THE EFFECTS OF THE GRASTON TECHNIQUE® ON CASES OF CHRONIC TENDINOPATHY MEASURED BY DIAGNOSTIC ULTRASOUND

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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

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ABSTRACT

The Graston Technique® is a beneficial treatment on tendinopathies[1] however, little research exists on the effects of the Graston Technique® on chronic cases of tendinopathy measured with diagnostic ultrasound. To determine the amount of changes in tendinosis, scar tissue and/or adhesions, or calcifications after the Graston Technique® treatments, fifteen athletes at NCAA division I, III, or NAIA institutions were recruited. Four days of the Graston Technique® as an overall protocol was used, including a warm-up, stretches, and strengthening exercises. Changes within the tendon were measured by diagnostic ultrasound. Lower Extremity Functional Scales (LEFS) and Numeric Pain Rating Scale (NPRS) were also used. The results showed a significant decrease of tendinosis in both axes. No significant changes were seen with tendon thickness or NPRS. There was a significant increase in the scores of the LEFS. In conclusion, the Graston Technique® protocol alone is beneficial in the treatment of tendinosis.

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CHAPTER 1. INTRODUCTION

The Graston Technique® is a form of Instrument Assisted Soft Tissue Mobilization (IASTM) that is increasing in popularity in athletic training and physical therapy settings. Instrument Assisted Soft Tissue Mobilization differs from Soft Tissue Mobilization (STM) because it uses instruments to supplement treatment. Using instruments allows the clinician to have an increased sense of tissue abnormalities, increased mechanical advantage, and decreased treatment times.[1] It can be performed in the form of Gua Sha, Astym, and the Graston Technique®. Gua Sha and Astym use instruments to create microtrauma that reintroduces the healing response within the injured tissue, allowing faster healing. Instrument Assisted Soft Tissue Mobilization provides a non-invasive treatment option that is beneficial to use on musculoskeletal conditions, as long as it is performed at the appropriate stage of tissue healing.[2-4]

One form of IASTM is the Graston Technique®. The purpose of the Graston Technique® is to reduce scar tissue, adhesions, and fascial restrictions that occur from musculoskeletal injuries, decreasing the pain and overall discomfort for the patient.[1] It is performed as an overall protocol that includes a warm-up, the Graston Technique® strokes, stretching, strengthening, and cryotherapy. The warm-up can be completed as an active warm-up in which the patient completes a form of cardiovascular exercise, or it can be localized. A localized warm-up includes using a moist hot pack to heat the tissues.[1] The Graston Technique® uses six different steel instruments to perform a variety of strokes and depths of pressure.[1] Although the Graston Technique® can be performed in conjunction with other modalities, the effects of the Graston Technique® alone has not been researched. The literature shows beneficial effects of the Graston Technique® on treating Achilles tendinitis, epicondylitis, and knee osteoarthritis.[4-6] It has also been shown to be beneficial for increasing range of motion (ROM) in collegiate athletes.[2] The majority of research with the Graston Technique® involves case studies and few studies have measured the effects with diagnostic ultrasound.

Diagnostic ultrasound (ultrasonography) is a fast growing tool for identifying a multitude of musculoskeletal conditions, including partial and full thickness tendon tears, tendinosis and calcifications.[7-12] It provides a high-resolution image, allows dynamic assessment, and can be used for guiding needle insertions.[12,13] The limitations of diagnostic ultrasound include poor intra and interrater reliability depending on the operator, time consuming to assess multiple joints in one session, and difficulty viewing deeper structures.[9,11-14] The appearance of the tissues will vary depending on the type, location, and tissue health. Structures that will appear brighter, or hyperechoic include bone, as well as tendons and ligaments. Bone will be the brightest and will have a smooth appearance, whereas tendons and ligaments will have a fibrillar appearance. Structures that are darker or more hypoechoic include muscle and fascia. However, muscle will have a pattern of fascicles that are both hyperechoic and hypoechoic. After an extensive literature search, no studies exist that use diagnostic ultrasound to measure the effects of the Graston Technique® on scar tissue adhesions, calcifications, and tendinosis.

Statement of the Problem

There are many research studies[2-6,35,36] that focus on the Graston Technique® in combination with other modalities and treatments, however little research exists on the Graston Technique® as a sole treatment for decreasing tendinosis, adhesions/scar tissue, and calcifications in cases of tendinopathy. Not only have no studies been reported on the Graston Technique® alone, none of the studies using the Graston Technique® have used diagnostic ultrasound as an objective method of measurement. Using diagnostic ultrasound will benefit the research because it allows the clinician to observe the changes within the tissue, thus helping to determine the effectiveness of the treatment.

The Purpose of the Study

The purpose of this study was to determine the effectiveness of the Graston Technique® for changes in tendinosis, adhesions/scar tissue, and calcifications in chronic musculoskeletal tendinopathies.

Research Questions

1. Did the Graston Technique® decrease tendinosis?
2. Did the Graston Technique® reduce scar tissue and/or adhesions in chronic tendinopathy?
3. Did the Graston Technique® reduce calcifications in chronic tendinopathy?
4. Did the Graston Technique® affect the patient's pain level?
5. Did the Graston Technique® affect the functionality of the patient?

Definition of Terms

IASTM: instrument assisted soft tissue mobilization is a variation of soft tissue mobilization in which the clinician uses tools or instruments to supplement the treatment process.[4]

Hemostasis: describes the controlling or stoppage of bleeding.[15]

Epithelialization: describes the development of a new tissue covering that protects the healing wound from further damage.[15]

Indication: a situation in which a certain modality or treatment should be used.[15]

Contraindication: a situation in which a certain modality or treatment should not be used.[15]

Sweeping: describes a type of Graston stroke that occurs at a steady rate and in one direction in either curvilinear or linear path.[1]

Fanning: describes a scanning stroke that is characterized by moving the instrument at different rates in an arched path with one end serving as the fulcrum.[1]

Brushing: describes a Graston stroke that is used for mobilization of superficial fascia, desensitization, and as a preparatory stroke for deeper treatment.[1]

Strumming: describes a stroke that is used to mobilize specific restrictions, and involves deep, linear, stroking motions of small amplitude that are perpendicular to the direction of the fibers.[1]

J-stroke: describes a Graston stroke that is used for mobilization superficial or deep restrictions and is completed in a J-shaped pattern.[1]

Framing: describes a Graston stroke that is used to lift the soft tissues from bony landmarks to release tissue tension, and is completed with small treatment edges.[1]

Tendinitis: inflammation of a tendon usually caused by overuse, repetitive activities.[16]

Tendinosis: degeneration of a tendon usually caused by chronic, untreated tendinitis in which the healing response has failed to activate.[16]

Hyperechoic: describes the very bright appearance of tissues such as tendons, ligaments, fascia, and bone.[17]

Hypoechoic: describes the characteristics of dark tissue, such as muscle.[17]

Isoechoic: has equal echogenicity between tissues.[17]

Anechoic: describes the characteristic of tissue that has a black appearance.[17]

Anisotropy: describes the artifact that occurs when the ultrasound beam is not perpendicular to the tissues, causing the tissues to appear less hyperechoic than normal. This can be corrected by angling the transducer to the correct position.[17]

Assumptions

1. It was assumed the participants were not receiving outside modality treatment during the two weeks of the study.

Limitations

1. The researcher administering the Graston Technique® treatments was M-1 certified since May 2017 with 7 months of practice prior to completing the study.
2. The researcher had one year of experience with diagnostic ultrasound.
3. If the subject was receiving previous treatment for their injury it might have affected the effectiveness of the Graston Technique®.

Delimitations

1. All subjects were free from any skin disorders and open wounds.
2. All subjects were male or female who had a chronic case of tendinopathy diagnosed by either an Athletic Trainer or Physician.
3. All subjects were categorized with respect to athletic division (NCAA I, NCAA III, NAIA).
4. All subjects received a treatment with the GT2, GT3, and GT4 instruments (Appendix B) using scanning, brushing, and strumming strokes.
5. All subjects completed a 10 minute cycling warm-up.
6. The Graston Technique® was up to 5 minutes in duration and included scanning, brushing, and strumming strokes.

CHAPTER 2. LITERATURE REVIEW

The purpose of this study was to determine the effectiveness of the Graston Technique® for changes in tendinosis, adhesions/scar tissue, and calcifications in chronic musculoskeletal tendinopathies. The following research questions guided this study: 1) Did the Graston Technique® decrease tendinosis? 2) Did the Graston Technique® reduce scar tissue and/or adhesions? 3) Did the Graston Technique® reduce tissue calcifications? 4) Did the Graston Technique® affect the patient's pain level? 5) Did the Graston Technique® affect the functionality of the patient? The review of literature is organized into the following areas: Instrument Assisted Soft Tissue Mobilization (IASTM), Graston Technique®, Graston Technique® and injury treatments, diagnostic ultrasound, tissue appearance normal and injured, specific injury appearance with diagnostic ultrasound, and conclusions and future research.

Instrument Assisted Soft Tissue Mobilization (IASTM)

Instrument Assisted Soft Tissue Mobilization (IASTM) is a variation of Soft Tissue Mobilization (STM). However, with IASTM the clinician uses instruments to manipulate the tissue to stimulate the body's natural healing process.[1,18] In addition to stimulating the body's natural healing process, the purpose of IASTM is to release the adhesions that cause restrictions within the body's normal range of motion.[1,19] Using instruments allows the clinician to increase the detection of tissue abnormalities in the body and to have an increased mechanical advantage. For both the clinician and the patient, it may be able to reduce treatment times as the instruments allow for deeper, more specific treatments.[1,18] Different types of IASTM utilized by clinicians include Gua Sha, Astym, and the Graston Technique®.

Knowledge of the healing process must be established to understand the basis behind IASTM and its effects on tissue. The healing process is a significant piece of IASTM and the

Graston Technique® specifically. The main components of tissue repair include hemostasis and inflammation, epithelialization, and proliferation.[15] Hemostasis is the controlling and stopping of bleeding. Although untrue, inflammation it is often thought to be detrimental. It is the body's local response to an injury or irritant, and is essential to the healing process. The purpose of the inflammatory phase is to defend the body against foreign substances and dispose of dead and dying tissue to allow repair.[15] There are eight stages within the inflammatory response that overlap and work together to repair the tissue. One of the most important of these is chemical mediation.[15] This phase activates the chemical mediators that include histamine, bradykinin, and cytokines. These chemical mediators signal to the rest of the body that cells have been damaged, thus sending the rest of the body's resources to respond.[15] The final phase of the inflammatory response is phagocytosis and its purpose is to reabsorb the dead tissue.[15] The remaining stages of the inflammation phase focus on the rebuilding of injured tissue and removing cellular debris and other foreign materials.[15]

Once the inflammation phase is complete, epithelialization takes place. This is the development of tissue covering an open wound for protection as the rest of the healing response occurs.[15] The purpose of the proliferation phase is to allow for the growth of new blood vessels, collagen synthesis, and closing of the wound edges.[15] Collagen is a fibrous protein that is the main component of connective tissue, and collagen synthesis is the process of the creation and arrangement of the collagen.[15,20] Collagen is typically laid down in a haphazard fashion before the fibers assemble in a parallel fashion to increase tensile strength of the connective tissue.[15,20] The purpose of IASTM is to create microtrauma within the tissue, initiating the healing process. This allows the facilitation of fibroblast proliferation, which helps the synthesis of collagen fibers in a more organized fashion.[21] It is one of the more significant purposes of IASTM and the

Graston Technique® because it is creating changes within the tissue. Facilitation of fibroblast proliferation can be achieved in the form of Gua Sha and more commonly, Astym and the Graston Technique®.

Gua Sha is a technique of Eastern Asian medicine that uses specifically designed tools to create temporary therapeutic petechiae also known as 'sha', which is the extravasation of blood in the tissue below the skin.[22] The body surface is stroked with a smooth, round edged instrument.[23] The purpose of Gua Sha is to promote normal circulation and metabolic processes, as well as move blood and metabolic waste from the tissues to the surface of the body. Gua Sha is used in the treatment of pain, acute and chronic disorders, and acute infectious illnesses.[24] Braun et al.[23] studied the effects of Gua Sha on patients with neck pain in a randomized controlled trial. The outcomes collected included scores from a Visual Analog Scale (VAS), pain at motion, the neck disability index (NDI), and Short-Form Health survey that measures quality of life. Reports from the patients were meaningful, showing a 50% decrease on the VAS, and a significant improvement of physical function with scores on the NDI decreasing from 32.8±11.5 to 21.8±12.9 at baseline and week 7, respectively. It was noted that these results lasted for up to 1 week.[23] To study the effectiveness of Gua Sha, Lauche et al[25] used it as a method of pain relief in cases of chronic neck and low back pain. Forty patients with a diagnosis of either chronic neck pain or chronic low back pain were assigned to a treatment group or waiting list control group. The treatment group received a single Gua Sha treatment, and the waiting list control group did not receive any treatment. The results indicated a significantly higher pain pressure threshold, as well as a positive change in the overall health of patients in the treatment group. Results of the studies completed by Braun et al[23] and Lauche et al[25] demonstrated positive effects of using Gua

Sha as a single treatment. Although Gua Sha as a form of IASTM in pain reduction has shown to be effective, more research should be conducted with Gua Sha on different pathologies.

