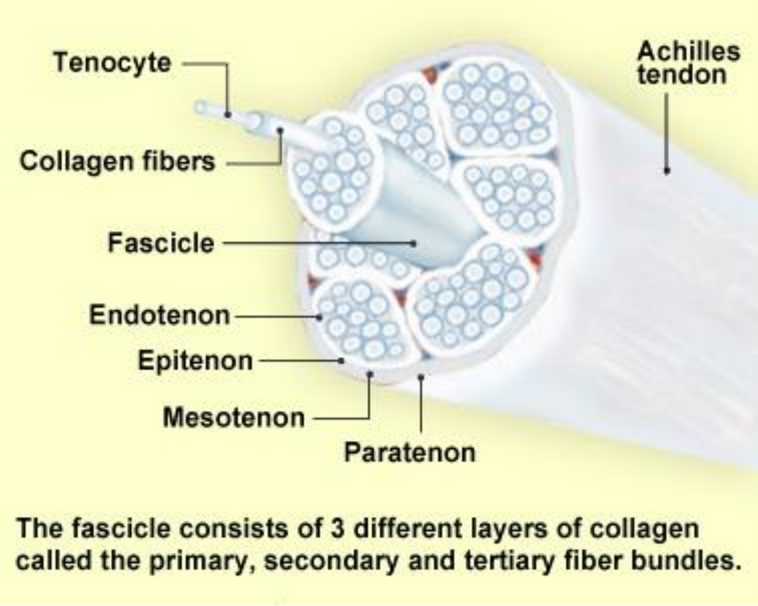
Achilles: 5.6 million/year

Glute Medius: 4 million/year

Patellar tendon: 2.5 million/year

Rotator cuff: 2 million/year

HIERARCHICAL STRUCTURE



- Collagen Fibers – primary bundles
  - Tenocytes: main cellular component
    - Synthesize ECM
- Fascicles – secondary bundles
  - Several fascicles form the whole tendon (tertiary)
- Endotenon
  - Allows fascicles to glide to each other
- Epitenon
  - Encloses groups of fascicles
  - With endotenon, carries blood vessels, nerves, and lymphatics to deeper portions of the tendon unit
- Paratenon
  - Outer layer, reduces friction between tendon and fascia

EXTRACELLULAR MATRIX

Dry mass of normal tendons makes up 30-45% of their total mass

- 60-85% collagen
  - 60-80% collagen I
  - 0-10% collagen III
  - 2% collagen IV
  - Small amount of type V, VI, X
- 15-40% non-collagenous components
- Remaining 70% tendon mass is water

TENDON STRUCTURE AND FUNCTION

- Connect muscle to bone and allow transmission of forces generated by muscle to bone, resulting in joint movement
- Collagen fibers – biomechanical strength and tensile force
- ECM/Proteoglycans – viscoelastic properties

TENDON VASCULARITY

- Compromised at junctional zones and sites of torsion, friction, or compression
  - Achilles: zone of hypovascularity 2-7cm proximal to the tendon insertion (rupture)

Tendon blood flow decreases with increasing age and mechanical loading

TENDON INNERVATION

Most nerve fibers do not enter the main body of the tendon but terminate as nerve endings in the paratenon

SO WHAT CAUSES TENDON PAIN?

- Combination of mechanical and biochemical factors
  - Breakdown of collagen
  - Chemical irritants and neurotransmitters
  - Substance P’s role on small sensory fibers

TENDON MECHANICS

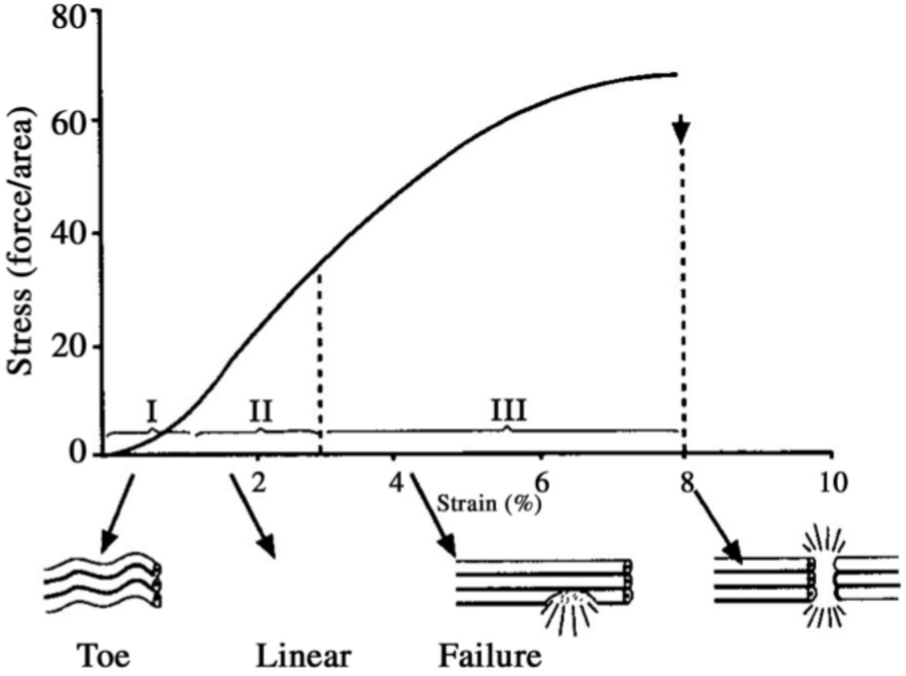


Fig. 2
Stress-strain curve demonstrating the basic physical properties of a tendon.

Strain < 4%, elasticity maintained

Strain exceeds 4%, microscopic failure

Beyond 8% strain, macroscopic failure

TENDON INJURY

Mechanical overuse

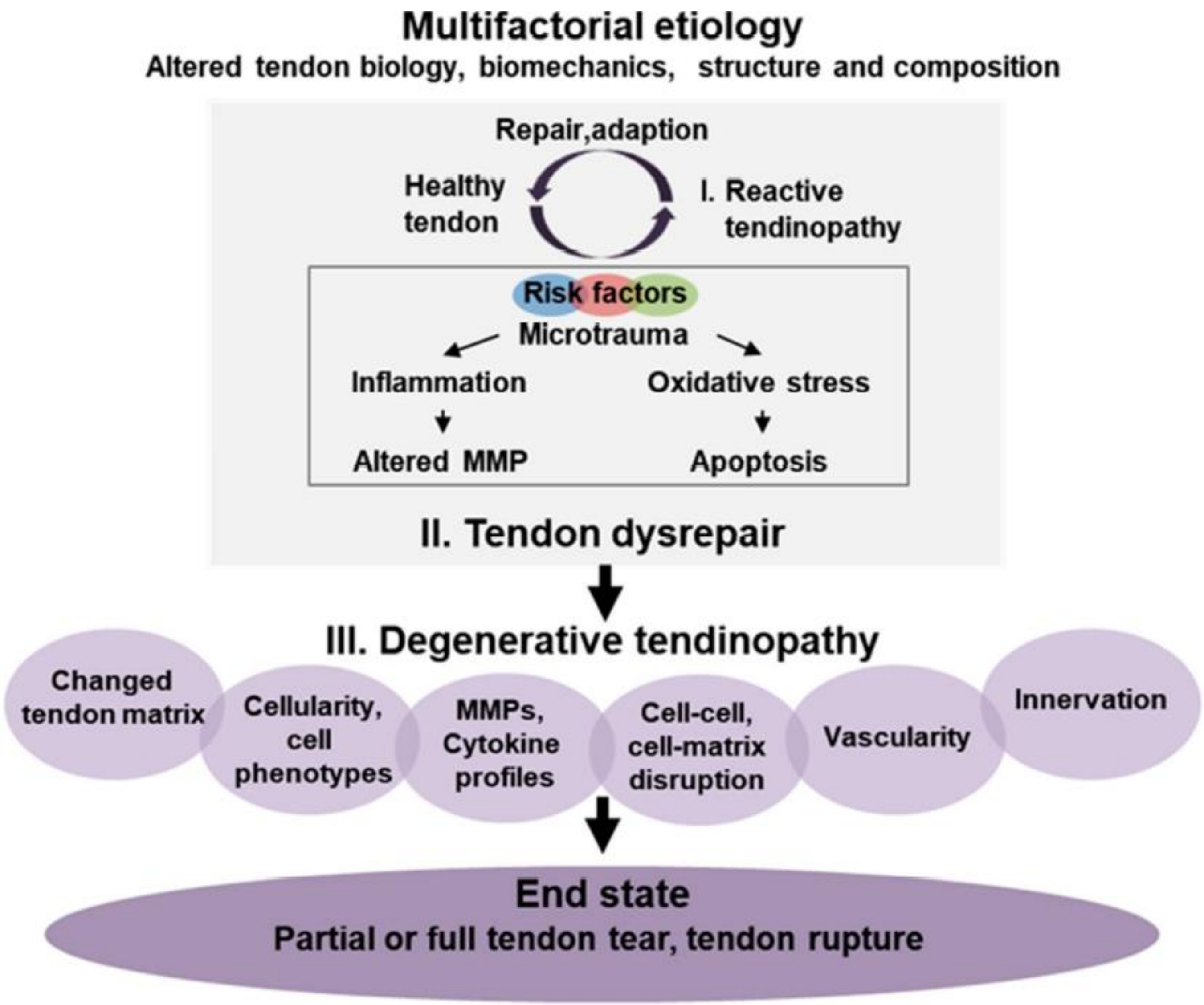
- Vigorous and repetitive excessive loading
- Muscle imbalance
- Malalignment
- Training errors

Intrinsic factors

- Normal aging
- Gender
- Body weight and height
- Hormonal background
- Genetic constitution
- Pre-existing disorders
- Prior tendon injuries

Extrinsic factors

- Workplace, sports, daily life
- Smoking
- Alcohol
- Bad nutritional habit
- Environmental factors(cold weather, faulty footwear and equipment)
- Pharmacological agents


Multifactorial etiology
Altered tendon biology, biomechanics, structure and composition
Repair,adaption
Healthy tendon
I. Reactive tendinopathy
Risk factors
Microtrauma
Inflammation
Oxidative stress
Altered MMP
Apoptosis
II. Tendon dysrepair
III. Degenerative tendinopathy
Changed tendon matrix
Cellularity, cell phenotypes
MMPs, Cytokine profiles
Cell-cell, cell-matrix disruption
Vascularity
Innervation
End state
Partial or full tendon tear, tendon rupture

INTRINSIC FACTORS

- Age
  - Over the age of 35
    - Collagen turnover slows
    - Stiffer muscle tendon unit
    - Achilles and rotator cuff tendon tear rare in young people
- Adolescents
  - Injury at the biomechanical weak points, origin/insertion
  - Patellar tendon
    - Proximal attachment increases through puberty
    - More load placed while not attached completely → pathology early on
      - Boys >> girls
- Gender: different parts of the body are affected differently by gender
  - Women protected in Gluteal and Achilles by estrogen
    - increased pathology post menopause

EXTRINSIC FACTORS

- Alignment and biomechanics
  - 2/3 of Achilles tendon disorders
    - Hyperpronation
    - Flexibility
- Training Errors
  - Sudden increase in volume or weight
  - Inadequate rest or abrupt increase after rest
- Poor environmental conditions
  - Hard floors
  - Cambered roads
  - Poor ergonomics
- Inadequate equipment
  - Old shoes
  - Bike seat height
  - Grip size

CLASSIFICATION

- Tendinopathy
  - Tendonitis
    - Intra-tendinous inflammation, role is less clear
  - Tendinosis
    - Degenerative tendon
    - Most common histologic finding in spontaneous rupture
  - Tenosynovitis (paratendonitis)
    - Inflammation of the paratenon alone or in combination with tendinosis

