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Review

Current concepts of shockwave therapy in chronic patellar tendinopathy

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HIGHLIGHTS

- Chronic patellar tendinopathies are common and difficult to treat.
- Patients that didnot respond to conventional treatment often require surgical procedures.
- Extracorporeal Shockwave Treatments ESWT have good results in treating chronic tendinopathies.
- We present the current knowledge on shockwave treatments for chronic patellar tendinopathies.
- We recommend the use of ESWT in chronic patellar tendinopathies.

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1. Introduction

Patellar tendinopathy (PT), a condition also described as "jumper's knee", is a frequent injury associated to sporting activities that involve jumping or running, as well as sudden changes of direction [1]. It is a common cause of complaint and leave in soccer, basketball and volleyball [2,3] The overall prevalence of PT has been reported as of 14.2% in the general population, being higher in athletes, with as much as 44.6% in elite volleyball players and 31.9% in basketball players [3]. There is an overall prevalence of 8.5%, being higher in volleyball players (14.4%) and lower in soccer players (2.5%) [13].

PT has been defined as an overuse injury caused by repetitive mechanical stress loads on the patellar tendon [4] that cause an initial inflammatory response followed by a stage of degeneration [5,6]. However, the etiology of the PT is uncertain. Slow and hypoxic tendon regeneration after an inflammatory reaction from a mechanical demand seems to be the most accepted physiopathological etiology [5,6,23,24]. The macroscopic appearance of the tendon is a brownish tissue described as mucoid. Microscopically it is characterized by an abnormal collagen array, with little cellularity and vascularity. The scar tissue is usually degenerative and dysplasia, and there is an increase in the concentration of glycosaminoglycans [25,26].

The first stage of PT can be described as a reactive tendinopathy and early tendon disrepair phase, that leads in many cases to a second stage of tendon late disrepair and degeneration phase [27]. Histological studies have shown there are an absence of inflammatory cells, normal levels of prostaglandin and a lack of vascularity, so it cannot be defined as a tendinitis but as a chronic avascular tendinopathy, usually on the inferior pole of the patella [55].

Even though PT has been related to high demand physical activity, it has also been described in sedentary individuals. Some intrinsic factors that increase the risk of PT are overweight [14,15] hamstring muscle retractions, quadriceps stiffness [14–16], limb length discrepancy [18], limited motion of the ankle joint [20], or flat feet [14,19]. The most relevant extrinsic factor, and probably the major cause in the development of PT, is inappropriate training and exercise [2,15,17]. Jumping and landing techniques, acceleration

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and deceleration protocols and sports gesture training are crucial in preventing PT [21,22,46].

Chronic patellar tendinopathy diagnosis is mainly clinical, and can be classified according to the scale of the Victorian Institute of Sport Assessment (VISA) [7] or the Blazina modified scale [1,2,8–10]. Many treatment strategies have been described, from load control to surgical procedures, all focused on a combination of pain control, regeneration of the damaged tissue and progressive re-training of the extensor mechanism [11,12]. Many of the conservative treatments are widely used without a high evidence based consensus, but it is a common finding to have good results in over 70% of the patients [7,8,13–15]. Surgery is usually indicated as a result of a failure of conservative treatments, with good and excellent results in only 45–50% of these group of patients.

The use of mechano-transductional stimulation of chronic tendinopathies has been a growing field of research in the past two decades [54,55,67]. The extracorporeal application of focused shockwaves, or direct mechanical impacts in the form of pressure waves on chronic tendinopathies, has shown good or excellent results similar or better to surgery, with the advantage of being a non invasive procedure with minimal side effects. It is currently a well-accepted and common treatment for tennis elbow, chronic plantar fasciitis and patellar tendinopathies [41,44,54,67]. There are still controversies regarding treatment protocols, as many different approaches have been published with relatively similar results. The use of focused or radial devices, the levels of energy required, the frequency of impacts and the number of sessions required, are just some of the extremely variable parameters in the literature, still with good results and no major complications [41,43,54].

2. Chronic patellar tendinopathy treatment

Patellar tendinopathy is the biggest challenge in the treatment of chronic insertional tendon overuse syndromes. The patellar tendon is a non-stretching structure that has to deal with the largest tensional load forces, the largest muscle groups, the longest bones and the largest sesamoid in the human body. It is the most important biomechanical point of the extensor mechanism, and is responsible for the ability of jumping, running and deceleration [58]. The vascular supply of the proximal insertion of the patellar tendon is relatively poor, an anatomic factor that may explain why tendon healing is lower on this site, and why chronic PT affects this particular spot. These vascular patterns have been studied in the development of techniques and avoidance of complications of ACL reconstructions with patellar tendon bone autografts [59].