Astym is another form of IASTM that uses tools to reintroduce the healing response to the injured tissue. Astym is similar to Gua Sha in that it uses tools to detect tissue abnormalities however, the method in which treatment is performed differs.[26] Astym uses three plastic tools to create specific microtrauma to tissues. This causes an inflammatory response as described above, allowing the excessive scar tissue or fibrosis to be reabsorbed by phagocytosis. The microtrauma that is created within the tissues initiates ultrastructural changes and causes the chemical mediators such as histamine, bradykinin, and cytokines to migrate to the injury site.[15] The tools used to re-initiate the healing process are various shapes and sizes to accommodate the different tissues that require treatment.[26] Astym contrasts traditional cross-friction massage because the tools are moved along the direction of the tissue fibers as opposed to the perpendicular direction to the tissues.[4] Sevier and Stegink-Jansen[27] compared the effects of Astym versus eccentric exercise in the treatment of lateral epicondylitis. The results of the study indicated that 78.3% of individuals in the Astym treatment group had complete resolution of symptoms with the initial treatment. Those individuals in the eccentric exercise group who did not have a resolution of symptoms were permitted to move to the Astym group as delayed entry, where 95.7% had complete resolution of symptoms within four weeks.[27]

Not only is Astym used to reduce symptoms of lateral epicondylitis, it has also been shown to increase muscle strength and power output immediately after treatment.[28] In a blinded randomized controlled trial performed by Kivlan et al,[28] Astym provided a significant increase of Newtons, allowing for greater maximal force output. The maximal force output was the amount of strength tested in the lower extremity, measured by a computerized leg press machine.[28] The

Astym applied was to the anterior and lateral compartments of the leg, the gastrocnemius/soleus complex, the gluteus medius/maxiumus, hamstring group, and quadriceps group.[14] The positive effects of Astym in the studies noted above, exemplify why Astym therapy is a popular therapy among health professionals.[27,28]

There are many advantages to using IASTM as it is non-invasive, provides shorter treatment durations, and is beneficial on chronic conditions.[21] The disadvantages include a greater chance to cause damage to the tissues if performed incorrectly or at an inappropriate stage of tissue healing.[26] IASTM can be performed with Gua Sha, Astym and the Graston Technique®, and is dependent upon the individual performing treatment, as well as the type of injury on the individual being treated. Proliferation and activation of the tendon fibroblasts are dependent upon the pressure and mechanical force of the treatments, thus they should be considered when performing an IASTM or STM treatment.[21] Sevier and Stegink-Jansen[27] reported that using Astym as a treatment method was beneficial in the resolution of lateral epicondylitis. Gua Sha has been shown to have positive effects on patients with neck pain, and overall function in patients with musculoskeletal pain.[23,25] Although the three research studies described above demonstrate the effectiveness of IASTM, more research needs to be completed for clinicians to support the use on specific musculoskeletal injuries.

Graston Technique®

Another form of IASTM that is increasing in popularity is the Graston Technique®. The Graston Technique® is a rapidly growing treatment method used in different professions, including athletic training and physical therapy. It is defined as a form of soft tissue mobilization in which instruments are used to identify and release scar tissue, fascial restrictions, and adhesions.[1] The Graston Technique® follows the principles of IASTM as it uses instruments to create an inflammatory response within the tissues, allowing for proper healing.[1] Current therapeutic approaches of the Graston Technique® include pro-inflammatory, edema reduction, pain reduction, scar mobilization, and fascial mobilization.[1] While the Graston Technique® is a beneficial tool for clinician use, it is important to implement it as one part of an overall therapy protocol. The overall protocol includes musculoskeletal evaluation, inflammation control, soft tissue mobilization, joint mobilization, stretching and strengthening, neuromuscular and posture re-education, and a home exercise program.[1] The Graston Technique® is beneficial for both the patient and the clinician as the patient may experience improved, quicker outcomes, and an improved quality of life. Use of the Graston Technique® enables the patient to learn more about their diagnosis and treatment to feel more in control of their injury. The clinician may experience decreased fatigue, increased mechanical advantage, and decreased treatment time in some cases.[1]

Indications, Contraindications, and Precautions

While using modalities, it is important to recognize the indications, contraindications, and precautions of the modality to eliminate the chance for injury or harm to the patient. An indication is defined as a situation in which a specific modality should be used, or conditions that would benefit from application of a certain modality.[15] However, a contraindication is defined as any situation in which a specific modality should not be used or situations in which it may do more harm than good.[15] Finally, a precaution is a situation that could potentially be harmful to the patient if the clinician is not using the appropriate application.[15] (Appendix A)

Instruments

The instruments that are used for the Graston Technique® are weighted and made of steel to allow for deeper treatment and less energy to be expended for the clinician.[1] The instruments have different shapes for the targeted tissues, contours and joint shapes. If the clinician is trying to increase comfort for the patient, or equalize the pressure over a large surface area, then a convex instrument should be used on a concave body part or vice versa. Conversely, if the clinician is trying to maximize pressure in a small area, or pinpoint pressure accurately, a convex instrument should be used on a convex body part.[1]

There are six instruments that differ in weight and size, allowing for use on different body parts and injuries.[1] The GT1 (Appendix B) is the largest of the six instruments, and is typically used for large muscle groups such as the hamstrings, gastrocnemius, upper trapezius, quadriceps, and latissimus dorsi.[1] It is long and bar-like, with convex and concave surfaces that allow preparation and localization of the tissue. The purpose of this tool is to evaluate and treat restrictions that are generalized throughout the muscle group.[1] The GT2 instrument (Appendix B) is smaller with a single and double-beveled edge used to treat smaller, deeper, convex areas. It is appropriate to use in regions around the malleoli, patella, thenar and hypothenar eminence, and subacromial region.[1] To reduce localized restrictions, the GT3 (Appendix B) is frequently used as it is a smaller, straight instrument.[1] The most commonly used instrument, GT4 (Appendix B), is able to successfully detect soft tissue abnormalities. This instrument has both a straight and curved edge allowing for treatment on concave and convex soft tissue surfaces.[1] For more aggressive treatments with muscle restrictions, as well as scanning convex shaped tissues, the GT5 instrument (Appendix B) is useful. It has a concave shape with a single-bevel.[1] A more complex instrument, the GT6 (Appendix B), has a single and double-bevel edge as well as a hook and two blunt angles. It is designed for use on smaller areas such as the wrist, metacarpals, metatarsals, and phalanges. The edges of the instrument allow the clinician to treat localized restrictions in small areas.[1] The Graston Technique® instruments are specifically designed to allow the patient and clinician a positive overall treatment experience.

Rate, Duration, Frequency, Intensity

Although the instruments are designed to supplement the treatment process, it is important to use the correct parameters for optimal results.[1] The rate, duration, frequency, and intensity will vary with each patient however, it is important to recognize the general guidelines the Graston Technique® recommends with treatment.[1] The stroke rate should be reduced over larger areas and areas where the patient is experiencing more pain, to minimize discomfort. In a smaller treatment area however, the patient should be able to tolerate shorter, quicker strokes.[1] The duration of the Graston Technique® will vary based on the type and length of injury however, the goal is 4-8 sessions.[1] There is potential that acute conditions will take less time than chronic conditions. However, every treatment should be different, and depend upon the patient and the goal of the treatment.[1] Similarly to the duration of the Graston Technique®, the frequency will depend on the patient tolerance, the aggressiveness of treatment, and patient injury.[1] The Graston Technique® manual recommends treatment two times per week with three days between treatments. For maximum benefit of therapy, the patient should be treated over a period of 10-14 days.[1]

Factors that affect the intensity of the treatment include: pressure, depth of penetration, session duration, rate, instrument, frequency, amplitude, and direction.[1] The depth and pressure of treatments are important as they have a direct effect on the changes in fibroblast proliferation and activation. Gehlsen et al[21] compared the effects of the depth of pressure in an IASTM treatment on fibroblast proliferation on rats with Achilles tendinitis. A pressure sensor was embedded in the solid Augmented Soft Tissue Mobilization (ASTM) instrument and interfaced to a computer. No other details were given on the type of instrument that was used for the soft tissue mobilization. Collagenase was injected into the Achilles tendon of the rats to induce

Achilles tendinitis. Rats were divided into three groups that received light (0.5 $N{\cdot}mm^{-2}$), medium (1.0 $N{\cdot}mm^{-2}$), and extreme (1.5 $N{\cdot}mm^{-2}$) pressure, respectively. Cocoa butter was applied to the Achilles tendon of the rat, and ASTM was applied longitudinally from distal to proximal and proximal to distal. This treatment was applied by performing three strokes each way every day for a total of six treatments. It was concluded that the rats that received heavy pressure showed the greatest fibroblast proliferation.[21] Although the results of the study showed heavy pressure is most effective, when performing IASTM, it is important to use an appropriate depth and pressure for the type of injury and tissue.[1,21]

Evaluation

The clinician must complete an overall evaluation on the patient to determine the diagnosis. The medical history should be detailed, identify previous injuries, and other relevant medical information.[1] The patient should rate their pain on a visual analog scale and the clinician should collect functional measurements as well as complete a soft tissue evaluation. The soft tissue evaluation should be completed with the clinician's hands, and then the Graston Technique® instruments.[1] Using hands as a method of soft tissue evaluation allows the clinician to feel changes in the tissue such as skin temperature, contour, size, moisture, position, shape, and anatomical landmarks. It is important to use an appropriate amount of pressure and not palpate too deeply, as it can diminish the sensation felt by the clinician.[1]

The GT instruments are able to amplify what the clinician's hands feel, and can detect thickening, adhesions, ridges, and scar tissue.[1] The validity of the GT4 instrument for identifying adhesions was researched on the medial gastrocnemius muscle in 100 participants.[29] The GT4 instrument was used with linear and sweeping strokes until an adhesion was located. The adhesion was then marked with a black sharpie. Each black mark was then imaged with diagnostic ultrasound and images were sent to two clinicians trained in diagnostic ultrasound. Rater 1 found that 78% of the images contained an adhesion, and rater 2 found that 93% of images contained an adhesion.[29] Although there are differences between the two raters, the results of this study show that diagnostic ultrasound is a useful tool in evaluation soft tissue adhesions. It is important to select the correct instrument for the evaluation process, as well as the proper sweeping strokes and speeds. The GT4 instrument (Figure B) is generally appropriate to use as it has a larger surface.[1] The rate in which the stroking/sweeping occurs should be slower than during treatment, as the clinician doesn't want to miss vital information about the tissue.[1] The evaluation should be over a larger surface area. Depth and intensity should not be high enough to decrease accuracy, or increase patient guarding.[1]

Warm-up

The Graston Technique® requires the target tissues to be warmed before treatment by either an active warm-up or local tissue heating. Although there are multiple options for heating the tissues, an active warm-up will be most effective to achieve optimal blood flow throughout the body.[1] An active warm-up allows the oxygen demands of the body to increase during exercise, which results in the proper nutrients to travel through the bloodstream.[30] This warm-up should last about 10-15 minutes to increase oxygenation to the tissues and promote total body heating. However, aerobic conditioning should not be achieved until the functional progression of the patient occurs.[1] An active warm-up will be dependent on the restrictions of the individual and their specific injury, as some may not be able to bear weight, or complete vigorous activity. During exercise, blood flow can increase up to 20 times of the resting conditions.[30] With this increase of blood flow throughout the body, the oxygen demands of the tissues are met, thus allowing for proper treatment with the Graston Technique®.[1,30] If the patient is unable to complete an active warm-up, other heating modalities may be used. These include a moist hot pack, paraffin wax, therapeutic ultrasound, or warm whirlpool.[15]

Graston Strokes

There are many different strokes that can be used with the Graston Technique®, all with a specific purpose. A sweeping stroke can be used with any of the instruments and is used to scan or assess the tissues, and help reduce edema.[1] Sweeping should occur at a steady rate and in one direction in either a curvilinear or linear path.[1] Another type of stroke that is beneficial for localized scanning is fanning which can be performed with the GT1, GT2, GT4, or GT5 instrument (Figure B1). It is characterized by moving the instrument at different rates in an arched path with one end serving as the fulcrum.[1] Brushing is completed with the GT3 instrument (Figure B1) for mobilization of superficial fascia, desensitization, and as a preparatory stroke for deeper treatment strokes. It is performed in one direction as a superficial, linear stroking motion that is of small amplitude.[1] To mobilize specific restrictions, a strumming stoke should be used with the GT3 (Figure B1). Strumming involves deep, linear stroking motions of small amplitude, and should be perpendicular to the direction of the fibers.[1] Similarly, a J-stroke is completed with the GT3 instrument and is for mobilizing superficial or deep restrictions and it is completed in a J-shaped pattern.[1] Lastly, framing is used with small treatment edges, such as the GT2 knobs or GT3 (Figure B1) edges, in a series of scooping maneuvers. It is used to lift the soft tissue from bony landmarks to release tissue tension.[1]

Stretching

It is important to stretch the tissue following the Graston Technique® strokes, prior to the exercises that are completed. Stretching is completed to encourage proper tissue alignment and help lengthen shortened muscle groups.[1] Initially in the Graston Technique® sequence, stretching should be introduced before strengthening. However, once the patient has progressed, stretching should be dispersed throughout the program, specifically after strengthening.[1] Stretching has many known benefits for both injured and uninjured individuals, which include increasing muscle length and ROM, encouraging the correct alignment of collagen fiber, and allowing proper alignment of scar tissue during the remodeling phase of injury.[1,31-33]

Stretching can be completed in a dynamic manner, in which the individual actively moves the limb through its full range of motion or in a static manner, which includes the limb being held at a point of tension by the individuals themselves or by a partner.[31] Static stretching is said to be the most beneficial for increasing ROM or tissue extensibility.[1,31,32] Davis et al. studied the effects of three different types of stretching on ROM of the hamstring. The Knee Extension Angle (KEA) was used as a measurement to determine the differences between no stretching, static stretching, self-stretching, and proprioceptive neuromuscular facilitation. The groups met with the examiners three times per week for four weeks, where each group performed the hamstring stretch once for 30 seconds per each treatment session. The results of this study indicated a significant increase in ROM in the static stretching group, with the KEA improving from 61.5° to 85.2° at four weeks.[32] There are discrepancies between the length of time a muscle should be stretched, with the most common times being 15-20 seconds, and 30 seconds.[31-33] The Graston Technique® recommends static stretching for 30 seconds throughout the day to achieve the desired effects that include tissue elongation, and correct alignment of collagen fibers and scar tissue.[1,31,32]

Strengthening

Once stretches have been completed to encourage proper tissue alignment, there are many different types of exercises that can be implemented during the strengthening portion of the overall treatment protocol. Strengthening can be performed with a variety of different contractions, including concentric, eccentric, and isometric. A contraction in which the muscle is shortened is considered concentric. On the contrary, it is considered an eccentric contraction when lengthened.[1] An isometric contraction is one in which the length of the muscle does not change.[1] The exercises that are prescribed to the patient must be specific to the target muscle group that is contributing to the dysfunction. It should not cause pain for the patient to complete and the patient should be able to complete them at home. It is important that the patient is completing the exercises with the proper form, as it will decrease the likelihood of injury. [1] With the Graston Technique® treatment protocol, the purpose of strengthening is to work the muscle to the point of fatigue. This is achieved by performing high repetition, low weight (one or two sets, 20-25 repetitions) with body weight, weights or therabands.[1] The patient should be progressed through a rehabilitation protocol that successfully meets their needs for treatment.[1]

Cryotherapy

While the Graston Technique® is a beneficial treatment for different conditions, it creates an inflammatory response within the tissues.[1] The inflammation phase is an essential component of the healing process however, cryotherapy serves to decrease or minimize the signs and symptoms during the inflammatory process.[1,15] Not only will cryotherapy decrease the signs and symptoms, it will also reduce metabolic demands.[1,15] The purpose of cryotherapy after acute injuries is to limit the amount of secondary injury and edema. Cryotherapy decreases the metabolic demands of the cells, thus allowing these cells to be more resistant to the ischemic state that is caused by compromised circulation.[15] The results of this process allows less secondary metabolic injury, thus less total injury.[15] Cryotherapy may be used after treatment of the Graston Technique® to prevent further injury and give some discomfort relief to the patient.[15]

However, it is now a recommendation and not a step of the process.[1] The Graston Technique® manual does not give specific cryotherapy requirements, however Dykstra et al[34] reported wetted ice bags may be more effective than regular ice bags without added water.[34] The effectiveness of different types of ice when using an ice bag was examined by recording tissue temperature in the gastrocnemius. The ice bags were applied to the gastrocnemius in a freestanding fashion for 20 minutes. The results indicated that a wetted ice bag had the greatest decrease in tissue temperature after 20 minutes compared with crushed and cubed ice.[34] Wetted ice bags demonstrated a tissue temperature decrease of 6°C, whereas crushed ice and cubed ice decreased 4.3°C and 4.8°C, respectively.[34] Using a wetted ice bag may be more beneficial in reaching the desired tissue temperature decrease to reduce secondary metabolic injury.

