THE PREVALENCE OF PATELLAR TENDINOPATHY IN ATHLETIC POPULATIONS AND THE EFFECTIVENESS OF GRASTON TECHNIQUE® AS A PATELLAR TENDINOPATHY TREATMENT

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Kiley Michelle Lovelace

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Health, Nutrition, and Exercise Sciences

September 2022

Fargo, North Dakota

North Dakota State University
Graduate School

Title

THE PREVALENCE OF PATELLAR TENDINOPATHY IN ATHLETIC POPULATIONS AND THE EFFECTIVENESS OF GRASTON TECHNIQUE® AS A PATELLAR TENDINOPATHY TREATMENT

By

Kiley Michelle Lovelace

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Yeong Rhee
Chair

Dr. Kyle Hackney

Ronda Peterson

Approved:

9/9/2022
Date

Dr. Yeong Rhee
Department Chair

ABSTRACT

The purpose of this paper is to examine both the prevalence of patellar tendinopathy (PT) in athletic populations and the effectiveness of Graston Technique® as a treatment for PT. Since PT is a common injury seen among athletes, it is important for clinicians to understand the condition and how common it is within athletics, especially those that involve an increased amount of jumping and landing such as volleyball or basketball. Graston Technique® is a popular treatment option among clinicians for various musculoskeletal injuries, including tendinopathies such as PT. Therefore, it is imperative for clinicians to understand the research surrounding Graston Technique as a treatment for PT to ensure the best treatment plan for patients with the condition.

ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. Kyle Hackney and Ronda Peterson for their continued support throughout the process of writing my master's research paper. I would also like to extend a special thank you to my committee chair, Dr. Yeong Rhee for her patience, helpful feedback, and kindness.

DEDICATION

I would like to dedicate this paper to my friends and family who supported me along the way through graduate school. Your love and support are greatly appreciated.

TABLE OF CONTENTS

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

CHAPTER 1. INTRODUCTION

Overview of Topic

Graston Technique® is a specific form of Instrument Assisted Soft Tissue Mobilization (IASTM) that is used to treat a variety of musculoskeletal conditions such as tendinopathies, strains, and sprains.[1] Patellar tendinopathy (PT) includes two injuries to the patellar tendon: tendonitis and tendinosis. Patellar tendonitis refers to the inflammation of the patellar tendon due to overuse with jumping activities. Characteristics of patellar tendonitis include pain, swelling, warmth to the touch, and stiffness.[2] Patellar tendinosis is a chronic injury to the patellar tendon caused by overuse that can lead to the degradation of the tendon tissues overtime.[2] Some characteristics of patellar tendinosis include pain, stiffness, increased tendon thickness, and other abnormalities seen on diagnostic imaging such a diagnostic ultrasound.[2] Diagnostic ultrasound is a diagnostic tool often used to detect musculoskeletal injuries or pathologies.[3]

Statement of Purpose

The purpose of this paper is to examine the prevalence of PT and determine the effectiveness of Graston Technique® as a treatment in cases of patellar tendinopathies, as well as the gap between Graston Technique® practice and recommendations.

Brief Review of Literature

Graston Technique® is a specific form of IASTM that is a popular treatment for various musculoskeletal injuries within athletic training and physical therapy.[1,4] As an addition to normal soft tissue mobilization, IASTM utilizes instruments during treatment to allow for deeper and more effective treatment.[1-2, 4] The IASTM instruments allow the clinician to treat deeper tissues to reduce adhesions, tissue restrictions, and scar tissue, as well as improve tissue fiber alignment. Some forms of IASTM include Graston Technique®, Gua Sha, and augmented soft tissue mobilization (ASTYM®). Gua Sha and ASTYM® create microtrauma to restart the healing process of the injured tissue, which may result in temporary side effects such as pain or petechiae. Long term benefits of IASTM may include increased range of motion (ROM), decreased pain, and increased function.[2,4-7]

A specific form of IASTM, Graston Technique®, utilizes its own unique stainless-steel instruments.[1,4] Similar to Gua Sha and ASTYM®, the goal of Graston Technique® is to restart the inflammatory process to promote quicker healing. Different from other forms of IASTM, Graston Technique® has a detailed protocol, which includes an active warmup, treatment, stretching, and strengthening. The six Graston Technique® instruments are used to perform several different strokes at varying speeds and angles to change the depth and intensity of treatment. Benefits of Graston Technique® treatment may include scar reduction, improved tissue fiber alignment, blood flow, ROM, and function as well as decreased pain. Graston Technique® is a popular and beneficial treatment choice for various musculoskeletal disorders due to its efficiency and hands-on approach.[1,4]

Diagnostic ultrasound is an imaging modality that is useful in the diagnosis of various musculoskeletal conditions and injuries.[3-4,8-9] Depending on the resolution, diagnostic ultrasound can be used to view both superficial and deep structures within the body. The benefits of ultrasonography include the ability to perform a dynamic evaluation, assess multiple joints, and help guide needle insertions into the body tissues. On the contrary, some limitations include poor intra and interrater reliability due to differing levels of experience, a steep learning curve for diagnostic ultrasound, and a time-consuming assessment when viewing multiple joints.[4] The different structures viewed with diagnostic ultrasound have varying brightness and texture appearances depending on the type of tissue and the health of the structure. For example, tendons and ligaments appear to have a high echogenicity, or brightness, while also appearing fiber-like in texture. Additionally, a higher resolution shows more superficial structures, while lower resolution allows the operator to view deeper structures. Overall, diagnostic ultrasound is a very useful tool in diagnosing many musculoskeletal conditions such as tendinosis, muscle tears, and more. [3-4,8-9]

Objectives

This review paper is to:

1. Examine the current research surrounding the prevalence of PT in athletic populations.
2. Examine the current research on Graston Technique ® as a treatment of PT.
3. Examine research on the effectiveness of Graston Technique® as a treatment of PT.

Significance of Review

Patellar tendinopathy is a common injury in athletes and recreationally active individuals. This review will examine, the prevalence of PT in athletic populations and the literature surrounding Graston Technique® as a treatment for PT and its effectiveness. The review of research surrounding of PT in athletes and the use of Graston Technique® is important for clinicians because it will provide important knowledge in understanding the effectiveness of a treatment that is commonly used among clinicians and to allow for better care of patients with this condition.

Steps to Conducting Review

PubMed was utilized through the NDSU library website to find related research articles. Search one used the search terms “patellar tendinopathy” and “prevalence”, which yielded 57 total results. The results were narrowed down to athletic patient populations and access to the articles. Search two used the terms “Graston Technique” and “tendinopathy”, which yielded four total results. Only two of these articles were included based on athletic patient population. Search three used the terms “diagnostic ultrasound” and “patellar tendinopathy”, which yielded seven results between the years 2008 and 2022. Only four of these results were reviewed due to relevance to PT and IASTM prevalence of PT or subject matter. An additional search through the NDSU Library Catalog was completed using the search terms “diagnostic ultrasound” and “patellar tendinopathy”, which yielded 82 results. The results were narrowed down based on articles that were already reviewed and cited, as well as relevant articles with athletic patient populations.

Definition of Terms

Instrument Assisted Soft Tissue Mobilization (IASTM): This includes the use of instruments to achieve effects and benefits of soft tissue mobilization.[1]

Indication: This describes conditions or pathologies that benefit from a specific treatment.[2]

Contraindication: This describes situations when the treatment should not be used, as it would likely cause harm to the patient.[2]

Sweeping: This describes a type of Graston Technique® stroke that occurs in a linear direction at a steady rate.[1]

Fanning: This describes a type of Graston Technique® stroke that occurs in an arched path in a clockwise or counterclockwise direction.[1]

Strumming: This describes a type of Graston Technique® stroke that uses deep, short strokes that are perpendicular to tissue alignment.[1]

Brushing: This describes a type of Graston Technique® stroke that is utilized to desensitize tissue in a paint-brush style stroke.[1]

J-stroke: This describes a type of Graston Technique® stroke that aggressively manipulates tissue away from bony prominences in a J-pattern.[1]

Framing: This describes a type of Graston Technique® stroke that combines other strokes to treat around bony prominences, such as the patella.[1]

Swivel: This describes a type of Graston Technique® stroke that moves back and forth over small lesions using the knob of a Graston Technique® instrument.[1]

Scoop: This describes a type of Graston Technique® stroke that treats deeper lesions using a concave shaped instrument starting at 90° then flattening out the instrument.[1]

Tendonitis: A condition where there is inflammation of the tendon.[2]

Tendinosis: A condition where there are microtears and degeneration of the tendon.[2]

Diagnostic ultrasound: A clinical imaging tool that uses sound waves to produce an image of musculoskeletal tissues and structures.[3,8-9]

Echogenicity: The brightness of the diagnostic ultrasound image based on the amount of sound waves reflected and absorbed.[3-4]

Hyperechoic: A high reflective pattern that makes a structure appear brighter than those around it on diagnostic ultrasound. [3-4]

Hypoechoic: A low reflective pattern that makes a structure appear less bright than the structures surrounding it on diagnostic ultrasound. [3-4]

Isoechoic: This describes structures on diagnostic ultrasound that have the same echogenicity as the surrounding tissues. [3-4]

Anechoic: The lack of echogenicity of structures such as simple fluids. [3-4]

Longitudinal axis (LAX): The diagnostic ultrasound is held lengthwise or parallel to the desired structure being viewed.[3]

Short axis (SAX): The diagnostic ultrasound transducer is held crosswise, or perpendicular, to the desired structure being viewed.[3]

Anisotropy: When a tendon or ligament being imaged in SAX view is two to three degrees off angle, it causes the tendon or ligament to appear more hypoechoic than normal. [3]

Shadowing: An anechoic area occurs on the ultrasound image when the ultrasound beam is either reflected, refracted, or absorbed by the body tissues. [3]

Refractile shadowing: A specific kind of shadowing that occurs at the edge of certain structures, such as a torn Achilles tendon. [3]

Posterior reverberation: When there is a smooth and flat surface being scanned, such as bone, the sound waves from the transducer reflect back and forth between the tissue and the transducer. This causes linear reflective echoes beneath the structure's surface. [3]

Ring-down artifact: A specific kind of shadowing that occurs when viewing a metal surface, which is seen as more continuous reflective echoes deep to the structure. [3]

Comet-tail artifact: An artifact that occurs when there is gas within the soft tissue, small, circular, bright echoes occur near the source of this artifact. [3]

Beam-width artifact: When the focal zone is too large for the desired structure, it may cause difficulty viewing it clearly. [3]

Posterior acoustic shadowing: This is a form of shadowing that occurs when a structure's surface strongly absorbs or reflects light, such as bone. [3]

Sensitivity: This refers to how well a test is able to rule out if a patient has a certain disorder or disease.[2]

Specificity: This refers to how well a test is able to rule in if a patient has a certain disorder or disease.[2]

Organization of Remaining Chapters

Chapter two contains a review of the literature examining the following topics: healing process, IASTM, Graston Technique®, patellar tendinopathy (PT), IASTM and tendinopathy, Graston Technique® and tendinopathy, diagnostic ultrasound, normal and injured appearance with diagnostic ultrasound, patellar tendinopathy and diagnostic ultrasound, as well as a summary of reviewed articles. Chapter three contains a discussion of the literature review and conclusions drawn from the research used with recommendation for future research on this topic. Additionally, all the included references are cited after chapter three. Lastly, appendices A-C follow the reference list.