Various forms of treatments have been proposed for chronic PT [11,28,29], and still there is no consensus on the most appropriate. Physical therapy, and especially eccentric exercise have shown the best evidence of good results [28–30]. Other types of conservative treatments include low intensity pulsed ultrasound (LIPUS) [31,32], manual therapy [33], and heavy-slow resistance training [34]. Injections of sclerosing agents or steroids have shown good short-term results, but have dose related complications such as crystallization of the tendon matrix and a higher risk of tendon rupture [34–37]. Biologic augmentation with platelet rich plasma, bone marrow aspirates, autologous growth factors or stem cells seem to be a promising therapy, but still have a lack of evidence and conflicting results [38–40].

Surgery has always been the last option in the treatment of chronic PT, and the results are usually good in short and long terms. Both open and arthroscopic procedures have been successfully used. Arthroscopic surgery limits the possibility of resecting pathologic tissue from inside the tendon [26,56]. Open tenotomies with resection of dysplastic tissue, removal of Hoffa's fat pad and drilling of the patella, fulfill the main goal of the procedure: revascularization, pain control and removal of angiofibroblastic tissue [57]. Even though the rate of complications after surgery is minimal, it is an invasive procedure that comes with all the inconveniences and costs of a surgical protocol. Coleman et al. [60,61] showed how postoperative recovery time may last up to 10 months.

The use of extracorporeal shockwave treatments (ESWT) evolved from the destructive properties of high-energy focused shockwaves used to implode kidney stones, to a highly efficient extracorporeal regenerative system that stimulates healing and vasculogenesis. On the past 15 years we have used shockwave treatments for tendinopathies with excellent results, both in pain control and in long term tendon healing. We know that the direct impact effect of ESWT creates a loop of hyper-stimulation analgesia, but the real potential for treatment with mechanotransduction is the modulation of neovascularization, migration and differentiation of mesenchymal stem cells, local angiogenic stimulation and enhancement of the natural healing microenvironment [12,43]. Several authors have proven that ESWT decreases tendon matrix metalloproteinases and interleukins [12,41–43]. Solid basic research have found biological responses that can only be explained by the cellular stimulation of metabolism and it's intercellular messengers through mechanotransduction [41].

3. Patellar tendinopathy and shockwave treatments

Understanding that Chronic PT is a combination of hypovascularity and fibrous dysplasia that changes the biomechanical properties of the tendon and causes pain, ESWT has become a popular therapeutic tool for this condition with high effectiveness and safety [44,68]. The first reports of PT treated with ESWT were done with focused devices. Vara in 2000 [45] reported in a well-designed blinded RCT on of 27 patients, 74% improvement in pain and function after 24 months in the ESWT treated group. Odgen [62] in 2003 presented for the first time in a ISMST world meeting the results of ESWT in 11 athletes with encouraging results. Taunton in 2003 [46] proposed ESWT as a useful complement to squat physical therapy protocols. He reported 20 cases in an RCT, and found an improvement of 77% in pain, function and a vertical jump score. Zwerver [49] reported his results on 19 high performance athletes treated with piezoelectric ESWT, with 63% improvement in VAS and 47% in VISA-P Score. Peers in 2003 [47] also found 61% pain and function improvement at 3 months in 41 athletes treated with ESWT. He also published a comparison between ESWT and surgery for PT [48], and did not find any statistically significant differences in pain or function after 24 months. He concluded that ESWT and surgery are similar in results, with a higher cost, risk, recovery time and inconveniences with surgical procedures.

Vulpiani [8] studied 73 patients in a prospective study on knees that did not respond to conservative treatments, and found improvement in pain and function of 43% after one month and 79% after 24 months. Wang [12] compared ESWT and physical therapy treatment in a controlled RCT of 50 patients. He had 90% good or excellent results in the ESWT group, as compared to 50% in the Physical Therapy group after 12 months. Using diagnostic ultrasound, he also reported vascular changes in the proximal insertion of the patellar tendon, and significant differences in tendon width and size in the ESWT treated patients.

After 2003, the development of radial pneumatic ballistic pressure wave devices changed the perspectives of shockwave medicine. Treatments for insertional tendinopathies were easier and less expensive. We had to change our protocols to adjust levels of energy, frequency and number of sessions. PT was not an exception, and results were not encouraging in the beginning.

Lohrer in 2002 [50] had the first report of treatment of PT with radial pressure waves. He reached 64% of good results in 50

patients, a good result, lower than those reported with focused protocols. In 2006 the senior author [63] reported better results using radial pressure waves and PRP augmentation in severe PT, and recommended the use of MRI to determine the size of the degenerative defect. In defects larger than 50% of the width of the proximal insertion of the tendon, the primary recommendation is surgery. The use of radial devices became popular due to good results, and for many years evidence and reports were growing. Furia showed in 2012 [51] good results in patients treated with a single session of low energy radial pressure waves, with a significant improvement in pain and function. Crupnik [64] reported 76% of good or excellent results in patients with PT, treated with a combination of eccentric exercises and 3 weekly sessions of 2000 pressure waves at 2.5–3.5 BAR.