HISTOPATHOLOGY

Poor healing response

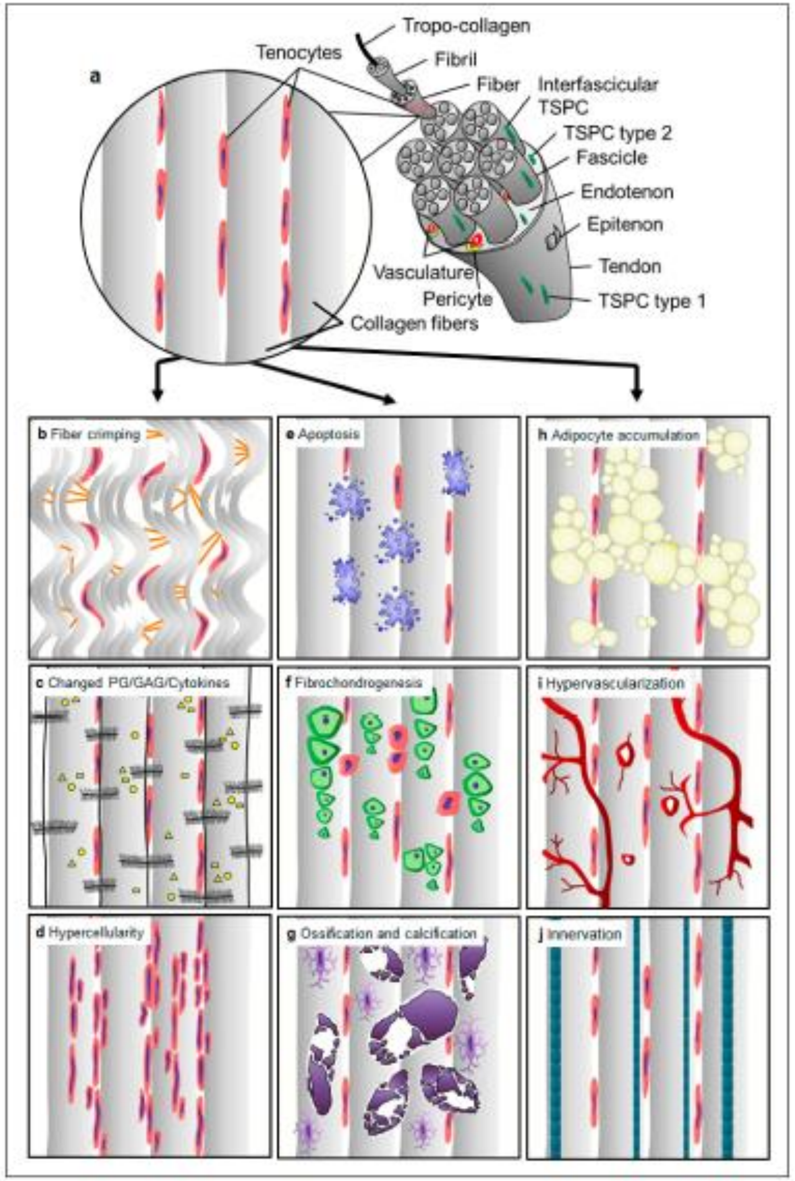
Noninflammatory intratendinous collagen degeneration

Fiber disorientation

Hypercellularity

Scattered vascular ingrowth

Decrease type I collagen, increase weak type III collagen



WHAT IS TENDON PATHOLOGY?

- Ischemia?
  - Free radicals produced during reperfusion of tendon during relaxation phase
  - Increased expression of anti-oxidant enzyme, Peroxiredin 5, in tendinopathy
  - Apoptosis
- Inflammation?
  - Sometimes, but doesn’t usually drive pathology
  - Can be seen with injuries or paratendinitis
- Collagen tearing?
  - Consequence of pathology and not primary event
- Continuum model?
  - Cell based model focused on loading tendons
  - Balance of function, pathology, pain

POPULAR THEORIES

Many theories - none of them have solid scientific backing

- Mechanical theory
  - overloading of the tendon, repetitive microtrauma
- Vascular theory
  - generally poor blood supply, ischemia/hypoxia
- Myofascial theory
  - proposes an explanation for many cases of pain around the tendon
- Neurogenic theory

INTRINSIC VS EXTRINSIC HEALING

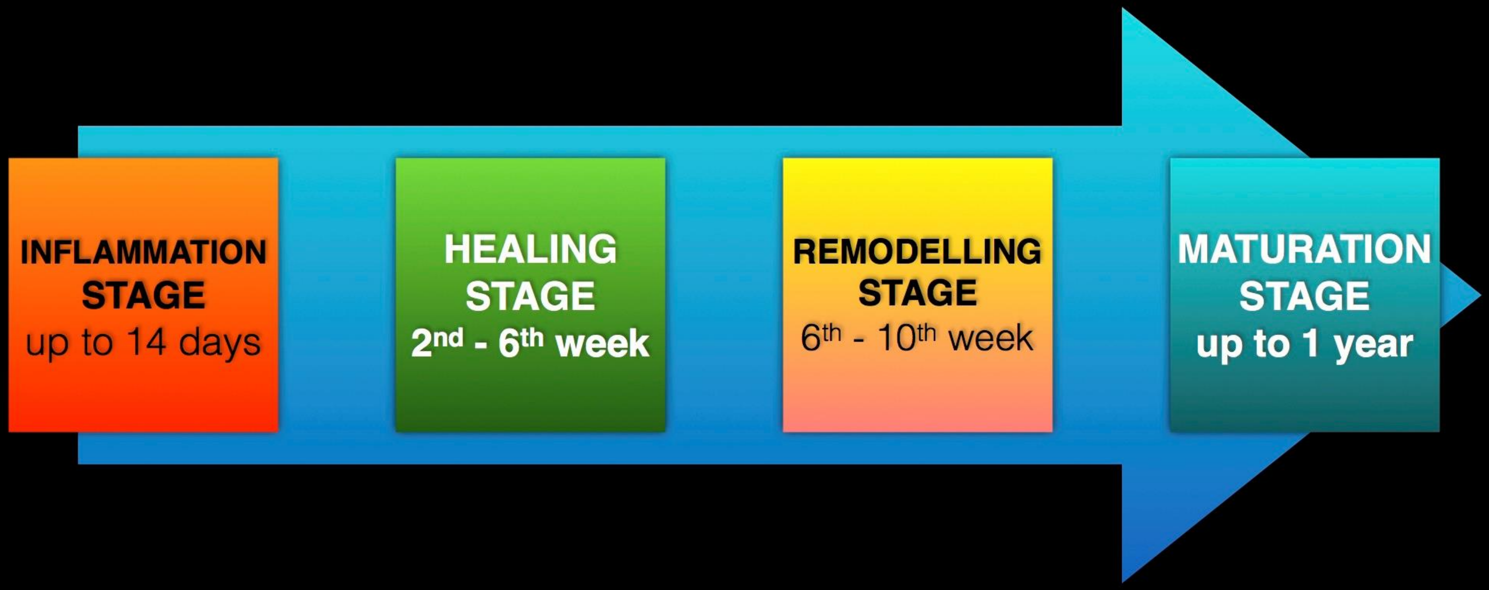
Studies of tendon healing predominantly have been performed on transected animal tendons or ruptured human tendons, and their relevance to healing of tendinopathic human tendons remains unclear.

Intrinsic: does not result in movement restriction of the tendon

- 3 phases (inflammation, proliferative, remodeling)
- Results in better biomechanics and fewer complications

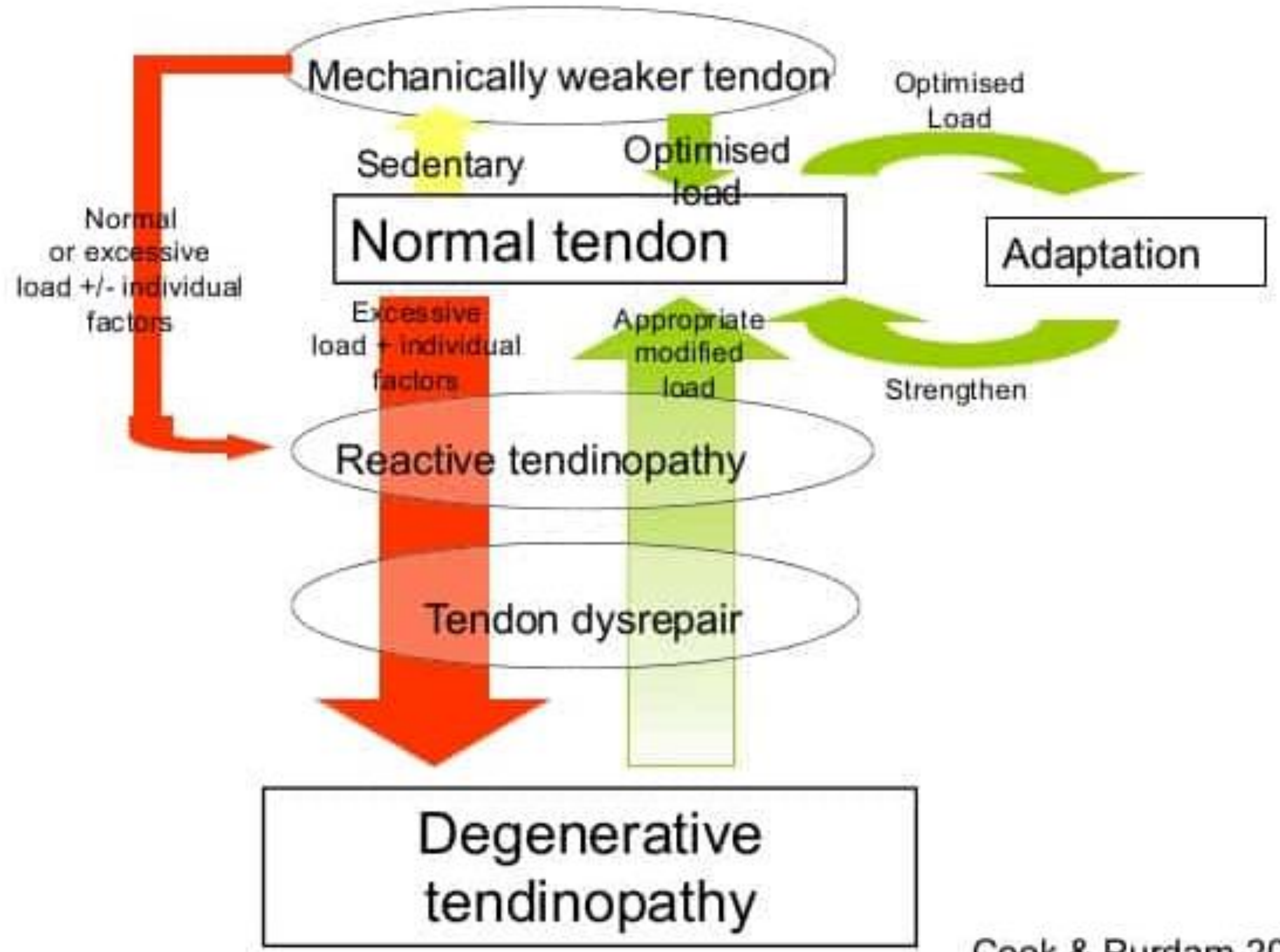
Extrinsic: adhesions between tendon and surrounding tissue. Occurs by proliferation of fibroblasts from epitenon, limiting tendon glide

TENDON'S HEALING STAGES



CONTINUUM MODEL OF TENDON PATHOLOGY

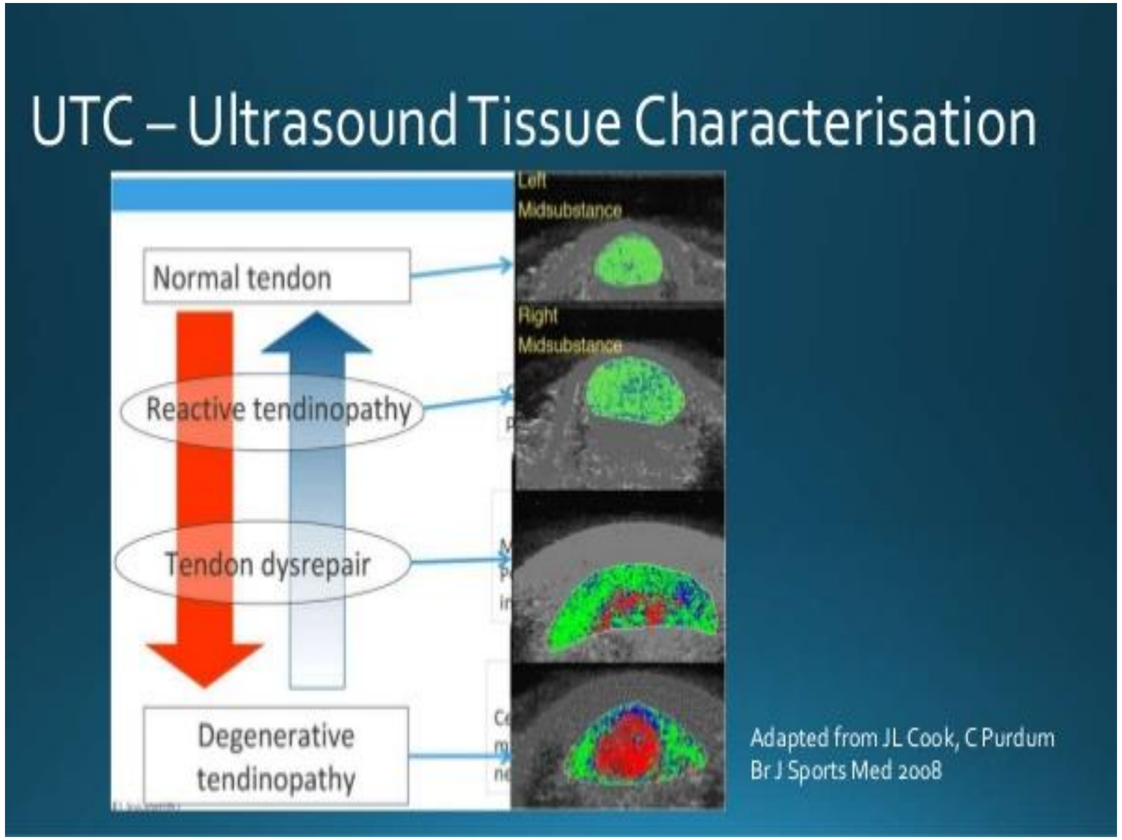
- Originally proposed in 2009 by Cook and Purdam
- Appropriately loaded tendons adapt without increasing size
- Inappropriately loaded tendons can become reactive and thickened
  - Normal tendon under excessive load
  - Deconditioned tendon under normal or excessive load
- Continued excessive load leads to tendon in disrepair, and potentially degenerative tendon and cell death
  - Early load modification can reverse this process, assuming there’s pain