Graston Technique® and Injury Treatments

The Graston Technique® has limited research in the databases as it is a relatively new modality. The studies provided demonstrate the Graston Technique® as a useful modality in treating acute and chronic conditions including Achilles tendinitis, lateral epicondylitis, knee osteoarthritis, and biceps tendinopathy.[3,5,6,35,36] The Graston Technique® has also been shown to be beneficial in increasing flexibility in the hamstrings and ROM in shoulders of collegiate athletes.[2] Although there haven't been any studies on the Graston Technique® specifically for the treatment of scar tissue, Astym has been shown to be beneficial in the treatment of scar tissue post mastectomy.[37]

Achilles Tendinopathy

The Graston Technique® is beneficial for individuals suffering from an overuse, chronic condition.[5,35] Achilles tendinopathy is a common overuse injury in the athletic population.[16] It can be caused from both intrinsic and extrinsic factors. Intrinsic factors include foot malalignment and biomechanical faults, limited range of motion of the subtalar joint, deformity of the hindfoot, decreased dorsiflexion, poor vascularity, gender, age, and endocrine or metabolic factors.[16] Extrinsic factors include changes in running/training surface, poor mechanics, or changes in shoe type.[16]

The Graston Technique® has shown to be effective in reducing the symptoms of Achilles Tendinitis.[5,35] A case study of the effectiveness of treatment on Achilles tendinitis with passive tissue warm-up, the Graston Technique®, Active Release Therapy (ART)®, eccentric exercise, and cryotherapy was reported.[5] The individual was a very physically active 40 year old who had progressively worsening symptoms over 3.5 years. Symptoms included bilateral intermittent Achilles tendon pain, achy stiffness first thing in the morning, and limping after the symptoms progressed. The patient received nine sessions of treatments over eight weeks. The tissue warm-up in this specific protocol followed the guideline of the Graston Technique® manual[1], as it was an active tissue warm-up. The patient cycled for five minutes in combination with a heating pack, however it was half the time of what is stated in the Graston Manual.[1] The authors used the GT3 instrument (Figure B1) to localize restrictions and provide treatment to a small area, which follows the Graston Technique® guidelines.[1] Active Release Therapy® was performed on the gastrocnemius muscle to improve tissue functions. Pressure from the clinicians thumb was applied to the affected site on the gastrocnemius while the tissue was shortened and lengthened by passive and active movements.[5] Eccentric exercises were given in the form of a home exercise program which included bilateral heel lowering exercises, along with straight and bent leg gastrocnemius stretching. The results of this study demonstrated the patient received almost absolute resolution of symptoms after nine sessions, as well as a positive therapeutic result that was maintained after a seven month follow up.[5]

The Graston Technique® is typically used with athletes, it has also been shown to be effective on an elderly patient. A case study was reported about the conservative management of Achilles Tendinopathy. A 77 year old female had a case of chronic Achilles Tendinopathy in the midportion of her right Achilles tendon, in which the pain was limiting her activities of daily living (ADLs). Upon inspection, swelling was noted around the right Achilles tendon, with visible bilateral hallux valgus, and left-sided subtalar varus. Her previous treatments included orthotics and cryotherapy, which provided no relief.

The patient received 12 treatment sessions over an eight week period, in which gradual improvements were reported. She received multiple different treatments including acupuncture with electrical stimulation, Graston Technique®, stretching and eccentric exercise, and proprioceptive exercises. The specifics of the Graston Technique®, including tissue warm-up, length and duration of treatment, and instruments used were not reported in this case study. The patient reported a Visual Pain Rating Scale (VPRS) as a 0/10 at week nine; with an improvement of her Lower Extremity Function Scale (LEFS) from 48 to 80.[35] The patient's follow-up at 12 months reported no recurrence of symptoms.[35] The Graston Technique® was demonstrated to be beneficial in the case studies described above. Both patients experienced full resolution of symptoms after treatment with the Graston Technique®. Although these indicate positive results, both case studies included other treatments and therefore it is unknown if the improvements were solely based from the Graston Technique®. Case studies are considered a low level of evidence and more research with a higher level of evidence should be conducted on the treatment of Achilles tendinitis with the Graston Technique®.

Patellar Tendinopathy

The Graston Technique® is a valuable option for increasing ROM in the upper and lower extremity, however it can also be used to help with tendinopathies. Patellar tendinopathy, also termed "Jumper's Knee", is a common overuse injury in the athletic population.[16] It is caused by repetitive eccentric activities and is most common in sports or activities that include jumping and running.[16] In cases of chronic tendinitis, there may be calcific nodule formations in the tendon, or cystic changes at the distal pole of the patella.[16] A limited amount of literature exists on the Graston Technique® as a treatment for patellar tendinopathy. Douglass Black[6] reported a case study on the treatment of knee arthrofibrosis after patellar tendon repair with the Graston Technique®. The patient was a 37 year old male who sustained a patellar tendon rupture. He underwent a surgical repair and could perform ROM exercises at seven days post-operative. The patient demonstrated decreased ROM that was subsequently treated with the Graston Technique®, joint mobilization, strengthening, and edema and pain control. Treatment began with a warm-up of a moist hot pack application for 5-7 minutes. The Graston Technique® strokes followed the manual[1], as they were applied to the prominent adhesions and along the length of the tibialis anterior, and the quadriceps group. Scanning stokes were used, and localized areas of adhesions were focused on more specifically, where a deeper instrument application with the GT5 instrument (Figure B1) was applied for bouts of 30-60 seconds. Areas that received specific treatment included the suprapatellar pouch, the medial and lateral patella borders, the infrapatellar fat pad, and the rectus femoris and proximal tibialis anterior muscles.

Throughout the treatment sessions, it was noted that the superficial adhesions were resolving well. Grade III and IV joint mobilizations of the patella were performed, as well as mobilizations of the tibiofemoral joint. Range of motion and strengthening exercises were implemented and included stationary biking, active-assisted ROM, short-arc quadriceps activation, mini-squats, and terminal knee extensions. After five treatments, the patient demonstrated an increase in active and passive ROM from 93° to 110° and 95° to 123°, respectively. A decrease in quadriceps lag was noted from 22° to 3° after five treatments.[6] The Graston Technique® was implemented as an addition to the traditional physical therapy protocol. The patient demonstrated an improvement in both clinical and functional measures, which may have been enhanced with the Graston Technique®. This case study shows promising results for using the Graston Technique® as a treatment for patellar tendinopathy. Further studies at a higher level of evidence should be completed to determine the effectiveness of the Graston Technique® in injury rehabilitation, as well as reduction in nodule formation and tendon thickening.

Lateral/Medial Epicondylitis

Lateral and medial epicondylitis is another common overuse injury that can be due to repetitive motions in combination with faulty mechanics.[16] The Graston Technique® as a treatment on lateral epicondylitis was studied on two females aged 47 and 48 years.[36] Patient one complained of pain in her right elbow that progressed over the course of six weeks due to repetitive flexion and extension of the wrist and fingers. Patient two complained of pain that progressed over four weeks that was due to excessive squeezing and gripping. Both females presented with pain and tenderness over the common extensor mass. Resisted range of motion testing elicited pain with forearm supination, wrist extension, and middle finger extension. The patients received similar treatments that included acupuncture with electrical stimulation, the Graston Technique®, and rehabilitative exercises. The exercises included in the program consisted of forearm flexor and extensor stretches, eccentric wrist extensor training, concentric wrist extensor training, and pronation and supination strengthening with a theraband. The specifics of the Graston Technique® were not listed however, the authors reported they followed the protocol and it was administered by a certified Graston Technique® provider.[36]

Both individuals received 12 treatments over a nine week period, and reported gradual decreases in symptoms. The first patient's VPRS decreased from a score of 7/10 to a 0/10 at week ten, and her Quick-DASH Work Module Score (QDWMS) decreased from a 95/100 to a 0/100. The second patient reported a decrease in VPRS from 5/10 to 0/10 and a decrease in QDWMS from 62.5/100 to 1/100. Lower numbers on both the QDWMS and VPRS are desired as they demonstrate a decrease in pain and functional impairments. The outcomes of this study supported conservative rehabilitation in combination with the Graston Technique® provided a full resolution of symptoms, and should be considered in other cases of lateral epicondylitis.[36] While the outcomes demonstrated positive effects, it is unknown which treatment method was most effective.

Surgical Scars

Although limited studies have been completed on scar tissue reduction with the Graston Technique®, one case was examined on a patient post-surgery. A 62 year old female underwent surgery to remove a carcinoma in the right breast.[38] After surgery, the patient presented with restricted right shoulder ROM and pain with activity due to scar tissue around the surgical area. The Graston Technique® was used as a method of treatment for decreasing the amount of scar tissue in the area. The patient was seen twice a week for three weeks, in which she received the complete Graston Technique® protocol (warm up, Graston Technique® strokes, high repetition and low load exercise, stretching), and KinesioTaping. The results of this study showed a decrease to 0/10 on the Numeric Pain Scale, an improvement on the Patient Specific Functional and Pain Scale, and an improvement on the QuickDASH Disability/Symptom Score. Visibly, the scar was less noticeable after treatment, indicating that the Graston Technique® was a beneficial treatment option.[38]

Similarly, Astym has been effective in reducing scar tissue on women post-mastectomy. Davies[37] et al examined the effects of Astym therapy on 40 women who had undergone a mastectomy. The patients' ADLs was the main outcome measure and was achieved by using the Disabilities of the Arm, Shoulder, and Hand (DASH) scores, Patient-Specific Functional Scale (PSFS), and a questionnaire that measured their ability and comfort to wear a bra. The clothing questionnaire included questions about the woman's ability to wear a bra, as well as questions about her body image. Inclusion criteria consisted of the patients with a minimum of three weeks from surgery to allow the incision to heal. The same therapist performed the Astym treatments that were administered two times a week for 4-6 weeks. All participants received eight total treatments which included therapeutic exercises and instructions for home stretching and exercises. The authors concluded that there was a significant difference ($P<.01$) in DASH scores, the clothing questionnaire, and PSFS scores. Meaningful improvements were reported in active range of motion in both shoulder flexion (17°) and shoulder abduction (19°), with no negative effects reported.[37] The results of these studies support the use of Astym and possibly IASTM for reduction of scar tissue. There are no other studies on the effectiveness of IASTM on scar tissue, therefore further studies are necessary to confirm the beneficial effects.

Range of Motion/Flexibility

Range of motion restrictions in the shoulder is a common problem in overhead athletes, specifically baseball players. Laudner et al[2] completed a blinded, randomized controlled trial on the effects of IASTM on improving posterior shoulder range of motion in collegiate baseball players. Thirty-five baseball players were randomly assigned to either the control or IASTM group. An athletic trainer and IASTM practitioner trained in the Graston Technique® applied the treatments in the IASTM group. The participants were placed in a prone position with the arm at 90° of shoulder abduction and 90° of elbow flexion with neutral rotation. The GT4 (Figure B1) instrument was used for treatment, in which strokes were applied both parallel and perpendicular to the muscle fibers of the posterior deltoid, teres major, teres minor, infraspinatus, and latissimus dorsi. An emollient was used to decrease the friction between the instrument and the skin. There was no full body or localized tissue warm-up noted. The treatments were based on the Graston Technique® recommendations and lasted 40 seconds on each muscle.[2]

The results indicated an increase in glenohumeral (GH) horizontal adduction and GH internal rotation range of motion for the patients in the IASTM group.[2] The results were measured as group by time interactions, which are the changes in the groups over a period of time. They presented as follows: a significant group by time interaction was present for GH horizontal adduction with an 11.1° increase in ROM in the IASTM group, and a significant group by time interaction present for GH internal rotation with a 4.8° improvement.[2] A single treatment of the Graston Technique® provided acute improvements in range of motion however, further research should be performed on the effectiveness of the Graston Technique® as an overall treatment protocol in improving range of motion (warm-up, stretching, strengthening, cryotherapy), and the long-term effects of a single treatment.

Not only is the Graston Technique® beneficial for improving upper extremity ROM, it can also be performed on the lower extremity. Nejo et al[19] examined the effects of the Graston Technique® on hamstring flexibility in college students. The methodology of this study was based on the Graston Technique® manual.[1] The participants were required to have hamstring tightness ranging between 40-70° of a straight leg raise, and were excluded if they had any hamstring injury within the previous two months. Three groups were included, one sham group, one group that received Graston Technique® strokes, and one group that received the whole Graston Technique® treatment with stretching and strengthening. The Graston Technique® instruments that were used included the GT1, GT3, and GT4 (Figure B1). For a warm-up, a 10 minute application of a hot pack was used instead of an active warm-up, due to convenience. The application of the Graston Technique® included six to ten long strokes with the GT1 instrument, ten to fifteen strokes on smaller areas with the GT4 instrument, and one minute of very short strokes on small areas with the GT3 instrument. Passive range of motion was measured directly after the Graston Technique® treatment in both the sham and Graston Technique® strokes groups. The whole Graston Technique® group performed stretching and strengthening after the Graston strokes and PROM was measured after the strengthening. The results indicated a mean ROM increase of 0.55°±6.18 (control group), 9.13°±5.86 (Graston Technique® strokes group), and 14.67°±8.47 (whole Graston Technique® treatment group). While the control group hamstring ROM did not significantly improve, the Graston Technique® strokes group and the whole Graston Technique® treatment group significantly increased hamstring ROM. Although these are only two studies that support how the Graston Technique® increases ROM, they both demonstrate a positive trend in upper and lower extremity ROM using the Graston Technique® as an overall treatment method.

