Clinical Trial

COCCYGEOPLASTY: AN EXPLORATION OF A NOVEL APPROACH FOR TREATING RESISTANT COCCYDYNIA IN PATIENTS WITH COCCYGEAL HYPERMOBILITY

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ABSTRACT

Coccydynia can be attributed to various factors, including fractures, subluxations, and hypermobility within the sacrococcygeal area. Current treatment options often fall short in effectiveness. Coccygeoplasty (CP) represents a relatively recent, minimally invasive approach that aims to tackle this challenging clinical issue. The aim of this study is to evaluate clinical outcomes immediately following the procedure and at 3- and 12-month follow-ups for patients suffering from coccydynia linked to coccygeal hypermobility and subluxation. Furthermore, we seek to assess any correlations between imaging results and clinical outcomes at the follow-up intervals. A prospectively maintained database was used to retrospectively assess all patients who received CP for chronic coccydynia from January 2005 until December 2023. Each participant exhibited painful hypermobility (greater than 25°) with anterior flexion verified through radiological assessments. Alternative coccydynia causes were ruled out using CT and MRI imaging techniques. Procedures were conducted under local anesthesia with a combination of fluoroscopic and CT guidance. Clinical assessments were performed at 3- and 12-months post-treatment utilizing the Visual Analogue Scale (VAS). A total of 19 patients underwent treatment at a single center. There were no complications linked to the procedures. At both the 3- and 12-months post-treatment, 75% of patients reported substantial reduction in VAS scores compared to baseline, with average reductions of 3.5 and 4.9, respectively. No instances of pain recurrence were noted at the 12-month follow-up,

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although one patient did not experience any pain alleviation. Post-treatment CT scans confirmed the fusion of sacrococcygeal segments in 14 patients, yet no significant correlation was identified between the imaging outcomes and clinical results (p=0.1). Patients suffering from chronic coccygeal pain due to subluxation and hypermobility exhibited positive clinical outcomes following CP, as evidenced at both the 3- and 12-month evaluations. Additional research is warranted to validate this technique further and identify factors that predict treatment success. Coccygeoplasty may serve as a viable alternative to coccygectomy.

KEYWORDS: *coccydynia, coccyx, pain, fractures, subluxations, hypermobility*

INTRODUCTION

The coccyx, often described as an inverted triangular structure at the base of the spine, typically comprises three to five fused segments (1). The joint connecting the sacrum and coccyx features an interposed fibrocartilage and synovial membrane that permits enhanced mobility under certain conditions, such as during pregnancy (2). Since its initial description by Simpson in 1859, coccydynia has been characterized as pain localized to the coccyx area without significant radiating discomfort. Pain that endures for more than two months is classified as chronic (3). Women between the ages of 30 and 40 are the most prevalent demographic affected, thought to be due to their anatomical configuration making the coccyx more vulnerable to injuries (4-6).

The spectrum of potential causes for coccydynia includes trauma, especially falls while seated, as well as repetitively induced microtrauma from activities like cycling, motorcycling, or horseback riding (6, 7).

Management options for coccydynia encompass conservative approaches as well as traditional surgical interventions. Conservative methods for alleviating pain include physiotherapy techniques, such as pelvic relaxation massage using supportive sitting aids like a donut pillow, non-steroidal anti-inflammatory medications, and warm baths. Additionally, techniques such as intrarectal manipulation of the coccyx and fluoroscopically guided steroid injections may be utilized. Although not employed in the patients discussed in this case series, more invasive conservative treatments are available, including radiofrequency ablation of the coccygeal discs and Walther's ganglion. In instances of chronic pain, a surgical procedure to remove the coccyx, referred to as coccygectomy, may be indicated (5-17).

Coccygeoplasty (CP), a technique inspired by vertebral augmentation methods, has recently emerged as a therapeutic option. This involved the percutaneous injection of polymethylmethacrylate (PMMA) cement into the sacrococcygeal segments. Although still rare, the limited literature available consists of reports discussing its application. The procedure aims to provide stability in cases where hypermobility or subluxation contributes to coccygeal pain (18-21).

The aim of this study is to present clinical outcomes at the procedure's initiation and follow-up periods of 3 and 12 months for individuals diagnosed with coccydynia resulting from subluxation and coccygeal hypermobility. It also aims to evaluate any associations between the imaging findings and clinical outcomes observed during the follow-ups.

MATERIALS AND METHODS

Eligible patients who underwent coccygeoplasty at a single center from January 2005 to December 2023 were selected based on a meticulously maintained database. This study included adult individuals over 18 years old with chronic painful coccygeal subluxation and hypermobility, defined as a greater than 25° difference between standing and seated X-ray imaging. Patients experienced pain localized to the coccyx region, which was resistant to conservative treatments for at least six months and led to significant functional impairment (22). All participants exhibited hypermobility and subluxation, which was evident on CT or dynamic radiographs of the sacrococcygeal region taken in both seated (painful) and standing positions. Subluxation and hypermobility of the coccyx were characterized by flexion exceeding 25° and luxation indicated by more than 25% displacement. Additionally, an MRI was conducted for surgical planning and to exclude other conditions in the sacrococcygeal region that could mimic coccygeal symptoms (Fig. 1).

Fig. 1. *MR before treatment documenting fracture-dislocation of the body of the second coccygeal vertebra (**arrow**).*

MRI scans were performed on a 1.5T machine, acquiring sagittal and axial T1SE and T2STIR images without contrast. Pre-treatment spiral CT scans were obtained at 1 mm intervals, with both 2D and 3D sagittal and coronal reconstructions, to facilitate procedure preparation. Post-treatment scans were conducted under the same parameters to evaluate outcomes, including the degree of fusion, cement filling of sacrococcygeal segments, and any cement leakage. Clinically, outcomes were assessed using the Visual Analogue Scale (VAS) prior to the intervention. This clinical study adhered to European Union privacy regulations and received approval from the hospital's ethics board.

Coccygeoplasty Procedure

All participants provided informed consent prior to the procedure. Patients were positioned prone on the CT table. Initially, a spiral CT study was performed to determine the appropriate angulation for the working needle. Although pre-procedure dynamic studies indicated hypermobility in the target area, once positioned prone, no patient demonstrated angulation exceeding 25°. A single Jamshidi-type needle was inserted along the midline, from the S4 level through to the coccyx.

The procedure was conducted under local anesthesia using lidocaine 2% as the sole agent, with no sedation or general anesthesia involved. Continuous monitoring of blood pressure, pulse oximetry, and heart rate was performed throughout the intervention. Antibiotics (1 gram of cefazolin) were administered approximately one hour before the procedure and continued for two days at 12-hour intervals. The procedure took place in a hybrid operating room utilizing a C-arm and CT combination for monitoring (20, 23, 24). A 13-gauge beveled trocar and high-density cement were used for all patients. The needle was introduced through the mid-axis of the sacrum towards the coccyx, and PMMA was injected while gently withdrawing the needle to fill both the coccyx and the caudal sacrum. The foramina was avoided due to the medial placement of the needle. Cement injection was carried out under C-arm fluoroscopy. A follow-up CT scan with 2D reconstruction was obtained immediately after the procedure (Fig. 2-5).

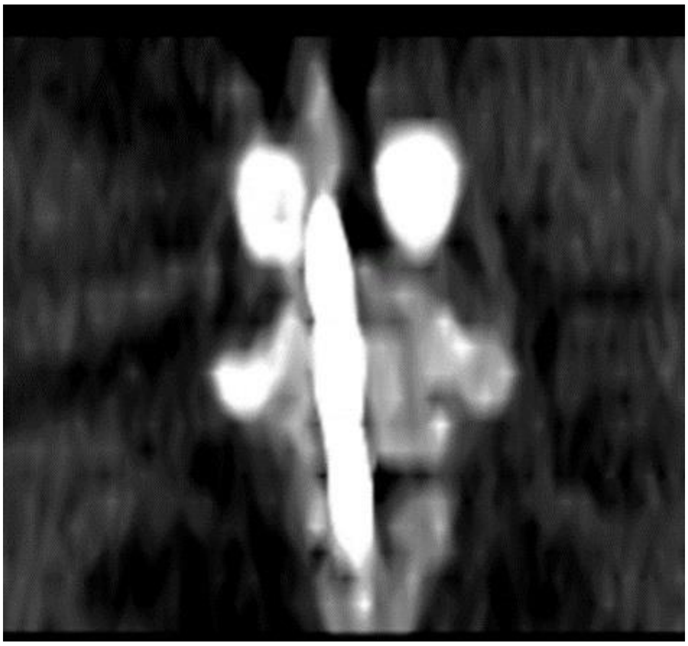

Fig. 2. *CT control: coccygeoplasty was performed with one needle along the midline, from the level of S4, passing through the coccyx.*

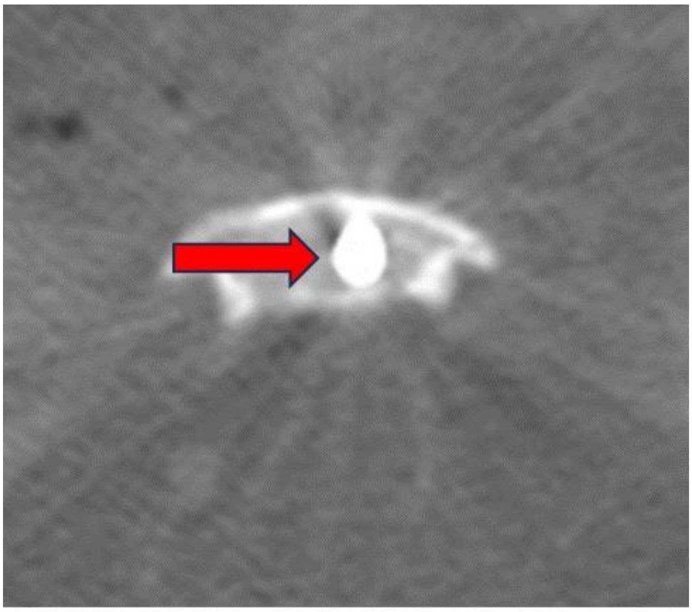

Fig. 3. *CT control axial view **(arrow)**.*

Fig. 4. *Spiral CT, sagittal reconstruction of control of the distribution of medical cement (**arrows**).*

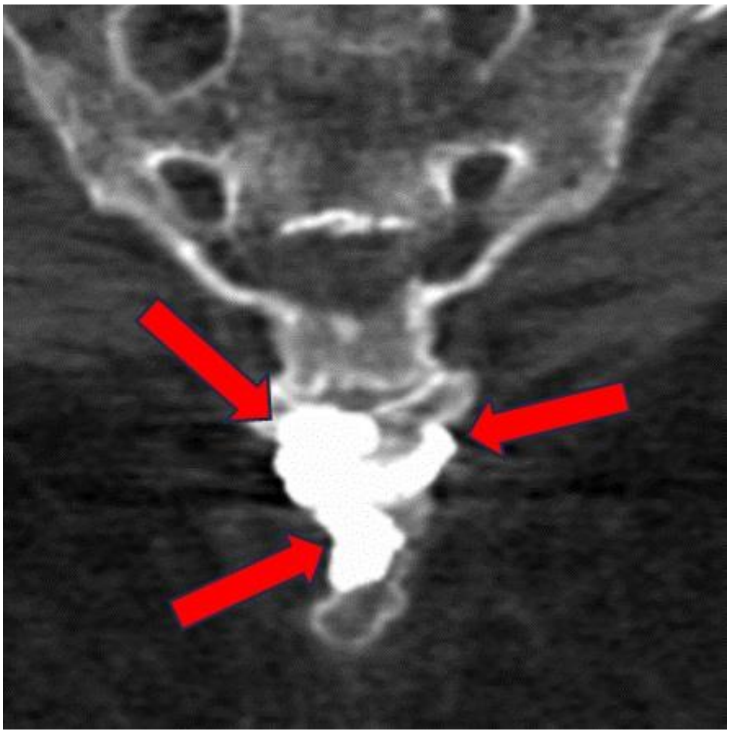

Fig. 5. *CT spiral, coronal reconstruction to control the distribution of medical cement (**arrows**).*

According to institutional protocol, patients were monitored in the hospital for 48 hours post-procedure and were permitted to ambulate four hours following the intervention. No complications were observed during this period.