Cook & Purdam 2009

CONTINUUM MODEL REVISITED (2016)

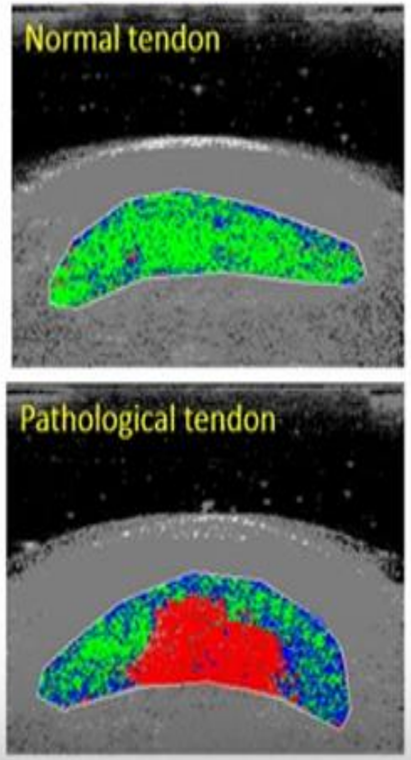
- Donut Hole Analogy
  - Reactive on Degenerative Tendinopathy
    - State of the tendon is fluid
    - Normal tendon drifts in and out of a reactive response
      - Rehab – how hard to push the tendon?



CONTINUUM MODEL (2016)

- Pathologic tendons with pain
  - Reactive tendon with first presentation of tendon pain following acute overload
  - Reactive-on-late disrepair or reactive-on-degenerative tendon pathology
- Pathologic tendons without pain
  - Threshold not yet reached, so undetected
  - Spontaneous rupture

	Normal	Pathological
Achilles tendon		
AP diameter (mm)	6.5 ± 0.5	8.4 ± 1.5
mCSA of poor structure(mm^2)	1.4 ± 1.4	4.7 ± 8.3
mCSA of good structure (mm^2)	80.8 ± 15.8	94.8 ± 26.5
Patellar tendon		
AP diameter (mm)	6.0 ± 0.6	7.8 ± 2.6
mCSA of poor structure (mm^2)	4.5 ± 3.4	17.1 ± 22.3
mCSA of good structure (mm^2)	125.9 ± 11.7	139.9 ± 23.1



Conclusions:

- Remaining tendon can compensate by increasing CsA healthy tendon

TREATMENT STRATEGIES

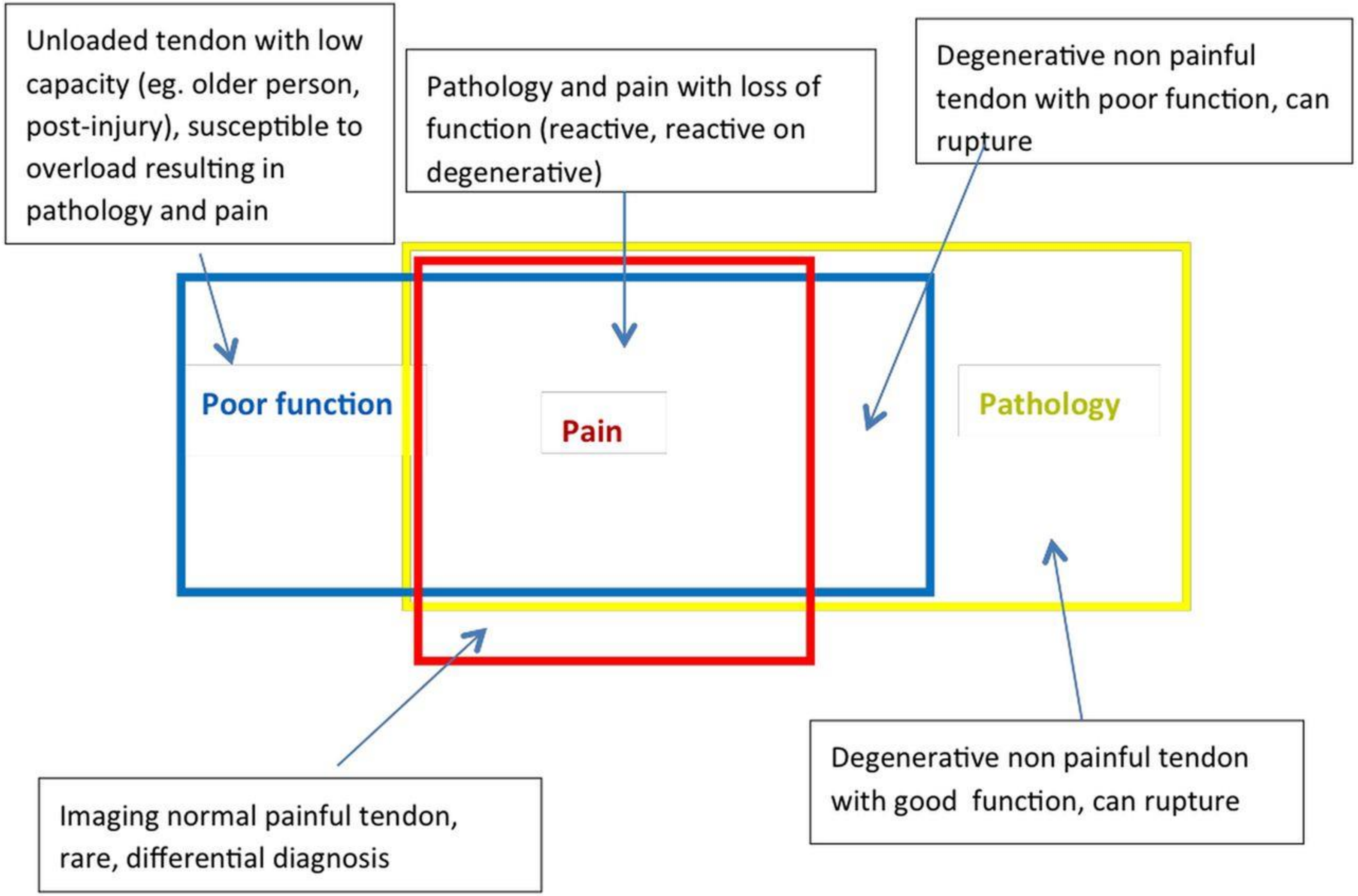


Table 1. Current options of tendinopathy management.

<table>
<tr><th colspan="2">Conservative Management</th><th>Surgical Management</th></tr>
<tr><th>Biomechanical Therapies</th><th>Biological Therapies</th><th>Operative Therapies</th></tr>
<tr>
<td>Classical physiotherapy:
Deep transverse friction massage
Myofascial manipulation
Controlled motion
Ultrasound
(0.75-3.0 MHz; pulsed or continuous)
Ionophoresis
Phonophoresis
Acupuncture
Electrical and laser stimulation:
Pulsed electromagnetic fields
Extracorporeal shock-wave therapy
Laser treatment (pulsed or continuous)
Stabilization and modification:
Taping
Splinting
Bracing
Straps
Orthotic devices
Modification of activity:
Rest
Eccentric exercises
Thermic treatments:
Cryotherapy (e.g., ice packs and baths)
Thermotherapy (heat)</td>
<td>Pharmaceutical agents:
Anti-inflammatory drugs (NSAIDs)
Systemic corticosteroids
Pain control (anesthetics)
Antibody therapy (e.g., IL-17, IL-1β antagonist and BMP)
Peritendinous (high volume) injections:
Corticosteroid injection
Saline injection
Hyaluronic acid injection
Botulinum toxin (BTA) injection
MMP inhibitor injection (e.g., Aprotinin)
Prolotherapy
Topical glyceryl trinitrate therapy
Polidocanol injection
Glycosaminoglycan polysulfate injection
Sclerosant injection
Low-dose heparin
Blood-based therapies:
Platelet-rich plasma injection
Autologous blood injection
Actovegin (deproteinized extract of calf's blood)
Cell-based therapies:
Autologous tenocyte implantation (Orthocell)</td>
<td>Arthroscopy
Debridement and decompression
Endoscopic/minimally invasive surgery
Percutaneous longitudinal tenotomy
Radiofrequency microtenotomy
Stripping and destruction of neovessels
Endoscopic tendon debridement
Tenolysis
Gastrocnemius recession
Tendon replacement strategies after rupture:
Tendon allografts
Tendon transfer
Tendon prosthesis</td>
</tr>
</table>

REHAB PROTOCOLS

- Maximize function through good rehab
  - Remaining healthy tendon will compensate for pathologic tendon
    - Increase collagen 1 synthesis and improve fiber alignment, resulting in higher tensile strength
  - Resolution of pain does not mean fit to return to play
  - Treatments/injections/modalities to relieve pain augment and do not replace rehabilitation

75% of patients respond to conservative care w/in 4 months

15% recurrence rate within 12 months

TOPICAL NITROGLYCERIN

Mechanism: NO enhances ECM synthesis, resulting in injured tendons having better material and mechanical properties

Challoumas D, et al BJSM 2018

- 10 RCT's
  - Rotator cuff (4)
  - Wrist extensors (3)
  - Achilles (2)
  - Patellar tendon (1)

Results:

- All chronic tendinopathies treated with topical NTG for up to 6 months saw positive effects on satisfaction (strong evidence), chance of being asymptomatic with ADL's (strong evidence), ROM (moderate), and tendon force (strong)

- Main adverse effects is headache

- Useful as an adjunct to loading programs

EXTRACORPOREAL SHOCKWAVE THERAPY (ESWT)

- Alternative to surgery for several chronic tendinopathies and non-unions because of its efficacy, safety, and noninvasiveness
- Variability in the treatment protocols limits quality of many ESWT studies
- Proposed mechanism
  - Promotes neovascularization at tendon-bone junction
  - Stimulates proliferation of tenocytes and osteoprogenitor differentiation
  - Increase leukocyte infiltration
  - Amplify growth factor and protein synthesis to stimulate collagen synthesis

EXTRACORPOREAL SHOCKWAVE THERAPY (ESWT)

Indications for chronic tendinopathy

1. Calcific tendonitis of the shoulder
2. Lateral epicondylosis
3. Greater trochanteric pain syndrome
4. Patellar tendinopathy
5. Achilles tendinopathy
6. Plantar fasciitis

IMAGING TENDINOPATHY

MRI: Gold standard

Ultrasound- Trained MSK sonographers can diagnose the underlying conditions

- Tendon subluxation/dislocation – dynamic exam
- Paratendinitis – fluid within the tendon sheath
- Partial tendon tears - hypoechogenicity within the tendon
- Neovascularization – helps confirm tendinosis