Conclusion

The Graston Technique® is used to identify and release scar tissue, fascial restrictions, and adhesions.[1] Unfortunately, after an extensive literature search, few articles were found on the effectiveness of the Graston Technique® as a treatment alone. Laudner[2] et al concluded that a single treatment improved the range of motion in collegiate baseball players, and Nejo et al[19] found a significant increase in ROM after a single treatment on the hamstring. As the Graston Technique® is increasing in popularity, it is important to ensure there is optimal evidence to support its use. Overall, the Graston Technique® shows positive results for increasing range of motion, and decreasing the symptoms of different tendinopathies, and epicondylitis. Due to the limited research on the Graston Technique® and the combination of treatments in the case studies described above, it is difficult to determine which treatments were most effective. Although the Graston Technique® has been shown beneficial as a treatment for tendinopathies, there are no studies that examine the effects on the structures affected. There is low level evidence that supports the Graston Technique® on injury treatments. In addition, there are no studies that examine the effects on the injured tissue without the combination of whole treatments. Thus, more research should be completed on the Graston Technique® as a treatment alone on scar tissues, adhesions, and tissue thickening in different chronic conditions.

Diagnostic Ultrasound

Diagnostic ultrasound (ultrasonography) is a fast growing tool for identifying a multitude of musculoskeletal conditions, including partial and full thickness tendon tears, tendinosis and calcifications.[7-10,12,39] It provides a high-resolution image, allows dynamic assessment, and can be used for guiding needle insertions.[12,13] Compared with Magnetic Resonance Imaging (MRI), diagnostic ultrasound offers an inexpensive alternative that allows a noninvasive, dynamic examination that can be compared bilaterally, without limitations on metal structures within the body, as contraindicated with MRI.[35,39] The limitations of diagnostic ultrasound include poor intra and interrater reliability depending on the operator, time consuming to assess multiple joints in one session, and difficulty viewing deeper structures.[9,12-14,39]

Diagnostic ultrasound transducers are chosen on the depth of penetration desired.[8,17,40] Higher frequencies (>10MHz) cannot penetrate deep into the tissues, however they provide greater resolution for superficial structures and should be utilized when viewing body parts such as the knee, elbow, shoulder, ankle and foot.[40,41] Medium frequencies should be used for viewing deeper structures on smaller body parts.[40,41] However, while the use of medium frequencies is beneficial, it is important to note that some of the resolution is lost creating a less clear image.[41] Lower frequencies can be used to assess deeper structures such as the hip.[17] Although the resolution decreases with lower frequencies, it is necessary to use on larger body parts, as the higher frequencies cannot reach the appropriate depth.[12,17] Choosing the highest frequency transducer possible is important in creating the clearest resolution image, thus providing the most accurate diagnosis.[12,41]

Diagnostic ultrasound allows the clinician to place the patient in different positions to assess the same structure in different views, or a different structure altogether. The transducer is not fixed in one location which allows the clinician to move it around to find the image with the best possible resolution.[12] The clinician is able to have the patient repeat the action(s) that cause pain, allowing those specific structures to be imaged.[12] The dynamic capability of diagnostic ultrasound is beneficial in evaluation of full-thickness tears of muscle, tendon, or ligaments.[3,42,43]

It is important for a clinician to have the proper knowledge and skills to achieve the most accurate diagnosis when using diagnostic ultrasound.[13] For correct performance of musculoskeletal ultrasound, there must be a sound knowledge of anatomy, the appearance of normal and abnormal musculoskeletal tissues, ultrasound technology and physics, the Doppler technique, and joint musculoskeletal sonographic scanning methods.[13] The Doppler technique allows the imaging of blood flow in the anatomic structures to be viewed.[12,13]

Many different resources are available for individuals looking to become a musculoskeletal sonographer including: relevant textbooks on musculoskeletal ultrasound, atlas on sectional anatomy, websites, published articles on musculoskeletal ultrasound, and DVDs on musculoskeletal ultrasound.[13] Forms of musculoskeletal ultrasonography training include: having a mentor, theoretical and practical courses, formal/informal training from radiologists and rheumatologists, e-learning, learning sonoanatomy in specimens, and self-teaching.[13] The experience of the clinician plays a key role in the outcomes of the examination. O'Connor et al[43] compared the interobserver variation of three different radiologists when using diagnostic ultrasound for the shoulder. Twenty-four shoulders were scanned for pathology by three different musculoskeletal radiologists that had varying levels of experience. Two of the radiologists had more than six years of experience with diagnostic ultrasound, whereas the third only had six months experience. After scanning the 24 shoulders, it was determined that the less experienced operator had poor agreement in all pathologies except calcific tendinitis, when compared with the other two operators. The less experienced operator suggested three false negative and two false positive diagnoses. The results indicated the experience of the examiner plays a key role in the effectiveness of obtaining an accurate diagnosis.[43] The examiner should go through the proper training to achieve optimal results.[13,43]

How Diagnostic Ultrasound Works

Diagnostic ultrasound uses electrical signals that are converted into ultrasonic energy by a piezoelectric crystal housed in the transducer.[17] Sound waves produced by the piezoelectric crystal are projected into the soft tissue and reflected back to create the image.[17,44] The amount of energy reflected back is dependent on the amount of tissue impedance or acoustic interface, which is a change in stiffness or density of the tissue.[17,44] Energy that is reflected back from the tissues is picked up by the transducer and produces an echo, allowing the clinician to determine abnormalities between the soft tissue structures.[17,41] A gel medium must be used with the transducer to allow the passage of the sound waves to the soft tissues. High frequency linear array transducers are the most common transducers used for diagnostic ultrasound imaging of tendons.[17,41]

The amount of energy reflected back to the transducer determines the brightness of the image.[17,44,45] If the image appears brighter or whiter on the screen, it means there was a large amount of sound energy reflected back and is referred to as hyperechoic.[17,44,46] The image will be termed hypoechoic if the returning echoes from the structure are weak or low. When there are no returning echoes, the appearance on the screen will be black or termed anechoic.[17] If the images appearing on the screen are of equal echogenicity, it is termed isoechoic.[17]

While imaging, the transducer should be placed in both the longitudinal axis (LAX) and the short axis (SAX) to obtain a larger field of view.[41] The LAX view is advantageous for the overall appearance of the structure and the SAX is beneficial for viewing anatomical structures such as nerves and vessels.[40,41] It is also beneficial to view tendons and muscles to help identify full or partial-thickness tears.[40,41] If the probe is turned 90°, the SAX view will turn into a LAX view and vice versa.[40] It is important for the clinician to be particular about the position of the transducer. The clinician should hold the transducer with the dominant hand, between the thumb and forefinger.[17] The transducer should be stabilized by either the small finger or heel of the imaging hand to maintain proper contact with the skin and placed perpendicular to the collagen fibers.[17] If the transducer is not perpendicular to the tissue, even as little as 2°, the possibility of a false positive diagnosis is increased causing an artifact to be seen.[12]

Artifacts

While using diagnostic ultrasound it is important to recognize the different artifacts that can be seen. Artifacts are abnormalities that appear with diagnostic imaging that can be indicative of pathology and can help identify specifics of it. The most common artifact is called anisotropy and occurs when the transducer is not perpendicular to the structure, as mentioned above (Figure C1). This causes the tissue to appear darker than usual as the normal sonographic appearance is lost.[12,17] Although anisotropy is an artifact, it can be beneficial to help to locate tendons and ligaments.[12,17,41] The tendon will become more hypoechoic when the angulation of the transducer is moved, and it helps to distinguish the difference between hyperechoic adipose tissue and the tendon or ligament itself.[17] If the clinician is using anisotropy to locate the structure it should be eliminated before examining or diagnosing the structure.[17] A second common artifact is called shadowing and it occurs when the ultrasound beam is refracted, absorbed, or reflected. The shadowing causes an image that has an anechoic area extending deep from the involved interface (Figure C2). Structures that can cause shadowing are bone or calcifications, some foreign bodies, and gas.[17]

A specific type of shadowing, refractile shadowing, may occur at the edge of some structures such as a torn Achilles tendon or patellar tendon, or a foreign body (Figure C3). A third common artifact is called posterior acoustic enhancement and occurs during imaging of fluid and soft tissue tumors (Figure C4). The deeper soft tissues will appear hyperechoic when compared with the adjacent soft tissues. A fourth common artifact is posterior reverberation and it occurs with a foreign body such as a needle or a metal object and appears as a series of linear reflective echoes (Figure C5).[17] If there are many of these reflective echoes, the term “ring-down artifact” is used. Lastly, the artifact termed “comet-tail” will appear when there are gas bubbles within the tissue and will look like a short section of hyperechoic echoes (Figure C6).[17] Artifacts are important to recognize as they can help identify tendons and ligaments, or give the examiner more awareness of the type and location of the pathology.[17]

Tissue Appearance Normal and Injured

The sonographic appearance of the tissue will be different when looking at healthy tissue compared with unhealthy tissue.[17] The echotexture of structures is the pattern that is seen in both the SAX and LAX views.[17] The sonographic appearance will vary depending on the axis view, as well as anisotropy.[17] Structures that give a hyperechoic appearance include bones, tendons, and ligaments, however some may appear brighter than others.[17,44,46]

Bone

The most hyperechoic of these structures is bone. Bone has a large rate of acoustic interface, as the sound beam is unable to penetrate through it.[46] This causes high reflectivity, which renders the image beyond the bone nearly black, and the cortex or top layer of bone is bright white.[17,46] Therefore, the overall appearance of bone is hyperechoic and has a distinctive, linear, and smooth border.[46] Bone injury on diagnostic ultrasound will appear as a discontinuity of the bone, with possible deformity.[17] Stress fractures or periostitis may appear as an irregularity in the smooth surface of the bone.[46] There may also be a hyperechoic callus formation present or a hyperechoic area adjacent to the bone.[17] Although diagnostic ultrasound can show fractures and deformities, further evaluation is warranted due to the limitations of imaging bone.[17,44]

Tendons and Ligaments

Similar to bone, tendons and ligaments will appear hyperechoic however, they will not be as distinct as bone. The structure of tendons as seen with diagnostic ultrasound in the longitudinal plane is parallel with fibrillar patterns. These fibrillar bands are hyperechoic, interwoven, and have anechoic lines in between from the ground substance between the fascicles (Figure D1).[9,12,45] In the SAX view, the tendons appear as closely joined dots in a round or oval structure and tendons and ligaments have a "broom end" appearance, which is created from the bundles of collagen fibers in the tissue.[46,12,45] The LAX view of tendons and ligaments has a fibrillar pattern, which is from the fibers that make up the structure (Figure D1).[17] In the early stages of tendinopathy, the sonography results will show a thickened tendon and changes in the normal echotexture and contour.[12,45] There may be residual scar formation within the tendon that appears hyperechoic (Figure D4).[17] If tendinosis is present, it will appear as ill-defined with hypoechoic swelling that may progress to partial and full thickness tears.[17] The degeneration causes the tendon to appear less defined and it may look hypoechoic similar to the surrounding muscle (Figure D2).[17] If the tendon has calcific deposits throughout, these deposits will appear hyperechoic with posterior shadowing and small calcifications appearing linearly along the tendon fibers (Figure D3).[17]

Although tendons and ligaments have similar appearances, ligaments typically appear less hyperechoic than tendons. Ligaments will appear hyperechoic with the echotexture as compact fibers.[17] If the ligament sustains a partial tear or sprain, it will appear as hypoechoic swelling.[17] A full thickness tear will appear with an anaechoic portion in the ligament that occurs from fiber disruption. There will be hypoechoic, and isoechoic fluid and hemorrhage that originates from the injury. [17] It may be difficult to differentiate between partial and full thickness tears due to the hemorrhage that occurs after injury.[17]

Muscle

The appearance of muscle tissue with diagnostic ultrasound differs from tendons and ligaments as it is more hypoechoic.[46] There is a pattern of muscle fascicles that are both hypoechoic and hyperechoic.[46] In the LAX view, the muscle fibers will give a feather or pennate appearance, and they appear more hyperechoic with closely jointed dots in the SAX view.[46] When there is a muscle injury, the muscle will produce subtle regions of hypoechogenicity depending on the grade of the injury.[46]. The image will look hyperechoic with a muscle contusion and hemorrhage and fiber disruption with a higher grade of muscle injury.[17] Faultus et al.[52] used diagnostic ultrasound to document the effectiveness of soft tissue mobilization on a quadriceps muscle tear. The defect was confirmed with a hyperechoic zone that was presumed to be fibrotic tissue that had filled the area. A hypoechoic region of surrounding tissue was observed which may have been due to fluid or hemorrhage from the injury.[52] This appearance of this injury is consistent with the literature that describes muscle injuries. Next, myositis ossificans, which is calcification within the muscle, appears as hyperechoic with posterior shadowing within the muscle.[17] Injury to the muscle or nerve supply may cause atrophy in the muscle that can be identified with diagnostic ultrasound.[17] To identify partial or full thickness tears of muscles, the patient should complete a dynamic voluntary muscle contraction, which allows the clinician to identify the injury better.[17]

Specific Injuries

While there are many different injuries that can occur throughout the body, this section will focus on tendinopathy of patellar and Achilles tendon research. It is important to note that every injury will be slightly different, however there are common signs that should be recognized when assessing the tissue for injury, which will be discussed below.