CHAPTER 2. REVIEW OF LITERATURE

Healing Process

To effectively perform the skill of IASTM, it is important to consider and understand the body's natural healing processes. The entire healing process includes three phases: inflammatory response, fibroblastic repair, and maturation-remodeling.[2] To promote healing, IASTM focuses on re-starting the inflammatory response phase.[1] Inflammation is a process that occurs as a response to injury and is characterized by signs such as swelling, redness, and pain, as well as loss of function and increased temperature of the injured area.[2]

Often, injury affects the blood vessels causing hemorrhage in the area that aids in attracting inflammatory cells. Following the initial injury, chemical mediators (histamine, leukotrienes, prostaglandins, and cytokines) begin limiting the amount of exudate, and therefore swelling, at the injury site.[2] Initial inflammation lasts approximately two to four days depending on the severity of the injury. During the fibroblastic repair phase, a clot continues to form in the area, then phagocytosis begins to occur in the injured area to clean up debris surrounding the injured tissues.[2] Within a few days, a gel-like matrix creates fibrosis, while also manufacturing and laying down collagen at the injury site to form the scar.[2] The pain during this phase begins to subside as scar formation continues to progress and the injured area becomes less tender. New capillaries begin to form during the fibroblastic repair phase, which brings essential oxygen delivery to the injured area to promote tissue regeneration.[2] In total, this phase begins around day four and may last up to six weeks.[2]

Finally, the maturation-remodeling phase promotes the realignment of collagen fibers within the scar formation. The body does this based on the tension forces put upon the scar and align into a taut formation.[2] As more stress and strain is placed on the scar from tensile forces, the strength increases as the scar tissue begins to align, though it will not likely reach the full strength of the surrounding, healthy tissue. While this is happening, capillaries are decreased to the scar and the injury site slowly begins to look like the tissue surrounding it.[2] The pattern of stress from performing ROM and rehabilitation exercises during this time continue to remodel the scar tissue. This process is longer than the other two phases, as it may only last about three weeks but can continue for years.[2]

Additionally, chronic injuries persist if the body does not properly go through the inflammatory phase. This leads to the production of granulation tissue and fibrous connective tissue that do not respond as well to physical and pharmacological interventions such as Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) or IASTM. One type of chronic injury is tendinosis, which is a specific chronic injury that may occur in many areas in the body. Tendons may become inflamed due to repeated activity where a tendon cannot slide during muscle contraction, which causes swelling, pain, warmth, and possible crepitus, or crackling feeling, upon palpation.[2] Initially, in the beginning phase, this is referred to as tendonitis, or the acute inflammation of a tendon. If the repeated activity continues for three to six weeks, there will be no markers of inflammation, thus becoming tendinosis. There may be tendon thickening, pain, and stiffness due to tendon degeneration.[2]

Instrument Assisted Soft Tissue Mobilization

Instrument Assisted Soft Tissue Mobilization is the use of instruments to achieve effects and benefits of soft tissue mobilization.[1] It can be defined as the forceful passive movement of musculofascial elements through its restrictive directions, beginning with the most superficial layers and moving deeper as the treatment progresses.[1] Initially created by James Cyriax, this technique is derived from cross-friction massage (CFM), but uses the addition of tools to assist the clinician.[5] Cross-friction massage (CFM) is a technique that aims to achieve structural changes by applying force in a perpendicular motion to the collagen structures within the specific target tissues.[10] The basis for IASTM is applying CFM techniques while using instruments.

Instruments used in IASTM also provide a mechanical advantage for the clinician, as they reduce stress on the hands and allow for deeper treatment than with the hands alone. With the help of various instruments, IASTM uses the body's natural healing processes to work through adhesions in the muscles, tendons, fascia, and skin.[4-5] Subsequently, IASTM works to decrease pain, increase ROM, and improve function.[6] The ultimate goal of IASTM is to ignite the body's inflammatory response to initiate the cascade of natural healing to eventually reach the maturation-remodeling phase.

Multiple types of IASTM, such as Gua sha, augmented soft tissue mobilization (ASTYM®), and Graston Technique® have their own specific set of IASTM tools designed with a variety of materials, such as metal or plastic, to perform treatment.[6] Differences in goals are seen between some of the IASTM types, as well as protocols that are specific to the brand. Some of these goals include creating changes to soft tissue such as muscle, tendon, or ligament, increasing ROM, improving scar mobility, and improving joint contracture.[12]

Gua sha is a specific form of soft tissue mobilization that falls under the IASTM category. While very similar to most forms of IASTM, Gua sha is an eastern medical treatment stemming from Asia that uses smooth-edged tools such as jade to scrape the skin.[5,12] Redness is a common side effect of Gua sha and is often referred to as blood stasis, or hemostasis. [5,12] This can usually be identified by the presence of petechiae, or redness at the treatment area, on the skin. This sets Gua sha apart from other IASTM treatments since petechiae are not usually a goal of treatment and just considered to be a possible side effect.[1]

Additionally, ASTYM® is a controversial topic within IASTM. While some clinicians who practice ASTYM® consider it to be a category of its own, others believe it is a part of IASTM.[4] Like some forms of IASTM, ASTYM combines techniques using instruments, stretches, and strengthening to provide treatment for soft tissue adhesions. Similar to Gua sha, ASTYM has some of its own evidence apart from IASTM backing it up through different research.[5] Overall, IASTM is a widely used treatment for many soft tissue injuries to help reduce adhesions, increase joint ROM, and manage pain.

Graston Technique®

A specific form of IASTM is Graston Technique®.[1] This technique utilizes specific treatment strokes, unlike other IASTM methods. Graston Technique® claims patients experience quicker outcomes and return to function, and the ability to feel the abnormal tissue texture during treatment, which increases their investment and interest.[1] The physiological effects of Graston Technique® include increased fibroblastic activity, piezoelectric effect, Davis's law effect, altered neural activity, increased stem cells, and enhanced blood perfusion.[1] Increased fibroblastic activity comes from the stimulation of connective tissue remodeling by facilitating the repair and regeneration of collagen secondary to fibroblast recruitment.[8-9] The piezoelectric effect is the ability of soft tissue to generate electrical signals when collagen fibers are sheared past one another, which has maximal effect at 45° of axial compression. [1]

Additionally, evidence exists to support increased perfusion one week following Graston Technique® treatment, as well as increased size of arteriole blood vessels.[13] Moreover, research has indicated that Graston Technique® provides an immediate mobilization of stem cells into circulation, which can lead to improved healing outcomes.[7] Furthermore, Davis's law states that soft tissue will elongate by the addition of new material when put under unremitting tension.[1]

The neural activity of mechanoreceptors that have larger axons is altered following treatment with Graston Technique®.[14] Due to its positive claims surrounding patient outcomes and decreased healing times, Graston Technique® is used to provide treatment for many different pathologies.[1]

Indications, Contraindications, and Precautions

As with any intervention, Graston Technique® includes clinical indications, relative contraindications, and absolute contraindications that are in place to ensure patient safety. They help avoid harm being done to the patient and give them the best possible outcome. Indications are conditions or pathologies that benefit from a specific treatment.[2] Relative contraindications are precautions, as the situation could potentially cause harm to the patient if considerations are not used. However, absolute contraindications include situations when the method should not be used, as it would likely cause harm to the patient.[1] Some of the pathologies that are most used with Graston Technique® and are considered indications include patellar tendinosis, Achilles tendinosis, plantar fasciitis, iliotibial band syndrome, and ankle sprains (Appendix A). Tendinopathies such as patellar or Achilles respond well to Graston due to increased fibroblastic activity, better fiber alignment, improved elasticity, and improved tissue organization.[4,13]

Furthermore, there are several relative and absolute contraindications to consider before performing Graston Technique® on a patient. Relative contraindications may include cancer, burn scars, kidney dysfunction, pregnancy, medications, age-related health issues, varicose veins, osteoporosis, chronic regional pain syndrome, autoimmune disorders, diabetes, congestive heart failure, and electronic implants (Appendix A). Some absolute contraindications include open wounds, thrombophlebitis, uncontrolled hypertension, inflammatory conditions due to infection, unstable fractures, infectious skin conditions, hematoma, myositis ossificans, osteomyelitis, and more (Appendix A). In conclusion, it is important to consider all possible indications and contraindications when performing Graston Technique® to ensure patient safety.

Instruments

Constructed with stainless steel, Graston Technique® instruments allow for a unique feel for both the patient and practitioner.[1] The Graston Technique® instruments work by detecting and amplifying the tactile feel within soft tissue restrictions to the practitioners hands due to the density and make of the steel. By magnifying what the hands feel, it is easier to detect thickening, ridges, adhesions, scar tissue, fibrotic nodules, and crystalline deposits within the soft tissues of the body. The six instruments that come in varied shapes with contoured edges to work on different body surfaces, including convex, concave, rounded, and pointed. Treatment edges come as either single or double beveled edge, with single bevel being the more intense of the two.[1] In summary, the material used to construct Graston Technique® instruments allows for unique feel for both the patient and clinician during each session.

Instrument Selection

Instruments should be chosen during each session based on the following criteria: instrument shape, treatment edge, and size of the body site or muscle group.[1] The GT1 instrument (Appendix B) is a single bevel, concave instrument that is used to scan or treat large muscle groups, as well as specific soft tissue restrictions with the knobs located on each end. It should be gripped with two hands and sweeping, fanning, swiveling, or scooping strokes are performed with this instrument.[1] Unlike the GT1 instrument, the GT2 instrument (Appendix B) is smaller with a single-beveled concave treatment edge and a double-beveled concave treatment edge that are helpful for treating smaller muscle groups with a convex surface, as well as two convex knobs used to treat specific tissue restrictions. This instrument can be used to treat smaller muscle groups or scan, using the following strokes: sweep, fan, swivel, and scoop.[1]

Similar to the GT2 instrument, the GT3 instrument (Appendix B) has a single beveled edge that is good for evaluating and treating specific, smaller soft tissue restrictions by performing J-stroke, brush, or strum stroke. [1] Next, the GT4 instrument (Appendix B) has a single bevel convex treatment edge that is good for treating and scanning performed with sweeping or fannning strokes. This works best for evaluating and treating concave shaped soft tissue and focal areas of convex tissue. Like the GT4 instrument, the GT5 instrument (Appendix B) has a single beveled, concave edge that is good for scanning and treating convex shaped tissues and treating intercostal areas using sweep, fan, swivel, and scoop strokes. Lastly, the GT6 instrument (Appendix B) has a single bevel concave edge, double bevel concave edge, a treatment tip, and a knob. This is positive for treating the carpal tunnel, digits, and specific localized soft tissue restrictions using sweep, scoop, brush, strum, and J-stroke strokes.[1] Due to the varied sizes, shapes, and specialities of the six Graston Technique® instruments, this allows a more thorough and successful session for each patient.