Follow-Up

Patients were discharged two days following their procedure, with no subsequent antibiotic treatments required. Clinical outcomes were documented upon discharge, with follow-up evaluations scheduled for 3 and 12 months afterward, assessing patient satisfaction alongside VAS scores. A clinical success was defined by a decrease of at least 2 cm in the VAS scores.

Statistical analysis

Descriptive analyses and comparisons between final imaging findings and clinical outcomes at the 3- and 12-month follow-ups employed SPSS software, specifically utilizing the chi-square test for correlation analysis.

RESULTS

Baseline characteristics

The cohort comprised 16 women and 3 men, averaging 47 years of age. Preoperative MRI scans revealed no alternative pathological findings. Each patient had previously engaged in conservative management strategies, including non-steroidal anti-inflammatory medications, with no clinical improvement. Additionally, out of the 19 patients, 13 had undergone prior steroid injections targeting the pudendal plexus, while all had received intrarectal coccygeal manipulation treatments. None had undergone radiofrequency interventions.

Technical findings

Of the patients, 14 achieved complete fusion of sacrococcygeal segments post-procedure, while 5 exhibited incomplete fusion. PMMA had filled all sacrococcygeal segments, and there were instances of cement leakage into surrounding areas in 3 individuals, but none into the central spinal canal; these leakages were deemed asymptomatic.

Clinical outcomes

Patients experienced a marked decrease in VAS scores at the 3-month (mean score reduced from 7.5 to 4.0) and 12-month follow-ups (mean score reduced to 2.6). The average changes in VAS scores were −3.5 and −4.9, respectively. Of the 19 patients, 75% experienced clinical success with a reduction greater than 2. At the one-year mark, 4 patients reported varying levels of coccygeal discomfort, with one patient experiencing no pain relief and three others achieving minimal changes below the predetermined threshold at either follow-up.

Analysis identified no meaningful correlation between technical radiographic outcomes and clinical results ($p=0.1$).

DISCUSSION

This preliminary study suggests that coccygeoplasty serves as a feasible treatment modality for individuals suffering from refractory coccydynia due to subluxation and hypermobility. The absence of complications further underscores the procedure's safety. In this patient group, there was a significant majority who reported notable pain alleviation, indicating the procedure's potential effectiveness. With additional research, coccygeoplasty has the potential to become a credible alternative to coccygectomy.

The proper selection of patients is essential for successful outcomes in coccydynia cases. Here, the focus was on individuals enduring chronic pain for over six months, presenting clear evidence of subluxation and hypermobility through dynamic imaging. Historical data reflects that a sizeable percentage of those with coccydynia exhibit signs of subluxation or hypermobility as contributing factors.

The role of MRI in this context remains somewhat ambiguous; it primarily assists in excluding other potential pathologies rather than providing definitive insights into typical coccygeal conditions (25-28).

Percutaneous vertebroplasty techniques, originally introduced in the late 1980s (28), are currently regarded as the standard practice for managing certain types of vertebral compression fractures. Drawing parallels between these procedures, CP aims to provide stabilization in cases of hypermobility or subluxation, which in turn may alleviate pain (29).

The methodology described in this study diverges from prior reports on coccygeoplasty, utilizing a single-needle approach that targets the sacrococcygeal axis directly. No complications were observed from this method, further validating its safety in the absence of critical structures at the procedural site. CT imaging played a crucial role in securing accurate needle placement (30-32).

In summary, the lack of symptomatic complications from the treatment suggests coccygeoplasty's suitability for well-selected patients. While some individuals did not achieve the desired level of pain relief, they did not exhibit worsening pain, affirming that the technique warrants consideration for those unresponsive to conservative treatments.

Coccygectomy, typically a last-resort measure, carries inherent risks and complications, including prolonged pain, infections, and rare serious adverse effects. Thus, less invasive alternatives such as coccygeoplasty should be considered prior to resorting to surgical interventions (33).

The study's limitations include its retrospective design, which may introduce biases. Although utilizing the VAS as a measure of clinical improvement is widely recognized, additional validation for this specific context may be needed. The fact that only a single, experienced practitioner conducted all procedures may raise questions about wider applicability. Furthermore, the lengthy recruitment period of over 18 years for just 19 patients highlights challenges in organizing such studies.

Despite these considerations, we advocate for the broader application of this approach, which could pave the way for larger-scale studies in the future.

CONCLUSIONS

Findings from this preliminary experience suggest that coccygeoplasty is a promising treatment for patients suffering from refractory coccydynia due to subluxation and hypermobility. Most patients reported meaningful pain relief following the procedure. Further investigations are necessary to substantiate this technique and identify factors that may influence treatment outcomes. Coccygeoplasty should be explored as a potential preference when considering coccygectomy for patients experiencing this condition.

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Narrative Review

LOWER LIMB TENNIS-RELATED INJURIES

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ABSTRACT

Tennis is among the world's most popular sports, widely practiced in the West at both amateur and professional levels. It is a fast-paced sport characterized by abrupt directional ranges, shots, and movements with significant forces at play. It is also often practiced outdoors in different weather conditions, on various types of terrain, with unsuitable clothing, and by players who are often inadequately physically and technically trained. This leads to a high rate of injuries among athletes of all levels; among the various body portions involved, the lower limbs are those most frequently affected, given their crucial role in movement. The injuries that can be encountered are many: joint and ligamentous involvements of the hip, knee, and ankle; tendon and muscle injuries of large muscle groups involved in movement; stress fractures and soft tissue lesions from repeated microdamage; injuries to skin and skin adnexa. These injuries substantially affect the affected person and, if not adequately treated, can deter the tennis player from playing the sport. This is even more evident in the professional athlete, where a sudden return to sport is of vital importance.

KEYWORDS: *tennis, sport, injury, lower limb, joint, ligament, hip, knee, ankle, muscle*

INTRODUCTION

Tennis, originating in England, has evolved globally and is now Italy's fourth most popular sport, ranking first among individual sports. Its growing recognition is largely due to the success of top Italian players. The sport involves rapid movements, sudden directional changes, and explosive gestures, particularly in the dominant upper limb, which place significant stress on the musculoskeletal system. Without proper technique and preparation, these stresses can lead to injuries, primarily affecting the lower limbs.

Tennis injuries vary by age and gender. Under 25, acute trauma-related injuries are more common, while over 25, functional overload injuries prevail. Female adolescents often experience patellar issues and lumbar pain, while male adolescents have a higher incidence of contusions, abrasions, ankle injuries, and lumbar pain.

Acute injuries occur when a force exceeds the strength of the affected structure, though they are less common in tennis due to limited physical contact. Chronic injuries stem from repeated stress and are influenced by factors such as playing surfaces, footwear, weather conditions, and individual predispositions like muscle imbalances. Poor athletic preparation increases injury risk, often leading to "weekend injuries" in sporadic players. Effective treatment requires categorizing injuries by anatomical location and tissue type.

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Hip

The hip is often the tennis player's weakest link, subjected to considerable stress yet frequently overlooked by athletes. Specific movements and technical gestures in tennis largely engage this joint. For instance, the forehand executed in an ‘Open Stance’, where the muscles on the dominant side produce a large force in the loading phase, has an effect on the hip during the thrust phase and subsequently affects the trunk, upper limb, and racket; the joint is also stressed in the stop after the shot. This stress is particularly pronounced among professional athletes, where greater power can lead to body elevation and return to the same side. The continuous repetition of such actions can result in damage to the joint capsule, acetabular labrum, muscles (especially the bi-articulars), tendons, and ligaments that support and stabilize the joint, resulting in reduced stability, reduced ROM, and pain. Among the most frequently encountered problems are femoral-acetabular conflict and lesions of the acetabular labrum (6).

Femoro-acetabular conflict (FAI) is an ever-increasing condition typical of sports with rapid changes of direction and jerks on hard terrain, which subject the hip joint to continuous trauma. The overall incidence of FAI diagnosis is 54.4 per 100,000 person-years, with a consistent increase observed between 2000 and 2016 (7).

Notably, female patients exhibit a higher incidence than their male counterparts (8). Its pathophysiology is related to the formation of a bony conflict between the femur and acetabulum, leading to a mechanical limitation to normal joint excursion with the presence of pain. There are different types of FAI: an alteration between the femoral head and neck with the formation of a bony outgrowth at the level of the neck, called CAM; an acetabular retroversion with an anterior conflict on the femoral neck, called PINCER; a mixed form between CAM and PINCER. Furthermore, a conflict can occur in the case of excessive joint laxity. The diagnosis, in addition to anamnesis, is based on the clinical-objective picture characterized by reduced joint excursion, pain exacerbated by prolonged sitting and exercises that lead to hip flexion, and the anterior impingement test (flexion, adduction, and intra-rotation from supine or FADIR).

The presence of pathology is confirmed with an X-ray examination that shows the presence of bony outgrowths and allows us to calculate specific indices for diagnosis (6). Treatment options vary based on severity, with conservative measures emphasizing strengthening exercises for mild to moderate cases. In contrast, the gold standard treatment in advanced conditions consists of arthroscopy to eliminate the bony outgrowths responsible for the conflict (8) (Fig. 1).

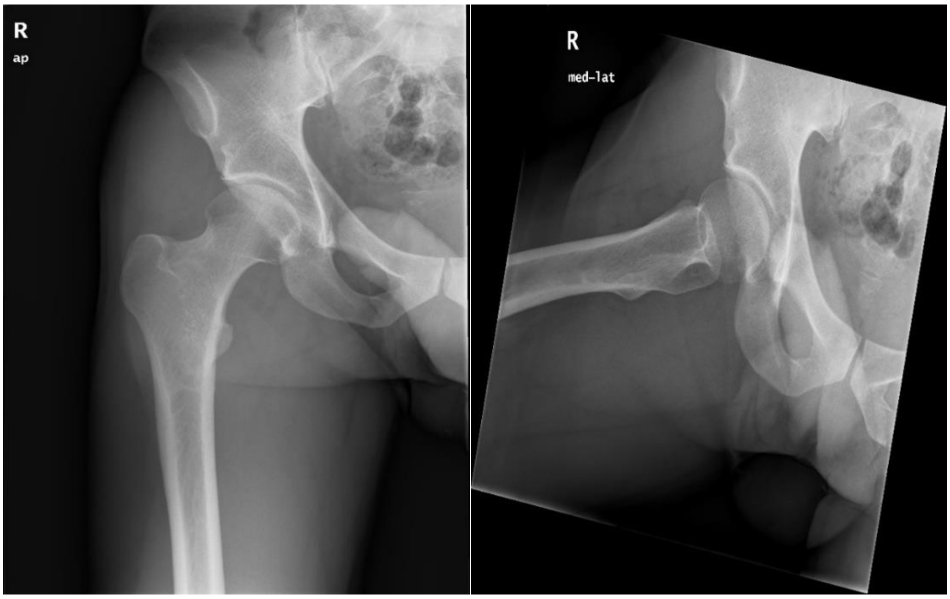

Fig. 1. *Hip X-ray of a 29-year-old male athlete, tennis player since adolescence. One notices the presence of an outgrowth of the acetabular labrum typical of the PINCER-type conflict.*

The acetabular labrum is a fibro-cartilaginous structure anatomically located in the rim of the cup and lines the femoral head. Its task is to widen the bearing surface of the acetabulum by supporting the load of the hip. Injuries to the labrum may result from overuse, acute trauma, or the presence of FAI.(9). Clinically, such injuries manifest as groin pain exacerbated by flexion and rotation, along with clicking or snapping sensation in the joint, constituting the clinical picture of a ‘snapping hip’. The clinical diagnostic suspicion is confirmed by an Arthro-MRI with contrast to visualize labral tears (10). The treatment in this pathology is predominantly surgical via arthroscopy with sutures and/or regularization of the lesions, yielding favorable outcomes even in elite athletes (10).