The patellar tendon is best evaluated on a stretch with the knee slightly flexed. This is to reduce the occurrence of anisotropy, and allows the patient to relax fully.[17] An uninjured patellar tendon will appear hyperechoic with a fibrillar pattern. If there is injury to the patellar tendon, hypoechoic diffuse thickening at either the proximal or distal end may occur.[9,47] There will be hypoechoic swelling with no disruption to the tendon fibers, however partial thickness tears will appear as hypoechoic or anechoic clefts.[17] Paratenon edema, which is swelling in the space between the tendon and its sheath, is rarely seen in patellar tendon injuries however, small amounts of deep infrapatellar bursal fluid may be seen.[47]

To determine the appearance of patellar tendinopathy with diagnostic ultrasound, semi-professional and professional athletes received a diagnostic ultrasound scan during a prospective study.[48] Patients presented with symptoms of patellar tendinopathy, and knees were scanned with a 7.5 and 10MHz power Doppler US to obtain an overall and structural view. They were then classified into grades ranging from 1-4 based on sonographic findings, the type of patellar tendon injury, and the effective therapy.[48] Grade 1 injuries were classified as an injured area <20% of the whole tendon section, grade 2 injuries were between 20% and 50% of the whole tendon section, grade 3 injuries >50% of the whole tendon section, and grade 4 injuries were submitted for surgery as they represented near total or total tears.[48] Out of 296 patellar tendon injuries, 80% were in the proximal and central areas of the tendon. These injuries appeared with hypoechoic or anechoic areas, tendon thickening, widespread and/or insertional fibrosis and calcifications.[48] The findings from this study are consistent with the textbook description.[17]

Similar to the patellar tendon, the Achilles tendon is best evaluated on a stretch by having the patient lay prone with both feet hanging off the table. This allows the clinician to passively dorsiflex and plantarflex the ankle as needed during the evaluation.[17,47] The Achilles tendon is displayed the same as the patellar tendon described above, however the fibers curve at the calcaneal insertion. The tendon is highly fibrillar and echogenic, and may appear thickened with focal or diffuse areas of hypoechogenicity if tendinosis is present.[9,45,47] Achilles tendinosis will appear as hypoechoic, fusiform swelling that may be localized or diffuse throughout the tendon. Tendon enlargement greater than one centimeter, or hypoechoic and anechoic clefts is indicative of a partial-thickness tear.[17] If the injury is occurring at the distal end of the attachment of the Achilles tendon, there may be retro-calcaneal bursa fluid present, and prominence of the posterior-superior corner of the calcaneus.[17] To determine the appearance of the Achilles tendon in patients with symptomatic Achilles tendon injury, Kainberger et al[7] researched the appearance in 73 symptomatic individuals. To evaluate the participants, they were placed prone with their ankle hanging off the end of the table. A linear transducer was used with a frequency of 5-10 MHz and scans were completed in both the symptomatic and asymptomatic tendon. Abnormalities findings were consistent with those described above and included focal or diffuse tendon thickening from 24 participants, hypoechoic lesions in 22 participants, calcifications in three participants, and inhomogeneity of the tendon structure indicating tendinitis was observed in 13 participants.[7] The appearance of the tendon with diagnostic ultrasound will vary depending on the type and degree of injury.

Conclusions and Future Research

Diagnostic ultrasound is a beneficial tool for identifying different musculoskeletal conditions, including partial and full thickness tendon tears, tendinosis and calcifications.[7,9,12,17,41] The clinician can compare bilaterally to achieve the most accurate diagnosis however, it is limited to more superficial structures. The appearances of the non-injured and injured tissues will vary depending on the axis the transducer, as well as the different artifacts, such as anisotropy, that can occur.[17] As there are many different tissue appearances, it is important for the clinician to have the proper training in diagnostic ultrasound to accurately recognize different conditions. Further research should be performed using diagnostic ultrasound as an objective measurement to determine the effectiveness of different treatments.

CHAPTER 3. METHODS

The purpose of this study was to determine the effectiveness of the Graston Technique® for changes in tendinosis, adhesions/scar tissue, and calcifications in chronic musculoskeletal tendinopathies. The following research questions guided this study: 1) Did the Graston Technique® decrease tendinosis? 2) Did the Graston Technique® reduce scar tissue and/or adhesions? 3) Did the Graston Technique® reduce tissue calcifications? 4) Did the Graston Technique® affect the patient's pain level? 5) Did the Graston Technique® affect the functionality of the patient? This chapter focused on the nature of the study/experimental design, the population of the study, instruments, procedures, and data analysis.

Nature of the Study/Experimental Design

A pre-test/post-test design was used in the experiment examining the differences in tendon measurements before and after Graston® treatments. Participants completed a 10 minute cycling warm-up, received the Graston Technique® strokes, and light stretching and strengthening. The independent variable was the Graston Technique® treatment. The dependent variables were the change in tendinosis, calcifications, and scar tissue adhesions. The change in tendinosis was determined by the amount of change of the tendon that appeared hypoechoic and swollen. The changes in calcifications and scar tissue adhesions were characterized by a reduction in hyperechoic nodules.

Population of the Study

Fifteen participants were recruited for the study. Participants were asked to join the study if they were a college athlete at a NCAA Division I, II, III, or NAIA institution. Participants were 18-26 years old. Both male and female athletes were recruited for this study. Participants were required to have a diagnosis by their Athletic Trainer or team Physician of a chronic condition (over 72 hours after injury) of patellar or Achilles tendinopathy. Participants were recruited through word of mouth from the Athletic Trainers at schools of various divisions.

Participants were excluded if they had an acute injury or an infection at or around the injury site as they are contraindications of the Graston Technique®. Participants were also excluded if they had uncontrolled hypertension, neurologic deficits in any body part such as decreased sensation or reflexes, a disc herniation in the spine, or any other Graston Technique® contraindications. Participants signed an informed consent before being included in this study and were compensated for their time and willingness to participate. This study was approved by the University's Institutional Review Board prior to data collection.

Instruments

The Graston Technique® consists of six stainless steel instruments that are used to perform treatment. They include GT1, GT2, GT3, GT4, GT5, and GT6 (TherapyCare Resources Inc., Indianapolis, IN).[1] Each instrument has a different purpose that corresponds to the tissue size and type of treatment that is being performed.[1] The emollient being used for the study was the Graston Technique Emollient with Vitamin E, 4oz jar (TherapyCare Resources Inc., Indianapolis, IN). For this study, GT2, GT3, and GT4 instruments were used. One of the smaller instruments, GT2, has a double beveled edge with both convex and concave surfaces. It is a beneficial instrument to use in areas that require deeper work in specific, localized areas. The GT3 is a small, straight instrument that has rounded edges. It can be used for treatment to small areas, and is advantageous for localizing restrictions. Lastly, GT4 is most commonly used, as its main purpose is to scan a region to determine the location of restrictions. It has both a straight and rounded edge however, the rounded edge is typically used for assessment.[1]

Diagnostic ultrasound was the method used for the outcome measures of this study. The Terason t3200™ Diagnostic Ultrasound (MedCorp, LLC., Tampa, FL) with the 15L4 Linear transducer (4.0-15.0 MHz) and 16H7 Linear transducer (MedCorp LLC, Tampa FL) was used to determine the amount of tissue changes. Aquasonic® 100 ultrasound gel (Parker Laboratories, Inc., Fairfield, NJ) was applied to the transducer to ensure proper conductivity.

Procedures

Participants were asked to maintain their current lifestyle prior to entering this study, however they were required to disclose previous treatments for their condition. If the participant was planning to continue receiving an Astym or IASTM treatment from their athletic trainer for the duration of the study, they were excluded. The experimental purpose, procedures, and risks were explained to the participants on the first day of the study. After the explanation and all participant questions were answered to his/her satisfaction, they were required to fill out the Report of Past and Current Treatment form (Appendix E) that served to explain any previous treatments.

Each participant received four treatments over the span of two weeks, with three days between treatments, as recommended by the Graston Technique®. Before beginning the experiment, the participant's tissue was viewed with diagnostic ultrasound, the pathology was confirmed and the baseline measurements were recorded. These included the trace of tendinosis and tendon thickness in both axes. Measurements were then taken before and after every treatment session with the final post treatment measurement being considered the final measurement. Once the diagnostic ultrasound measurements were recorded, the participant rated their pain level with the Numeric Pain Rating Scale (NPRS) (Appendix E), and completed the Lower Extremity Functional Scale (LEFS) (Appendix E). These were completed before every treatment session. The participant completed a 10 minute active cycling warm-up. If the participant was unable to complete a cycling warm-up due to pain or functional limitations, they received a 10 minute moist hot pack (MHP) application. After the warm-up, participants received the designated treatment that was intended for his/her pathology. It should be noted the examiner had one year of experience with diagnostic ultrasound and the Graston Technique®.

Achilles Tendon Procedures

Participants were asked to wear shorts to treatment sessions for optimal access to the Achilles tendon and gastrocnemius. The Achilles tendon was examined with the patient lying prone on the table with the ankle passively dorsiflexed. The transducer was moved from the distal calf to the calcaneus in both the LAX and SAX. When the transducer was in LAX, it was moved medially and laterally to assess the entire tendon. Once the pathology had been identified, the image was frozen and measurements were recorded. The participant was marked with a black marker to identify the location of the pathology for future sessions. The calipers function of the diagnostic ultrasound was used to measure the thickness and width of the tendinosis, or the thickness of the tendon.

The Graston Technique® treatment for the Achilles tendon began with the participant laying prone with their ankle passively placed into 90° of dorsiflexion and held for the duration of the treatment. An inch of Graston Technique® emollient was applied to the skin, and manually spread out from the distal Achilles tendon to the popliteal fossa. The Graston Manual[1] states that GT1, GT4, or GT5 may be used for sweeping/scanning. The GT4 instrument was used to scan the gastrocnemius/soleus complex (Figure F1) as it is the most versatile and commonly used instrument in the set. It is often the first instrument used for scanning a body region.[1] Sweeping/scanning began proximal to the Achilles tendon up to the popliteal fossa. Strokes moved distal to proximal and medial to lateral. The instrument was then reversed, and strokes were moved from proximal to distal and lateral to medial. The strokes were completed for a total of one minute. The participant received a maximum of 10 sweeping strokes over the length of the Achilles tendon from the calcaneus to the musculotendinous junction with the double-beveled concave surface of GT2 (Figure F2). Next, GT3 was used with strumming motions away from the medial and lateral borders of the distal Achilles tendon (Figure F3). Treatment was completed to the insertion of the tendon on the calcaneus. Treatment on both the medial and lateral borders lasted up to 10 strums per width of the instrument, for the length of the Achilles tendon.

After the Graston® strokes had been completed on the Achilles tendon, the participant received a passive stretch of the gastrocnemius and hamstring muscles and was instructed to complete exercises. To perform the gastrocnemius and hamstring stretches, the participant laid supine on the table and the researcher passively flexed the hip while maintaining knee extension. The ankle was then passively placed into dorsiflexion. Once the participant felt enough of a stretch, it was held for 30 seconds and was repeated three times by recommendation of the Graston Technique® manual.[1] Following the stretches, exercises were completed and included two sets of 20 eccentric heel lowering exercises. This exercise was chosen based off the studies by Miners et al[5] and John Papa[35] which is constructed off of the Alfredson protocol.[49] Both of these studies included eccentric heel lowering exercises, and obtained positive results. These results included an increase in overall function and decrease or resolution of tendinitis. Eccentric heel lowering exercises were performed by the participant standing with a hand placed on a table for balance. They rose up onto the toes with the unaffected leg and lowered down slowly with the affected leg. Once they reached neutral, the same process was repeated.

Patellar Tendon Procedures

Participants were asked to wear shorts to treatment sessions for optimal access to the patellar tendon and quadriceps group. For evaluation of the patellar tendon, the participant laid supine on the table with a bolster under the posterior knee to flex it 20-30°. To view the patellar tendon in LAX, the transducer was placed with the small notch up, over the patella. While maintaining good pressure, the transducer was moved inferiorly towards the tibial tuberosity. It was important to scan the patellar tendon laterally and medially to assess the entire width of the tendon. The same process was completed to view the tendon in the SAX. Once the pathology had been identified, the image was frozen and measurements were recorded. The participants skin was marked with a black marker to identify the location of the pathology. The calipers function of the diagnostic ultrasound measured the thickness and width of the tendinosis, or the thickness of the tendon.

Participants with patellar tendinopathy were seated with their legs hanging off the table. An inch of Graston Technique® emollient was applied to the skin, and manually spread out from the tibial tuberosity to the insertion of the rectus femoris. Sweeping and fanning was used over the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis with GT4 (Figure G1). The GT4 instrument was chosen because it is used for both scanning and treatment.[1] To complete this, GT4 was moved from distal to proximal and medial to lateral over each muscle area. The instrument was then reversed, and the strokes moved from proximal to distal and lateral to medial. These sweeping strokes lasted up to one minute. The patella was worked around with a series of framing maneuvers with GT3 (Figure G2). Framing was completed around the patella with a clockwise and counter-clockwise strumming stroke. Framing was then completed around the tibial tuberosity in both a clockwise and counter-clockwise manner with a strumming stroke (Figure G3). Following the framing of the tibial tuberosity, the participant received brushing strokes for up to 20 seconds over the length of the patellar tendon with GT3 to desensitize the tissue and prepare for deeper treatment. Lastly, deeper treatment with GT3 instrument was used for 10 strokes per width of the instrument over the length of the patellar tendon with strumming strokes moving lateral to medial, and medial to lateral (Figure G4).

After the Graston® strokes were completed, participants received a passive stretch of the quadriceps and hamstrings and were instructed to complete exercises. For the quadriceps stretch, the participant laid prone on the table and the researcher passively flexed the knee until a stretch was felt. To stretch the hamstring, the participant laid supine on the table and the researcher flexed the hip with the knee extended until a stretch was felt. The stretches were held for 30 seconds and repeated three times, with 30 seconds of rest in between sets.

Next, exercises were performed and included two sets of 20 mini-squats, and two sets of 20 clamshells with a theraband. These two exercises were chosen since they are similar to those in the case study by Douglass Black[6] that were used to target the quadriceps and gluteus medius. Low weight with high repetitions was used as recommended by the Graston Technique® manual.[1]. The mini-squats directly targeted the quadriceps group, and the clamshells targeted the gluteus medius for knee stabilization.[16] To perform mini-squats, the participant held on to the edge of a table with the feet shoulder width apart and squatted down about 30° before coming back up into the starting position. Clamshells included the use of a theraband positioned around both knees, just above the patella. The participant was side-lying with the affected knee facing up and the knees bent at 90°. Keeping the feet together, the participant abducted the top leg as far as possible and brought it back to neutral slowly and controlled.