Parameters

When performing Graston Technique®, it is important to recognize and follow the correct parameters to ensure optimal patient outcomes.[1] Tension, angle, rate, pressure, amplitude, direction, frequency, duration, and intensity are the parameters given in the Graston Technique® manual to follow for best patient care. Tissue tension is how much slack or tension you apply to the tissue being treated. For the tissue tension, it is important to position the joint or body part so the tissues are stretched for more tension. The more tension that is applied, the more superficial the treatment area becomes. Moreover, the target tissue depth, as well as patient tolerance, should be taken into consideration when deciding how much slack or tension to use.[1] Additionally, the instrument angle should be between 30° to 60° and placed in the direction of the treatment stroke.[1] When the angle is increased, there is a deeper penetration into the tissue.

Similar to tension, the stroke rate depends on the body part and the individual patient's tolerance. Larger areas and incidences of high pain levels should have a reduced stroke rate.[1] The pressure, or the force over a given area, depends on the tolerance of the patient and the amount of slack or tension put on the tissue being treated. When using instruments with a smaller contact area, less force is needed and if using high force in a small area, this creates deeper penetration. Furthermore, the amplitude, or stroke distance, may increase discomfort when using larger strokes. Larger strokes used with less pressure are good to prepare the treatment area for deeper penetration. It is important to treat adhesions in multiple directions, or in a clock-wise motion if treating circular lesions.[1]

Additionally, the frequency is the amount of times an intervention should be performed over a given period of time.[1] Graston Technique® recommends that treatment be performed two times per week, with at least 2 - 3 days in between each session. The duration, or session time, should be 8 - 10 minutes total per session. Graston Technique® recommends performing 30 – 60 seconds of treatment on each individual lesion and 3 - 5 minutes per muscle group, though larger areas such as the illiotibial band may take longer. Finally, treatment intensity is varied by changing the various parameters for Graston Technique® therapy.[1] Based on the patient's tolerance and session goals, it is important to keep the parameters in mind when deciding on a treatment plan for Graston Technique®.

Strokes

Many different strokes are utilized in Graston Technique® to provide the most effective patient treatment and outcomes.[1] These strokes include sweep, fan, brush, strum, J-stroke, swivel, and scoop. Sweeping can be performed with the GT1, GT2, GT4, and GT5 instruments for scanning or treatment in a single direction. This scanning can be done in either a linear or curvilinear pattern. Similarly, fanning can be used as another scanning stroke when performing Graston Technique®.[4] Fanning should be performed in the direction of the treatment edge in a clockwise or counterclockwise arched pattern and can be accomplished with the GT1, GT4, or GT5 instruments.[1,4] In addition, the brush stroke should be performed with the GT3 instrument to desensitize tissue, prepare for deeper treatment, or treat superficial fascial tissue.[1] Brushing is done by performing short, superficial strokes over a smaller area.

Similar to brushing, the strum is also performed with the GT3 or GT6 instrument with short, deep strokes that are perpendicular to the fiber alignment of tissue and is used to mobilize specific adhesions or restrictions in the tissue.[1,4] These strumming strokes should be small in amplitude and cover a small area such as a tendon or a specific adhesion. On the contrary, the J-stroke is an aggressive, manipulative stroke that goes away from bony prominences and can be performed with either the GT3 or GT6 instrument. The J-stroke can be used to treat superficial or deep adhesions and is performed in a J-shaped pattern.[1,4] Next, the swivel stroke can be performed over trigger points or a specific lesion using the GT1 or GT2 knobs by keeping the knob in place at 90° and turning, or swiveling, the instrument back and forth.[1] Furthermore, scooping is for deeper lesions using the GT1, GT2, or GT5 instruments and moves from a perpendicular to flat position. Finally, framing is not a stroke itself, but combines many strokes and goes along bony prominences such as the patella and malleolus with the GT2, GT3, or GT6 instruments.[1]

Graston Technique® Protocol

Unlike other IASTM treatments, it is important to perform the entire Graston Technique® protocol to allow for the best patient outcomes. The full protocol includes assessment, an active warmup, Graston Technique® strokes, stretching, and strengthening. First, to accurately assess and treat the patient, it is important to perform a thorough evaluation before treatment.[1] Assessment should include the following four steps: 1) obtain a thorough medical history, 2) have the patient rate their pain and functionality, 3) collect objective data such as the depth and size of lesions through an evaluation, and 4) set appropriate goals for the patient.[1] The soft tissue is manually assessed with the clinician's hands and then with Graston Technique® instruments to find areas of lesions and soft tissue restrictions.[1] Manual assessment allows for the clinician to palpate for anatomical and physiological deviations such as skin temperature, anatomical landmarks, skin moisture, shapes, and tissue layers.[1]

Graston Technique® claims the instruments allow for a unique feel for both the patient and clinician, as they provide feedback by magnifying what the hands feel.[1] The instruments help the clinician detect thickening, ridges, adhesions, fibrotic and scar tissue. It creates a vibrating sensation through the instrument that is felt both by the clinician and patient, which helps identify and localize lesions. Unlike using the hands, these instruments do not compress the tissue, which lets the clinician identify lesions deeper in the tissues.[1] The instruments also allow the clinician to separate out muscular anatomy more easily than when using their fingers alone. Following the evaluation, the patient should complete a whole-body systemic warmup to allow for the most effective treatment.[1] The combination of these two techniques allows the clinician to have a holistic assessment of the patient before beginning treatment followed by a proper, systemic warmup of the tissues.

Following treatment with the Graston Technique® instruments, stretching allows for tissue elongation, which promotes proper alignment of the tissues following treatment.[1] Proper alignment helps restore gliding of the affected tissues.[1] Lastly, strengthening should be progressive and is a vital component to treatment.[1] A progressive strengthening program should initially consist of high repetition, low weight exercises for the affected area, especially if dealing with shortened, tight muscles.[1] The goal of strengthening after Graston Technique® is to promote a corrected moving environment for the affected tissues.[1] Later, the clinician can increase strength once pain has subsided and the patient can progress to higher weight, lower repetition exercises.[1] It is important to follow all steps of Graston Technique® protocol to allow for the best patient treatment outcomes.

Few studies have examined the immediate effects of Graston Technique® on the extensibility of body tissues without the full recommended protocol on athletic patient populations. A study by Palmer et al.[10] examined the effect of Graston Technique® on ankle dorsiflexion (DF) in 50 healthy, collegiate track and field athletes. Participants were assigned to 3 groups: IASTM, stretch, or control. The IASTM group received 10-minute IASTM treatment, averaging eight total treatments over 5 weeks, while the stretching group only performed weight bearing gastrocnemius and soleus stretches on a slant board. The control group did not receive any interventions. Progress was measured using a weight-bearing lunge test to assess the range of DF for each participant. They found over a 6-week period, the Graston Technique® IASTM group had significant increases in DF when compared to both the control and stretching groups.[10] In conclusion, though this study did not utilize the whole Graston Technique® protocol, the findings show that the treatment portion of the protocol provides promising results and the whole protocol is important as it provides a more holistic treatment for better patient outcomes.

Cryotherapy and Modalities

After completing all previous steps of the treatment protocol, cryotherapy and other modalities may be used to ease discomfort.[1] Graston Technique® claims to reset the body's natural inflammatory response, but ice is used to control any inflammation symptoms following treatment that is excessive or unpredictable.[1] Ice may also be used to mitigate bruising that can occur during or following treatment.[1] Modalities may also be used to help control symptoms, as long as they align with the treatment goals set by the clinician. While icing is vital to optimize treatment effectiveness, modalities are another option for clinicians to utilize to move the patient closer to their treatment goals.[1]

Potential Treatment Responses

Due to the nature of Graston Technique®, the possibility for several negative treatment responses exists. Patients may experience pain, discomfort, or bruising during treatment.[1] Though the patient may experience some discomfort during treatment, it is not harmful, and the clinician should localize the discomfort to the lesion as much as possible. Bruising may temporarily occur with the treatment of musculoskeletal conditions, localized microtrauma, or scar tissue. The goal of Graston Technique® treatment is to restart the inflammatory process. Therefore, bruising is usually an indicator that restrictions in the tissues have been released and should be localized to the lesion site.[1]

Since several negative side effects may occur, it is important to discuss these with the patient before and during the treatment.[1] Should any of these side effects occur, temporarily adjust the treatment intensity by decreasing treatment duration and pressure. For bruising, ensure that the patient ices and continues to perform an at home exercise program. The clinician should focus on stretching the softened tissues and icing to control the patient's inflammation. To help avoid any unwanted side effects and keep the patient informed, it is vital to keep open and honest communication with the patient before, during, and after treatment.[1]

Patellar Tendinopathy

The patellar tendon is the insertion of the quadriceps muscle that extends to the tibial tuberosity.[15] The quadriceps muscle group is responsible for extension of the knee and assists with flexion of the hip. Often referred to as jumper's knee (JK), PT most often occurs in athletes who have increased mechanical loading on their knees including rapid acceleration and deceleration, such as jumping and landing.[2,16] These athletes tend to be part of sports such as volleyball, soccer, and basketball, all of which have high demands placed on speed and power.[15,17] Constant jumping and landing put more stress onto the tendon, which leads to increased tendon stretching and then many microtraumas over time.[15] Microtraumas lead to weakening and possibly failure of the tendon.[17] Other factors may predispose individuals to PT such as heavy body weight, high body mass index (BMI), leg length discrepancies, muscle imbalances between quadriceps and hamstring muscles, hip malalignment, patellar laxity, or patella alta.[16-17]

At the beginning stages of injury, PT is referred to as patellar tendonitis when there is active inflammation of the tendon that may become chronic.[2,15] Pain and inflammation usually occur at the proximal, posterior portion of the tendon, below the inferior border or the patella.[16] Inflammation may last up to three to six weeks depending on the activity level of the patient.[2] If inflammation persists, it may lead to degenerative changes in the tendon, which is referred to as patellar tendinosis.[2] By the time a diagnosis occurs of PT, patients are past the inflammatory response and into the degenerative tendinosis stage.[11,15,17-18] When using diagnostic imaging, the markers for patellar tendinosis include the presence of degeneration of collagen, an increase of ground substance in the tendon, and neovascularity of the tendon with an absence of inflammatory cells.[18]