- Can affect threshold for allowing return to activity

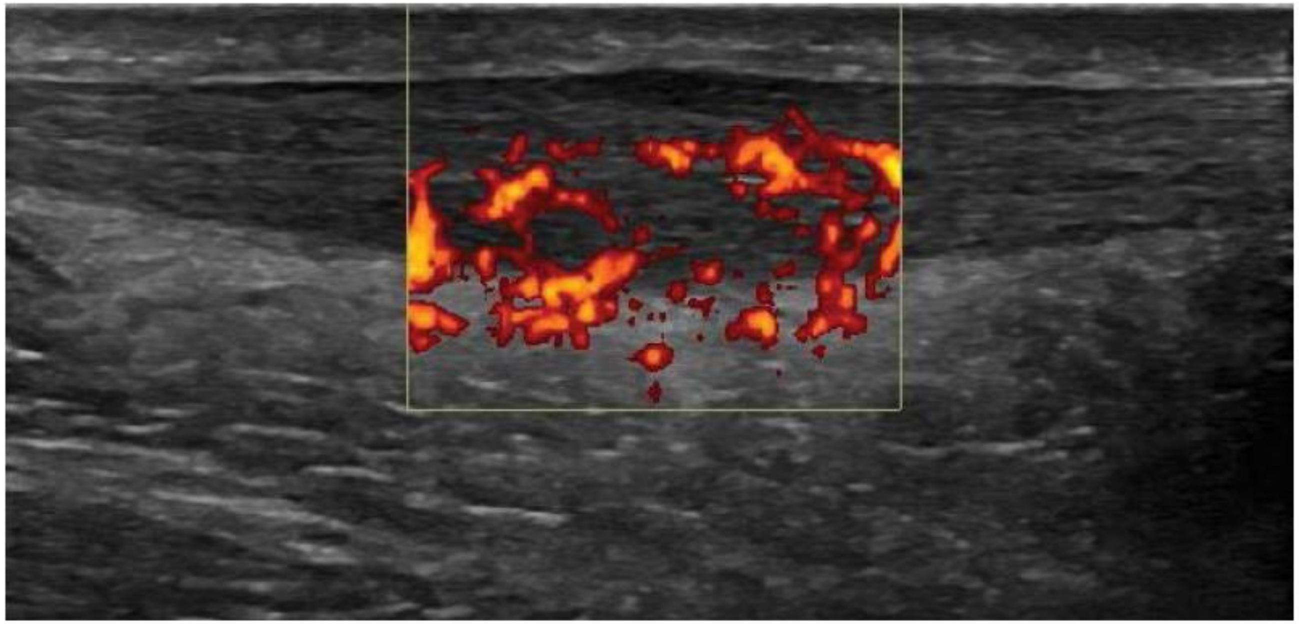
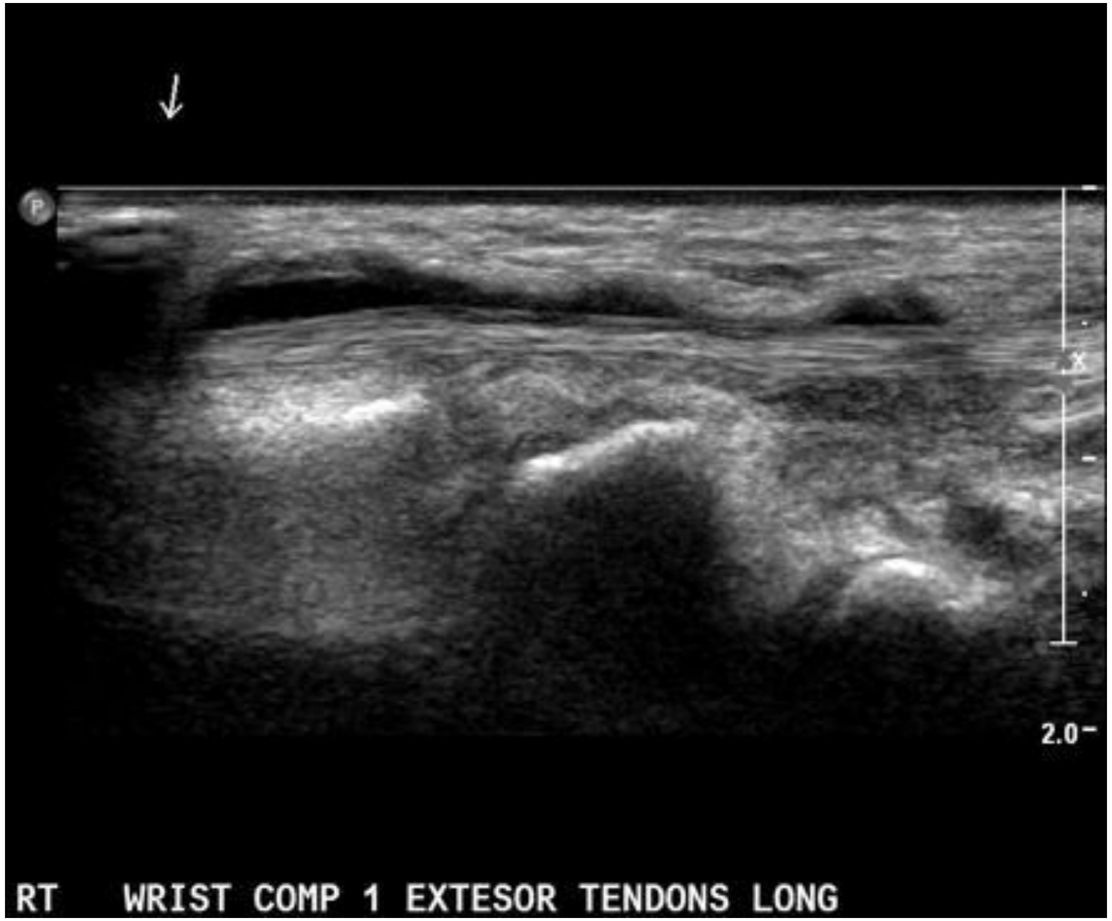


Figure 1: Longitudinal ultrasound view of Achilles tendinopathy. Gray-scale and power-doppler ultrasound showing the sonographic findings characteristic of Achilles tendinopathy. The sonogram reveals the hypoechoic, darken area of the Achilles tendon, tendon thickening and neovascularization.


2.0
RT WRIST COMP 1 EXTESOR TENDONS LONG


SUPRASPINATOUS
L 0.93 cm

ULTRASOUND PERCUTANEOUS TENOTOMY

- Ultrasound imaging is used to diagnose and identify the pathology of diseased tissue
- Treatment can be performed in a clinical or ambulatory surgical center
- Cutting and removing the "tendonotic" tissue and stimulating a healing response
  - Tissue with less structural strength, collagen or elastin fragments more efficiently.
  - Tissue with more collagen and/or elastin has greater strength and aspirates less efficiently

PERCUTANEOUS NEEDLE TENOTOMY

Conservative

Conservative Care

- Rest
- Ice
- OTC Meds
- PT

Minimally Invasive

TX System

- Local Anesthesia
- Single Treatment
- Cut/Remove Source of Pain

Cortisone Injection

- Mask Pain
- Degenerates Tendon

Fully Invasive

Open Surgery

- General Anesthesia
- Rehab/PT
- Long Recovery

Over 100,000 patients since 2012

34% tennis and golfers elbow

35% plantar fascia

12% achilles

8% gluteal

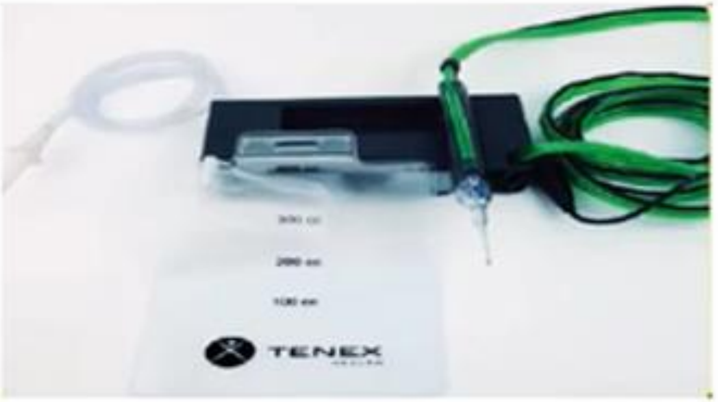
5% knee

5% shoulder

1% other

TENEX

HEALTH



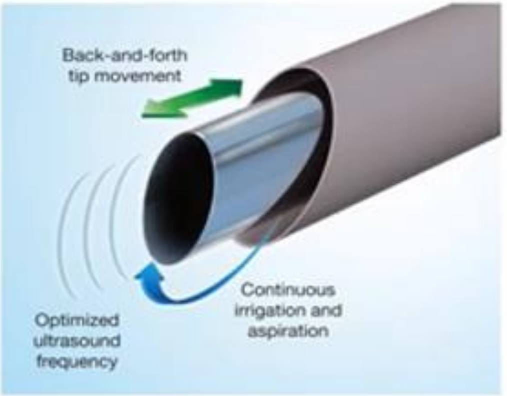
Console

- Touch screen control
- Foot pedal activation

MicroTip

- Single use, entirely disposable

Proprietary Technology - MicroTip

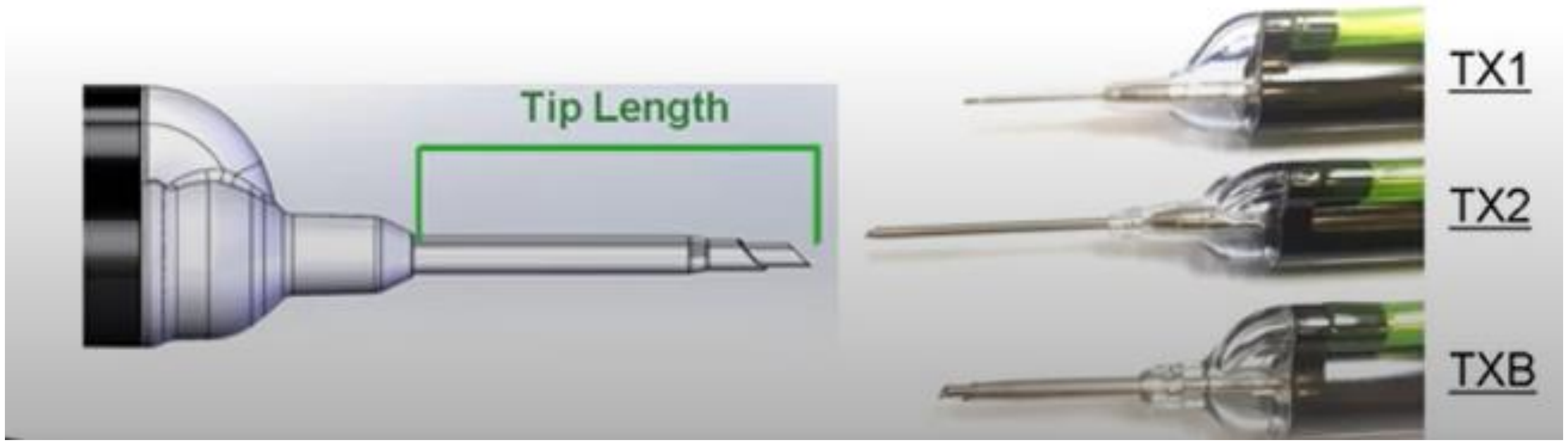


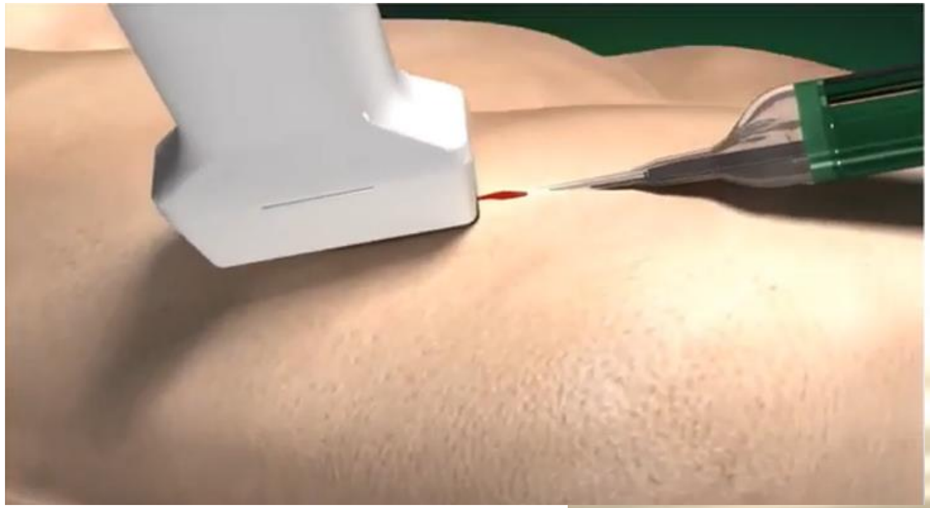
- Optimized ultrasonic energy that **precisely cuts** diseased tendon tissue and **spares healthy tissue** – diseased, necrotic tissue is bio-mechanically different from healthy tissue (elastic)
- Cutting of targeted tissue is achieved through longitudinal movement of needle at **>speed of sound** (ultrasonic) – tissue is cut via "jack-hammer effect"
- Continuous saline **irrigation cools** Microtip **and emulsifies** to efficiently remove target tissue