Knee

The knee is the joint most affected by sports injuries. Although knee injuries are not exclusive to tennis, they frequently arise due to the sport's demands, which involve constant lateral movements, abrupt stops, and flexion. Key injuries include meniscal tears, capsuloligamentous injuries, and extensor apparatus injuries.

Meniscal injuries in tennis players are a consequence of knee sprains induced by varo-valgus stress movements and rotational movements in sudden flexion extension. Clinically, they are characterized by sudden and significant pain, often necessitating withdrawal from play. In an isolated injury, pain is exacerbated by rotational movements and full extension of the affected limb. An important swelling may develop a few hours after the traumatic event, and mechanical joint locking may occur in the following days due to the interposition of the meniscal fragment between the femur and tibia.

The diagnosis is clinical-anamnestic supported by an accurate, objective examination with specific tests (Appley, McMurray, Cabot), which combined have a high sensitivity and specificity rate (11), and by specific instrumental examinations such as MRI. Meniscal lesions can be of multiple types and can be distinguished into longitudinal, transverse, radial, flap, and 'bucket-handle'. Furthermore, the location of the lesion is crucial because the healing capacity is contingent upon tissue micro-vascularization of the affected area (12).

It is possible to distinguish, according to Arnoczky, the red/red zone, adequately vascularized; the red/white zone, with partial vascularization; and the white/white zone, without vascularization (12). The gold standard treatment of meniscal lesions is arthroscopy, which facilitates direct visualization of the lesion, the possibility of employing meniscal adjustments and sutures and testing the stability of the meniscus and its possible interference with joint movement (13).

The important mechanical and proprioceptive functions of these structures should be kept in mind, which is why treatment should be as conservative as possible (14).

Knee ligament injuries are not among the most frequent injuries of tennis players; of all anterior cruciate ligament (ACL) injuries, which is the most frequent ligament injury of the knee, only a mere 1.8 percent occur during the practice of the sport (15). Such injuries predominantly arise from slips, abrupt directional changes, or abnormal falls during jumps. It is possible to distinguish anterolateral instabilities due to partial or total ruptures of the ACL and posterior instabilities due to ruptures of the posterior cruciate ligament (PCL), which are much rarer.

The diagnosis is based on history, clinical picture characterized by significant pain and swelling, specific objective tests (Lachman, Jerk, anterior and posterior drawer) (11), and MRI. The treatment of ACL injuries depends on the degree of instability, the age, and, above all, the functional demands of the patient. It can be conservative, aimed at increasing the muscular trophism and stability of the knee, or surgical, with various techniques available. Of these, to date, the most widely used is the 'all-inside' technique, which involves the use of allografts or synthetic grafts that 'mimic' the function of the ACL (16). This technique allows immediate loading and mobilization of the knee, return to normal daily activities in about 25-30 days, and the resumption of competitive sports in 5-6 months, with excellent clinical-functional results and low cases of residual instability (16).

Untreated ACL injuries have disastrous consequences in athletes, as knee instability increases the possibility of meniscal and cartilage injuries and predisposes to early arthrosis (17).

Injuries of the extensor apparatus are the most frequent pathologies of the knee in tennis players as it is subjected to overload due to constant semi-flexion work; the most frequent forms are tendinitis, chondromalacia, and patellar instability. The latter is favored by specific conditions such as muscular imbalances in the thigh, between flexors and extensors and between the vastus medialis and vastus lateralis fasciae of the quadriceps femoris, malalignment, external pressure, congenital ligament laxity (18). In addition, an increase in traumatic forms has been observed in recent years.

Patellar instability is more frequent in young females and is characterized by chronic and aggravating anterior pain. It is a pathology that, if not adequately treated, leads to the establishment of chronic inflammatory processes responsible in the long term for pictures such as patellofemoral arthrosis and tendon ruptures (18).

The diagnosis is based on anamnesis, clinical picture, and objective examination with specific clinical tests (Sage sign, J sign, apprehension test, Q angle measurement) (11). Imaging techniques, such as axial Rx of the patella (Marchant projection), which allows the staging of the pathology' severity by calculating the joint angles of the patella and femoral trochlea, and CT scans, which are useful for defining the condition of external hyper pressure (19), are fundamentals.

The treatment of patellar instability can be conservative and surgical. Surgical treatment is usually the main therapeutic choice for this pathology; reconstruction of the medial patellofemoral ligament (PFML) is among the most widely used techniques today (20) (Fig. 2).

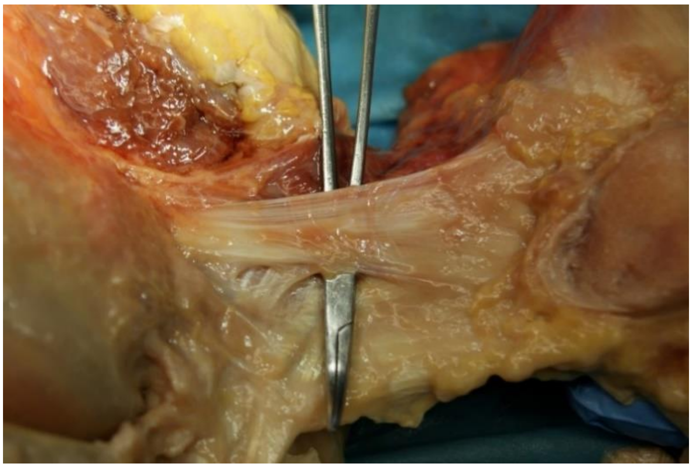

Fig. 2. *Cadaver image of the PFML, with its typical fan shape, representing the main medial stabilizer of the patella.*

Tendon injuries are often seen as stand-alone pictures or associated with patellar instability conditions, as they often share the same causes and consequences. The main role here is played by muscular imbalances and patellar malalignment with increased functional load on the tendon structures. The diagnosis is based on clinical examination and various instrumental methods such as X-ray, CT scan, biomechanical evaluation of muscle forces, kinetic and kinematic tests, and electromyography (21).

In young tennis players, osteochondrosis (i.e., inflammation of the growth cartilage) is widespread, especially at the proximal or distal insertion of the patellar tendon. When the inflammation affects the lower pole of the patella, Sinding-Larsen-Johanson's disease occurs; when the anterior tibial apophysis is involved, Osgood-Schlatter's disease occurs.

Osteochondrosis are pathology typically associated with muscular imbalances and functional overload with excessive traction at the tendon insertion points and tissue suffering such as to lead, in the most extreme cases, to the detachment of the part of bone connected to the tendon (11). Given the high incidence of tennis-related knee pathologies, prevention plays a key role; this is based on adequate athletic preparation aimed at strengthening the muscle-tendon, capsular ligament, and joint components with a correct balance of muscular forces, proprioceptive training, and improvement of playing technique (22).

Leg and foot

The legs and feet serve as the foundation for a tennis player's performance, where the demands for speed and explosive force are paramount. The pathologies that can be encountered are among the most diverse, ranging from muscle-tendon forms to rarer pathologies such as stress fractures. In addition, pathologies of the ankle and foot are very frequent, linked to the overloading of joints and rapid changes of direction on ever-changing playing surfaces.

Among the muscle-tendon forms, the typical tennis pathology is ‘tennis leg’, characterized by traumatic dislocation of the tendon of the inner twin muscle on the tendon blade of the soleus muscle. This condition, often referred to as a ‘calf tear’, typically occurs when making abrupt changes of direction that result in a contraction conflict between the mono-articular muscle of the soleus and the bi-articular muscle of the twin, causing it to rupture. The most affected individuals are short, male athletes between 30 and 40 years of age, with voluminous muscle mass and typically during the technical gestures of volley, serve, smash, and counterattack.

The diagnosis is anamnestic and clinical, highlighting a voluminous ecchymosis swelling in the sural region; sometimes, the palpatory finding of a rising muscle belly and lesion gap is possible. Confirmatory diagnosis is obtained by ultrasound, which also allows the extent of the lesion to be assessed in order to properly decide on treatment. Surgical treatment is relegated only to exceptional cases, and conservative treatment is based on immobilization and offloading, ice, topical and systemic anti-inflammatories, and physical therapy, with rather long recovery times (23).

The second most frequent form of musculotendinous pathology is Achilles tendonitis, which is more common under 30 years of age. Contributing factors include inappropriate footwear, anatomical variations, and hard playing surfaces. A chronic phlogistic process of the most vascularized portions of the tendon, such as the paratenonium and peritenonium, can occur, leading over time to ischemic suffering and tendon degeneration known as tendinosis. This is characterized by reduced cellularity, homogenization of the intercellular fibers, appearance of areas of cartilage metaplasia, and fatty infiltration.

Clinically, tendinitis presents itself with insertional pain that arises after sporting activity, stiffness with reduced dorsiflexion of the foot, increased thickness and pre-insertional tension (2 to 6 cm before insertion on the heel), presence of nodules and possible radiating pain in the sural region. In these cases, the treatment is conservative consisting on rest, cryotherapy, anti-inflammatories, orthotics, and physical therapy such as stretching and muscle strengthening; rarely, surgery with scarification and removal of the degenerated tendon tissue become necessary. If left untreated, tendinosis predisposes to subcutaneous rupture of the Achilles tendon.

This is the most frequent tendon injury with an increasing incidence in recent years, having risen from 11 to 37 cases per 100,000 population (24) and with a prevalence of approximately 11.7% in athletes. Overall, it is more frequent in individuals between 30 and 40 years of age who practice sports occasionally, the so-called ‘week-and-warriors’, i.e. people with sedentary jobs who practice sports at the weekend without adequate sports training. The rupture is characterized by an audible ‘crack’, many times without pain and usually during intense sport.

Thereafter, ecchymosis, retraction of the calf muscles, tendon gap on palpation, and reduced or absence of calf strength with positive Thompson's test is evident. Pain is awakened by local palpation and passive dorsiflexion of the foot. The diagnosis is supported by muscle-tendon ultrasound. Conservative treatment, which involves the use of a cast guard with a club foot to be worn for several weeks, is rarely used because it does not guarantee adequate healing with a high rate of recurrence. Treatment is, therefore, surgical with tendon suturing, rapid recovery, and low incidence of recurrence (25).