Multiple symptoms are associated with PT that change as the injury progresses further. Pain usually has a gradual onset for PT, which starts as a dull ache and is related to activity.[16,19] Initially, the pain fades as the tissue is warmed up for activity, but it then progresses to all activity. Sometimes patients complain of pain after extended periods of inactivity or when going up or down stairs.[16] Pain and disability associated with this injury also cause many athletes to take time out of their sport. Specifically, tendinosis may not present any pain at all and only have abnormalities detected with imaging.[20] Once symptoms start to resolve, there is a high rate of symptom recurrence.[15]

Multiple studies have researched the occurrence of PT in athletic populations. Hutchison et al.[21] examined the prevalence and risk factors of PT among male collegiate basketball players. Researchers used diagnostic ultrasound to scan a total of 95 participants for patellar tendon abnormalities (PTA) in their off-season from National Collegiate Athletics Association (NCAA) Division II and III, National Collegiate Athletics Association (NAIA) and community college institutions. In this study, patellar tendon abnormalities were defined by the presence of hypoechoic areas within the patellar tendon found using diagnostic ultrasound. Approximately one third of all participants (32 of the 95) had signs of PTA on at least one side, 20 of which were diagnosed with PT due to having pain associated with an abnormality. The risk factors assessed included age, height, weight, BMI, starter status, and player position. The results indicated age, height, weight, BMI, and college division had no statistical differences in this study. Nonstarters were three and a half times more likely to develop PTA than those with starter status. Though it was hypothesized that those in forward and center positions would have a higher likelihood of having PTA, the researcher's reported guards were just as likely to develop abnormalities.[21]

A similar study by Zwerver et al.[19] examined the prevalence of PT among different athletes in non-elite sports. Through 891 athlete interviews (502 males, 389 females) completed directly after a training session, researchers analyzed the differences in PT in relation to sport, gender, age, BMI, height, total years in sport, total number of match and practice hours, and weight. For the interviews, participants filled out a specifically designed questionnaire related to presence of PT. In this study, JK was diagnosed in the study as a presence of gradual onset anterior knee pain that was related to activity and/or previous diagnosis of PT by a physical therapist or physician. A diagram of the knee indicated the location of most pain to be at the superior or inferior pole of the patella, on the patellar tendon, or at the tibial insertion of the patellar tendon. Furthermore, severity was rated using the Victorian Institute of Sport Assessment – Patella (VISA-P) questionnaire by assessing pain and function. The VISA-P questionnaire has a minimal clinically important difference (MCID) of 13 points, which means any improvements of 13 points or more indicate significant clinical improvement.[21] Korakakis et al.[23] reported a range of reliability for the VISA-P as 0.74 to 0.994, with a score closer to one indicating higher reliability between testers, as well as a high level of validity.

Overall, the study by Zwerver et al.[19] had a total prevalence of PT was 8.5% (76 out of 891 athletes). Unlike Hutchison et al.[21], Zwerver showed significant differences in height, weight, and age of athletes diagnosed with JK.[19] Those with JK were statistically younger (22.8 ± 3.1 years vs. 73.6 ± 11.6 years; $P = 0.006$), heavier (77.4 ± 11.1 kg vs. 73.6 ± 11.6 kg; $P = 0.006$), and taller (185 ± 10.3 cm vs. 181 ± 9.8 cm; $P = 0.001$). Furthermore, males had significantly higher prevalence (10.2%) compared to females (6.4%). However, BMI, total years in sport, total number of match and practice hours were not statistically significant.[19]

Similarly, Comin et al.[24] also examined the prevalence of PT, along with Achilles tendinopathy, in asymptomatic ballet dancers. In total, 79 dancers were scanned (35 male, 44 female) using diagnostic ultrasound to detect abnormalities of the Achilles or patellar tendon. The following abnormalities were recorded and compared: thickness, hypoechoic change, tendon clefts or tears, neovascularization, calcifications, and any other anomalies found.[24] Hypoechoic changes were the most common abnormality found within the patellar tendon at a prevalence of 19 out of 91 dancers (approximately 21% prevalence), which is similar to the overall prevalence found by Zwerver et al.[19,24] After hypoechoic abnormalities, the number of dancers with other abnormalities included: 18 dancers with intra-tendon defects, 16 dancers with calcifications, and six dancers with neovascularity. Of the 19 dancers who were found to have hypoechoic changes in their baseline, 16 remained asymptomatic and three became symptomatic by the 24-month follow-up, which is a significant change ($P = 0.0381$). No significant changes were found at the 24-month follow-up with the other patellar tendon defects.

Additionally, a study by Kulig et al.[25] examined the prevalence of patellar tendinopathy in both symptomatic and asymptomatic volleyball athletes. Ninety-four male volleyball players above six feet tall were recruited for the study and an additional 10 nonathlete male subjects served as the control group. The VISA-P was used to report pain and function of the subjects and they were scanned using diagnostic ultrasound to detect patellar tendon micro- and macromorphology abnormalities. For this study, micromorphology was defined as the peak special frequency (PSF), or “the distance from the spectral origin to the spatial frequency peak of greatest amplitude on the two-dimensional Fast Fourier Transform (2-D FFT) spectrum, which indicates the sparseness of the striated speckle pattern of the tendon on an ultrasound image".[25] The higher the PSF value indicated a tighter and more compact striation pattern within the tendon. Macro morphology was defined as tendon thickness as measured by diagnostic ultrasound.[25]

Overall, the athletes had thicker patellar tendons towards the proximal end when compared to nonathletes, though not all athletes were symptomatic.[25] Results of the micromorphology revealed significant differences in lower PSF values between the volleyball athletes with pain when compared to both the nonathletes ($p=0.006$) and asymptomatic volleyball athletes ($p=0.024$). Differences in proximal tendon thickness was statistically significant between both the symptomatic athletes and non-symptomatic athletes when compared to the nonathlete group, with a p-value of $p=0.002$ and $p < 0.001$, respectively. Additionally, symptomatic athletes had thicker distal patellar tendons when compared to nonathletes ($p=0.001$) and asymptomatic athletes ($p=0.043$). In conclusion, athletes had an overall thicker and less compact patellar tendons than nonathletes.[25]

Following diagnosis of PT, it is important to begin rehabilitation to help with the healing process and alleviate symptoms. Typical rehabilitation for PT may include conservative interventions or potentially surgical interventions if conservative measures fail. Conservative management may include eccentric exercises, stretching, activity modification, nonsteroidal anti-inflammatory drugs (NSAIDs), ice, bracing, or corticosteroid injections.[15,17] Eccentric strengthening exercises are the most common non-operative treatment for PT, which may include exercises such as decline board squats, drop squats, and slow eccentric knee flexion.[17] Furthermore, stretching of tight structures is helpful to correct muscle imbalances between the quadriceps and hamstrings that may place additional load onto the quadriceps tendon. Complete rest or activity modification may be used to decrease the stress put on the tendon depending on the patient's level of pain and at the discretion of the treating clinician. Moreover, ice and NSAIDs may both assist with patient pain and inflammation, and are usually in conjunction with another form of conservative treatment.[15-17] Additionally, bracing helps add extra support and decreases the load placed on the tendon, though there is not much research specifically on the effect of bracing in PT.[26] Another conservative treatment option is corticosteroid injections, though they remain a controversial choice of treatment for patellar tendinopathies.[17] The injections affect collagen production and synthesis of the extracellular matrix, which may lead to tendon ruptures if not paired with proper strengthening.[17]

Surgical intervention is also a very controversial treatment option that has variable results that are used if conservative treatments fail.[18] Options for surgical treatment are varied and the best choice for each patient depends on their individual signs and symptoms. Some options may include drilling a hole in the inferior pole of the patella, debridement of necrotic tissue, repair of tearing or defects in the tendon, and more.[15] Since it is controversial and the outcomes may be unreliable from patient to patient, surgery is only recommended if a conservative treatment program has not been successful.[18]

IASTM and Tendinopathy

Multiple studies have used IASTM, including Graston Technique®, as a treatment for different types of tendinopathies. One common tendinopathy treated by IASTM is lateral epicondylitis, also known as tennis elbow. This pathology is the inflammation of the forearm extensor tendons at the elbow usually due to overuse from repetitive motion such as a tennis swing. Papa et al.[27] reported case studies of two patients with lateral epicondylitis that were treated with Graston Technique® and acupuncture with electrical stimulation. The patients included a 48-year-old woman with right lateral elbow pain and a 47-year-old woman with left lateral elbow pain, both with gradual onset pain due to work-related repetitive movements. Patient outcomes were assessed with a Verbal Pain Rating Scale (VPRS) and Quick DASH Work Module Score (QDWMS).[27]

For treatment, the first patient was seen for a total of 10 visits while the second patient was seen for 12 visits.[27] Initially, the patients were treated with acupuncture and electrical stimulation, followed by Graston Technique®, stretching of the forearm extensors, and eccentric strengthening. By the last session, both patients reported their pain to be at a 0/10 on the VPRS and their QDWMS had improved to a zero, which means patients had no pain and full function, respectively.[27] While this study used another treatment in conjunction with Graston Technique®, positive outcomes were observed and may aid further research on the treatment of lateral epicondylitis.

Another common tendinopathy treated with IASTM is Achilles tendinopathy. A case study by McCormack et al.[28] utilized ASTYM as a treatment for mid-portion Achilles tendinopathy. Assisted Soft Tissue Mobilization is a specific form of IASTM. The case study was about a 53-year-old female recreational tennis player referred to physical therapy for mid-portion Achilles' tendinopathy that had started approximately six weeks prior. Treatment was twice a week for a five-week period, in which the patient warmed up, stretched, then received ASTYM and performed eccentric rehabilitation exercises that were to be completed twice a day. At visits four, six, and ten, progress was measured using the Numerical Pain Rating Scale (NPRS) and the Lower Extremity Functional Scale (LEFS).[28]

Before beginning the study, the patient noted that pain fluctuated between 0/10 and 8/10 on the NPRS.[28] The patient's initial LEFS score was 70/80, with a score closer to 80 indicating higher function. For the intervention, the patient received treatment with ASTYM for 10 – 15 minutes then performed stretching of the gastrocnemius and soleus on a slant board. Each visit finished with eccentric calf raises performed both with the knee straight and knee bent. As the patient progressed, they increased the difficulty of the calf raises by adding weights or using a leg press machine.[28]

Following the 10th visit, the patient was discharged from physical therapy and instructed to complete her home exercise program for two additional weeks.[28] Outcome measures that were assessed during the 10 total visits showed promising results. By the last visit, the patient's LEFS score had improved from 70/80 to 79/80, which is within the minimal clinically important MCID of nine points. Pain had also improved to a 0/10 on the NPRS overall. Though this study was only conducted on a single patient, it could provide a good basis for future research on the effect of IASTM on Achilles' tendinopathy.[28]

Another case study by McCormack et al.[29] examined the effects of IASTM and eccentric exercise on bilateral high hamstring tendinopathy in a 41-year-old female runner. Onset of symptoms began approximately one year before beginning treatment for this study. Initially, the score on the LEFS was a 64/80, with score closer to 80 indicating higher function. The patient received treatment twice a week for eight weeks, totaling 16 treatments overall. Each session began with a warmup, followed by 15 – 20 minutes of ASTYM, eccentric exercises, and concluded with stretching. The eccentric exercises increased in difficulty from prone hamstring curls to Nordic hamstring exercises as the patient progressed through the 16 total treatments.[29]

Over the course of the treatment sessions, the patient reported improvement in both pain and function.[29] By visit eight, the patient was able to walk for two and a half miles without any pain in the hamstring. At visit 12, the patient indicated feeling 90% improvement and being able to jog for a mile without pain. At the conclusion of treatment, the patient stated feeling 95% improvement. LEFS score had increased from a 64/80 to a 74/80 at visit 16, which reached the threshold of MCID of 9 points.[29] Similar to the other case study by McCormack et al.,[29] this study yields promising results for future research regarding IASTM and hamstring tendinopathies.