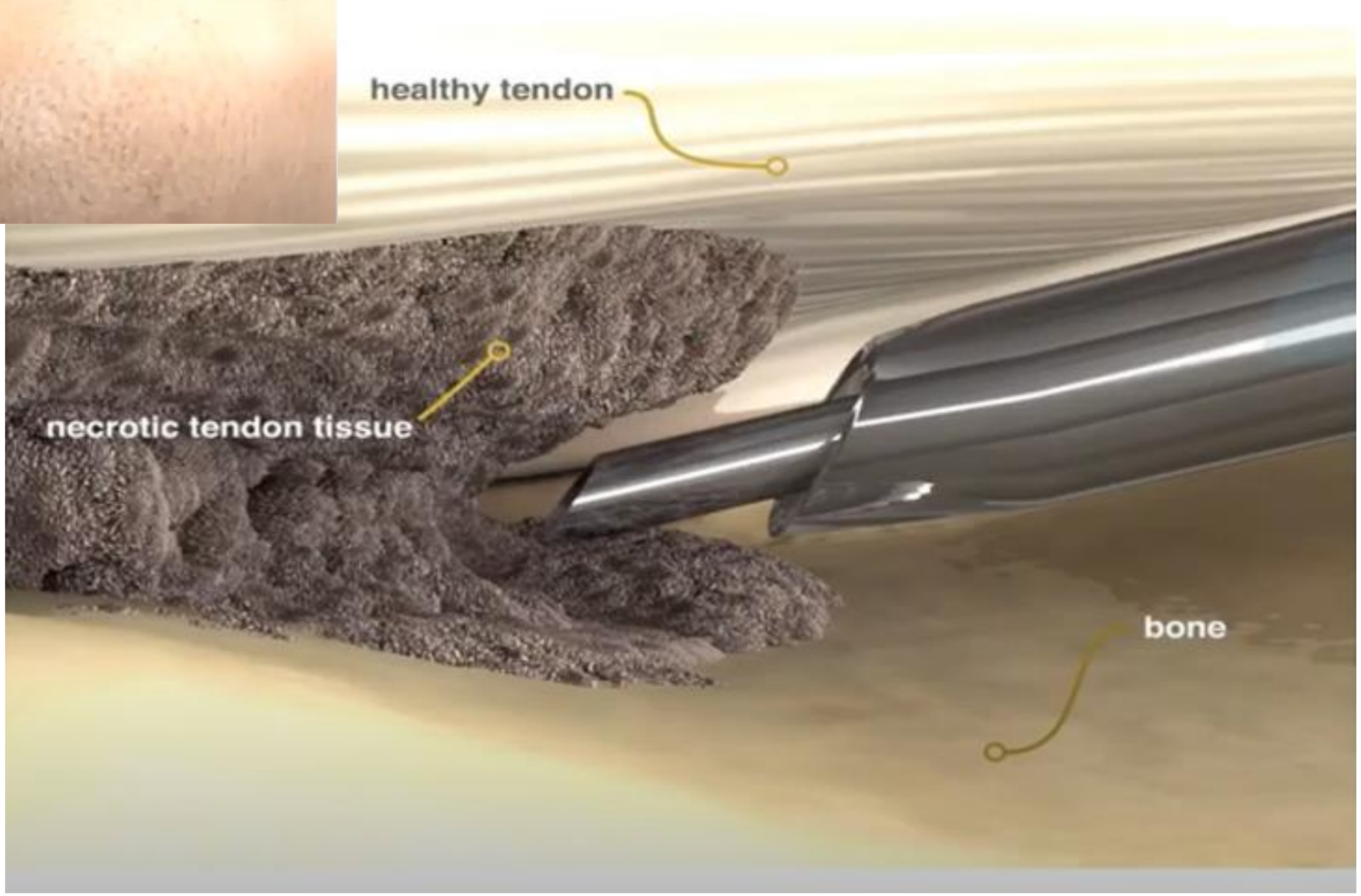
TX System Setup

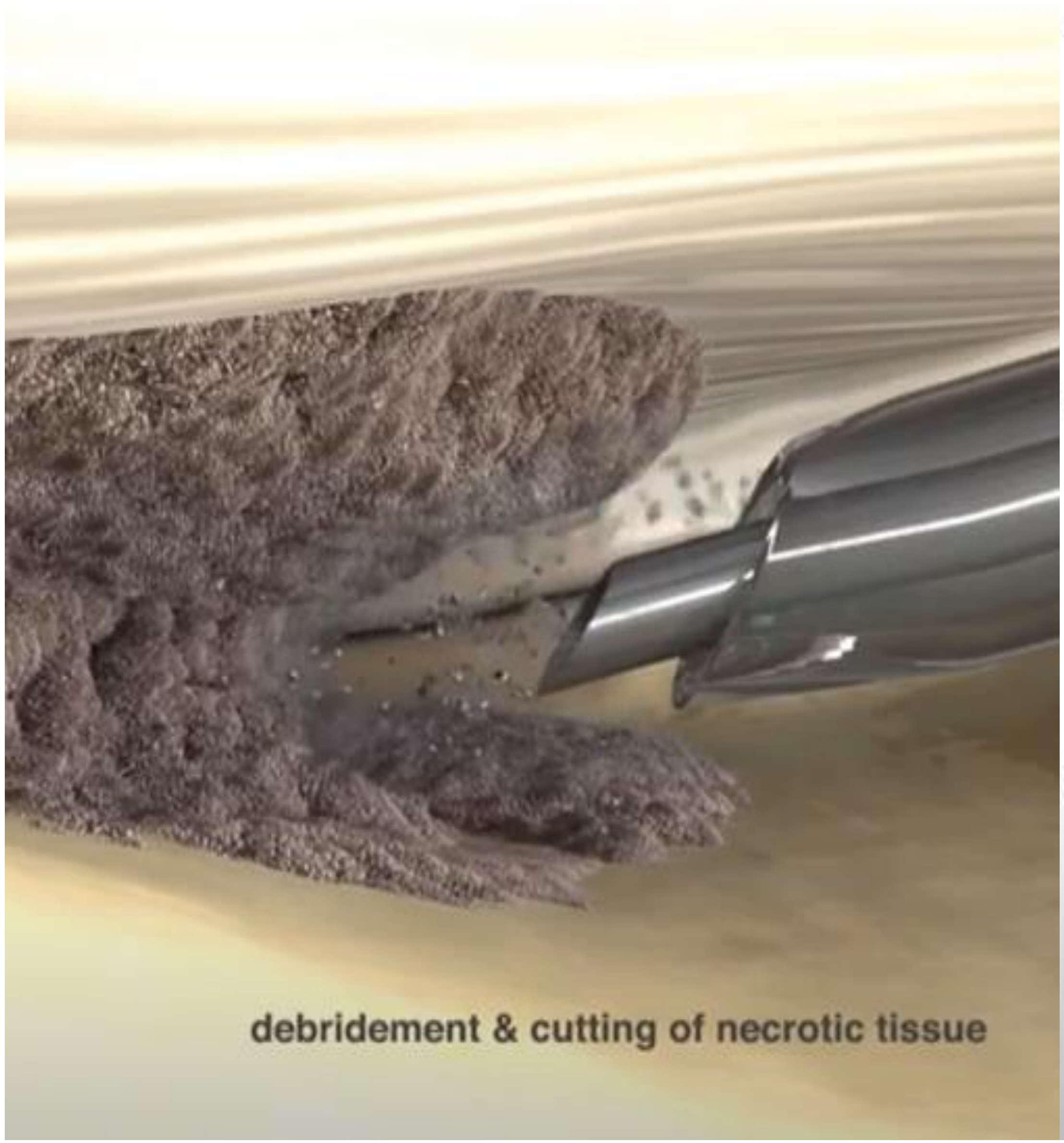
MicroTip Options

MicroTip Offering	TX1	TX2	TXB
Tip Length	1.0" (25.4 mm)	1.7" (43.2 mm)	1.3" (33.0 mm)
Tip Gauge (approx. inner lumen OD)	19 (1.1 mm)	18 (1.3 mm)	15 (1.9 mm)
Sheath Gauge (approx. outer lumen max OD)	11 (3.0 mm)	14 (2.1 mm)	11 (3.0 mm)
Volume as % of TX1 Baseline (per stroke @26.5 kHz)	100%	200%	650%






healthy tendon
necrotic tendon tissue
bone



1. VISUALIZE DAMAGED TENDON (DARK REGION) VIA ULTRASOUND
2. GUIDE TX™ MICROTIP TO DAMAGED TISSUE WITH ULTRASOUND GUIDANCE
3. FOOT-PEDAL ACTIVATION OF TX™ MICROTIP CUTS & REMOVES TARGET DAMAGED TISSUE

PATIENT SELECTION

Chronic pain (>3 mo) – not responsive to conservative medical treatment

Point tenderness – typically corresponds to location of damaged tissue

Ultrasound confirmation – underlying area of tenderness is region of degenerated tendon tissue, visualized as hypoechoic region due to disorganized fibers and thickened tendon tissue

PERCUTANEOUS NEEDLE TENOTOMY

- No restrictions before the procedure, but I will wait 30 days after a steroid injection
  - Short procedure time, usually less than 20 minutes
  - Little to no pain during the procedure
  - Same day procedure
  - Low risk of infection, bleeding, or tendon tearing

PERCUTANEOUS TENOTOMY

- Post Procedure
  - OTC pain medications, ice as needed
  - Steri-strip, occlusive dressing, compression wrap
  - Sling 1-2 weeks (shoulder)
  - Wrist brace 2 weeks (elbow)
  - Walking boot 2 weeks (plantar fascia and achilles)
  - Hinged knee brace locked at 20 degrees and NWB x 2 weeks (patella/quad)
  - No lifting more than a coffee cup or PWB 2 weeks.
  - No lifting more than 5lbs or normal walking from week 2 to week 6.
  - Return to full activity at 6 weeks.

Clinical Publication Summary

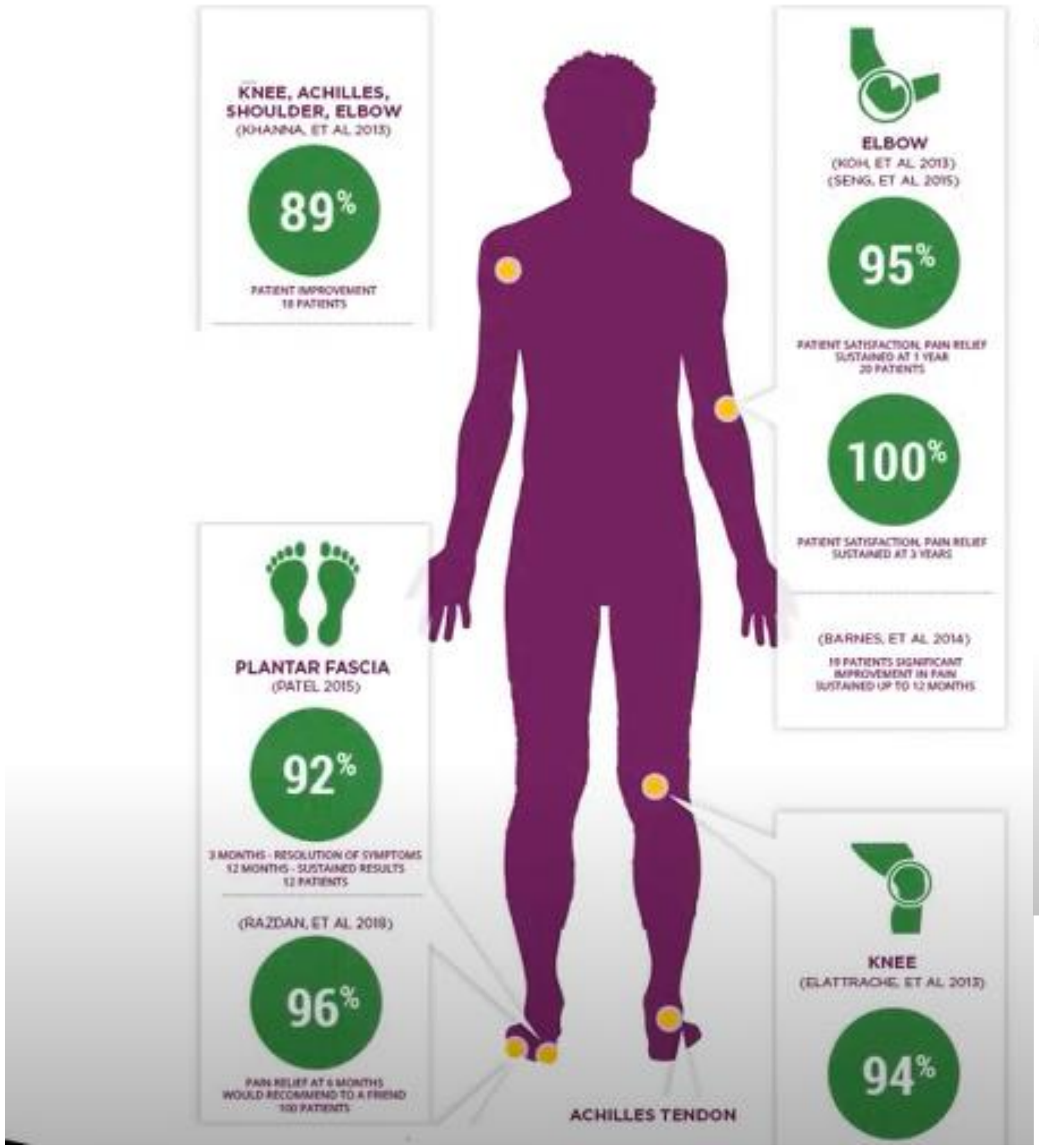
- 32 Articles In Print
- 3 Articles Under Review
- CLI-001: Clinical Publication Table
- CLI-007: Clinical Pub. Summaries