The most common ligament involvement occurs in ankle sprains, which represent the most frequent acute injury in tennis. It typically occurs during sharp turns, falls from a jump, and slips on the ground, especially on synthetic ground, which offers more friction and can block the shoe in lateral movements. The most affected ligaments are the ‘lateral’ ligaments, such as the anterior peroneo-astragalic (APA), posterior peroneo-astragalic (PPA) ligaments, and the peroneo-calcaneal (PC) ligaments.

Involvement of the sub-astragalic and medial ligaments is less frequent. Rarer is the involvement of the distal tibio-peroneal syndesmosis, whose involvement is responsible for tibio-astragalic instability, and tibia and fibula fractures.

The severity of the ligamentous injury depends on the degree and number of ligaments involved: Grade 1 involvement of the APA, Grade 2 involvement of APA and PC, and Grade 3 involvement of APA, PC, and PPA. Diagnosis is based on the exclusion of fractures and evidence of peri- and sub-malleolar swelling and ecchymosis, as well as anterior drawer and inversion maneuvers, to detect an unstable condition. Diagnostic completion is achieved by X-ray, which is useful to exclude fractures and syndesmosis openings, and MRI to highlight the degree of ligament injury. Treatment depends on the grade of the injury; grade 3 injuries require surgical treatment, grade 1 injuries are treated conservatively with ice, drainage, anti-inflammatories, and anti-edema, grade 2 injuries also require a brace for about 3 weeks.

In all cases, the return to sporting activity is gradual and must be preceded by a period of joint exercises, muscle strengthening, and proprioception (26) (Fig. 3).

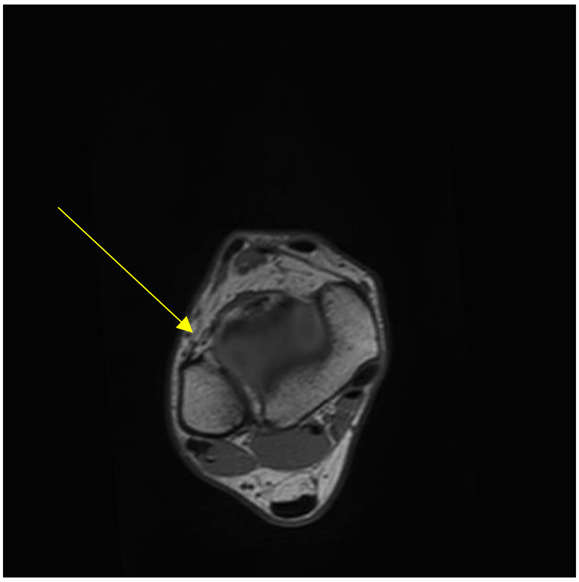

Fig. 3. *Ankle MRI, with the evidence of an APA injurie*

Foot-related pathologies in tennis are heel pain, plantar fasciitis, and tennis hallux. Heel pain refers to a painful syndrome localized in the hindfoot, which has several causes; the most frequent are insertional tendonitis of the Achilles tendon and Sever's disease. The latter is an apophysitis of the calcaneus, i.e., an osteochondrosis of the bony protrusion of the calcaneus in which the Achilles tendon is inserted.

Like the other forms of osteochondrosis, it affects young people under 16 years of age and occurs after strenuous exercise. The pain is aggravated by pressure on the calcaneus and, typically X-ray show an irregularity in the ossification areas of the calcaneus with the possibility of fragmentation of the growth nuclei.

Therapy is purely conservative with rest, anti-inflammatories, and orthoses. Insertional tendinopathy of the Achilles, on the other hand, is typical of the adult subject, linked to functional and repeated overload, and favored by Haglund's deformity and heterotopic calcifications of the bone-tendon junction, all conditions requiring surgical removal treatment.

Plantar fasciitis is a painful syndrome affecting the sole, favored by inadequate footwear and playing on hard ground. Etiology is related to repeated microtrauma that establishes an insertional syndrome of the plantar fascia at the calcaneus and/or metatarsals. Excessive pronation of the foot or forced contraction of the calf muscles contribute to its onset.

The diagnosis is based on an accurate history and physical examination that shows pain referred to the plantar surface of the heel that is more intense during walking, standing, and sports activity; sometimes pain may be referred to the midfoot. The pain is worse in the morning and during walking and then resolves during the day. X-ray examination is useful to exclude the presence of a bony spine, which can form in the case of chronic inflammation. Treatment is conservative, and prevention is fundamental, which must be carried out by wearing suitable footwear (27).

A rather frequent pathology among tennis players and runners is a subungual hematoma, mainly in the first toe and often bilateral. It is associated with an alteration of the nail plate, as in the case of a fungal infection, although the triggering cause is the continuous slipping of the foot inside the shoe with the crushing of the nail and back-flexion of the toes.

In the case of acute pain and severe hematoma, it is necessary to drain the blood to resolve the symptomatology, all in a sterile manner, observing proper rest from sporting activity. Prevention and treatment include the use of appropriate footwear in terms of size and elasticity, proper nail cutting, and the prevention of fungal and bacterial infections.

Sometimes, excessive and repeated dorsiflexion of the fingers can lead to the involvement of the metatarsophalangeal joint with localized pain and swelling and decreased dorsiflexion. On radiographic examination, a decreased joint space between the metatarsal head and proximal phalanx and subchondral sclerosis is revealed, configuring the clinical picture of ‘tennis toe’.

The treatment, initially conservative, often due to the persistence of pain, becomes surgical with debridement of the joint and, in the most severe cases, arthrosis to 20° dorsal flexion to allow optimal gait (25).

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Letter to the Editor

KOHLER DISEASE

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To the Editor,

INTRODUCTION

Kohler's disease (KD) is a rare pediatric condition that primarily affects the tarsal navicular bone in the foot. It is named after the German radiologist Alban Kohler, who first described it in 1908 (1, 2). This condition typically occurs in children between the ages of 5 and 10 and is more common in boys. Key features of KD include pain, swelling and limping or favoring one foot. Radiographic imaging, especially X-rays, plays a crucial role in diagnosing KD. X-rays often reveal changes in the affected navicular bone, such as fragmentation, sclerosis, and flattening. KD is generally self-limiting, meaning that the symptoms tend to resolve on their own over time as the affected bone undergoes a healing process. The condition is usually benign, and the long-term prognosis is favorable. Management of KD is typically supportive. This may involve relieving pain through over-the-counter pain medications, providing supportive footwear, and advising reduced weight-bearing activities until the condition resolves.

Etiology

The exact cause of KD remains unclear, but several factors may contribute to its development (1-18). One theory suggests KD results from temporary disruption of blood supply to the tarsal navicular bone, leading to avascular necrosis. Trauma or repetitive microtrauma, particularly in active children engaged in high-impact activities like running or jumping, is considered a potential factor. Developmental factors may also play a role, as the navicular bone undergoes ossification during childhood, and abnormalities in this process could contribute to KD. Though unproven, a genetic predisposition has been speculated. KD is a self-limiting condition, and treatment focuses on symptom management, including pain relief and restricted weight-bearing, until it resolves.

Clinical presentation

KD typically between the ages of 5 and 10. The clinical presentation of KD involves a set of characteristic signs and symptoms related to the foot, particularly the tarsal navicular bone (1-18). The most common and prominent symptom of KD is localized pain and tenderness in the midfoot, specifically over the tarsal navicular bone. The pain may be exacerbated by activities that involve pressure on the affected foot, such as walking, running, or jumping.

Due to the discomfort and pain associated with the affected foot, children with KD may develop a limp or an altered gait. They may avoid putting full weight on the foot to minimize pain. Swelling around the midfoot area may be observed. This swelling is often localized to the region overlying the tarsal navicular bone and may contribute to the

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overall discomfort. Children may experience a reduction in the normal function of the affected foot. This can include difficulty with activities that require normal foot movement, such as running or participating in sports. Radiographic imaging, especially X-rays, plays a crucial role in diagnosing KD.

X-rays typically reveal characteristic changes in the tarsal navicular bone, such as fragmentation, sclerosis, and flattening, confirming the diagnosis. KD is generally considered a self-limiting condition, meaning that the symptoms tend to improve and resolve spontaneously over time. As the blood supply to the tarsal navicular bone improves and the bone undergoes healing, the pain and other symptoms typically diminish.

Diagnosis

The diagnosis of KD involves a combination of clinical evaluation, imaging studies, and the exclusion of other possible causes of foot pain in children (1-18). A thorough medical history is obtained, with a focus on the onset, duration, and characteristics of foot pain. Information about recent activities, trauma, or any developmental concerns is crucial. Clinical assessment includes a physical examination of the foot, with specific attention to the midfoot region overlying the tarsal navicular bone. The physician evaluates for tenderness, swelling, and any signs of altered gait or limping. Radiographic imaging, particularly X-rays of the foot, is a key diagnostic tool for KD.

X-rays can reveal characteristic changes in the tarsal navicular bone, such as fragmentation, sclerosis, and flattening. These findings are crucial in confirming the diagnosis. Other potential causes of foot pain in children, such as trauma, stress fractures, inflammatory conditions, or infections, need to be considered and ruled out through careful evaluation and sometimes additional tests. Blood tests or other laboratory investigations may be ordered if there is suspicion of an underlying systemic condition contributing to foot pain. However, these tests are not typically required for the diagnosis of KD.

Given the self-limiting nature of KD, close clinical follow-up is often recommended. Regular assessments help monitor the progression of symptoms and healing of the tarsal navicular bone over time.

Differential diagnosis

The differential diagnosis of KD involves considering other conditions that may present with similar symptoms of foot pain in children (1-18). It's crucial to differentiate KD from various potential causes to ensure appropriate management.

Freiberg's disease is a condition characterized by avascular necrosis of the metatarsal head, particularly the second metatarsal. Like KD, it can cause pain and swelling in the foot. Stress fractures, sprains, or other traumatic injuries to the foot can mimic the symptoms of KD. A careful history of recent activities or trauma is essential to differentiate between these conditions. Conditions such as juvenile idiopathic arthritis can cause foot pain in children. Inflammatory arthritis may present with joint swelling, stiffness, and other systemic symptoms.

Osteomyelitis or septic arthritis can cause localized pain and swelling. Infections should be considered, especially if there is a history of trauma or breaks in the skin. Inflammation of the tendons around the foot, such as Achilles tendonitis or posterior tibial tendonitis, can lead to foot pain. These conditions may be associated with overuse or repetitive stress. Conditions affecting the growth plates, such as apophysitis or Sever's disease, may cause foot pain in children. These conditions typically involve the heel or other growth plate areas. Although rare, benign or malignant tumors affecting the foot bones can cause localized pain and swelling.

Imaging studies, including X-rays and possibly advanced imaging like MRI, may be necessary to rule out such conditions. Systemic conditions affecting bone health, such as vitamin D deficiency or metabolic bone disorders, may present with foot pain. Laboratory tests and clinical evaluation are essential for diagnosis. Overuse or repetitive stress on the foot can lead to stress fractures, which may present with pain and swelling. This condition is more common in athletes or individuals engaged in repetitive activities.

Therapies

The treatment of KD is generally conservative and focuses on managing symptoms while allowing for the natural healing of the affected navicular bone (1-18). Nonsteroidal anti-inflammatory drugs may be prescribed to alleviate pain and reduce inflammation associated with KD. These medications can help improve the child's comfort during the healing process. Restriction of weight-bearing activities on the affected foot is commonly advised to reduce stress on the navicular bone. This may involve using crutches or other assistive devices to limit pressure on the foot during the initial stages of treatment.