Similarly, a case study by Miners et al.[30] also examined the effects of IASTM on chronic Achilles' tendinopathy but did so using Graston Technique® in addition to Active Release Technique (ART®). The patient in the case study was a 40-year-old active male that had Achilles' tendinopathy symptoms persisting for approximately three and a half years. The treatment protocol included a five-minute warmup, Graston Technique®, ART®, eccentric calf lowering exercises, stretching, and a 10-minute ice application. When initially examined, the patient rated their pain as 6-7/10 and complained of having to significantly reduce activity level due to the pain.[30]

Overall, the patient received nine total sessions over an eight-week period. Graston Technique® and ART® were concentrated to the posterior lower leg musculature.[30] By the sixth visit, the patient's pain was reduced to a 3-4/10. On the final visit, the patient almost saw a complete resolution of symptoms. His pain was rated at 0-1/10 following the study, and even improved slightly at the seven-month follow-up. Though this study includes additional treatment other than just IASTM, the results are promising to show its effect on pain and function when used in conjunction with a treatment protocol.[30]

Graston Technique® and Patellar Tendinopathies

Tendinopathy is a common pathology that can be treated with Graston Technique®.[1] Graston Technique® is used as a pro-inflammatory tool that helps restart the inflammatory process to aid in healing the injured tissue. After several treatments, this allows the remodeling process to begin again, as treatment aims to normalize damaged tissues within the injured tendon. A patient with patellar tendinosis is no longer in the inflammatory phase, as the tendon has begun to degrade and thicken causing pain and stiffness when the patellar tendon fibers are not aligned correctly.[1] Therefore, Graston Technique® treatment may be used to help restart the healing process and help realign tissues within the patellar tendon.

Few studies have examined the effects of Graston Technique® specifically on patellar tendinopathies. Labodi et al.[4] assessed the effects of Graston Technique® on both patellar and Achilles' tendinopathies using diagnostic ultrasound. The results indicated a significant decrease in the amount of tendinosis measurements for both pathologies over the course of four total treatments.[4] The long-axis (LAX) tendon views showed a significant decrease from day one to four, from 0.28 cm ± 0.19 cm to 0.16 cm ± 0.13 cm, while short-axis (SAX) tendon views showed a significant decrease from 0.26 cm ± 0.17 cm to 0.12 cm ± 0.12 cm. Both LAX and SAX had a significant difference with a p-value of $p=0.001$. This is thought to be due to SAX views showing the whole tendon, making it easier to see the healing process and decrease of tendinosis.[4]

In this study, the LEFS was used to assess patient functionality with a variety of questions that add up to a total of 0-80, with 80 meaning complete function. The LEFS scores of patients with both Achilles' and patellar tendinopathies improved from 65.3 ± 8.0 to 68.1 ± 6.8 from day one to day four, respectively.[4] The NPRS did not show significant improvement but showed results trending towards significance with a P value of 0.060. Though this study was part of a master's thesis and did not follow the entirely recommended Graston Technique® protocol of 8-10 treatments, the positive effects on the Achilles and patellar tendons are encouraging about the impact Graston Technique® has on tendon healing.

While there are multiple additional studies utilizing Graston Technique ®, most of this research is either case studies or case series. For example, a case study by Black et al.[31] examined the outcomes using Graston Technique® after patellar tendon reconstruction surgery. The patient was a 37-year-old male who was playing basketball when the patella tendon completely ruptured. For a four-week period, the patient was given the following interventions: warmup, soft-tissue mobilization (Graston Technique®), joint mobilizations, rehabilitation exercises, and modalities as well as a home exercise program to complete. Measurements of ROM, pain, functionality, and strength were taken at visits one, three, and five.[31]

After 5 - 7 minutes of using a moist hot pack for warmup, Graston Technique® strokes were used to perform soft-tissue mobilization.[31] Strokes started with lighter intensity while scanning, then moved into 30 – 60 second bouts of higher intensity throughout the treatment duration using unspecified strokes. Active ROM was introduced while performing Graston Technique® strokes after the first two visits as more superficial adhesions began to resolve. At the end of the study, the patient reported improvements in ROM, strength, and function when performing activities of daily living. By the end of the fourth visit, the patient's pain was reported as completely resolved. These findings are promising to move forward with research using Graston Technique® on patellar tendon healing.[31]

Studies utilizing Graston Technique® often do not follow the entire protocol of warm up, treatment, stretching, and strengthening. This case study by Black et al.[31] followed the correct protocol, but did not complete the recommended 8 - 10 total treatments.[1] Neither the overall time for treatment nor the strokes used were specified, but the time used for using higher intensity strokes aligns with the protocol, which recommends no more than 30 – 60 seconds per restriction. Overall, Black et al.[31] followed the majority of the Graston Technique® protocol but did not specify the strokes used or total treatment time per session. While the results are promising moving forward in Graston Technique® research, it is important to consider all recommendations included with the protocol to determine the true effectiveness of treatment.

Diagnostic Ultrasound

Diagnostic ultrasound (ultrasonography) is a clinical imaging tool that is popular when diagnosing many different musculoskeletal conditions such as tendinopathies, muscle tears, bursitis, and soft tissue infections.[32] Compared to Magnetic Resonance Imaging (MRI), it is a minimally invasive technique that gives efficient results and is relatively inexpensive compared to other imaging options.[4] Additionally, diagnostic ultrasonography allows for a bilateral evaluation that can be performed dynamically and in multiple different positions to find the best joint position to view each structure.[4,32] Some limitations of ultrasonography include a long learning period for operation, a lack of uniformity due to the dynamic nature of the examination, and poor intertester reliability depending on the clinician.[4,8-9] Despite its limitations, diagnostic ultrasound is a reliable and efficient option when diagnosing musculoskeletal disorders.

How Diagnostic Ultrasound Works

Diagnostic Ultrasound operates by using sound waves that are transmitted from the transducer into the body tissues.[3,9] Reflection is when the sound wave strikes the tissue and bounces back to the transducer, while refraction is when the sound waves are deflected and scattered. These sound waves are absorbed and reflected at different rates depending on the tissue, which is returned to the transducer to create the images. The amount of energy reflected back to the transducer is dependent on tissue impedance and the acoustic interface, or the change in stiffness or density of the tissue. Depending on the energy picked up by the transducer when scanning structures, an image is created. The echogenicity, or the brightness of an image, is based on how much of the ultrasound waves are reflected to the transducer, which helps determine what structure is being viewed.

Echogenicity can be further described as hyperechoic, hypoechoic, isoechoic, and anechoic when looking at structures on diagnostic ultrasound. Hyperechoic refers to a high reflective pattern that appears bright or white. On the other hand, hypoechoic structures have a low level of reflection that causes a structure to appear darker than hyperechoic structures. When structures have the same echogenicity as the surrounding tissues, it is termed isoechoic. Lastly, anechoic refers to structures with no echogenicity, which appear black, such as simple fluids.[3-4,9]

To obtain an image, the operator of the diagnostic ultrasound device uses a transducer to scan over the desired body part in either a longitude or transverse view. [3-4,9] A longitudinal or long axis view is performed lengthwise or parallel to the desired structure being viewed. On the other hand, a transverse or short axis view is performed crosswise, or perpendicular of the desired structure. To determine the resolution and depth of the ultrasound image, clinicians may choose to use a higher or lower frequency depending on the structure being viewed. When the ultrasound is set to a higher frequency (typically between 7.5 to 20 MHz)[9], the lower the depth of penetration. The lower the frequency, the higher the depth of penetration. In addition, resolution is better with a higher frequency and decreases as frequency decreases. [3-4,9]

Diagnostic Ultrasound Artifacts

When performing diagnostic ultrasound, there are several important artifacts to be aware of that may commonly appear during imaging. Artifacts are phenomenon that occur within diagnostic ultrasound that may alter the image of the desired structure being viewed.[32] Anisotropy occurs when a tendon or ligament is being viewed in either LAX or SAX and the transducer is a few degrees off of perpendicular, therefore causing the structure to lose its normal hyperechoic appearance.[3-4, 32-33] To correct anisotropy, the transducer should be perpendicular to the tendon or ligament in a long axis view. Additionally, shadowing is another common artifact that occurs when using diagnostic ultrasound. An anechoic area occurs deep from the involved tissues when the ultrasound beam is either reflected, refracted, or absorbed by the body tissues. Shadowing can occur from calcifications, foreign bodies, or gasses. Moreover, refractile shadowing is a specific kind of shadowing that occurs at the edge of certain structures such as a torn Achilles tendon.[3] Additionally, another kind of shadowing is posterior acoustic shadowing, which occurs when the surface of a structure either absorbs or reflects a lot of light. Therefore, this causes shadowing deep to that structure.[3]

While shadowing appears hypoechoic, posterior reverberation appears hyperechoic. Posterior reverberation occurs when there is a smooth, flat surface being scanned, such as bone.[3] Due to the flat surface, the sound waves bounce back and forth between a smooth, flat surface (bone) and the transducer. This produces linear reflective echoes beneath the structure. Similarly, a ring-down artifact is a posterior reverberation that occurs when viewing a metal surface, appears as continuous reflective echoes deep to the structure. Similarly, comet-tail artifact occurs when there is gas within the soft tissue. Small, circular, bright echoes occur near the source of this artifact.[3]

Additionally, beam-width artifact may occur when the focal zone is too large for the object being viewed.[3] A focal zone describes the area of focus within a diagnostic ultrasound image, which can be changed with either the depth or width. An example is when viewing a small calcification, where the wider view may make it more difficult to view the small object. To fix this artifact, the operator may specify the focal zone to the specific object that is intended to be viewed. Artifacts are a common occurrence when operating diagnostic ultrasound. Therefore, it is important to understand what each artifact is and their meanings.[3]

Normal and Injured Tissue Appearance with Diagnostic Ultrasound

When looking at tissues with diagnostic ultrasound, different types of healthy tissues have specific appearances when compared to unhealthy tissues.[3] The pattern appearance of structures can be described as the echotexture when viewed with diagnostic ultrasound.[3-4] Differences in texture and echogenicity can be used to determine the tissue being imaged. Some structures may appear more hyperechoic, while others are hypoechoic. Appearance of the structures will also depend on which axis view is being used.[3-4]

Bone

Bone is one of the most hyperechoic structures.[3-4] Healthy bone tissue has a smooth surface with a hyperechoic top layer, also called the cortex. Since the sound waves cannot transmit through the bone and reflect back to the transducer, only the top layer appears hyperechoic, therefore causing posterior acoustic shadowing. Additionally, posterior reverberation may occur if the bone is very flat, and the transducer is perpendicular to the surface. Bone injuries that may be seen with diagnostic ultrasound may include fractures such as stress or avulsion injuries. A fracture may be diagnosed using ultrasound if there is a visual, stepoff deformity or discontinuity of the bone seen upon imaging. Another indicator may be a callous forming over the spot where a fracture is beginning to heal.