	Peer Rev. Manuscript	Book Chapter	Other (Poster, Technique)	In Review	Total
2013	3		3		6
2014			1		1
2015	6	1	2		9
2016		1	1		2
2017	1	1			2
2018	4		2		6
2019	6			3	9
Totals:	**20**	**3**	**9**	**3**	**35**

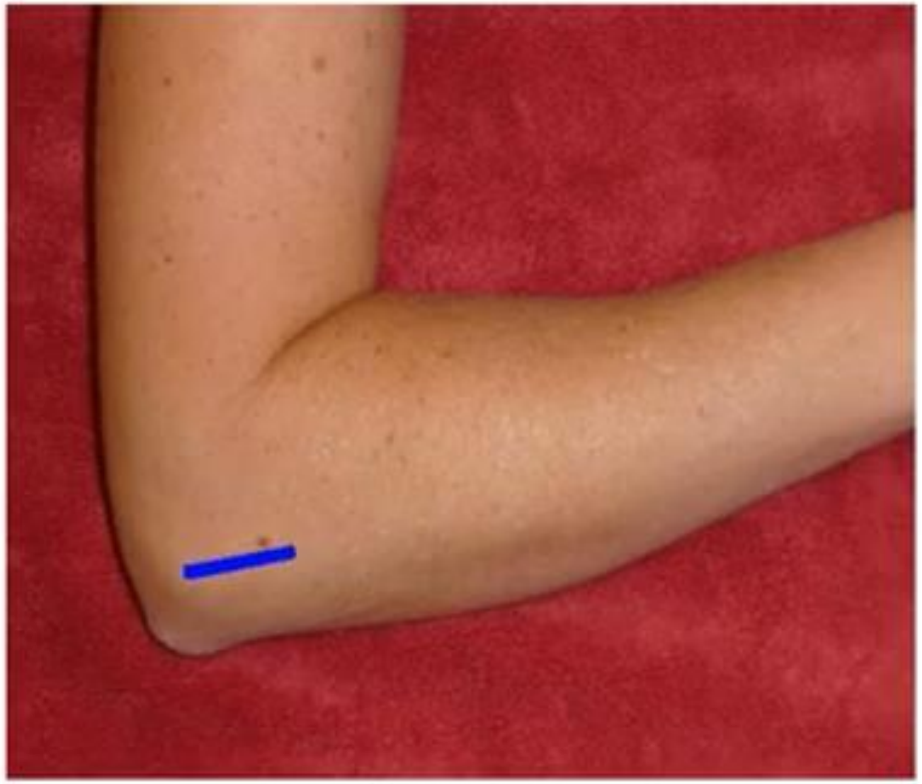
Data as of August 2019

Clinical Evidence

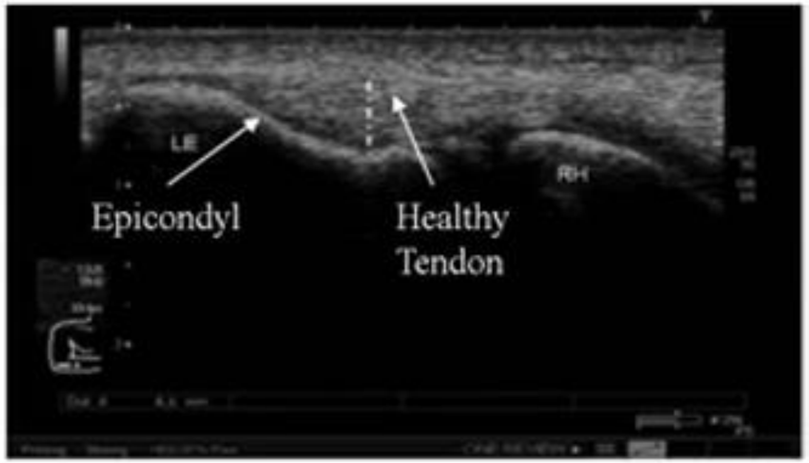
≥85% Patients have Pain Relief within weeks of treatment



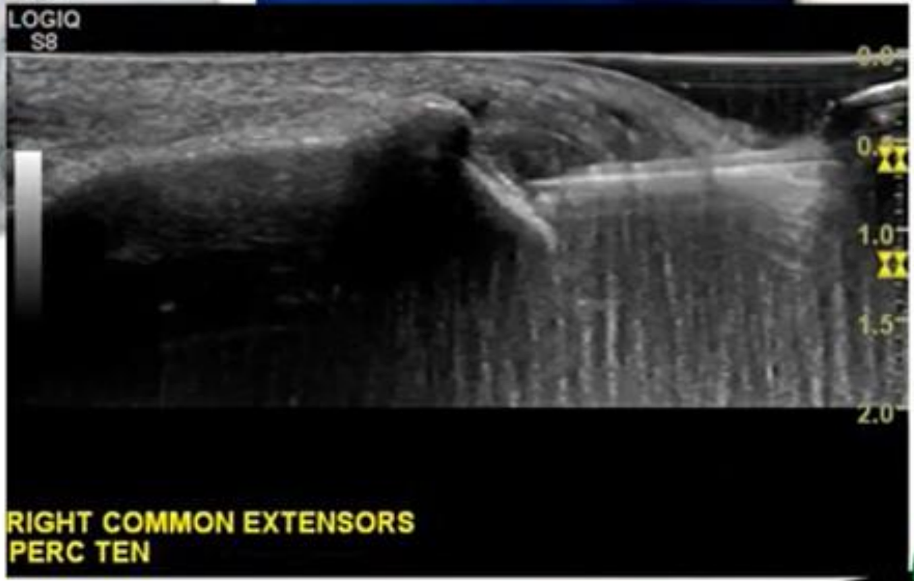
Epicondyle / Elbow Tendonosis



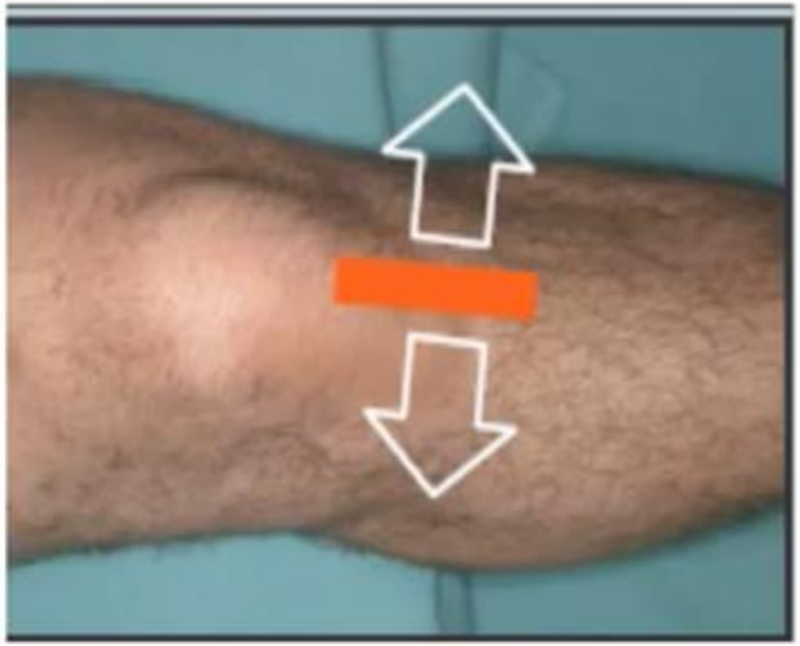
Blue strip marks placement of ultrasound transducer



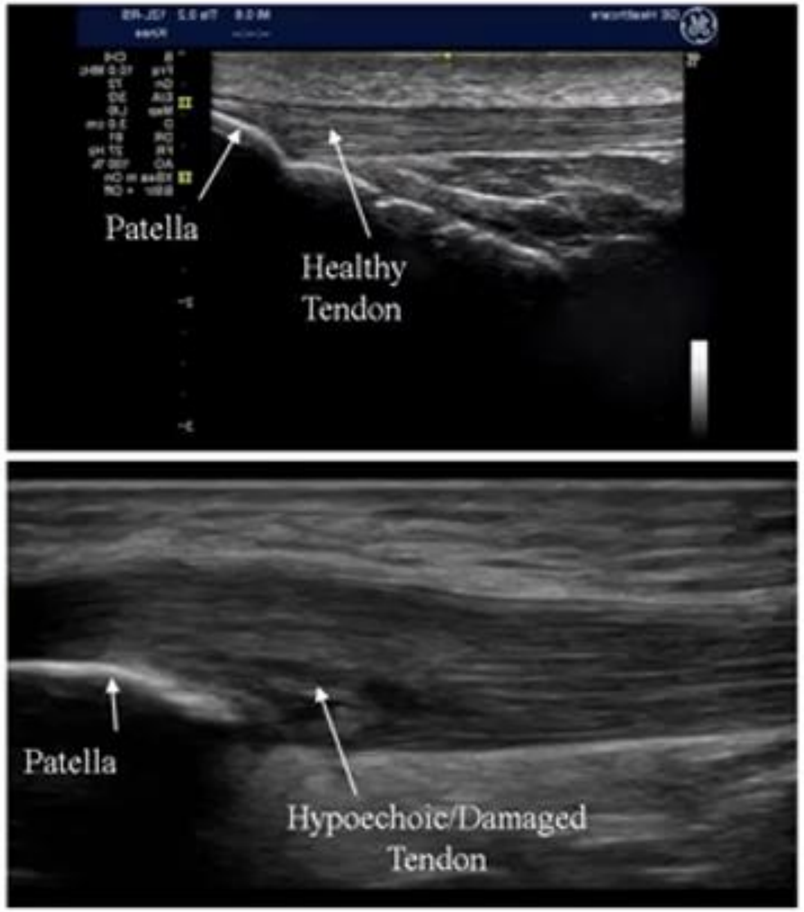
TX1 Micro-Tip Placement



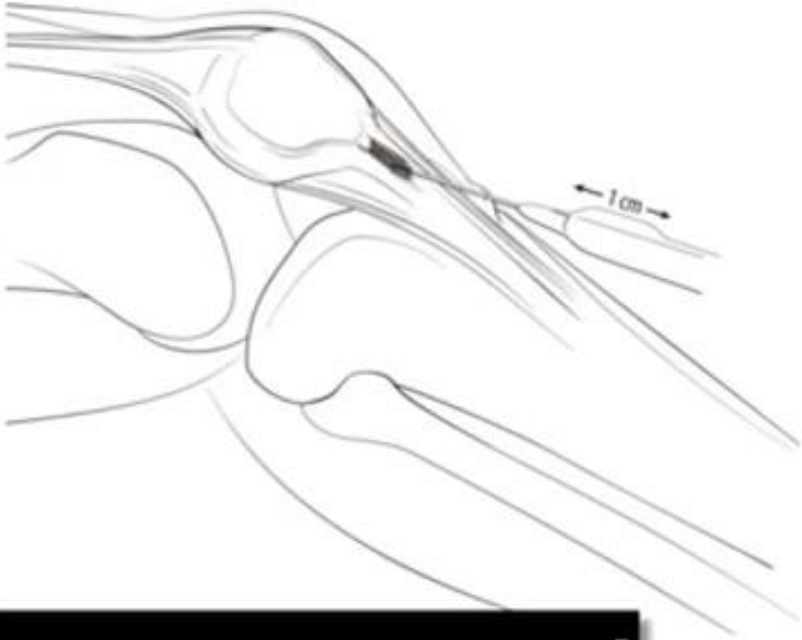
Patellar Tendonosis

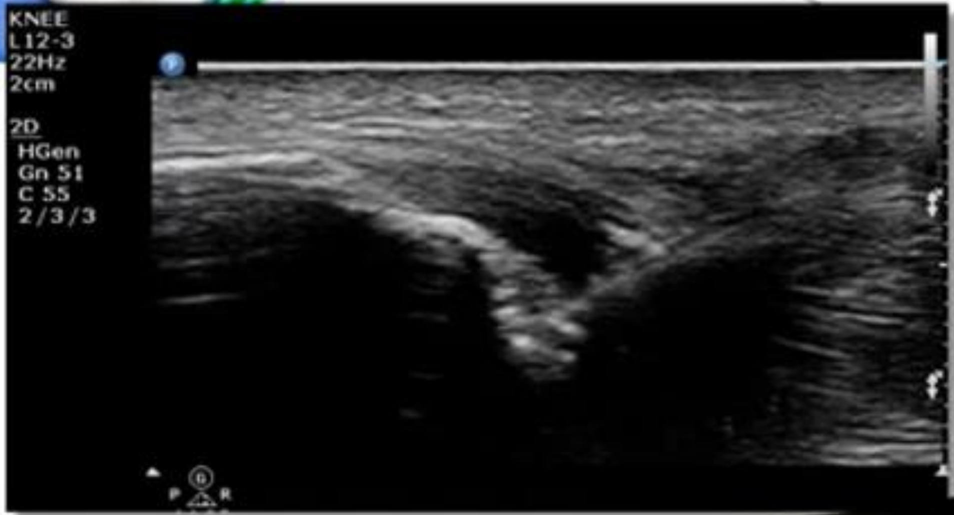


Orange strip marks placement of ultrasound transducer on inferior pole of patella