Providing supportive footwear with cushioning and arch support enhances comfort and reduces pressure on the navicular bone, aiding healing. Orthotic devices or insoles may help by redistributing pressure and addressing biomechanical issues. Regular follow-ups with pediatric orthopedic specialists are crucial for monitoring progress through clinical assessments and, if needed, imaging studies. Physical therapy can maintain joint mobility, strengthen muscles, and improve foot function with tailored exercises. Educating the child and caregivers about KD's self-limiting nature, expected recovery timeline, and treatment adherence fosters compliance and satisfaction.

CONCLUSIONS

In conclusion, KD is a rare condition first documented by Alban Kohler. Diagnosis involves clinical evaluation, imaging studies, and ruling out other causes of foot pain in children. A detailed medical history and X-rays help narrow the diagnosis. KD is typically benign with a favorable prognosis. Management focuses on symptom relief through pain medication, supportive footwear, and reduced weight-bearing activities until recovery.

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Comparative Analysis

ULTRASOUND-GUIDED OXYGEN-OZONE THERAPY: A NOVEL APPROACH FOR MANAGING SPINAL PATHOLOGIES

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ABSTRACT

This document presents an overview of oxygen-ozone (O_2-O_3) therapy for spinal pathologies, focusing on ultrasound-guided infiltration techniques. The ultrasound method appears to be suitable alongside traditional closed-sky, X-ray, and Computer Tomography (CT)-guided techniques due to its characteristics, such as the absence of ionizing radiation, enhanced specificity in targeting pain points, and a reduced number of required treatment sessions. The procedure entails detailed patient preparation, informed consent, and careful ultrasound guidance for infiltration at lumbar, cervical, and dorsal levels, along with considerations for potential complications and contraindications. Indications include zygapophyseal syndromes and extruded disc herniations. Overall, this therapeutic approach is positioned as a valuable option in treating spinal disorders, maximizing efficacy while minimizing risks.

KEYWORDS: *pain, therapy, oxygen, ozone, infiltration techniques, oxygen-ozone therapy, spine, disorders*

INTRODUCTION

In addition to traditional closed-sky, X-ray, and Computed Tomography (CT)-guided techniques employed in paravertebral spinal ozone infiltration therapy (1-20), the ultrasound-guided method warrants particular attention due to its evolving role in contemporary clinical practice (21-26).

This article intends to delineate the authors' experiences in applying oxygen-ozone therapy for the management of spinal pathologies. The objective of this document is to conduct a comparative analysis of the various protocols and procedures that have been established within this domain.

By engaging with existing methodologies, practitioners may critically evaluate and enhance their clinical approaches, informed by empirical evidence and the latest advancements in the field. Such examination not only contributes to the state of the art in spinal therapy but also fosters the optimization of patient outcomes through more refined and targeted treatment strategies. The main peculiarities of this method are as follows:

1. absence of exposure of the operator and patient to ionizing radiation;
2. the possibility of performing paraforaminal infiltrations (especially at the lumbar level) and zygapophyseal infiltrations;
3. reduction in the number of sessions required due to the greater specificity and precision of the infiltrations compared to classic paravertebral intramuscular injections (a maximum of 2-3 infiltrations required for facet syndromes).

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INFILTRATIVE TECHNIQUE

Upon securing comprehensive informed consent from the patient, steps are undertaken to proceed with the infiltrative technique.

Lumbar and lumbosacral level

The patient is placed in the prone position, and a thorough disinfection of the skin in the area to be treated is performed. A 2-4 MHz curved probe is used, protected with an appropriate transparent sterile probe cover. In the longitudinal section, the spinous processes are counted in a caudo-cranial direction starting from the posterior margin of the sacral profile (Fig. 1).

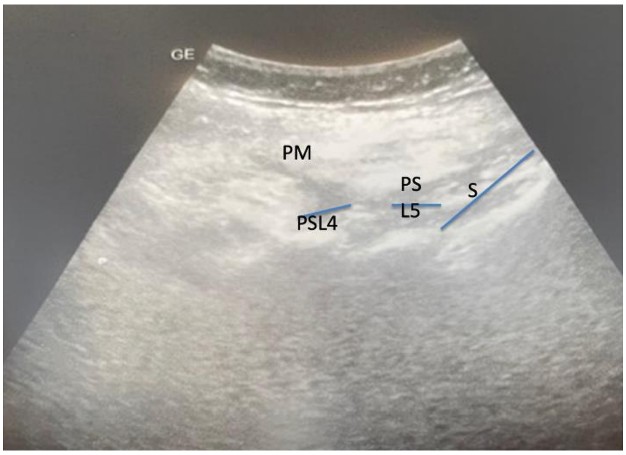

Fig. 1. *Sacral (**S**); spinal process L5 (**PS L5**); spinal process L4 (**PS L4**); paravertebral muscle (**PM**).*

Once the spinous process of the level to be treated has been reached, the probe is rotated on the transverse plane, and the profile of the vertebra with the central spinous process, laminae, zygapophyseal joints, and transverse processes appears (Fig. 2).

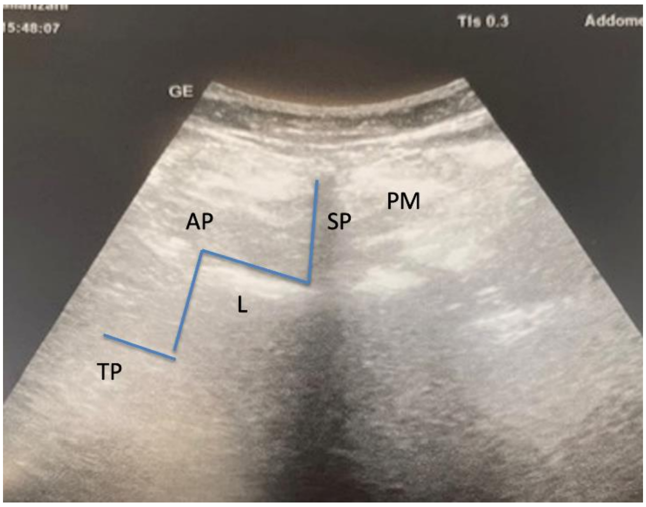

Fig. 2. *Spinal process (**SP**); lamina (**l**); articular process (**AP**); transverse process (**TP**); paravertebral muscle (**PM**).*

An eco-reflective needle (21-22 G, 100-120 mm) is introduced laterally to the probe and directed with a lateral-medial inclination of 15-20° under ultrasound guidance at the joint, transverse, or paraforaminal level depending on the pathology to be treated. Once the correct position of the needle has been documented with a photo (Fig. 3), 5 ml of a concentrated oxygen-ozone (O_2-O_3) mixture (20 mcg/ml) is infused (mono or bilaterally) at a deep level, after aspiration, and 5 ml of the same mixture on a paravertebral intramuscular level after retracting the needle by 3-5 cm. At the end of the procedure, the needles are removed and the area is kept compressed for 30-60 seconds. The expansion of the gas can cause transient lumbar pain, potentially radiating to the groin or abdomen and more rarely to the lower limbs; the patient must be informed of this before the procedure.

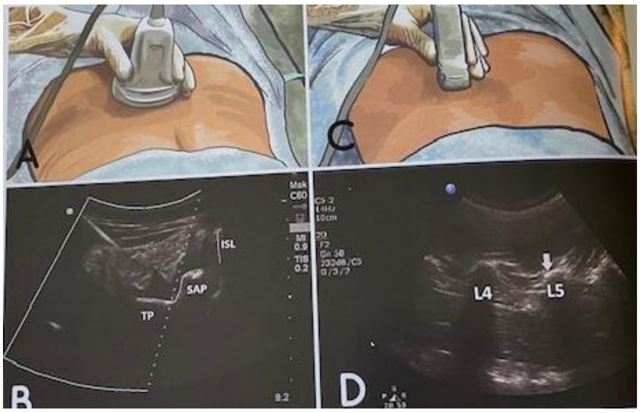

Fig. 3. *Needle (N); transverse process (**TP**); superior articular process (**SAP**); intra spinal ligament (**ISL**).*

The patient is then placed in a sitting position, after which he is placed in an upright position and after approximately 10 minutes of observation, discharged from the outpatient setting. The procedure can be repeated for three sessions spaced 7-10 days apart.

Cervical level

After obtaining adequate written consent as specified above, the patient is placed in a prone position with a pillow under the chest, hyperflexing the head with hands crossed under the forehead. A 5-7 MHz linear probe, protected by an appropriate sterile probe cover, is used to count the spinous processes in a cranio-caudal direction from C1 to C7 (Fig. 4).

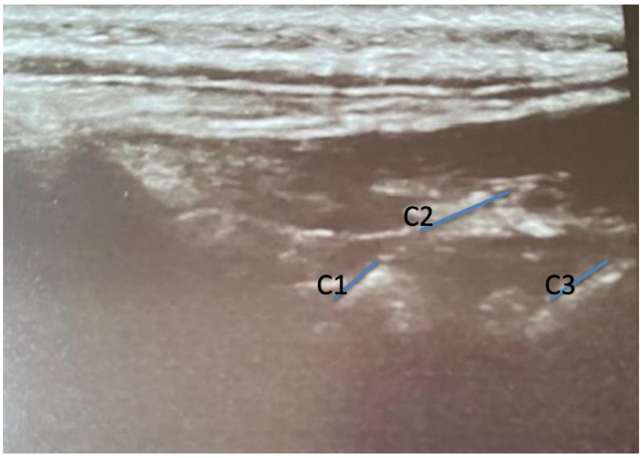

Fig. 4. *Spinal process C1-C2-C3.*

Once the level to be treated has been identified, the probe is placed in a cross-section to visualize the central spinous process, the two lateral laminae, and the horizontal articular processes (Fig. 5).

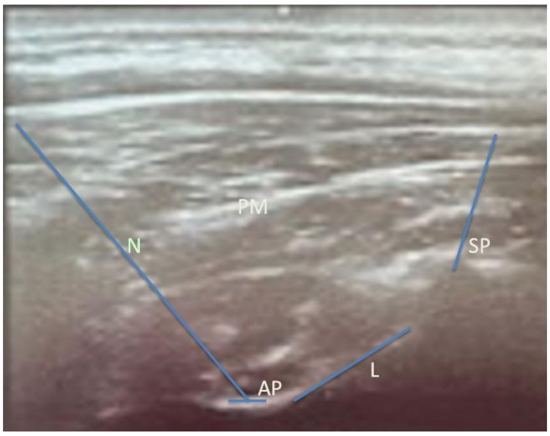

Fig. 5. *needle (**N**); articular process (**AP**); lamina (**L**); spinal process (**SP**); paravertebral muscle (**PM**).*

A 22 G L 50 mm echo-reflecting needle is inserted into the side of the probe and, under ultrasound guidance, is advanced in the muscular plane with a 10-15° inclination towards the articular process (seeking bone contact and documenting the correct position of the needle with photos) (Fig. 6).

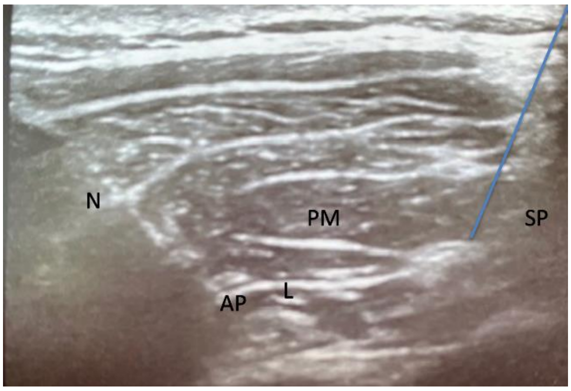

Fig. 6. *Needle (**N**); articular process (**AP**); lamina (**L**); spinal process (**SP**); paracervical muscle (**PM**).*

A second possible technique is the paravertebral one. Still using a 5-7 MHz linear probe in the longitudinal section, the spinous processes are highlighted, followed by placing the probe in the paravertebral position until the articular processes (convexity) and the intervertebral foramina (concavity) are highlighted (Fig. 7).

