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
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
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
- 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
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

Strain < 4%, elasticity maintained
Strain exceeds 4%, microscopic failure
Beyond 8% strain, macroscopic failure

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

INFLAMMATION STAGE
up to 14 days

HEALING STAGE
2nd - 6th week

REMODELLING STAGE
6th - 10th week

MATURATION STAGE
up to 1 year
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
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
Conclusions:

• Remaining tendon can compensate by increasing CsA healthy tendon
TREATMENT STRATEGIES

- Unloaded tendon with low capacity (e.g., older person, post-injury), susceptible to overload resulting in pathology and pain
- Pathology and pain with loss of function (reactive, reactive on degenerative)
- Degenerative non-painful tendon with poor function, can rupture

Imaging normal painful tendon, rare, differential diagnosis

Degenerative non-painful tendon with good function, can rupture
<table>
<thead>
<tr>
<th>Conservative Management</th>
<th>Surgical Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomechanical Therapies</strong></td>
<td><strong>Pharmaceutical agents:</strong></td>
</tr>
<tr>
<td>Classical physiotherapy:</td>
<td>Anti-inflammatory drugs (NSAIDs)</td>
</tr>
<tr>
<td>Deep transverse friction massage</td>
<td>Systemic corticosteroids</td>
</tr>
<tr>
<td>Myofascial manipulation</td>
<td>Pain control (anesthetics)</td>
</tr>
<tr>
<td>Controlled motion</td>
<td>Antibody therapy (e.g., IL-17, IL-1β antagonist and BMP)</td>
</tr>
<tr>
<td>Ultrasound (0.75-3.0 MHz; pulsed or continuous)</td>
<td>Peritendinous (high volume) injections:</td>
</tr>
<tr>
<td>Ionophoresis</td>
<td>Corticosteroid injection</td>
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<tr>
<td>Phonophoresis</td>
<td>Saline injection</td>
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<tr>
<td>Acupuncture</td>
<td>Hyaluronic acid injection</td>
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<tr>
<td><strong>Electrical and laser stimulation:</strong></td>
<td>Botulinum toxin (BTA) injection</td>
</tr>
<tr>
<td>Pulsed electromagnetic fields</td>
<td>MMP inhibitor injection (e.g., Aprotinin)</td>
</tr>
<tr>
<td>Extracorporeal shock-wave therapy</td>
<td>Proliferation</td>
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<tr>
<td>Laser treatment (pulsed or continuous)</td>
<td>Topical glyceryl trinitrate therapy</td>
</tr>
<tr>
<td>Stabilization and modification:</td>
<td>Polidocanol injection</td>
</tr>
<tr>
<td>Taping</td>
<td>Glycosaminoglycan polysulfate injection</td>
</tr>
<tr>
<td>Splinting</td>
<td>Sclerosant injection</td>
</tr>
<tr>
<td>Bracing</td>
<td>Low-dose heparin</td>
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<tr>
<td>Straps</td>
<td><strong>Blood-based therapies:</strong></td>
</tr>
<tr>
<td>Orthotic devices</td>
<td>Platelet-rich plasma injection</td>
</tr>
<tr>
<td>Modification of activity:</td>
<td>Autologous blood injection</td>
</tr>
<tr>
<td>Rest</td>
<td>Actovegin (deproteinized extract of calf's blood)</td>
</tr>
<tr>
<td>Eccentric exercises</td>
<td><strong>Cell-based therapies:</strong></td>
</tr>
<tr>
<td>Thermic treatments:</td>
<td>Autologous tenocyte implantation (OrthoCell)</td>
</tr>
<tr>
<td>Cryotherapy (e.g., ice packs and baths)</td>
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<tr>
<td>Thermotherapy (heat)</td>
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</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
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
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.
ULTASOUND 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
<table>
<thead>
<tr>
<th>Conservative Conservative Care</th>
<th>Minimally Invasive TX System</th>
<th>Fully Invasive Open Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>Local Anesthesia</td>
<td>General Anesthesia</td>
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<tr>
<td>Ice</td>
<td>Single Treatment</td>
<td>Rehab/PT</td>
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<tr>
<td>OTC Meds</td>
<td>Cut/Remove Source of Pain</td>
<td>Long Recovery</td>
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<tr>
<td>PT</td>
<td>Cortisone Injection</td>
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<tr>
<td></td>
<td>Mask Pain</td>
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<tr>
<td></td>
<td>Degenerates Tendon</td>
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</table>
Over 100,000 patients since 2012
34% tennis and golfers elbow
35% plantar fascia
12% achilles
8% gluteal
5% knee
5% shoulder
1% other
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 "jackhammer effect".
- Continuous saline irrigation cools Microtip and emulsifies to efficiently remove target tissue.
TX System Setup