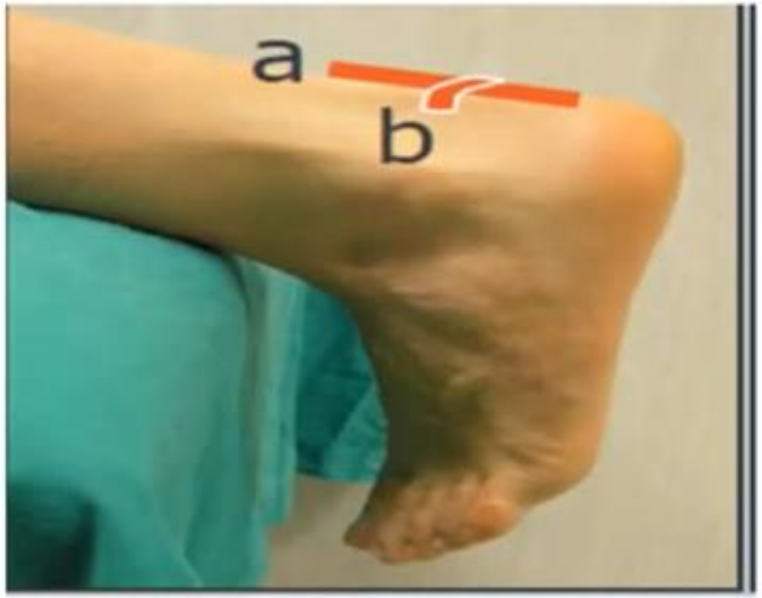


TX1 Micro-Tip Placement



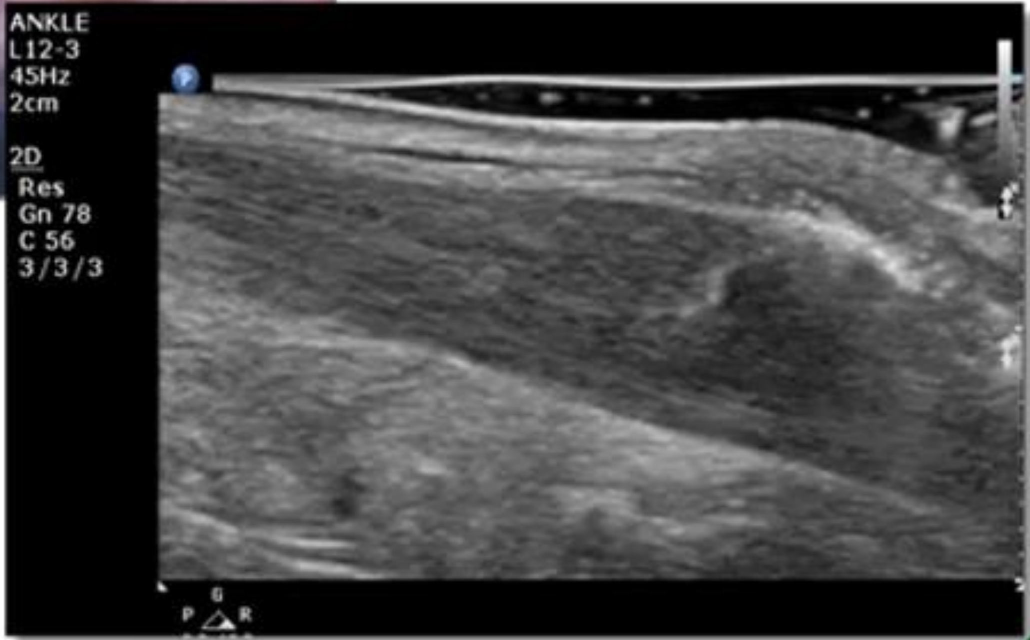


Achilles Tendonosis



Orange strip (a) marks placement of ultrasound transducer on Achilles and (b) shows cross section view to identify mid-substance tendonosis

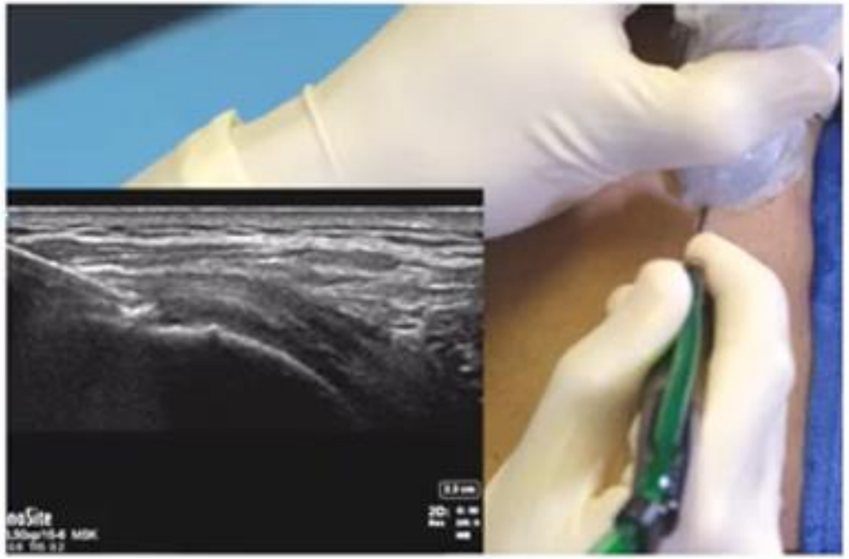
TX1 Micro-Tip Placement



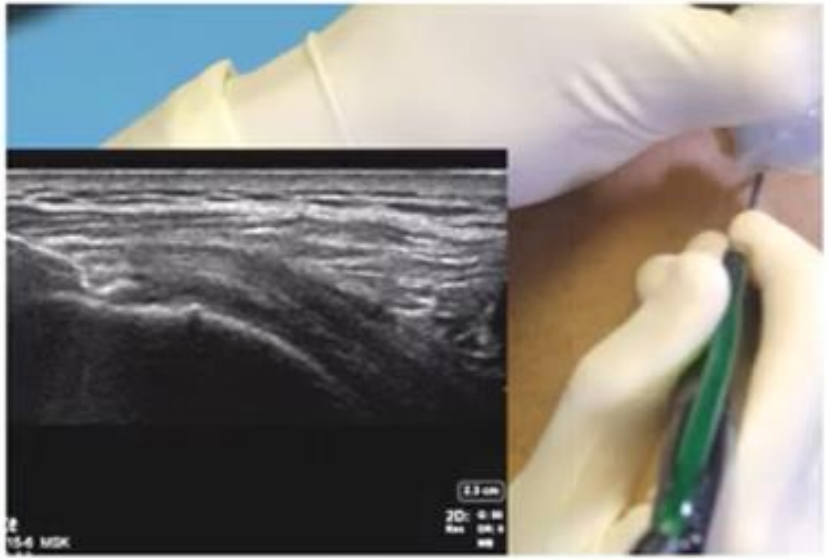
Plantar Fascia

TX1 Micro-Tip Placement

Treatment with TX System



Treating hypoechoic region

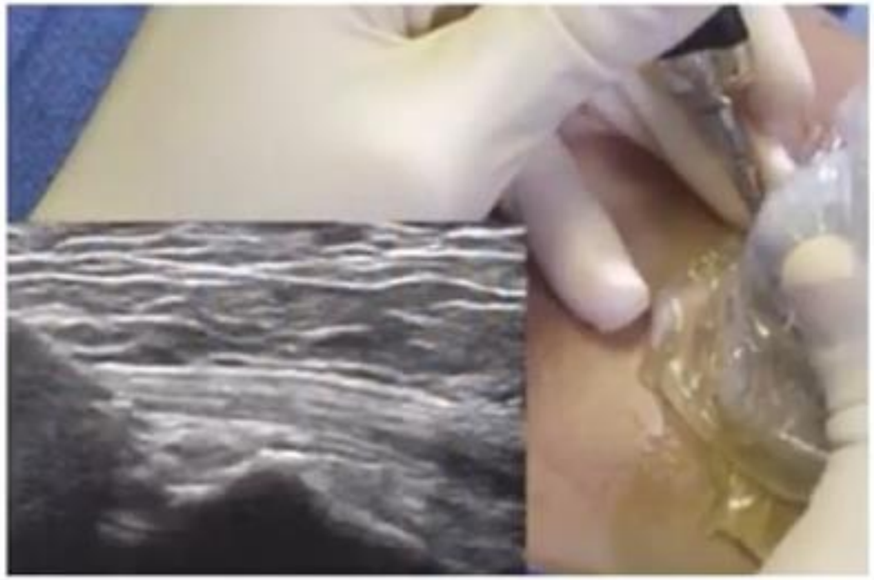


Treating calcific deposit

GLUTEAL

Treatment with TX System

Prepping the site



Treating calcific deposit

ELBOW

Barnes D. Ultrasonic energy in tendon treatment. Operative Tech in Orthopaedics 2013;23(3). [Elbow]

Koh J, et al. Fasciotomy and surgical tenotomy for recalcitrant lateral elbow tendinopathy. AJSM 2013;41(3):636-644. [Elbow]

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HIP

Ostrom E, Joseph A. Ultrasound guided percutaneous tenotomy of the abductor longus. MOJ Sp Med 2018;2(1):1-6. [Hip: Abductor Longus]

Baker C., Mahoney JR. Ultrasound-guided percutaneous tenotomy for gluteal tendinopathy. (Submitted for publication, May 2019). [Hip: Gluteus]

KNEE

Elattrache N, Morrey BF. Percutaneous ultrasonic tenotomy as a treatment for chronic patellar tendinopathy-jumper's knee. Oper Tech in Orthopaedics 2013;23(2). [Knee]

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COMBINED / OTHER ANATOMY

Khanna M, Wiederholz M, Rizkalla M, Jiminez J. A novel approach to the treatment of chronic tendon pathology: a pilot study. Abstract presentation at: Annual Meeting American Academy of Phys Medicine & Rehabilitation 2013 Oct. [Elbow/Shoulder/Knee/Achilles]

Traister E, Lingor R, Simons S. The effect of percutaneous tenotomy using Tenex on short term average pain scores in refractory tendinopathies. Presented at Annual Meeting of American Medical Society for Sports Medicine 2014 Apr. [Elbow/Knee/Plantar Fascia]

Hall M, Woodroffe L. Ultrasonic percutaneous tenotomy for recalcitrant calcific triceps tendinosis in a competitive strongman: a case report. Curr Sp Med Rep 2017;16(3):150-152. [Triceps]

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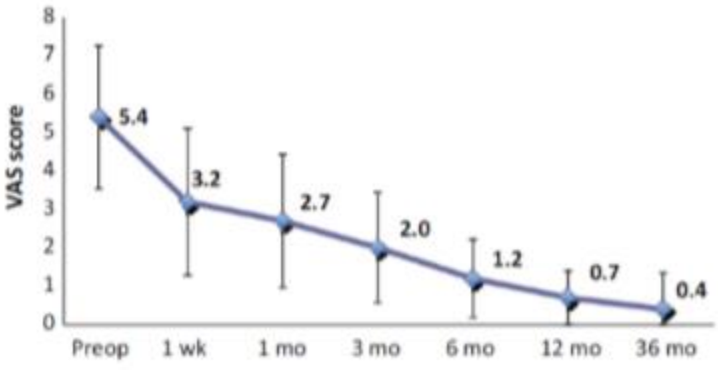