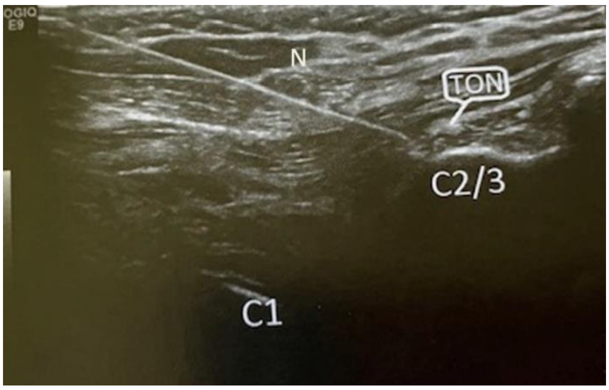

Fig. 7. *Needle (**N**); articular process (**C1, C2/3**); third occipital nerve (**TON**).*

Intra-articular processes from C2-C3 to C6-C7 are counted, and the level to be treated is identified. The needle is positioned (inserted in a cranio-caudal direction) on the caudal margin of the joint convexity, always seeking bone contact (Fig. 8). At this point, 5 ml of a gaseous O_2-O_3 mixture (concentration 15 mcg/ml) is infused mono or bilaterally; 3 ml is injected at the joint plane, and 2 ml at the intramuscular plane after retracting the needle by 2-3 cm.

For zygapophyseal syndrome at the single-level cervical, the closed technique is more suitable in cases of cervicalgia due to cervicouncoarthrosis, as it is simpler and less burdened by side effects. An ultrasound-guided technique with 3 sessions spaced 7-10 days apart is often sufficient.

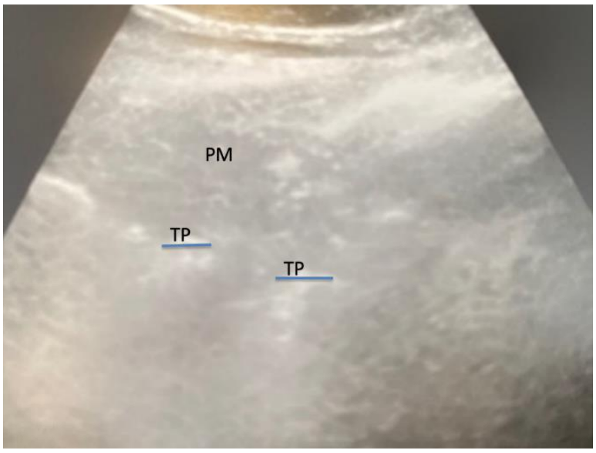

Fig. 8. *transverse process (**TP**); paravertebral muscle (**PM**).*

Dorsal level

After obtaining adequate written consent, the patient is positioned prone, with a cushion placed at the epigastric level to accentuate physiological dorsal kyphosis. Back pain localized to one segment may be due to a MID (Minor Intervertebral Disorder) or, less frequently, to zygapophyseal arthrosis or an extruded herniated disc. Therefore, it is essential, at the lumbar and cervical levels, to evaluate MRI for correct diagnosis.

Once the point to be treated has been identified and marked (often unilateral), a 5-7 MHz linear probe is positioned in the transverse plane to visualize the spinous process, laminae, zygoapophyseal processes, and costo-transverse joints (Fig. 9).

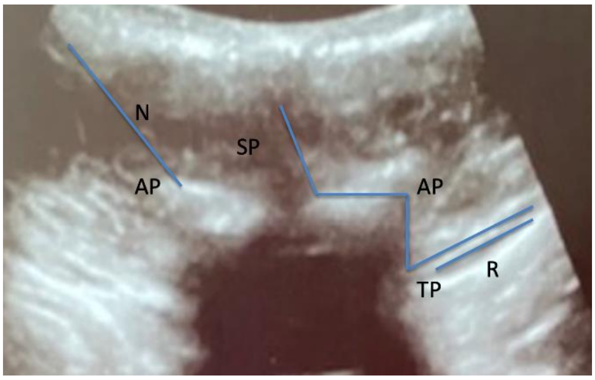

Fig. 9. *spinal process (**SP**); articular process (**AP**); transverse process (**TP**); rib (**R**); needle (**N**).*

The 21 or 22 G L 50-70 mm needle is inserted laterally to the probe and, with a 10-15° inclination, is directed to the lateral angle of the vertebral profile, the site of the zygoapophyseal joint, looking for bone contact and documenting the position of the needle (Fig. 9).

Then, 5 ml of O_2-O_3 gas mixture (concentration 15 mcg/ml) is infused: 3 ml on the joint plane and 2 ml on the paravertebral intramuscular plane, after retracting the needle by 2-3 cm, depending on the type of patient.

Ultrasound-guided dorsal infiltrations are particularly indicated, as noted earlier, in cases of DIM or facet syndrome at a single level or extruded disc herniations with intercostal neuritis. In the case of diffuse, multilevel, and bilateral back pain, the closed technique is more suitable due to fewer side effects.

Indications and advantages of ultrasound-guided techniques

As previously mentioned, ultrasound-guided ozone infiltration techniques are particularly indicated in treating extruded disc herniation and vertebral zygoapophyseal syndrome. In these cases, they can represent a valid alternative to closed-air and X-ray or CT-guided techniques, even if these latter two remain the most effective for the treatments mentioned above.

A significant advantage of ultrasound-guided techniques is the patient's non-exposure to ionizing radiation. Compared to closed-air techniques, the needle is placed closer to the area to be treated (intra-articular and paraforaminal), which should increase the therapeutic efficacy of the ozone while reducing the number of sessions required.

DISCUSSION

The combination of oxygen-ozone therapy and ultrasound-guided infiltration represents a contemporary approach allowing precise intervention in various spinal pathologies. Compared to traditional methods, this technique provides advantages regarding safety and patient comfort. The reduced exposure to ionizing radiation and greater specificity in infiltrating target areas can potentially lead to better clinical outcomes, including reduced pain and fewer repeat procedures.

This article aims to demonstrate that the choice of technique can affect patient safety and treatment efficiency. By comparing different protocols, practitioners can gain insights into their effectiveness, optimize their practices, and enhance patient care.

CONCLUSIONS

Ultrasound-guided ozone infiltration techniques are the middle ground between closed-sky methods and guided X-ray and CT techniques. They are particularly indicated in treating facet syndromes and vertebral extruded disc herniation compared to classic paravertebral intramuscular injections.

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Case Report

LUMBAR PEDICLE STRESS FRACTURE IN A YOUNG SOCCER PLAYER: A CASE REPORT

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ABSTRACT

This case report details the presentation, diagnosis, and management of a lumbar pedicle stress fracture in a 19-year-old male soccer player. Lumbar pedicle stress fractures are uncommon in young athletes, and their diagnosis can be challenging due to subtle clinical manifestations. This report aims to contribute to the understanding of this specific injury pattern, emphasizing the importance of early recognition and appropriate management in young individuals engaged in high-impact sports.

KEYWORDS: *lumbar pedicle, fracture, sports, spine, vertebra, spondylolysis, surgery*

INTRODUCTION

Lumbar pedicle stress fractures represent a unique subset of spinal injuries characterized by microstructural damage resulting from repetitive mechanical loading. They consist of the breakage of one or both vertebral pedicles, the bony structures connecting the posterior arch of the vertebra to the vertebral body (1-12). Most spinal injuries typically involve the posterior elements, while lumbar pedicle fractures stand out due to their unique location and potential impact on spinal stability. The most common causes are spondylolysis (13-18), congenital anomalies (19, 20), and previous spinal surgery (21-24).

Lumbar pedicle stress fractures are often subtle and may elude initial detection, posing a diagnostic challenge for clinicians. Stress fractures in weight-bearing bones are well-documented; conversely, the literature on lumbar pedicle stress fractures remains limited.

The underlying etiology, biomechanics, and optimal management strategies for such fractures remain areas of active investigation. Through the detailed examination of this case, including the patient's clinical history, imaging findings, and therapeutic interventions, we aim to elucidate the complexities of lumbar pedicle stress fractures.

Our report underscores the importance of a heightened clinical suspicion for such injuries and the implications of early detection ensuring favorable patient outcomes. Lumbar pedicle stress fractures are rare occurrences, particularly in the younger population. This case involves a 19-year-old male soccer player who presented with persistent lower back pain following an intense training session. The atypical nature of these fractures in young athletes presents an interesting challenge that merits exploration.

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CASE REPORT

A 17-year-old soccer player was referred to our radiology department for an activity related low back and right leg pain suddenly appeared during an intense football match. Despite initial attempts at conservative management, the pain persisted, prompting further investigation. His height was 176 cm and BMI was 23. The patient had no history of previous traumatic injury, orthopedic surgery, underlying metabolic disorders. His soccer training routine involved high-intensity drills, frequent accelerations, and sudden stops, likely contributing to the repetitive stress on the lumbar spine. Clinical examination revealed localized tenderness over the left lumbar region without neurological deficits. Lasegue and Wasserman's test allow us to exclude slipped discs.

The young man was not responsive to non-steroidal anti-inflammatories to manage his pain. Initial assessments, including conventional radiographs, were inconclusive. Spinal radiography showed no signs of vertebral pathologies as spondylolisthesis. Initial radiographs did not show any overt abnormalities. However, recognizing the possibility of a stress fracture, advanced imaging studies, including magnetic resonance imaging (MRI) and computed tomography (CT) scans, were ordered (Fig. 1A-C).

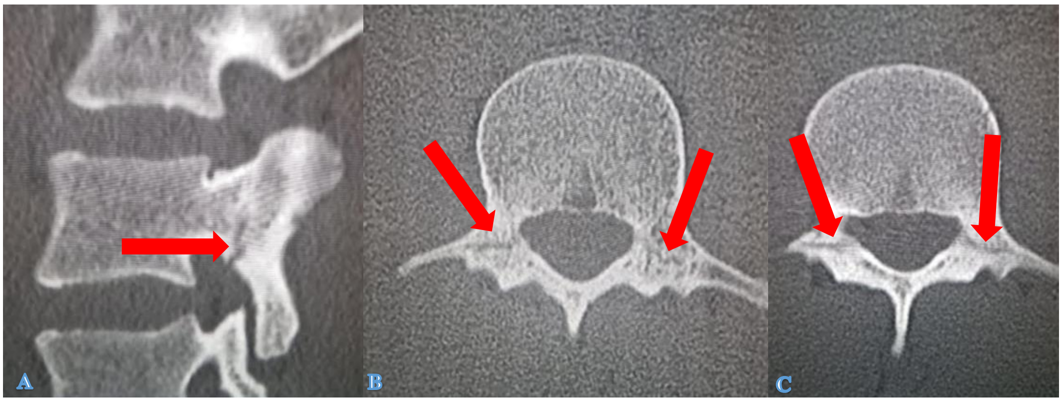

Fig. 1. ***A****): CT scan pedicle fracture line longitudinal course (arrow);* ***B****-****C****): axial CT scans with reconstruction algorithm for bone, bipenducular fracture of L3 (****arrows****).*

The MRI revealed a subtle linear hyperintensity in the left lumbar pedicle, consistent with bone marrow edema, a characteristic found in stress fractures. Confirmatory evidence was obtained through CT imaging, which displayed a well-defined fracture line through the left pedicle of the L3 vertebra. No focal bony lesion or osteopenia were observed (Fig. 2).