Tendons and Ligaments

Tendons are another hyperechoic structure, but unlike bone, they have a fiber-like echotexture.[3-4,8-9] In long axis, the fibers appear more linear in a continuous fashion. When in short axis, these fibers have a bristle-like appearance, like the end of a brush. Tendinopathies are common injuries that may be diagnosed through diagnostic ultrasound, which includes tendonitis and tendinosis. Tendonitis is an overuse injury that causes the tendon to appear thickened with changed texture and contour, appearing less defined and more hypoechoic than normal.[4] If the tendinopathy has progressed to tendinosis, there may be notable hypoechoic thickening areas within the tendon and the tendon appears less defined than a healthy tendon, though the fibers are still visible. It may be accompanied by partial or full thickness tendon tears. Posterior shadowing up may be seen with imaging due to calcium deposits within the tendon.[3-4,8-9,32]

Like tendons, ligaments are also hyperechoic structures, but they have a more striated appearance and compact appearance when compared to tendons.[3-4,8] Ligaments can also specifically be identified because they connect bone to bone. Long axis is the best way to view ligaments, though they can often appear hypoechoic. The hypoechoic appearance is due to anisotropy but can be fixed by adjusting the transducer to be perpendicular to the ligament. [3-4,9]

Injury to both ligaments and tendons may cause either partial- or full-thickness tears. [3-4,8] A tear is diagnosed with diagnostic ultrasound from a disruption of fibers that causes deformity and discontinuity of the normal tendon or ligament tissue. Partial-thickness tears do not extend through the entire structure and can be identified by hypoechoic swelling around the tendon or ligament. Full-thickness tears extend through the entire structure and can be identified by a complete disruption of the fibers, which is shown by an anechoic space. The gap is usually accompanied with fluid from hemorrhaging and swelling from the injury. [3-4,9]

Muscle

Unlike tendons and ligaments, muscle tissue appears relatively hypoechoic on diagnostic ultrasound. [3-4,8-9] The hypoechoic area is separated by hyperechoic septa that creates muscular bundles. Septa creates different bundles or groups within the muscle known as fascicles. These septations within the muscle appear more as hyperechoic dots in the SAX view, as opposed to the longer striations in the LAX view. A hallmark characteristic of muscle tissue in diagnostic ultrasound is the change of alignment of these septations during a muscle contraction.

Common muscular injuries include contusions, strains, tears, and hematomas. Contusions, or a blunt trauma to the muscle tissue, appear as hyperechoic regions of the muscle with little definition. Hematomas often accompany contusions, which are seen as a hypoechoic region within the injured area of muscle. Muscular strains and tears can be further classified into three grades depending on the amount of tissue disruption. A grade one, or a strain, has no torn fibers. Grade two muscle tears show partial thickness tearing of the muscle that does not extend through the entire muscle. Lastly, a grade three or full-thickness tear causes fiber disruption across the entire muscle, which may include the retraction of the ruptured muscle ends. [3,8-9]

Nerve

Similar to muscles, nerves have a fascicle-like appearance in LAX view.[3,9] In SAX, nerves have a hypoechoic region with hyperechoic speckles, also referred to as a “honeycomb”. In LAX, the nerve has a fascicular appearance. The nerve may change appearance with the surrounding tissue due to its mixed echogenicity. One of the most common nerve injuries seen within sonography is nerve entrapment, such as carpal tunnel syndrome in the wrist. Entrapment causes the nerve to appear enlarged, especially near the proximal end of the nerve entrapment site.[3,9]

Patellar Tendinopathy and Diagnostic Ultrasound

Diagnostic ultrasound is an effective tool for diagnosing PT in both symptomatic and asymptomatic patients.[4,8] Patellar tendinopathy encompasses two conditions: patellar tendonitis and tendinosis. Tendonitis of the patellar tendon refers to active inflammation of the tendon during the acute injury phase. Tendinosis is a degenerative injury due to overuse of the tendon. When viewed on diagnostic ultrasound, patellar tendinosis appears as poorly defined hypoechoic regions of the patellar tendon with thickening, in more advanced cases, bone spurs may also be present.[8]

Patient position is important when scanning the patellar tendon to get the best view.[8] Having the knee slightly flexed with an object such as a towel underneath allows for optimal view of the tendon while it is on stretch. Both SAX and LAX view should be utilized to get a full picture of the tendon and any thickening, swelling, or tearing. Additionally, dynamic evaluation is also especially useful in detecting partial- or full-thickness tears. Overall, diagnostic ultrasound is an extremely helpful tool in diagnosing patellar tendinosis and its associated defects within the tendon.[8]

While it is often used to diagnose patellar tendinopathy, diagnostic ultrasound can also be used to guide needles into the patellar tendon for procedures such as patellar tenotomy, biopsies, and both platelet-rich plasma and cortisone injections. Elattrache et al.[34] specifically looked at research surrounding diagnostic ultrasound and patellar tenotomy. Patellar tenotomy is a procedure that uses ultrasound to guide a needle and create small holes within the patellar tendon to facilitate healing in patients with chronic PT. The technique of patellar tenotomy is typically used when a patient has PT that has persisted for longer than six months, interferes with desired physical activity and does not respond to conservative treatment measures. After diagnostic ultrasound is used to diagnose the presence of PT, the patellar tenotomy procedure can be completed using diagnostic ultrasound as a guide to properly place the holes within the patellar tendon. Elattache states that 15 of 16 patients treated with this technique in his clinic saw positive results, though more research will need to be completed to determine the true effectiveness of patellar tenotomy.[34]

Multiple studies have examined the prevalence, accuracy, and various treatments of PT in athletic populations using diagnostic ultrasound. Warden et al.[35] examined the accuracy of MRI compared to diagnostic ultrasound in diagnostic PT. This study had a population of 30 physically active participants diagnosed with PT and 33 asymptomatic participants that were considered the control group, all with the same activity level. All participants were scanned first with an MRI, and then with diagnostic ultrasound (both grey scale and color doppler). The PT group had their most symptomatic knee scanned, while the asymptomatic group had the knee of their dominant leg scanned. All images were taken and reviewed by experienced radiologists that were blinded to the participants injury status.[35]

Results found that the accuracy for MRI and both color doppler ultrasound (CD-US) and grey scale ultrasound (GS-US) were 70% and 83% respectively, which was clinically significant with a p-value of 0.04. Specificity, or the ability for a test to rule in a disorder, of both MRI and GS-US was equal at 82% ($p = 1.0$). Sensitivity of GS-US was 87%, while MRI was 57% ($p = 0.01$). However, the specificity of MRI was higher than GS-US at 70% and 87%, respectively ($p = 0.06$). The sensitivity and specificity were not significantly different between CD-US and GS-US. Lastly, the likelihood ratios of a positive MRI, GS-US, and CD-US were reported as 3.1, 4.8, and 11.6, respectively, with a number greater than one indicating a higher likelihood of a positive result indicating the presence of the disorder. Overall, the results found that diagnostic ultrasound had a higher overall accuracy in diagnosing PT when compared to MRI, as it showed a strong likelihood of diagnosing a symptomatic individual.[35]

Similarly, Hyman et al.[36] examined current research surrounding the diagnosis and treatment of patellar tendinopathy with the use of diagnostic ultrasound. Hyman reports that diagnostic ultrasound has advantages over MRI that include easier access, lower cost, increased patient comfort, the use of both color and power doppler to examine tendon vascularity, and high resolution to detect subtle changes within the tendon. Current research has also indicated a possible link to tendon abnormalities and neovascularity in asymptomatic individuals may lead to the future development of PT. On the other hand, research also shows that asymptomatic individuals with normal diagnostic ultrasound and physical exam findings are less likely to develop PT with only approximately 2% developing PT later on.[35] The current research findings show positive results for the use of diagnostic ultrasound as a tool for diagnosing PT when compared with MRI due to ease of access, increased patient comfort, and high accuracy with diagnosis of PT.[35-36]

As previously mentioned, studies by Comin et al. and Hutchison et al. examined the prevalence of PT using diagnostic ultrasound and found a prevalence of approximately 21% and 33%, respectively.[21,24] Both of these studies utilized diagnostic ultrasound to detect the presence of patellar tendon abnormalities in both asymptomatic and symptomatic individuals. Hutchison et al. diagnosed PT only using hypoechoic areas in the patellar tendon, which was the most common tendon abnormality found by Comin et al.[21,24] Similarly, Bode et al.[37] examined the prevalence of PT in a group of elite soccer athletes using diagnostic ultrasound. Patellar tendinopathy was determined to be present in 13.4% of the 119 players scanned. These athletes reported lower function scored on their VISA-P questionnaires.[37]

Accordingly, players with PT also presented with pain distal to their patella, pain with quadriceps stretching, and tendon thickening upon physical examination ($p = 0.02$).[37] Upon diagnostic ultrasound examination, the players with PT had significantly increased tendon thickness of approximately 0.15 mm when compared to those without PT ($p = 0.00$). Findings of hypoechoic areas in the patellar tendon as well as neovascularization were both significantly increased in those with PT ($p = 0.02$).[37] These findings are similar to the findings in the studies by Comin et al. and Hutchison et al., which also found a high prevalence of hypoechoic areas in people with PT.[21,24,37]

Lastly, a case report by Cuddeford et al.[38] examined the effects of blood flow restriction (BFR) on patellar tendinopathy using diagnostic ultrasound. The two track athletes included in the study were 19-year-old males who presented with unilateral patellar tendinopathy as demonstrated by both patellar tendon thickness and hypoechoic regions. Both athletes attended physical therapy twice a week for a total of 20 sessions. Two therapeutic exercises were completed with BFR attached to the injured limb, single leg press and unilateral squat, which were increased in difficulty over the 10 weeks of physical therapy. The standard limb occlusions pressure of 80% for the lower limb was used on both athletes while they performed their exercises.[39]

Overall, both athletes saw improvements in strength, function, and pain, as well as improvements in hypoechoic regions.[38] Athlete one showed a decrease in patellar tendon thickness from 0.39 cm to 0.28 cm at his final visit. Athlete two, however, showed an increase in patellar tendon thickness from 0.36 cm to 0.38 cm. Both athlete one and athlete two showed improvements in hypoechoic regions from their baseline. Athlete one presented with one hypoechoic region at baseline, which had completely resolved upon rescanning of his patellar tendon. Athlete two saw a reduced hypoechogenicity in his patellar tendon by his final visit. While these results are promising in the improvements of diagnostic ultrasound findings of the patellar tendon following BFR, the study did not provide any p-values, so significance is not able to be determined.[38]

While Graston Technique® is a commonly used treatment for PT, few studies have specifically examined its effectiveness on PT using diagnostic ultrasound. As previously discussed, Labodi et al.[4] examined both patellar and Achilles' tendinopathies and the effect of Graston Technique® utilizing diagnostic ultrasound to detect changes in hypoechoic areas, tendon thickness, scar tissue, adhesions, and calcifications. More research will need to be completed to further investigate the effectiveness that Graston Technique® has on PT using diagnostic ultrasound.