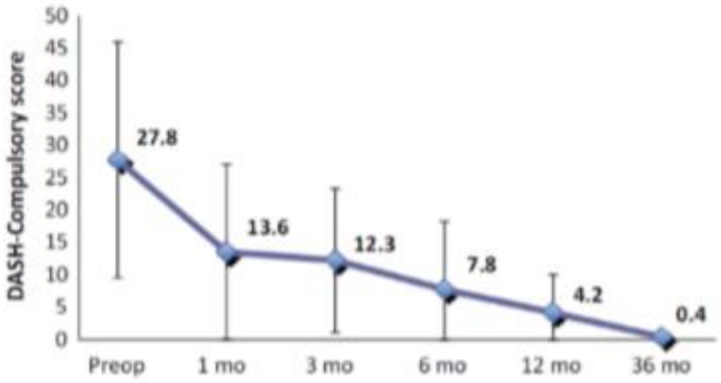

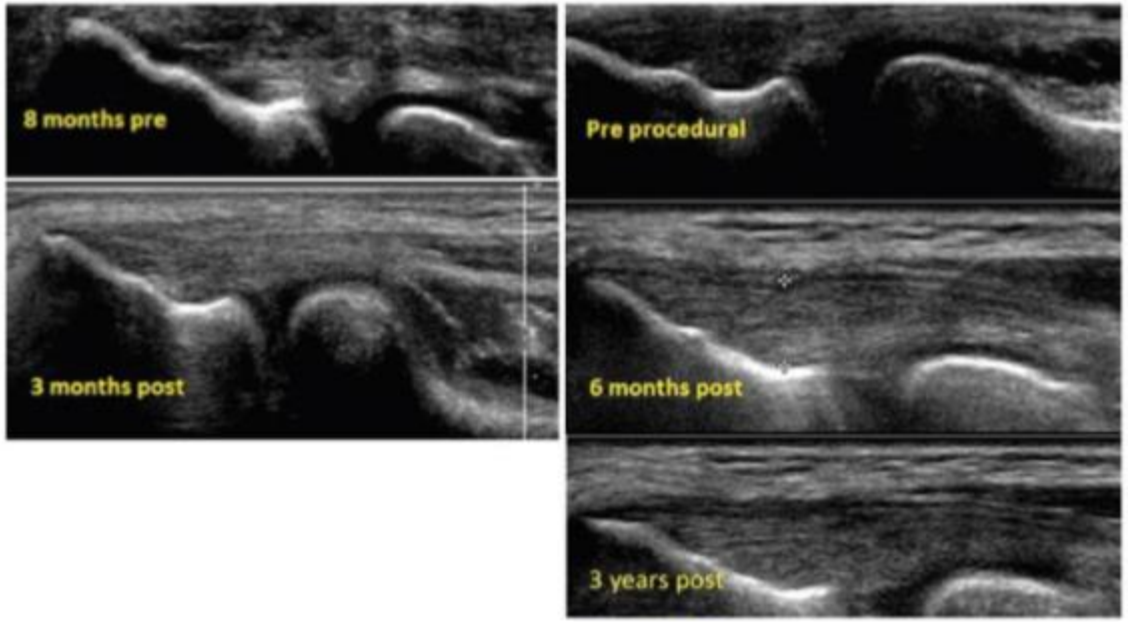

All patients reported no or minimal pain at 3 years, with median VAS score of 0.7 at 3 years (range 0-2.5, $p<0.001$).

Functional outcomes of patients also improved, with median DASH-Compulsory score of 0.4 at 3 years (range 0-10.8, $p<0.001$).

Barnes D, Beckley J, Smith, J. Percutaneous ultrasonic tenotomy for chronic elbow tendinosis: A prospective study. JSES 2015;24(1):67-73. [Elbow]

Nineteen consecutive patients ages 38-67 years failing conservative management for > 6 months with either medial (7) or lateral (12) tendinopathy were prospectively studied.

Results revealed no procedural complications and a significant improvement in pain VAS scores from 6.4 pretreatment to 2.6 at 6 weeks and sustained at 12 months post-procedure ($p < 0.0001$), pre-treatment DASH of 44.1 to 8.6 at 12 months ($p < 0.0001$), and MEPS pre-treatment score of 59.1 while at 12 months 83.4 ($p < 0.0001$).

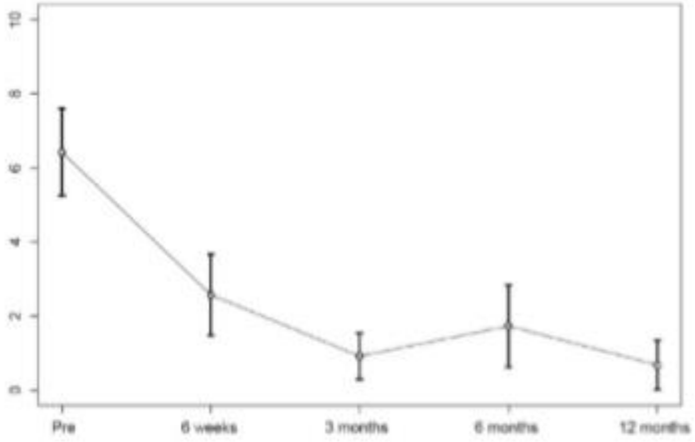

Figure 3 Visual analog scale (VAS) pain scores (range, 0-10)

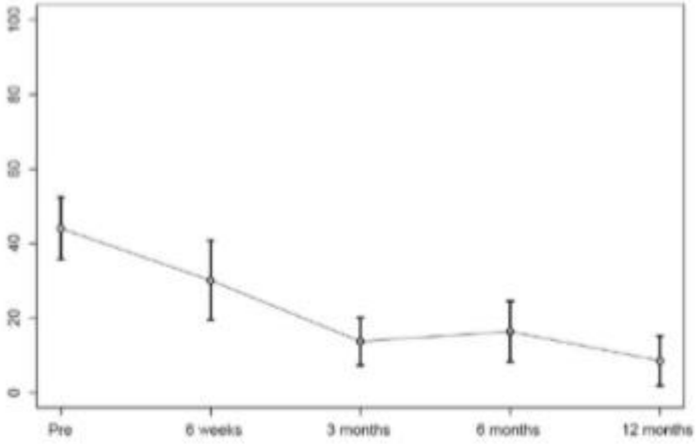

Figure 4 Scores for the Quick (11-item versio iti

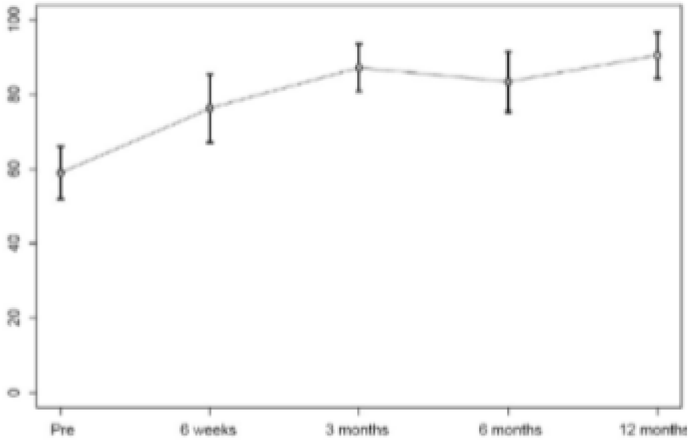

Figure 5 Mayo Elbow Performance Scores (MEP! 10

Razdan R, Vanderwoude E, Braun A, Morrey B. Percutaneous ultrasonic fasciotomy: a novel approach to treat chronic plantar fasciitis. J Surg Proced Tech 2018;3(102):1-6. [Plantar Fascia]

A total of 100 patients with a minimum of 4 months of symptoms and failure of at least one conservative treatment were treated in an out-patient setting

At 6 months, 96% of patients were satisfied with the procedure

Chimenti R, Stover D, Fick B, Hall M. Percutaneous ultrasonic tenotomy reduces insertional achilles tendinopathy pain with high patient satisfaction and a low complication rate. J Ultras Med 2019;39(6):1629-1635. Epub 2018 Oct. [Achilles]

85% patients reported no pain or mild pain at long term follow-up

Kamineni S, Butterfield T, Sinai A. Percutaneous ultrasonic debridement of tendinopathy – a pilot achilles rabbit model. J Orthop Surg Res 2015;10:70:1-8. [Stimulates Healing]

Mature female New Zealand White rabbits (n= 12) were treated by ultrasonography-guided injection of 0.150 ml of collagenase injected into the central region of the achilles tendon

Histopathological examination revealed that tendons injected with collagenase showed focal areas of hypercellularity, loss of normal tissue architecture, and regions of tendon disorganization and degeneration, when compared to control tendons.

In animals treated with the TX System, expression of collagens I, III, and X, returned to levels similar to a normal tendon

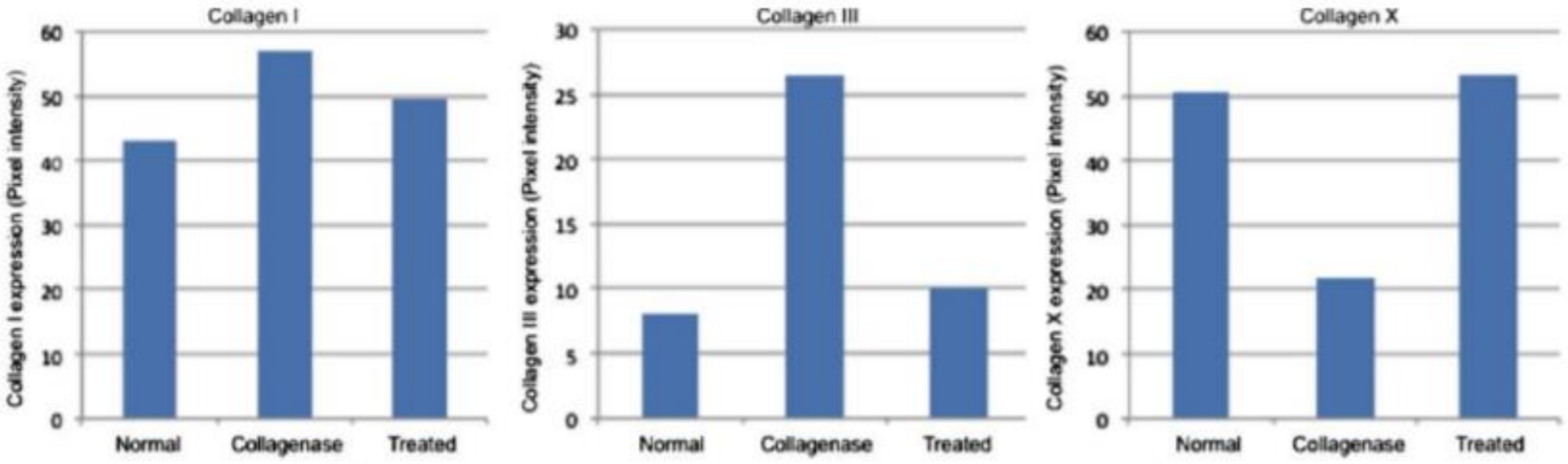

Fig. 4 **a** Semi-quantification of collagen subtypes using western blot analysis. **b** The *Y*-axis corresponds to signal intensities: (*A*) collagen I (129 kDa), (*B*) collagen III (138 kDa), and (*C*) collagen X (66 kDa)

Baker C., Mahoney JR. Ultrasound-guided percutaneous tenotomy for gluteal tendinopathy. (Submitted for publication, May 2019). [Hip: Gluteus]

30 patients over the age of eighteen who had failed more than 4 months of conservative treatment

All patients had an MRI demonstrating tendinopathy of the gluteus minimus/medius tendons prior to UGPT

24/28 patients (84%) were considered satisfactory outcomes. There were no complications.

Improvements in the patient's status are usually evident by 1 to 3 months after the procedure.

Traister E, Lingor R, Simons S. The effect of percutaneous tenotomy using Tenex on short term average pain scores in refractory tendinopathies. Presented at Annual Meeting of American Medical Society for Sports Medicine 2014 Apr. [Elbow/Knee/Plantar Fascia]

Review of average pain scores on a cohort of 43 patients that had recalcitrant tendinopathy and underwent percutaneous tenotomy via the Tenex Health TX system in an outpatient sports medicine clinic.

- Tenotomy sites included lateral epicondyle (24 patients), patellar tendon (8 patients) and plantar fascia (11 patients).