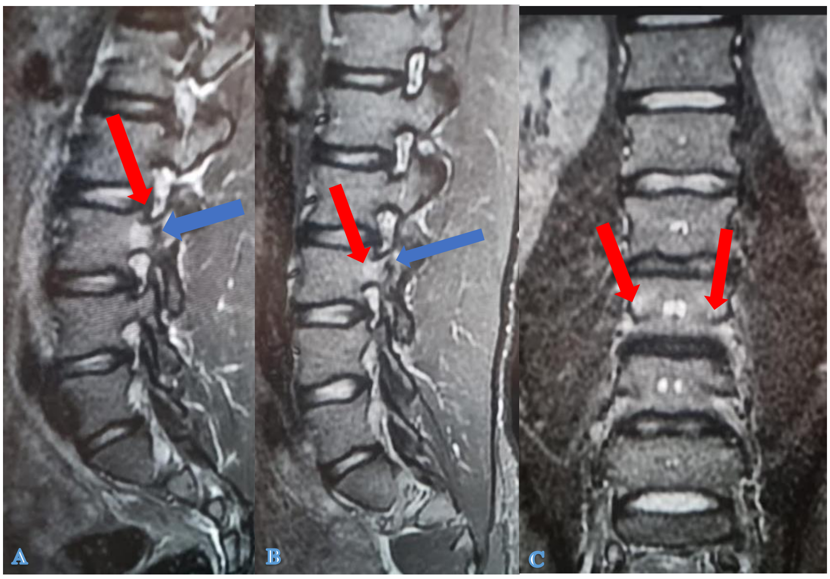

Fig 2. ***A-B****): Flair sagittal MRI scans (A right, B left) documenting the post-traumatic edema at the pedicle level (****red arrows****), and the longitudinal stress fracture line (****blue arrows****);* ***C****): coronal MRI scan: confirmation of pedicle stress fractures (****red arrows****).*

Considering the clinical presentation and imaging findings, a diagnosis of lumbar pedicle stress fracture was established. The rarity of this condition in a young athlete and the potential impact on his sports participation raised questions about the most appropriate management strategy, necessitating a comprehensive and individualized approach.

This case highlights the importance of a thorough clinical evaluation, including advanced imaging, in diagnosing subtle spinal injuries such as lumbar pedicle stress fractures, particularly in the context of high-impact sports. The subsequent management decisions were tailored to address both the unique characteristics of the fracture and the patient's athletic aspirations, leading to a multidisciplinary treatment plan.

DISCUSSION

Lumbar pedicle stress fractures, though infrequent in young athletes, necessitate careful consideration due to their potential impact on performance and long-term spinal health. In this case, the patient's involvement in soccer, a sport demanding rapid changes in direction, frequent accelerations, and abrupt decelerations, likely contributed to the development of stress fracture.

The diagnostic challenges associated with lumbar pedicle stress fractures are noteworthy. Initial radiographic assessments may not reveal the subtle nature of these fractures, emphasizing the importance of advanced imaging modalities, such as MRI and CT scans, for accurate diagnosis. Understanding the biomechanics of stress fractures and their varied presentations is crucial for clinicians to promptly identify and appropriately manage these injuries.

This case prompts a discussion on the optimal management of lumbar pedicle stress fractures in young athletes. Conservative management, as employed in this instance, involves activity modification, physical therapy, and a gradual return to sports. It is essential to balance the need for recovery with the athlete's eagerness to return to play, ensuring that the healing process is not compromised. Monitoring the patient's progress through regular follow-ups and imaging assessments is vital to gauge the effectiveness of the rehabilitation program and to identify any potential complications.

Additionally, the psychological impact of a stress fracture on a young athlete should not be overlooked. The extended period of restricted activity and potential fears of re-injury may contribute to emotional stress and anxiety. Incorporating psychological support into the overall management plan can be beneficial in addressing these aspects and promoting a holistic recovery.

This case report contributes to the growing body of literature on lumbar pedicle stress fractures in young athletes, emphasizing the need for a comprehensive approach to diagnosis, management, and rehabilitation. Further research is warranted to establish standardized protocols for the prevention, early detection, and effective management of lumbar pedicle stress fractures, with a focus on optimizing the return-to-play process while prioritizing the long-term musculoskeletal health of the athlete.

Management

The patient was managed conservatively with a tailored rehabilitation program, including activity modification, physical therapy, and gradual return to sports. Regular follow-ups and imaging assessments monitored the healing process, ensuring a safe and successful return to soccer activities.

CONCLUSIONS

In conclusion, this case report highlights the importance of recognizing and managing lumbar pedicle stress fractures in young athletes, particularly those involved in high-impact sports. The diagnosis of this condition can be challenging due to its subtle nature, and advanced imaging modalities such as MRI and CT scans are often necessary for accurate diagnosis. A multidisciplinary approach, involving sports medicine specialists, orthopedic surgeons, and physiotherapists, is essential for developing a comprehensive treatment plan that addresses both the unique characteristics of the fracture and the athlete's athletic aspirations. Conservative management, including activity modification, physical therapy, and gradual return to sports, can be effective in promoting healing and facilitating a successful return to athletic pursuits. Further research is needed to establish standardized protocols for the prevention, early detection, and effective management of lumbar pedicle stress fractures in young athletes.

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Evaluation Study

USE OF PROPRIOCEPTION DURING KNEE REHABILITATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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ABSTRACT

Sport practices without basic training, training with large loads, with high and little recovery time, can provoke traumatic injuries. Damage to the anterior cruciate ligament is a very common traumatic injury in many sports disciplines. In recent years we have seen an increasing trend of its injury from the practice of sports by non-professionals caused by non-compliance with pre- and post-workout preparation stages. The purpose of this article is to highlight through clinical cases the effectiveness of treatment through proprioceptive rehabilitation after intervention of ligament reconstruction of the anterior cruciate ligament. To gather theoretical information, bibliographic research based on literature after the 2000s and selected online materials obtained from recent studies has been conducted. The study is based on clinical cases and was conducted during the period September 2023-January 2024, in which five patients were studied. Subjects were treated at the physiotherapy center "Orthomed Sport". Assessment of functional progression in patients has been performed every week, where pain, goniometer articular Range of Motion (ROM), muscle strength, and intra-articular bleeding have been measured. Exercises were performed gradually and under the control of a physiotherapist. From the result of the therapy, it is evident how proprioceptive reeducation is very important in the chronic phase of rehabilitation, as it improves engine control, postural stability, sensitivity after movement, and muscle strength.

KEYWORDS: *genu articulation, ACL, post-operative, rehabilitation, physiotherapy*

INTRODUCTION

Over the past few years, rehabilitative treatment following anterior cruciate ligament (ACL) surgery has accelerated, but the primary objective of the physiotherapist remains the same: to restore the patient to their pre-injury functional level. To achieve this goal, normal recovery of joint mobility, muscle strength, and knee stability must be ensured, allowing the patient to return to activity as quickly as possible.

The reconstructed ligament must be carefully protected to allow for proper healing and prevent damage to the transplanted tissue. However, prolonged immobilization is not advisable due to several side effects, such as muscle hypotrophy, alterations in articular cartilage and ligaments, and reduced joint mobility resulting from intra-articular scar adhesions.

Previously, patients who underwent ACL surgery were immobilized for a long period to protect the new ligament. Brotzman (1) noted that quadriceps femoris muscle atrophy after 5 weeks of immobilization was 40%, while atrophy of this muscle due to immobilization in knee flexion was even greater at 60%. Additionally, he reported that using

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an accelerated rehabilitation protocol results in a reduction of knee stiffness in flexion by 10° and a decrease in joint fibrosis from 12% with classical treatment to 4% with accelerated treatment (1).

Recent studies show that the bundles of the anterior cruciate ligament (ACL) perform different roles during knee movements: the anteromedial bundle is stretched during flexion, while the posterolateral bundle is stretched during extension; the latter also has greater resistance to hyperextension (2).

The most common mechanisms of ACL injury are:

- external rotation in knee valgus;
- knee flexion combined with internal rotation;
- hyperextension combined with internal rotation.

In these cases, the ligament can be damaged in less than 2/100 a second, making it impossible for the athlete to execute a voluntary corrective muscular response that requires more than 200 milliseconds.

The most frequent and traumatic injury to the knee joint is ACL rupture. The consequences of this ligament rupture are:

- joint instability leading to mechanical stress on other structures such as the menisci and cartilage. The patient experiences a sensation that the knee is shifting forward or out of its natural position each time they stand up;
- pain localized in the joint, with the patient reporting a numb feeling in the lateral part of the thigh;
- joint blockage (reduction in range of motion or ROM) resulting from joint pain during movement and the lack of integrity of a crucial component of joint function, such as the ACL;
- swelling (joint effusion): typically, it does not appear immediately but a few hours after the injury. The swelling may decrease on its own after a few days, but the knee will remain unstable, and returning to sports activity without proper physiotherapeutic treatment may lead to further knee problems;
- muscle hypotrophy (quadriceps femoris) because of joint immobility due to pain and walking with slight knee flexion (2).

As a result of the rupture, knee stability is reduced, and the tibia shifts forward by 0.5-1 cm relative to the femoral surface. This forward shift constitutes the so-called anterior drawer syndrome, which is provoked as follows: the knee is flexed to 90°, and with the hands placed on the popliteal fossa, the tibia is pulled forward. If the tibia shifts forward, it indicates an ACL rupture. Often, ACL rupture is accompanied by medial collateral ligament rupture and medial meniscus rupture (3).

Thanks to arthroscopic techniques, ACL reconstruction has become a very common procedure. The most modern surgical treatment for ACL injury is arthroscopic reconstruction using the patient's own tendon.

The most commonly used grafts are those from the semitendinosus-gracilis tendons and the patellar tendon (4).

Recent studies have confirmed the effectiveness of both types of interventions in the functional recovery of the injured knee joint(5).

ACL injury results in joint instability and, over time, in the absence of proper surgical treatment, leads to progressive reduction in joint mobility, degeneration of articular cartilage, meniscal damage, and the development of post-traumatic osteoarthritis (6).

In addition to the quadriceps femoris muscle, strengthening of the hamstring and gastrocnemius muscles is also addressed. The main objective is to ensure that the strength of the flexor muscles matches that of the extensor muscles (7).

Classic rehabilitation protocols are based on the concepts of strength and movement, while accelerated protocols also incorporate proprioceptive exercises, making the rehabilitative treatment more functional. Proprioceptive exercises should be performed progressively.

Given that there is no definitive base protocol for ACL rehabilitation, physiotherapists rely on various protocols aimed at:

- rapid mobilization and loading;
- swift control of edema;
- muscle strengthening;
- proprioceptive re-education;
- cardiovascular training.

This article aims to provide a comprehensive overview of ACL rehabilitation following surgical intervention. In this work, the ACL has been examined by describing its function, methods of injury, incidence, symptoms following injury, types of surgical intervention, and rehabilitation according to accelerated protocols.

Five patients were studied as case examples to highlight the importance of proprioceptive treatment. Thanks to proprioceptive treatment, these patients achieved good results in knee joint functionality following surgical intervention.