CHAPTER 3. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Patellar tendinopathies are a common group of injuries seen in the athletic population, especially those in sports that require repetitive jumping. These sports include basketball, volleyball, and others due to an increased load and microtrauma overtime.[2,15, 17] The prevalence of PT is as high as 33.3% in some studies, including those who are symptomatic and asymptomatic, while other studies show a lower prevalence as low as 8.5%.[19,21] Males also appear to have a higher chance of developing PT, as reported by Zwerver et al.[19], with 10.2% of males in the study having PT compared to 6.4% of female subjects. Some additional factors may include height and weight, which have had mixed results as far as significance between several studies.[19,21] Also, multiple studies analyzing the prevalence of PT within athletic populations use diagnostic ultrasound to diagnose the disorder in their subjects. While the current research provides promising insight into the condition, more research should be done to investigate the prevalence and possible risk factors surrounding PT in athletic populations.

Additionally, current research suggests that diagnostic ultrasound is an effective and accurate option when diagnosing PT when compared to MRI. Diagnostic ultrasound is not only a cheaper and more accessible option, but it is also more effective and accurate option.[4,8-9,32] Though there is a learning curve, more clinicians should consider utilizing diagnostic ultrasound to diagnose PT within their athletes to get a more accurate diagnosis prior to treatment and rehab. Diagnostic ultrasound allows for clinicians to see a more accurate depiction of what areas of the tendon are abnormal and how far progressed their condition is, which allows for a more personalized and accurate treatment from patient to patient.

Furthermore, Graston Technique® is a popular treatment used by clinicians to treat different tendinopathies, though the research is limited on the effectiveness with these different injuries. Specifically, the research on PT together with Graston Technique® is very limited. Research surrounding ASTYM, IASTM, and Graston Technique® all show promising results for many different tendinopathies, including PT. The research utilizing ASTYM and IASTM on tendinopathies are encouraging, but the results of studies utilizing these techniques do not have the same exact instruments. The protocols differ when specifically using Graston Technique®, so while IASTM and ASTYM are similar, they cannot be directly linked. Several studies have examined the effects of Graston Technique® treatment without any other part of the protocol and shown positive results when compared to control groups, but it does not all for a holistic approach to treating a patient's injury.[10]

Moreover, there is little research utilizing Graston Technique® that follows the full recommended protocol. The Graston Technique® protocol as outlined in the manual recommends 8 – 10 treatments along with a proper active warm-up, stretching, and strengthening, which may be completed 1 – 2 times per week with at least 2 – 3 days between sessions. Since not many studies utilizing IASTM are specific to Graston Technique® and the studies that do utilize the technique do not follow the proper protocol outlined in the Graston Technique® manual, the true effectiveness of treatment is difficult to determine. Nevertheless, the research using Graston Technique® for shorter than the recommended protocol still shows promising results for future research into the treatments effectiveness.

In conclusion, the takeaway from this review is that while Graston Technique® is a common treatment used by clinicians treating PT, the true effectiveness is unclear due to a disconnect between utilizing the full recommended protocol within current research studies. In the future, more specific studies should be completed not only utilizing the full Graston Technique®, but also more specifically examining its effects on PT in athletic populations. On the other hand, even though the research is limited, it appears to be an effective course of treatment that clinicians should still consider using for patients with this condition. Future research should not only have a focus on the entire Graston Technique® protocol, but also the specific injury of PT.

REFERENCE LIST

1. Carey-Loghmani MT, Schrader JW, Hammer WI. *Clinical Foundations for Graston Technique ®*. (Ploski MR, Shakar JJ, Vincent RE, eds.).; 2021.

2. Prentice WE. *Principles of Athletic Training*. 16th ed. McGraw-Hill Education; 2017.

3. Jacobson JA. *Fundamental of Musculoskeletal Ultrasound*.; 2018.

4. Labodi K. The Effects of the Graston Technique® on Cases of Chronic Tendinopathy Measured by Diagnostic Ultrasound. 2018. https://hdl.handle.net/10365/28771.

5. Cheatham SW, Lee M, Cain M, Baker R. The efficacy of instrument assisted soft tissue mobilization: a systematic review. *J Can Chiropr Assoc*. 2016;60(3):200-211.

6. Seffrin CB, Cattano NM, Reed MA, Gardiner-Shires AM. Instrument-assisted soft tissue mobilization: A systematic review and effect-size analysis. *J Athl Train*. 2019;54(7):808-821. doi:10.4085/1062-6050-481-17.

7. Loghmani MT, Fuller EM, Hardt R, et al. Instrument-assisted soft tissue mobilization in healthy young adult males mobilizes tissue-resident mesenchymal stem cells into circulation. *J Orthop Sport Phys Ther*. 2016;46(1):A107.

8. Chew K, Stevens KJ, Wang TG, Fredericson M, Lew HL. Introduction to diagnostic musculoskeletal ultrasound - Part 2: Examination of the lower limb. *Am J Phys Med Rehabil*. 2008;87(3):238-248. doi:10.1097/PHM.0b013e31816198c2

9. Lew HL, Chen CPC, Wang TG, Chew KTL. Introduction to musculoskeletal diagnostic ultrasound: Examination of the upper limb. *Am J Phys Med Rehabil*. 2007;86(4):310-321. doi:10.1097/PHM.0b013e31803839ac

10. Palmer TG, Wilson DB, Kohn M, Miko S. The Effect of Graston Massage Therapy on Talocrural Joint Range of Motion. Int J Athl Ther Train. 2017;22(3):66-75. doi:10.1123/ijatt.2015-0096

11. Bayliss AJ, Crandall T, Farmer DL, Warden SJ. Instrument assisted soft tissue mobilization alters material and mechanical properties in healthy, shortened Achilles tendons. *J Orthop Sport Phys Ther*. 2015;45(1):A24.

12. Cheatham SW, Baker R, Kreiswirth E. Instrument Assisted Soft-Tissue Mobilization: a Commentary on Clinical Practice Guidelines for Rehabilitation Professionals. *Int J Sports Phys Ther*. 2019;14(4):670-682. doi:10.26603/ijspt20190670

13. Loghmani MT, Warden SJ. Instrument-assisted cross-fiber massage accelerates knee ligament healing. *J Orthop Sports Phys Ther*. 2009;39(7):506-514. doi:10.2519/jospt.2009.2997

14. Ge W, Roth E, Sasone A. A quasi-experimental study on the effects of instrument assisted soft tissue mobilization on mechanosensitive neurons. *J Phys Ther Sci*. 2017;29(4):654-657.

15. Khan KM, Mavulli N, Coleman BD, Cook JL, Taunton JE. Patellar tendinopathy: some aspects of basic science and clinical management Tendon injuries account for a substantial proportion of overuse injuries in sports. *Br J Sport Med*. 1998;32:346-355.

16. Warden SJ, Brukner P. Patellar tendinopathy. *Clin Sports Med*. 2003;22(4):743-759. doi:10.1016/S0278-5919(03)00068-1

17. Schwartz A, Watson JN, Hutchinson MR. Patellar Tendinopathy. *Sports Health*. 2015;7(5):415-420. doi:10.1177/1941738114568775

18. Cook JL, Khan KM, Maffulli N, Purdam C. Overuse tendinosis, not tendinitis. Part 2: Applying the new approach to patellar tendinopathy. *Phys Sportsmed*. 2000;28(6):31-46. doi:10.1080/00913847.2000.11439512

19. Zwerver J, Bredeweg SW, Van Den Akker-Scheek I. Prevalence of jumper's knee among nonelite athletes from different sports: A cross-sectional survey. *Am J Sports Med*. 2011;39(9):1984-1988. doi:10.1177/0363546511413370

20. Ackermann PW, Renström P. Tendinopathy in Sport. *Sports Health*. 2012;4(3):193-201. doi:10.1177/1941738112440957

21. Hutchison MK, Houck J, Cuddeford T, Dorociak R, Brumitt J. Prevalence of patellar tendinopathy and patellar tendon abnormality in male collegiate basketball players: A cross-sectional study. *J Athl Train*. 2019;54(9):953-958. doi:10.4085/1062-6050-70-18

22. Hernandez-Sanchez S, Hidalgo MD, Gomez A. Responsiveness of the VISA-P scale for patellar tendinopathy in athletes. *Br J Sports Med*. 2014;48(6):453-457. doi:10.1136/bjsports-2012-091163

23. Korakakis V, Kotsifaki A, Stefanakis M, Sotiralis Y, Whiteley R, Thorborg K. Evaluating lower limb tendinopathy with Victorian Institute of Sport Assessment (VISA) questionnaires: a systematic review shows very-low-quality evidence for their content and structural validity—part I. *Knee Surgery, Sport Traumatol Arthrosc*. 2021;29(9):2749-2764. doi:10.1007/s00167-021-06598-5

24. Comin J, Cook JL, Malliaras P, et al. The prevalence and clinical significance of sonographic tendon abnormalities in asymptomatic ballet dancers: a 24-month longitudinal study. *Br J Sports Med*. 2013;47(2):89-92. doi:10.1136/bjsports-2012-091303

25. Kulig K, Landel R, Chang Y-J, et al. Patellar tendon morphology in volleyball athletes with and without patellar tendinopathy. *Scand J Med Sci Sports*. 2013 Mar;23(2): e81-8. doi: 10.1111/sms.12021.

26. Khan KM, Cook JL, Taunton JE, Bonar F. Overuse tendinosis, not tendinitis. Part 1: A new paradigm for a difficult clinical problem. *Phys Sportsmed*. 2000;28(5):38-48. doi:10.3810/psm.2000.05.890

27. Papa JA. Two cases of work-related lateral epicondylopathy treated with Graston Technique® and conservative rehabilitation. *J Can Chiropr Assoc*. 2012;56(3):192-200. https://pubmed.ncbi.nlm.nih.gov/22997469/.

28. McCormack JR. The management of mid-portion achilles tendinopathy with astym® and eccentric exercise: a case report. *Int J Sports Phys Ther*. 2012;7(6):672-677. https://pubmed.ncbi.nlm.nih.gov/23316430/.