After completion of the Graston Technique® strokes, exercises, and stretches; the subjects had their post-treatment measurements taken by diagnostic ultrasound as previously described. The post-treatment measurement procedures were the same as the pre-treatment measurement procedures. The participants were given a Home Care Instruction sheet when they left for management of possible side-effects, including tissue sensitivity, pain, or bruising.[1] After the first two sessions, subjects were paid $10 and after the last two sessions they were given the remaining $10 for a total of $20 compensation. This same procedure was repeated for four sessions.

To minimize threats to internal validity, a faculty member with seven years of experience with diagnostic ultrasound supervised the researcher operating diagnostic ultrasound. Supervision occurred until the researcher was able to accurately confirm diagnoses. Performance of the Graston Technique® was supervised by a faculty member who is an M-1 certified instructor. Supervision occurred until the faculty member was comfortable with the researcher's performance with the Graston Technique®.

Data Analysis Procedures

The mean pre and post treatment measurements for the Graston Technique® were analyzed with paired samples t-tests for values of tendinosis in the LAX and SAX views. Paired samples t-tests were also used to analyze the differences in the NPRS and LEFS scores between day one and day four. A repeated measures ANOVA with a Greenhouse-Geiser correction was used to determine the difference between pre and post measurements of the trace of tendinosis and tendon thickness in the LAX and SAX views, comparing all 4 treatments. It was also used to determine the number of treatments needed to see a change or complete resolution. All statistical analysis was calculated by IBM SPSS Statistics version 21 (2013, IBM). The alpha was set a priori at $P < 0.05$. Scar tissue/adhesions and calcifications within the tendons were planned to be recorded. However, no statistical analysis was performed on scar tissue/adhesions or calcifications as none were observed with diagnostic ultrasound.

CHAPTER 4. MANUSCRIPT

Abstract

Context: The Graston Technique® is a beneficial treatment on tendinopathies as recommended by the Graston Technique® manual.[1] Little research exists on the effects of the Graston Technique® on chronic cases of tendinopathy measured with diagnostic ultrasound. **Objective**: Determine the amount of changes in tendinosis after the Graston Technique® treatments on Achilles and patellar tendons, as well as the changes in patient oriented outcomes. **Design**: Pre-test/post-test design. The independent variable was the Graston Technique® treatment. The dependent variable was the change in tendinosis before and after treatments determined by the amount of hypoechoic areas. **Setting**: Research laboratory. **Patients/Other Participants**: 15 collegiate athletes from NCAA division I, III, and NAIA institutions participated. **Intervention:** Four days of the Graston Technique® as an overall protocol was used, including an active warm up, stretches, and strengthening exercises. **Main Outcome Measures**: Changes within the tendon measured by diagnostic ultrasound and Lower Extremity Functional Scales (LEFS) were used. **Results**: A significant decrease of tendinosis was observed. No significant changes occurred in tendon thickness and the NPRS. The LEFS scores statistically improved, but showed no clinical difference in the pre and post scores. **Conclusions:** The Graston Technique® protocol is beneficial in the treatment of tendinosis. A decrease occurred in the patellar tendons after four treatments of the Graston Technique®. Clinicians should consider using the Graston Technique® when treating patellar tendinosis. **Key Words**: instrument assisted soft tissue mobilization, diagnostic ultrasound, tendinosis, Graston Technique®.

Introduction

Tendinopathy is the overarching term used to describe pathology within the tendon. This can include tendinitis or tendinosis, two terms which are commonly misused.[2,3] Tendinitis arises when inflammation within the tendon occurs that results from tissue overload, creating microtears within the tendon.[2] The term tendinitis can often be misused when referring to a chronic condition, as the individual is actually suffering from tendinosis; a degeneration of the tendons collagen.[2,3] Tendinosis is an overuse condition that occurs when the tendon is not given enough time to heal. Although similar in nature, tendinosis is more prevalent than tendinitis, and it is important to recognize the difference when creating a treatment plan.[2,3] One goal in the treatment of tendinitis is to decrease the inflammation within the tendon however, this inflammation is not present in tendinosis.[2,3] This leads to how the Graston Technique® may be a beneficial modality in structures that are suffering from tendinosis. The Graston Technique® helps to reinitiate the healing response that has become stagnant in tendinosis, as well as reduce scar tissue, adhesions, and fascial restrictions that occur from musculoskeletal conditions.[1]

The Graston Technique® is a form of Instrument Assisted Soft Tissue Mobilization (IASTM) that is increasing in popularity in athletic training and physical therapy settings.[1] It is performed as an overall protocol that includes a warm-up, the Graston Technique® strokes, stretching, strengthening, and cryotherapy. The warm-up can be completed as an active warm-up in which the patient completes a form of cardiovascular exercise, or it can be localized. A localized warm-up includes using a moist hot pack, paraffin, or therapeutic ultrasound to heat the tissues.[1] Although the Graston Technique® can be performed in conjunction with other modalities, the effects of the Graston Technique® alone has not been researched. The literature shows beneficial effects of the Graston Technique® on treating Achilles tendinitis, epicondylitis, and knee osteoarthritis.[6-8] In addition, the Graston Technique® has been beneficial for increasing range of motion (ROM) in collegiate athletes.[4] The majority of research with the Graston Technique® involves case studies and few studies have measured the effects with diagnostic ultrasound.

Diagnostic ultrasound (ultrasonography) is a fast-growing tool for identifying a multitude of musculoskeletal conditions, including partial and full thickness tendon tears, tendinosis and calcifications.[9-14] It provides a high-resolution image and allows dynamic assessment however, the appearance of the tissues will vary depending on the type, location, and tissue health.[14,15] Normal tendon appears bright or hyperechoic, with a fibrillar echotexture. Tendinosis specifically, appears more hypoechoic (darker) than healthy tendon. Diagnostic ultrasound is a beneficial tool to view different pathologies, especially tendinosis.[3] After an extensive literature search, no studies exist that use diagnostic ultrasound to measure the effects of the Graston Technique® on tendinosis.

Methods

Design

A pre-test/post-test design was used to examine the differences in tendinosis before and after Graston treatments. The independent variable was the Graston Technique® treatment. The dependent variable was the change in tendinosis determined by the amount of hypoechoic and swollen tendon.

Participants

Fifteen local NCAA Division I, III, and NAIA athletes (2 males, 13 females, age 20.06±1.44 years) were recruited for the study. All participants met the inclusion and exclusion criteria and zero dropped out. Participants were required to have a diagnosis of a chronic condition of patellar or Achilles tendinopathy by their Athletic Trainer or team Physician. One participant did not have a traceable area of tendinosis however, the tendon was slightly thickened with small hypoechoic areas. This participant was not included in the statistical analysis of the tendinosis tracing, but was included in the statistical analysis of the tendon thickness and patient oriented outcomes. Participants were excluded if they were continuing to receive Astym or IASTM for the duration of the study, or if they had an acute injury or an infection at or around the injury site as these are contraindications of the Graston Technique®. Participants were also excluded if they had uncontrolled hypertension, neurologic deficits in any body part such as decreased sensation or reflexes, a disc herniation in the spine, or any other Graston Technique® contraindications. This study was granted approval by the University's Institutional Review Board prior to data collection. All participants signed an informed consent before being included in this study and were compensated for their participation.

Instruments

The Graston Technique® consists of six stainless steel instruments that are used to perform treatment. They include GT1, GT2, GT3, GT4, GT5, and GT6 (TherapyCare Resources Inc., Indianapolis, IN).[1] Each instrument has a different purpose that corresponds to the tissue size and type of treatment being performed.[1] Graston Technique® Emollient with Vitamin E, 4oz jar (TherapyCare Resources Inc., Indianapolis, IN) was used as the emollient forthe Graston instruments to be applied smoothly to the skin. One of the smaller instruments, GT2, has a double-beveled edge with both convex and concave surfaces to use in areas that require deeper work in specific, localized areas. The GT3 is a small, straight instrument that has rounded edges to treat small areas, and localize restrictions. Lastly, GT4 is most commonly used, as its main purpose is to scan a region to determine the location of restrictions. It has both a straight and rounded edge, however, the rounded edge is typically used for assessment.[1] For this study, GT2, GT3, and GT4 were utilized.

Diagnostic ultrasound was used to scan for tendinosis and measure the amount of the tendon affected by tendinosis. The Terason t3200™ Diagnostic Ultrasound (MedCorp, LLC., Tampa, FL) with the 15L4 Linear transducer (4.0-15.0 MHz) and 16H7 Linear transducer (MedCorp LLC, Tampa FL) was used to determine the amount of tissue changes. Aquasonic® 100 ultrasound gel (Parker Laboratories, Inc., Fairfield, NJ) was applied to the transducer to ensure proper conductivity.

Procedures

Participants were asked to maintain their current lifestyle prior to entering this study, however they were required to disclose previous treatments for their condition. If the participant was planning to continue an Astym or IASTM treatment for the duration of the study, they were excluded. The experimental purpose, procedures, and risks were explained to the participants on the first day of the study. After the explanation and all participant questions were answered to his/her satisfaction, participants signed a consent form. They were required to fill out the Report of Past and Current Treatment form (Appendix E) that served to explain any previous treatments for their tendinopathy.

Each participant received four treatments over the span of two weeks, with three days between treatments, as recommended by the Graston Technique® manual.[1] Before beginning the experiment, the participant’s tissue was examined with diagnostic ultrasound, the tendinosis was confirmed and the baseline measurements were recorded. These included the trace of tendinosis and tendon thickness in both axes. The measurements were taken before and after every treatment session with the final post treatment measurement recorded as the final measurement.

Once the diagnostic ultrasound measurements were recorded, the participant rated the pain level with the Numeric Pain Rating Scale (NPRS) and completed the Lower Extremity Functional Scale (LEFS). These were completed before every treatment session. Next, the participant completed a 10 minute active cycling warm-up. After the warm-up, participants received the designated treatment that was intended for his/her pathology. It should be noted the examiner had one year of experience with diagnostic ultrasound and seven months of experience with the Graston Technique®.

Achilles Tendon Procedures

Participants wore shorts to treatment sessions for optimal access to the Achilles tendon and gastrocnemius muscle. The Achilles tendon was examined with the patient lying prone on the table and the ankle passively dorsiflexed to 90°. The transducer was moved from the distal calf to the calcaneus in both the long axis (LAX) and short axis (SAX). When the transducer was in LAX, it was moved medially and laterally to assess the entire tendon. Once the pathology was identified, its location was marked on the participants skin with a black marker. The image was frozen and measurements were recorded. The caliper function of the diagnostic ultrasound was used to trace the area of the tendinosis.

The Graston Technique® treatment for the Achilles tendon began with the participant laying prone with their ankle hanging off the end of the table. Their ankle was passively placed into 90° of dorsiflexion and held for the duration of the treatment. An inch of Graston Technique® emollient was applied to the skin, and manually spread out from the distal Achilles tendon to the popliteal fossa. The manual[1] states the GT1, GT4, or GT5 may be used for sweeping/scanning. The GT4 instrument was used to scan the gastrocnemius/soleus complex (Figure F1) because it is the most versatile and commonly used instrument in the set. It is usually the first instrument used for scanning a body region.[1] Sweeping/scanning began proximal to the Achilles tendon up to the popliteal fossa. Strokes moved distal to proximal and medial to lateral. The instrument was then reversed, and strokes were moved from proximal to distal and lateral to medial for a total of one minute. The participant received a maximum of 10 sweeping strokes over the length of the Achilles tendon from the calcaneus to the musculotendinous junction with the double-beveled concave surface of GT2 (Figure F2). Lastly, GT3 was used with strumming motions away from the medial and lateral borders of the distal Achilles tendon (Figure F3). Treatment was completed to the insertion of the tendon on the calcaneus. Treatment on both the medial and lateral borders lasted up to 10 strums per width of the instrument for the length of the Achilles tendon.

After the Graston strokes had been completed, the participant received a passive stretch of the gastrocnemius and hamstring muscles and completed exercises. To perform the gastrocnemius and hamstring stretches, the participant laid supine on the table and the researcher passively flexed their hip while maintaining knee extension. The ankle was then passively placed into dorsiflexion. Once the participant felt enough of a stretch, it was held for 30 seconds and was repeated three times by recommendation of the Graston Technique® manual.[1]

Following the stretches, exercises included two sets of 20 eccentric heel lowering exercises. This exercise was chosen based off the studies by Miners et al[7] and John Papa.[17] Both of these studies included eccentric heel lowering exercises, and obtained positive results. These results included an increase in overall function and decrease or resolution of tendinitis symptoms.[7,17] Eccentric heel lowering exercises were performed by participants standing with a hand placed on a table for balance. They rose up onto the toes with the unaffected leg and lowered down slowly with the affected leg. Once they reached neutral, the same process was repeated.

Patellar Tendon Procedures

Participants with patellar tendinosis wore shorts to their treatment sessions for optimal access to the patellar tendon and quadriceps muscles. For evaluation of the patellar tendon, the participant laid supine on the table with a bolster under the posterior knee to flex it 20-30°. To view the patellar tendon in LAX, the transducer was placed with the small notch up, over the patella. While maintaining good pressure, the transducer was moved inferiorly towards the tibial tuberosity. It was important to scan the patellar tendon laterally and medially to assess the entire width of the tendon. The same process was completed to view the tendon in the SAX. Once the pathology had been identified, its location was marked on the participants skin with a black marker. The image was frozen and measurements were recorded. The caliper function of the diagnostic ultrasound was used to trace the area of the tendinosis.

Participants with patellar tendinopathy were seated with their legs hanging off the table. An inch of Graston Technique® emollient was applied to the skin, and manually spread out from the tibial tuberosity to the insertion of the rectus femoris. Sweeping and fanning was used over the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis with GT4 (Figure G1). The GT4 was chosen because it is used for both scanning and treatment.[1] For this study, GT4 was moved from distal to proximal and medial to lateral over each muscle area. The instrument was then reversed, and the strokes moved from proximal to distal and lateral to medial for up to one minute. The patella was worked around with a series of framing maneuvers with GT3 (Figure G2). Framing was performed around the patella with a clockwise and counter-clockwise strumming stroke. Next, framing was performed around the tibial tuberosity in both a clockwise and counter-clockwise manner with strumming strokes (Figure G3). Following the framing of the tibial tuberosity, the participant received brushing strokes for up to 20 seconds over the length of the patellar tendon with GT3 to desensitize the tissue and prepare for deeper treatment. Lastly, deeper treatment with GT3 was used for 10 strokes per width of the instrument over the length of the patellar tendon with lateral to medial and then medial to lateral strumming strokes (Figure G4).