One of the most active groups studying the effects of ESWT on patellar tendon is the University of Groningen – The Netherlands. Their first report in 2007 was positive [44], but later on, using a Piezoelectric device, they reported in their TOPGAME study no statistically significant differences in treating patients with three sessions of medium energy as compared with Physical Therapy alone [53,65]. However, in 2011 their results were better, and recommend ESWT in certain cases. These research findings led to the design of the TOPSHOCK Study. Van der Worp [52] reported the first randomized controlled trial to compare the effectiveness of FSWT and RSWT in the treatment for patellar tendinopathy. They used a three session protocol with energiews of 1.2 mJ/mm in FSWT and 2.4 BAR in RSWT. They found a slight improvement in all patients after 14 weeks, and no statistically significant difference in the effectiveness of FSWT and RSWT for treating patellar tendinopathy.

Serrano [66] in 2015 reported a comparative study between radial and focused shockwaves for PT. In the first group he used only radial waves in 5 weekly sessions of 2000 pressure waves at 2 BAR. In the second group he applied 2 weekly sessions of 1000 focused shockwaves at 0.15 mJ/mm^2. Both groups received radial analgesic pressure waves before and after the treatment in every session, and the focused group had three extra sessions of radials in order to make the two groups comparable. Only radials had 67% of good and excellent results, as compared with Focused that had 88%.

The latest application reported on patellar tendinopathy was done by our group [76], in patients with anterior knee pain after a total knee arthroplasty. This is a relatively common condition that causes anterior pain and discomfort in patients with total knee replacement that are physical active. Our results were good in 69% of the patients after three months of treatment. We found no complications and we are currently running a phase-two case control study.

To date there are only two reports in the literature showing poor results of ESWT in PT: Zwerver [65], using a piezoelectric device in high performance athletes, and Vetrano [9], that compared ESWT with PRP. The first study was done in athletes during competition, and that may be the reason for having lower good results than others reported in the literature. In Vetrano's study, he used an unusual protocol of one session every 48–72 h, that has no previous validation and is not used by other authors.

The ISMST world meeting is the scenario where the experiences of ESWT researchers, experts and clinicians are exposed and evaluated. Since September 21 of 1997 the ISMST has done 18 world congresses with more than 720 conferences, lectures and posters. Only 14 of these presentations were about patellar tendinopathy and ESWT [68–75], five from the Groningen Group and four from the authors of the present article. In contrast, more than 250 shockwave centers in the world include patellar tendinopathy in their portfolios, and all the ESWT device producers recommend this treatment. The ISMST has included the use of Shockwave Treatments for Patellar tendinopathy in the list of Approved Applications since 2008, based upon the good results in safety and efficacy in clinical trials of all levels of evidence. The recommended protocols for RSWT and FSWT are summarized in Fig. 1.

4. Conclusion

Shockwave treatment for chronic patellar tendinopathies that have not responded to conservative measures and physical therapy is an effective and safe procedure. We do not recommend it for acute conditions, as more than 80% of the cases improve with conventional treatments, and only 20% develop a dysplastic insertional tendinopathy. ESWT must be seen as part of a treatment protocol for PT, and not as an isolated treatment. The best results are obtained when used in combination with eccentric exercises and standardized physical therapy protocols. Anesthesia is not recommended during the sessions, and a rest period of 2 weeks improves results.

There is not enough evidence to recommend the use of radial instead of focused devices for chronic patellar tendinopathy. In taking the decision of using one or the other, variables different from clinical outcomes must be taken into account, such as economics, availability of devices and experience. The use of radial SWT may require more sessions, but the use of Focused SWT does require a larger investment. The final point is that ESWT provides a good non-invasive, safe and effective solution for chronic patellar tendinopathies, a clinical situation that is a real challenge in orthopedics and sports medicine.

Ethical approval

None declared.

	RADIAL SWT	FOCUSED SWT
Shockwaves	> 2000	1000 - 2000
Energy	> 2 bar	0.1 – 0.2 mJ/mm^2
Frequency	6 – 12 Hz	4 -5 Hz
Sesions	2 – 5	1 – 2

Fig. 1. The radial and focused shockwave protocols recommended. As RSWT is also used for analgesia, the recommendation is to use at least 2000 shockwaves at energies over 2 BAR in every session. We recommend two sessions, and only a third one if there is no clinical response after two weeks. In FSWT we do a second session only if there is no clinical response after two week. Protocols can be different accordingly to the source: for the focused devices 0.15–0.20 is the maximum recommended Energy flux density, and 1–2 is the minimum number of sessions for obtaining results.

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Author contribution

Prof Dr Carlos Leal MD is the principal author. Silvia Ramon, John Furia, Arnold Fernandez, Luis Romero and Leonor Hernandez-Sierra participated as collaborators and coauthors.

Conflicts of interest

The authors do not have any conflict of interests for the present publication.

Guarantor

Prof Dr Carlos Leal MD is the Guarantor of this review Article.

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