Supply Kit
- Needles, 23G (2x)
- Syringe, 10CC
- Scalpel, #11
- Probe Cover with Gauze, 4” x 4” (2x)
- Wound Closure Strips (6x)
- Dressing

Saline Irrigation (with pressure cuff)

Foot Pedal (for cutting power, plugs into Console)

TX MicroTip (cartridge inserts into Console)
# MicroTip Options

<table>
<thead>
<tr>
<th>MicroTip Offering</th>
<th>TX1</th>
<th>TX2</th>
<th>TXB</th>
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</thead>
<tbody>
<tr>
<td>Tip Length</td>
<td>1.0&quot; (25.4 mm)</td>
<td>1.7&quot; (43.2 mm)</td>
<td>1.3&quot; (33.0 mm)</td>
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<tr>
<td>Tip Gauge (approx. inner lumen OD)</td>
<td>19 (1.1 mm)</td>
<td>18 (1.3 mm)</td>
<td>15 (1.9 mm)</td>
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<tr>
<td>Sheath Gauge (approx. outer lumen max OD)</td>
<td>11 (3.0 mm)</td>
<td>14 (2.1 mm)</td>
<td>11 (3.0 mm)</td>
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<tr>
<td>Volume as % of TX1 Baseline (per stroke @26.5 kHz)</td>
<td>100%</td>
<td>200%</td>
<td>650%</td>
</tr>
</tbody>
</table>
1. VISUALIZE DAMAGED TENDON (DARK REGION) VIA ULTRASOUND

2. GUIDE TX™ MICROTOP TO DAMAGED TISSUE WITH ULTRASOUND GUIDANCE

3. FOOT-PEDAL ACTIVATION OF TX™ MICROTOP 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

<table>
<thead>
<tr>
<th>Year</th>
<th>Peer Rev. Manuscript</th>
<th>Book Chapter</th>
<th>Other (Poster, Technique)</th>
<th>In Review</th>
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<td>2019</td>
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<tr>
<td>Totals:</td>
<td>20</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>35</td>
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</tbody>
</table>

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

Epicondyl Healthy Tendon

Epicondyl Hypoechoic/Damaged Tendon
Patellar Tendonosis

Orange strip marks placement of ultrasound transducer on inferior pole of patella.
Achilles Tendonosis

Orange strip (a) marks placement of ultrasound transducer on Achilles and (b) shows cross section view to identify mid-substance tendonosis.
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
Barnes D. Ultrasonic energy in tendon treatment. Operative Tech in Orthopaedics 2013;23(3). [Elbow]...


Williams R, Pourache A. Percutaneous ultrasonic tenotomy for refractory common extensor tendinopathy following failed open surgical release: a report of two cases. PM R 2018;10(3):313-316. [Elbow]...


Yanish GJ, Moore CT, Pinegar C. Percutaneous ultrasonic tenotomy with ultrasound guidance vs open lateral epicondylectomy: a prospective cost comparative analysis. (Submitted for publication, JSES, April 2019). [Elbow]...
FOOT AND ANKLE


HIP


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]


COMBINED / OTHER ANATOMY


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).

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).

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.

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

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
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.

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).