After the Graston strokes were completed, participants received a passive stretch of the quadriceps and hamstrings muscles and completed exercises. For the quadriceps stretch, the participant laid prone on the table and the researcher passively flexed the knee until a stretch was felt. To stretch the hamstring, the participant laid supine on the table and the researcher passively flexed the hip with the knee extended until a stretch was felt. The stretches were held for 30 seconds and repeated three times, with 30 seconds of rest in between sets.

Next, exercises were performed and included two sets of 20 mini-squats, and two sets of 20 clamshells with a theraband. These two exercises were chosen since they are similar to those in the case study by Douglass Black[7] that were used to target the quadriceps and gluteus medius. We used low weight with high repetitions as recommended by the Graston Technique® manual.[1] To perform mini-squats, the participant held on to the edge of a table with the feet shoulder width apart and squatted down about 30° before coming back up into the starting position. Clamshells included the use of a medium strength theraband positioned around both knees, just above the patella. The participant was side-lying with the affected knee facing up and the knees bent at 90°. Keeping the feet together, the participant abducted the top leg as far as possible and brought it back to the starting position slowly and controlled.

After completion of the Graston Technique® strokes, exercises, and stretches; the post-treatment measurements were taken by diagnostic ultrasound as previously described. The participants were given a Home Care Instruction sheet for management of possible side-effects, including tissue sensitivity, pain, or bruising. This same procedure was completed for all four sessions. After the first two sessions, subjects were paid $10 and after the last two sessions they were given the remaining $10 for a total of $20 compensation.

To minimize threats to internal validity, a faculty member with seven years of experience with diagnostic ultrasound supervised the researcher operating diagnostic ultrasound. Supervision occurred until the researcher was able to accurately confirm diagnoses. Performance of the Graston Technique® was supervised by a faculty member who is an M-1 certified instructor and has been performing Graston for approximately three years. Supervision occurred until the faculty member was comfortable with the researcher's performance with the Graston Technique®

Statistical Analysis

The mean pre and post treatment measurements for the Graston Technique® were analyzed with paired samples t-tests for values of tendinosis in the LAX and SAX views. Paired samples t-tests were also used to analyze the differences in the NPRS and LEFS scores between day one and day four. A repeated measures ANOVA with a Greenhouse-Geiser correction was used to determine the difference between pre and post measurements of the trace of tendinosis and tendon thickness in the LAX and SAX views, comparing all four treatments. It was also used to determine the number of treatments needed to see a change or complete resolution. All statistical analysis was calculated by IBM SPSS Statistics version 21 (2013, IBM). The alpha was set a priori at $P < 0.05$. We initially intended to record any scar tissue/adhesions and calcifications within the tendons. However, no statistical analysis was performed on scar tissue/adhesions or calcifications since none were observed with diagnostic ultrasound.

Results

With a total of 15 participants, 11/15 attended a NCAA division III institution, 1/15 attended a NCAA division I institution, and 3/15 attended an NAIA institution. The average length of the tendinopathy was 19.87±1.45 months. Two participants had Achilles tendinosis, 13 had patellar tendinosis, and 2/15 subjects were male. The trace of tendinosis in the short axis (SAX) showed a significant decrease from day one to day four ($0.26cm^2 \pm 0.17cm^2$ to $0.12cm^2 \pm 0.12cm^2$ $p<0.05$) (Table 1). The repeated measures ANOVA with a Bonferroni correction showed the trace of tendinosis in the SAX decreased significantly between time points [$F(2.810, 36.536)=10.792$, $p=0.001$] η^2 0.454. The trace of tendinosis in the long axis (LAX) showed a significant decrease from day one to day four ($0.28cm^2 \pm 0.19cm^2$ to $0.16cm^2 \pm 0.13cm^2$). The repeated measures ANOVA with a Bonferroni correction showed the trace of tendinosis in the LAX decreased significantly between time points [$F(3.338, 44.046)=4.277$, $p=0.001$] η^2 0.248. The Lower Extremity Functional Scale (LEFS) showed a significant decrease from day one to day four ($t(14)= -2.650$, $p=0.19$). The Numeric Pain Rating Scale showed no significant differences between day one and day four ($p=0.60$) (Table 2).

Table 1. Descriptive statistics of the mean changes in the pre and post measurements of the trace of tendinosis in both LAX and SAX.

Table 1		Trace of Tendinosis LAX(n=14)		Trace of Tendinosis SAX(n=14)	
Day	Session	Mean	SD	Mean	SD
Day 1	Pre	0.276	0.193	0.259	0.174
	Post	0.299	0.183	0.254	0.184
Day 2	Pre	0.256	0.149	0.196	0.126
	Post	0.259	0.191	0.189*	0.157
Day 3	Pre	0.229	0.187	0.155	0.147
	Post	0.231	0.169	0.154	0.154
Day 4	Pre	0.200	0.143	0.124	0.126
	Post	0.163	0.130	0.119	0.124

* Indicates significant time point difference.

Table 2. Results of Paired Samples T-Test for changes in Numeric Pain Rating Scale (NPRS) and Lower Extremity Functional Scale (LEFS).

Table 2		(n=15)	
Scale	Day	Mean	SD
NPRS	Day 1	3.767	1.591
	Day 4	3.270	1.163
LEFS	Day 1	65.27	8.004
	Day 4	68.13	6.833

Discussion

The Graston Technique® is beneficial as a supplemental modality in the treatment of Achilles tendinitis, epicondylitis, and knee osteoarthritis.[5-7] The Graston Technique® manual[1] states that the treatment time, frequency, and intensity will vary with each patient however, it recommends treatment two times per week with three days between treatments. The patient should be treated over a period of 10-14 days.[1] Our study examined the effects of the Graston Technique® as a treatment alone over the course of four sessions, and found significant results with the decrease of trace measurements of tendinosis, as well as a statistically significant increase in the LEFS. While the NPRS scores were not significantly different between day one and day four, they were approaching clinical significance. Due to consistency of the study, we kept the rate, duration, and frequency of the Graston Technique® protocol the same between patients.

Tendinosis Measurements

Our results indicate that after four sessions of the Graston Technique® treatment as an overall protocol, a significant decrease in the amount of tendinosis existed in both the SAX and LAX views. As shown in table 1, the trace of tendinosis significantly decreased in the SAX view from 0.26cm±0.17cm to 0.12cm±0.12cm from session one of day one to the final session on day four. After the Bonferroni correction was applied, it was determined that the pre and post measurements of tendinosis from day four was significantly less than the pre measurement of day one. In addition, the pre and post measurements of tendinosis from day four were significantly less than the post measurement of day two. No significant differences existed when comparing day three pre and post measurements to days four and one.

Although we did not see a complete resolution in the tendinosis, the results from the SAX view indicate that after two sessions of the Graston Technique® protocol, the area of tendinosis starts to fill in with hyperechoic fibers. Similarly, Faltus et al[20] documented a tear of the rectus femoris, and found a hyperechoic defect with a hypoechoic zone around the defect. The hypoechoic zone was presumed to be edema and tissue damage. After soft tissue mobilization, the size of the defect remained unchanged however, the surrounding hypoechoic zone had decreased. Although this study was completed on a muscle tear, it shows that soft tissue mobilization was effective in repairing the damaged tissue around the defect.[20] The Faltus et al. results are consistent with ours, in which the damaged tissue starts to fill in with hyperechoic fibers after tissue mobilization treatment. This “filling in” could be due to the microtrauma that is occurring, that allows the reinitiating of the ultrastructural changes, and the chemical mediators such as histamine, bradykinin, and cytokines to migrate to the injury site.[21] This process, combined with stretching and strengthening encourages proper tissue realignment increase the tensile strength of the structure.[1]

The LAX view showed a significant decrease from 0.28cm±0.19cm to 0.16cm±0.13cm when comparing the pre measurements of day one to the post measurements of day four. After completing a Bonferroni correction the only significant difference when comparing each session occurred between the post measurement of day one and the post measurement of day four. One of the reasons the decrease in tendinosis was more significant in the SAX view than the LAX view may be due to the cross section that is seen with diagnostic ultrasound with a SAX view. Although diagnostic ultrasound is a very beneficial tool for viewing pathology, it only gives about a credit card thin slice of the tissue. The SAX view shows the overall tendon which allows the examiner to see a complete view of how widespread the tendinosis is throughout the tendon. The LAX view shows the depth and length of the pathology. Therefore, if the pathology is starting to resolve from the outside in, we may not see results on the LAX view until complete resolution.

Tendon Thickness

The thickness of the patellar tendon was measured in the SAX view however, no significant decreases were noted after any of the treatment sessions. Changes in tendon thickness may not have been seen due to various reasons. First, the microtrauma occurring to the tissues with IASTM may have caused excess swelling and inflammation that thickened the tendon or kept the thickness the same. Second, the treatment time and frequency may not have been long enough to see a substantial difference in the thickness of the tendon. Lastly, not all tendons may have been thickened due to the pathology. The normative data was not collected on the tendon thickness.

Patient Oriented Outcomes

Patient Oriented Outcomes were included to determine if the subject was able to feel or see a difference in pain or functionality. The Lower Extremity Functional Scale (LEFS) (Appendix E) was used to determine if the participant had an increase in their functional activities throughout the course of the study. The LEFS scores increased from 65.27± 8.00 to 68.13 ± 6.83 from day one to day four, respectively (Table 2). It should be noted that the LEFS is rated out of 80 points, and a higher score on the LEFS is positive. The minimal level of detectible changes for the LEFS instrument is nine points.[19] If a difference in scores is not nine points or higher, the change could be due to measurement error. Therefore, the functional outcome in our study was statistically significant, but not clinically different. The results of the LEFS are similar to a study on Achilles tendinitis that used the same functionality scale. However, the scores of this patients LEFS were clinically different as they improved from 48/80 to 80/80 after eight weeks, and 12 treatments.[17]

The differences between our study and the one described by Papa[17] is that they had statistically significant and clinically different results. As our study was only two weeks in length, the change in function may not occur that quickly. The subjects may need more time and treatments to see a true increase in function. Also, the beginning scores on the LEFS in our study were not very low to begin with (65/80 points), so it may be more difficult to see a substantial change with higher initial scores. It is unknown when functional differences would be seen on the LEFS. Therefore, further research on tendinosis with individualized treatments, more restrictions on activity, and an increase in Graston® treatments should be conducted to determine if the patient functionality can return to normal.

The Numeric Pain Rating Scale (NPRS) was used to determine if the participants had a decrease or resolution of pain after the Graston Technique® protocol. The NPRS is rated out of 10 points and a lower score is desired. Although there were no significant results with the NPRS, we saw the results trending towards significance at P=0.060. The starting pain number of the subjects in our study was 3.8±1.6 and the ending number was 3.3±1.2. With numbers this low, it may be difficult to decrease it even further in the short duration of our study. The results of the NPRS challenge those in a case study on medial and lateral epicondylitis. The results of the case study[17] showed both patients Visual Pain Rating Scales (VPRS) decreased from 7/10 and 5/10 to 0/10, respectively. However, Papa[18] treated the medial and lateral epicondylitis with acupuncture and electrical stimulation, rehabilitative exercises, and the Graston Technique® 12 times over a nine week period, whereas we only treated with the Graston Technique® over a 2 week period. The results of our study could be due to the small population size or short duration of the study. With a larger population, an increase in treatment sessions, or more restrictions on the activity of the participants, the results of the NPRS may improve to near resolution or complete resolution.

Limitations

Limitations exist within this research study that may have affected the outcomes. First, the entire protocol including the warm up, Graston treatments, stretches, and strengthening that were used were the same for each participant. This was to keep the methods consistent. A downfall of this however, is that we were unable to individualize treatment to each individual and each pathology. Although the participants were unable to continue receiving treatment throughout the course of the study, activity was not regulated. They were instructed to continue living current daily lives without alteration. Therefore, if the participant was continuing to perform excessive activity, it may have affected the results of this study.

Additionally, an increase in treatment times and sessions should be considered for future research. The Graston Technique® manual states that optimal treatment frequency is 4-8 sessions.[1] Due to time and resource constraints, we were unable to complete more than four treatment sessions on each participant. Although we completed the lesser amount of sessions, it was promising to see a decrease in tendinosis after only four sessions. More research needs to be conducted to determine how may sessions it takes to see a full resolution of tendinosis.

Finally, this study had a small population of 15 participants. There was a limited number of participants that were recruited, which may have been due to multiple factors, including the inability to continue treatment for the duration of the study. Although the sample size included 15 participants, the ratio between patellar tendon pathology and Achilles tendon pathology was inconsistent. There were only two Achilles tendons in this study, both of which revealed insignificant results. Future research should be conducted with a larger sample size to obtain more statistically significant results, namely, in the scores that were trending towards significance.

Conclusion

After four treatment sessions over the span of two weeks, the Graston Technique® was shown to be beneficial in decreasing the amount of tendinosis in the patellar tendon. As tendinosis is a chronic condition that includes a degeneration of the collagen within the tendon, it takes a substantial amount of time to resolve.[2,3] The literature states that valuable treatment for tendinosis includes active release therapy, acupuncture with electrical stimulation, and IASTM or Astym.[6-8] One of the more promising treatments that is mentioned is eccentric exercise, which serves to stimulate collagen production and improve tensile strength.[3] The information we obtained through this study indicates that the Graston Technique® can be included among the more promising treatments for tendinosis. Viewed with diagnostic ultrasound in the short axis, the results showed that it takes at least two Graston Technique® treatments to begin to see the tendon start to fill in. Changes within the tendon were observed in the long axis with diagnostic ultrasound after only four Graston® treatments over two weeks. Therefore, while the study was of short duration, it demonstrates the effectiveness of the Graston Technique® as a protocol alone in the treatment of tendinosis. While more studies should be performed with diagnostic ultrasound and the Graston Technique® on tendinopathies, this supports the use of the Graston Technique® on patellar tendinosis. This new information is valuable, and demonstrates that the Graston Technique® is an option that clinicians should consider using as part of their treatment for patients with tendinosis.