29. McCormack JR. The management of bilateral high hamstring tendinopathy with ASTYM ® treatment and eccentric exercise: A case report. *J Man Manip Ther*. 2012;20(3):142-146. doi:10.1179/2042618612Y.0000000003

30. Miners AL, Bougie TL. Chronic Achilles tendinopathy: a case study of treatment incorporating active and passive tissue warm-up, Graston Technique, ART, eccentric exercise, and cryotherapy. *J Can Chiropr Assoc*. 2011;55(4):269-279. https://pubmed.ncbi.nlm.nih.gov/22131563/.

31. Black DW. Treatment of knee arthrofibrosis and quadriceps insufficiency after patellar tendon repair: A case report including use of the Graston Technique®. *Int J Ther Massage Bodyw Res Educ Pract*. 2010;3(2):14-21. doi:10.3822/ijtmb.v3i2.79

32. Taljanovic MS, Melville DM, Scalcione LR, Gimber LH, Lorenz EJ, Witte RS. Artifacts in musculoskeletal ultrasonography. *Semin Musculoskelet Radiol*. 2014;18(1):3-11. doi:10.1055/s-0034-1365830

33. Robinson P. Sonography of common tendon injuries. *Am J Roentgenol*. 2009;193(3):607-618. doi:10.2214/AJR.09.2808

34. Elattrache NM, Morrey BF. Percutaneous ultrasonic tenotomy as a treatment for chronic patellar tendinopathy—jumper's knee. *Oper. Tech. Orthop*. 2013; 23:98–103

35. Warden SJ, Kiss ZS, Malara FA, et al. Comparative accuracy of magnetic resonance imaging and ultrasonography in confirming clinically diagnosed patellar tendinopathy. *Am J Sports Med*. 2007 Mar;35(3):427-36. doi: 10.1177/0363546506294858.

36. Hyman GS. Jumper's knee in volleyball athletes: advancements in diagnosis and treatment. *Curr Sports Med Rep*. Sep-Oct 2008;7(5):296-302. doi: 10.1249/JSR.0b013e31818709a5.

37. Bode G, Hammer T, Karvouniaris N, et al. Patellar tendinopathy in young elite soccer–clinical and sonographical analysis of a German elite soccer academy. *BMC Musculoskelet Disord*. 2017 Aug 8;18(1):344. doi: 10.1186/s12891-017-1690-2.

38. Cuddeford T, Brumitt J. In-season rehabilitation program using blood flow restriction therapy for two decathletes with patellar tendinopathy: a case report. *Int J Sports Phys Ther*. 2020 Dec;15(6):1184-1195. doi: 10.26603/ijspt20201184.

APPENDIX A. GRASTON TECHNIQUE® INDICATIONS AND CONTRAINDICATIONS

Table A1. Graston Technique® Indications, Relative Contraindications, and Absolute Contraindications.

Indications	Relative Contraindications	Absolute Contraindications
Lateral epicondylosis/itis Medial epicondylosis/itis Supraspinatus tendinosis/itis Achilles tendinosis/itis Patellar tendinosis/itis De Quervain’s syndrome Medial collateral ligament/Lateral collateral ligament sprains Acromioclavicular ligament sprains Ankle sprains Ulnar collateral sprains Edema reduction Postsurgical scar tissue/adhesion reduction Traumatic scar/adhesion reduction Carpal/tarsal tunnel syndrome Ulnar entrapment Thoracic outlet syndrome	Cancer Burn scars Kidney dysfunction Pregnancy Medications Age-related health issues Varicose veins Osteoporosis Body art Reflex sympathetic dystrophy /Chronic regional pain syndrome Polyneuropathies Autoimmune disorders Diabetes Vitamin C, D, or calcium deficiencies Congestive heart failure Electronic implants Mesh inserts Surgical hardware Flu or illness with flu-like symptoms Acute inflammation Lymphedema Skin conditions Post-injection Recent surgery	Open wounds Thrombophlebitis Uncontrolled hypertension Inflammatory conditions due to infection Unstable fractures Hypersensitivity/intolerance Contagious or infectious skin conditions Hematoma/myositis ossificans Osteomyelitis Insect bite of unexplained origin

Note: Obtained from the Graston Technique® M1 Manual.[1]

APPENDIX B. GRASTON TECHNIQUE® INSTRUMENTS

Figure B1. Graston Technique® instruments.

Top left: GT4, top right: GT5, top middle: GT6, bottom left: GT3, bottom right: GT2, bottom middle: GT1.

APPENDIX C. SUMMARY OF REVIEWED ARTICLE

Table C1. Summary of reviewed articles, Graston Technique® and IASTM as a treatment for patellar tendinopathy and prevalence of patellar tendinopathy within athletic populations.

Author	Population, Duration of Study, or Participant characteristics	Type of Study	Aim	Key Findings
Labodi et al.[4]	15 athletes with diagnosed patellar or Achilles tendinopathy received Graston Technique® for a total of 4 sessions over 2 weeks.	Cohort study	Investigate the effects of Graston Technique® on pain and function associated with patellar and Achilles tendinopathies as measured by diagnostic ultrasound.	Both Achilles and patellar tendinopathies saw significant improvements in pain, function, and tendon abnormalities.
Palmer et al.[10]	53 healthy collegiate track and field athletes were divided into three groups: Graston Technique IASTM group, stretching-only group, and control group.	Single-blind randomized controlled trial	Investigate the effects of Graston Technique® on ankle dorsiflexion in health athletes over a six-week period.	Weightbearing ankle dorsiflexion was significantly improved in the Graston Technique® group when compared to the control and stretching-only groups.
Bayliss et al.[11]	25-year-old active female with chronic calf pain seen for 8 visits over 6 weeks.	Case study	Investigate the effect of Graston Technique® on function and pain due to chronic calf injury.	Reassessment after baseline showed no restrictions within calf tissue and complete resolution of pain.
Loghmani et al.[13]	51 rodents received MCL injuries, and seven additional rodents were included as control group and received either 9 total treatments over 4 weeks (31 experimental and 2 control or 30 total treatments over 12 weeks (20 experimental and 5 control).	Controlled animal study	Investigate the effects of Instrument Assisted Cross Friction Massage (IACFM) on Medial Collateral Ligaments (MCL) injuries using Graston Technique®.	IACFM treated ligaments showed an improvement in both strength and stiffness in rodents.

Author	Population, Duration of Study, or Participant characteristics	Type of Study	Aim	Key Findings
Zwerver et al.[19]	A total of 891 (502 male and 389 female) athletes were interviewed.	Cohort study	The VISA-P questionnaire was used to determine the prevalence of PT within a group of 891 athletes from 7 different sports.	The questionnaire showed an overall prevalence of 8.5% for the presence of PT. Additionally, males were found to have a higher prevalence then females.
Hutchison et al.[21]	95 male collegiate basketball players were scanned for the presence of patellar tendon abnormalities.	Cross-sectional study	Determine the prevalence of PT within a group of male collegiate basketball players using diagnostic ultrasound.	Though 53 of the 95 players (55.8%) were asymptomatic upon scanning, 33.7% of all players scanned presented with hypoechoic regions or patellar tendon abnormalities.
Comin et al.[24]	79 professional ballet dancers were scanned for patellar and Achille's tendon abnormalities over a 24-month period.	Longitudinal study	Examine the prevalence of patellar and Achilles tendinopathies (both symptomatic and asymptomatic) within a group of 79 professional ballet dancers.	Out of the 91 dancers scanned, the most common patellar tendon abnormality found (21%) was hypoechoic changes. Out of the 19 with hypoechoic changes, 3 became symptomatic by the 24-month follow-up.
Kulig et al.[25]	94 volleyball players and 10 nonathletes were scanned using diagnostic ultrasound for the presence of PT.	Case report	Examine the prevalence of PT among volleyball players compared to nonathletes.	Volleyball players were found to have an overall increased tendon thickness compared to nonathletes.
Papa et al.[27]	One 47-year-old female and one 48-year-old female with lateral epicondylitis due to work related activities were seen for a period of 12 and 10 visits, respectively.	Case series	Examine the effectiveness of Graston Technique® in combination with acupuncture, electrical stimulation, stretching, and eccentric strengthening.	By the last session, both patients reported completely improved pain as reported by the VPRS and QDWMS questionnaires.

Author	Population, Duration of Study, or Participant characteristics	Type of Study	Aim	Key Findings
McCormack et al.[28]	A 53-year-old recreational tennis player with chronic mid-portion Achilles tendinopathy was seen twice a week for a total of 10 visits.	Case report	Examine the effectiveness of ASTYM along with exercises and stretches as a treatment for mid-portion Achilles tendinopathy.	Following her 10th visit, the patient reported no pain and 100% return to sport with no limitations.
McCormack et al.[29]	A 41-year-old recreational runner with chronic bilateral high hamstring tendinopathy was seen twice a week for a total of 16 treatments.	Case report	Determine the effectiveness of ASTYM along with strengthening and stretching as a treatment for high hamstring tendinopathy.	The patient reported a return to jogging with little pain by her 12th visit and significant increase in function by her last visit.
Miners et al.[30]	One 40-year-old physically active male with chronic Achilles tendinopathy received a total of nine treatment sessions over eight weeks.	Case study	Examine the effectiveness of Graston Technique® in combination with heat, eccentric strengthening, stretching, and cryotherapy as a treatment for chronic Achilles tendinopathy.	Improved pain and function were observed over an 8-week period.
Black et al.[31]	One 37-year-old male with a non-contact patellar tendon rupture that was repaired.	Case study	Examine the effectiveness of Graston Technique® as a post-operative treatment following patellar tendon repair.	Improvements in ROM, strength, and function over the course of 5 treatments as measured by LEFS score, AROM, PROM, and quadriceps lag.

Author	Population, Duration of Study, or Participant characteristics	Type of Study	Aim	Key Findings
Warden et al.[35]	30 symptomatic physically active participants previously diagnosed with PT and 33 physically active non-symptomatic participants were all scanned with both MRI and diagnostic ultrasound.	Cohort study	Examine the accuracy of MRI and diagnostic ultrasound in the diagnosis of PT.	Diagnostic ultrasound (both color doppler and grey scale) was more accurate in diagnosis PT when compared to MRI.
Bode et al.[37]	119 male elite soccer athletes were scanned using diagnostic ultrasound.	Case-control study	Examine the prevalence of PT in a group of elite soccer players using diagnostic ultrasound.	A total prevalence of 13.4% of the 119 soccer athletes were diagnosed with PT using diagnostic ultrasound.
Cuddeford et al.[38]	Two freshman collegiate decathletes were both diagnosed with patellar tendinopathy using diagnostic ultrasound and completed a total of 20 physical therapy sessions each.	Case report	Examine the effects of BFR treatment on pain, strength, and function associated with patellar tendinopathy.	Both athletes showed significant gains in pain, strength, and function over the 20 total physical therapy sessions.