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APPENDIX A. THE GRASTON TECHNIQUE® SUPPLEMENTARY MATERIALS

Table A1. The Graston Technique® Indications, Contraindications, and Precautions

Indications	*Contraindications*	*Precautions*
Achilles Tendinitis/osis	Open Wound	Medications
Medial/Lateral Epicondylitis/osis	Unhealed or Unstable Fracture	Cancer
Carpal Tunnel Syndrome	Thrombophlebitis	Varicose Veins
Plantar Fasciitis/osis	Uncontrolled Hypertension	Burn Scars
Rotator Cuff Tendinitis/osis	Patient Intolerance	Acute Inflammatory Conditions
Patellar Tendinitis/osis	Non-Compliance	Kidney Dysfunction
Tibialis Posterior Tendinitis/osis	Hypersensitivity	Lymphedema
De Quervain's Syndrome	Hematoma	Infection
Post-Surgical and Traumatic Scars	Osteomyelitis	Rheumatoid Arthritis
Myofascial Pain and Restrictions	Myositis Ossificans	Pregnancy
Chronic and Acute Sprains/Strains	Hemophelia	Osteoporosis
Non-Actue Bursitis		Polyneuropathies
IT Band Syndrome		
Wrist Tendinitis/osis		
Reduced ROM Due to Scar Tissue		
Pre-Competition Warm-Up		
Post-Competition Recovery		
Milking Edema		

Table note. Obtained from the Graston Technique® manual. [1]

APPENDIX B. GRASTON TECHNIQUE® INSTRUMENTS

Figure B1. Graston Technique® Instruments
Left top: GT4, right top: GT5, top middle: GT6, left middle: GT3, right middle: GT2, bottom: GT1.[1]

Figure B2. Achilles Tendon Instruments
Left: GT4, middle: GT2, right: GT3

Figure B2. Patellar Tendon Instruments
Left: GT4, right: GT3

APPENDIX C. DIAGNOSTIC ULTRASOUND ARTIFACT APPEARANCES

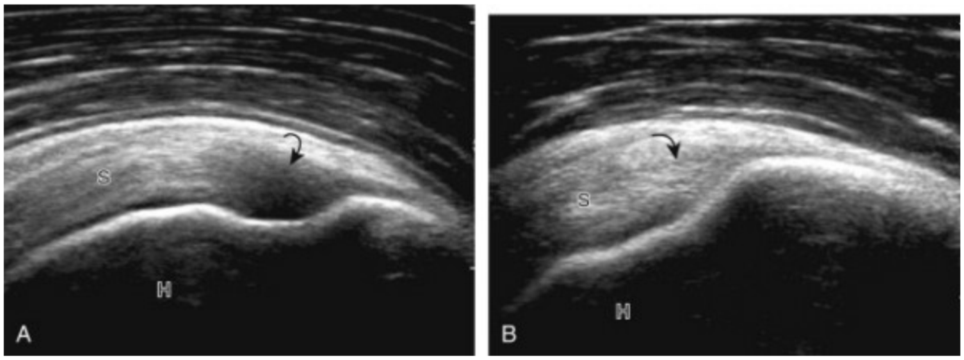


Figure C1. Anisotropy
SAX view of the supraspinatus.[17]

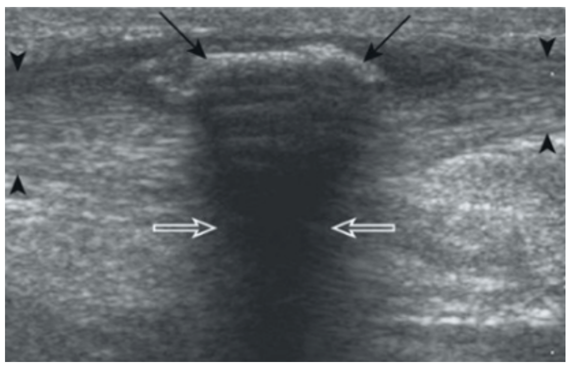


Figure C2. Shadowing
SAX view of the Achilles tendon.[17]

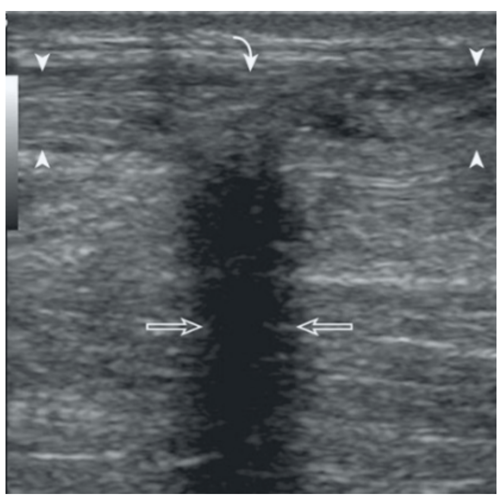


Figure C3. Refractile Shadowing
SAX view of the Achilles tendon.[17]

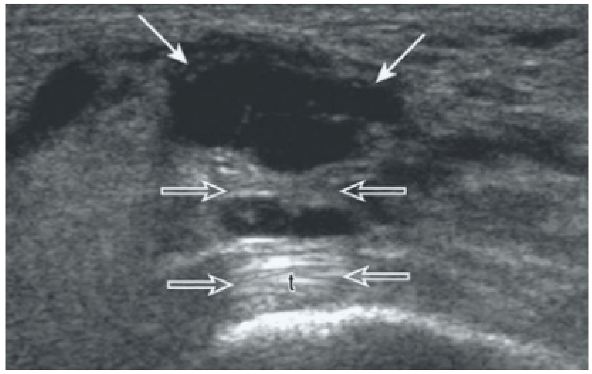


Figure C4. Posterior Acoustic Enhancement
SAX view of a ganglion cyst of the flexor hallicus longus.[17]

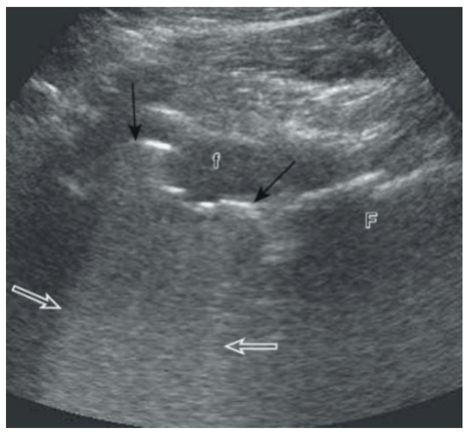


Figure C5. Ring Down Artifact from Posterior Reverberation
LAX view of the femoral component of the hip.[17]

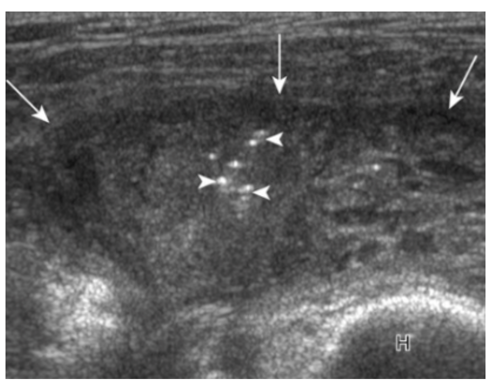


Figure C6. Comet Tail Artifact
SAX view of the infected subacromial-subdeltoid bursa.[17]

APPENDIX D. DIAGNOSTIC ULTRASOUND INJURY APPEARANCES

Figure D1. Normal Tendon Appearance
Normal hyperechoic, fibrillar pattern of the patellar tendon.[50]

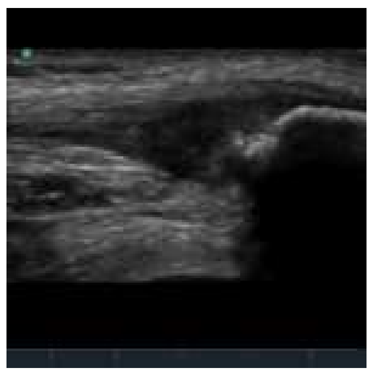


Figure D2. Abnormal Tendon Appearance
Longitudinal view of the patellar tendon with significant hypoechoic areas, indicating tendon pathology.[50]

Figure D3. Abnormal Tendon Appearance
Transverse view of the patellar tendon with hyperechoic calcific deposit.[50]

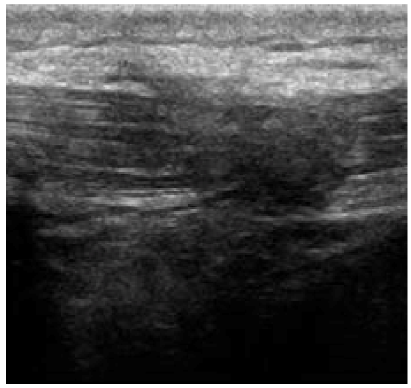


Figure D4. Abnormal Tendon Appearance
Longitudinal view of the patellar tendon with hyperechoic scar tissue.[51]

APPENDIX E. REQUIRED FORMS

Report of Past and Current Treatment(s)

Name:______________________________

Condition: (Circle one)

Achilles Tendinopathy *Patellar Tendinopathy*

Please indicate below if you have had previous treatments or if you are currently receiving treatment. Include the type of treatment (ie. ice, electrical stimulation, ultrasound, etc.), the numbers of times treatment was received, and the dates of the treatments. Be sure to include ALL treatment(s) that you have received. See example below for reference.

Ex: *Received ultrasound 3x/week for 2 weeks (July 1-14th, 2017)*
Ice everyday for 1 month (July 1st, 2017-August 1st, 2017).

Previous Treatments:____
____
____
____

Current Treatments:____
____
____
____
____

Additional Comments:____
____
____
____

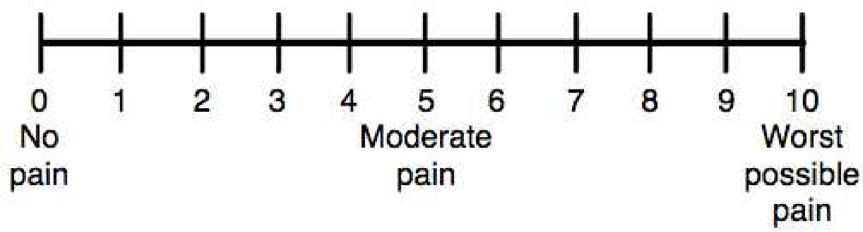
I, ______________________________ acknowledge that the above information is true to the best of my knowledge. I agree to disclose any treatments that may begin during the course of this research study.

Name: ______________________________

Signature:______________________________ Date:______________

Numeric Pain Rating Scale

0–10 Numeric Pain Rating Scale



Lower Extremity Functional Scale

The Lower Extremity Functional Scale

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your lower limb problem** for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, *do you* or *would you* have any difficulty at all with:

	Activities	Extreme Difficulty or Unable to Perform Activity	Quite a Bit of Difficulty	Moderate Difficulty	A Little Bit of Difficulty	No Difficulty
1	Any of your usual work, housework, or school activities.	0☐	1☐	2☐	3☐	4☐
2	Your usual hobbies, re creational or sporting activities.	0☐	1☐	2☐	3☐	4☐
3	Getting into or out of the bath.	0☐	1☐	2☐	3☐	4☐
4	Walking between rooms.	0☐	1☐	2☐	3☐	4☐
5	Putting on your shoes or socks.	0☐	1☐	2☐	3☐	4☐
6	Squatting.	0☐	1☐	2☐	3☐	4☐
7	Lifting an object, like a bag of groceries from the floor.	0☐	1☐	2☐	3☐	4☐
8	Performing light activities around your home.	0☐	1☐	2☐	3☐	4☐
9	Performing heavy activities around your home.	0☐	1☐	2☐	3☐	4☐
10	Getting into or out of a car.	0☐	1☐	2☐	3☐	4☐
11	Walking 2 blocks.	0☐	1☐	2☐	3☐	4☐
12	Walking a mile.	0☐	1☐	2☐	3☐	4☐
13	Going up or down 10 stairs (about 1 flight of stairs).	0☐	1☐	2☐	3☐	4☐
14	Standing for 1 hour.	0☐	1☐	2☐	3☐	4☐
15	Sitting for 1 hour.	0☐	1☐	2☐	3☐	4☐
16	Running on even ground.	0☐	1☐	2☐	3☐	4☐
17	Running on uneven ground.	0☐	1☐	2☐	3☐	4☐
18	Making sharp turns while running fast.	0☐	1☐	2☐	3☐	4☐
19	Hopping.	0☐	1☐	2☐	3☐	4☐
20	Rolling over in bed.	0☐	1☐	2☐	3☐	4☐
	Column Totals:		0	0	0	0

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE: 0 / 80 (fill in the blank with the sum of your responses)**

Source: Binkley et al (1999): The Lower Extremity Functional Scale (LEFS): Scale development, measurement properties, and clinical application. Physical Therapy. 79:371-383.

APPENDIX F. GRASTON TECHNIQUE® TREATMENTS ON ACHILLES TENDON

Figure F1. Sweeping/scanning
Sweeping and scanning of the gastrocnemius/soleus complex.

Figure F2. Sweeping
Sweeping of the Achilles tendon.

Figure F3. Strumming
Strumming of the Achilles tendon.

APPENDIX G. GRASTON TECHNIQUE® TREATMENTS ON PATELLAR TENDON

Figure G1. Sweeping/scanning
Sweeping and scanning of the quadriceps group.

Figure G2. Framing
Sweeping of the patella.

Figure G4. Framing
Framing of the tibial tuberosity.

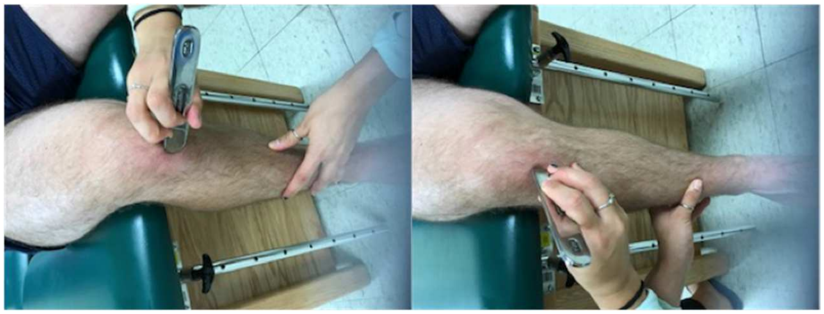


Figure G3. Strumming
Strumming of the patellar tendon.