MATERIALS AND METHODS

In this study, the selected therapeutic protocol is the Campbell Clinic protocol, as it includes mobilization, extension, loading, and functional rehabilitation in the early stages. This protocol is not considered "aggressive" regarding the rehabilitative phase and returns to sports activity.

The article examines and treats five patients aged 19 to 32, four of whom are professional athletes, and one is an office worker. All patients, in addition to having an ACL injury, also had a medial meniscus tear. The study is a case study conducted from September 2023 to January 2024. The subjects were treated at the physiotherapy center 'Orthomed Sport'. All patients were presented at the clinic following ACL surgical intervention. The subjects were informed about the study's purpose and that their personal data would not be published. They were assessed through questionnaires and various measurements (goniometer, tape measure, etc.). Their treatment at the clinic lasted for 12 weeks, with the first 8 weeks at a frequency of 5 days per week and the remaining 4 weeks at a frequency of 3 days per week, alternating physiotherapy with hydrotherapy.

The physiotherapeutic protocol used is Campbell Clinic because it includes mobilization and knee joint extension in the early stages. It also allows for a return to sports activity without the use of a brace 6 months after surgical intervention.

After taking the patient's history, a static postural assessment and a dynamic postural assessment were conducted. Following the visit and objective examination, the patients began treatment with Continuous Passive Motion (CPM), which helps to increase the joint ROM of the knee. In addition to CPM, an electrical stimulator was used as an adjunct to achieve quadriceps femoris muscle contraction. Functional progress was evaluated weekly, focusing on pain, ROM with a goniometer, muscle strength, and intra-articular bleeding.

Rapid joint mobilization not only promotes tissue nourishment but also maintains good muscle tone. Once a good, pain-free active mobilization of the knee joint is achieved, patients perform muscle strengthening exercises through isometric contractions of the quadriceps to achieve good tonotrophy. In addition to strengthening the quadriceps femoris muscle, emphasis was also placed on other muscles in the femoral region, without neglecting the gastrocnemius and gluteus muscles, which play a role in stabilizing the knee joint. At the end of each session, patients performed stretching exercises and cryotherapy.

Once a full, pain-free ROM and good muscle strength are achieved, patients perform proprioceptive exercises using tools such as the Freeman Table, Bosu, resistance bands, balance boards, etc. The exercises are conducted in a gradual and controlled manner, with 8-10 repetitions for 3 sets.

During the "motor reprogramming" phase through proprioceptive exercises, patients also engage in sport-specific training related to their activity. They perform directional changes, stationary jumps, diagonal jumps, step exercises, etc. These patients perform proprioceptive exercises on the Freeman Table before each workout or match; specifically, they complete bipodal exercises for one and a half minutes and monopodal exercises for one and a half minutes. The aim of these exercises is to enhance the effectiveness of proprioceptive treatment in post-surgical rehabilitation of the ACL.

For each patient, two physiotherapy records were used: one at the initial assessment (in) for evaluating the patient and one at discharge (out) to assess the effectiveness of the treatment. At the conclusion of the rehabilitation program, conclusions for all five patients are presented with corresponding tables (Table I) and Graphs (1-10).

RESULTS

By observing the results of the treated clinical cases, the use of a well-designed rehabilitation protocol combined with a robust proprioceptive program yields satisfactory results in patient recovery following ACL reconstruction.

From the data, it is evident that proprioceptive re-education is crucial in the rehabilitation phase, as it enhances motor control, postural stability, movement sensitivity, and reduces the risk of re-injury.

Proper proprioceptive re-education is essential for achieving good functional outcomes in the knee joint following surgical intervention.

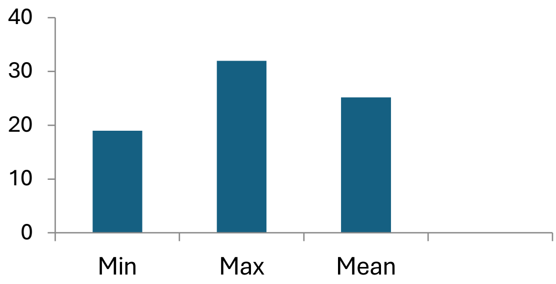
All treated patients utilized the same rehabilitative techniques, and at the conclusion of the rehabilitation cycle, the following results were observed:

- patients who experienced significant pain: 80% achieved complete pain relief, while 20% experienced partial improvement in knee pain;
- patients with joint limitation: 100% achieved full recovery of joint mobility;

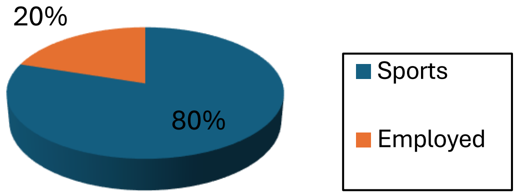
- patients with intra-articular bleeding: 100% achieved complete resolution of the bleeding;
- patients with reduced muscular capacity: 100% achieved full improvement in muscle strength.

Table I. *Descriptive statistics.*

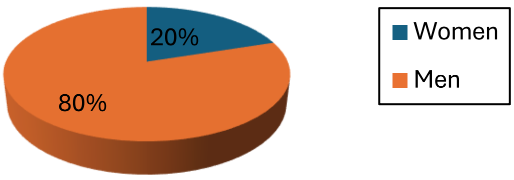
Age	Mean Minimum Maximum	25.2 years 19 years 32 years
Patient Type	Sports Employed Unemployed	4 1 0
Gender	Female Male	1 4
Pain	Total reduction Partial reduction	4 1
Joint Limitation	Full recovery Partial recovery	5 0
Muscular Capacity	Full recovery Partial recovery	4 1
Use of Assistive Devices	Crutches Braces Crutches + Braces None	2 0 1 2
Intra-Articular Bleeding	Full recovery Partial recovery	5 0
Type of Intervention	Patellar tendon graft Semitendinosus/Gracilis tendon graft	1 4
Physiotherapy Description	Kinetek/Patellar mobilization Electrical stimulator/Bike Isometric contractions Isotonic contractions Squat (single/double leg) Freeman table/Motomed/Bozu Bands/skimmy/Hydrotherapy Balance exercises Theraband exercises Final degree leg extensions Cryotherapy post-exercise	5 5 5 5 5 5 5 5 5 5 5



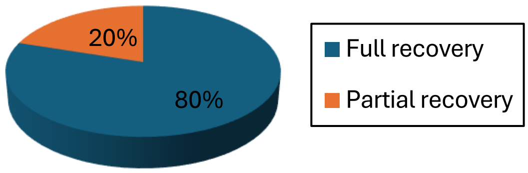
Graph 1: *Age.*



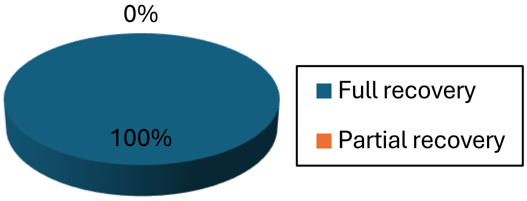
Graph 2: *Patient Type.*



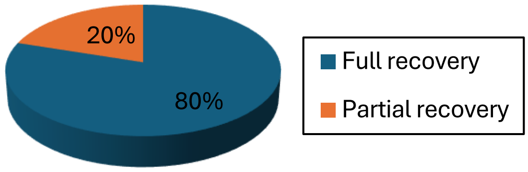
Graph 3: *Gender.*



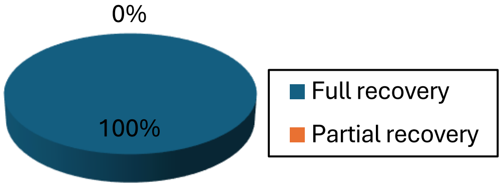
Graph 4: *Pain.*



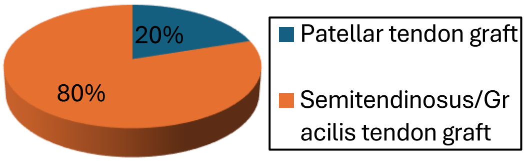
Graph 5: *Joint limitation.*



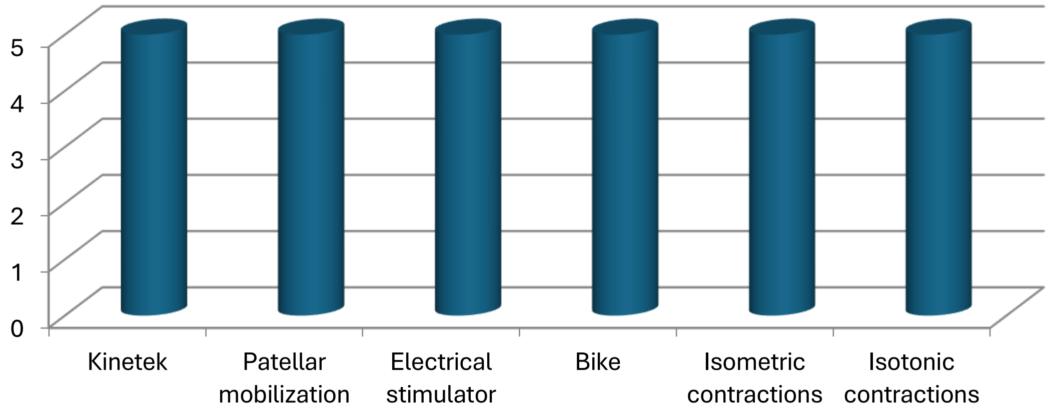
Graph 6: *Muscular capacity.*



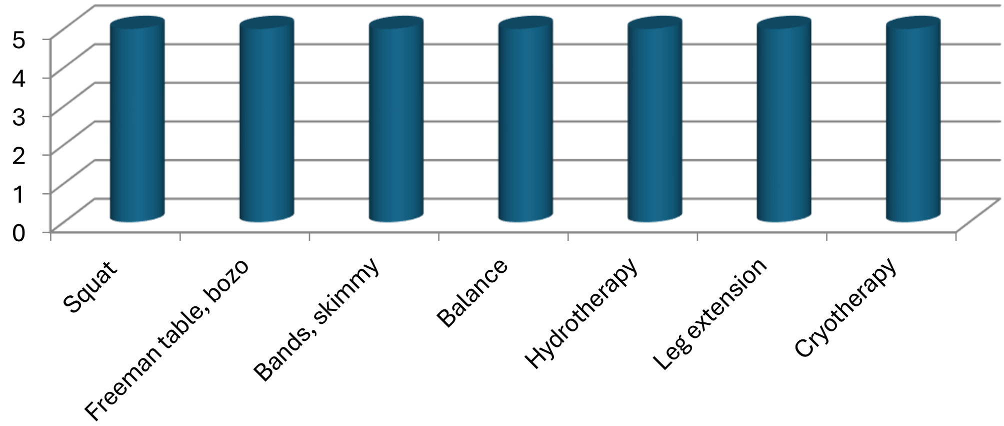
Graph 7: *Intra articular bleeding.*



Graph 8: *Type of Intervention.*



Graph 9. *Physiotherapy description.*



Graph 10. *Physiotherapy description.*

DISCUSSION

Numerous aspects of rehabilitation following ACL reconstruction have been investigated with Level I and II clinical trials. As with most systematic reviews, including published studies often involves a publication bias in favor of positive findings. This is less relevant when studying rehabilitation, as both positive and negative findings are deemed important. Although many of the included studies have a selection bias, it is still possible to draw some valuable conclusions.

Overall, no brace or length of brace wear demonstrated an advantage over another type of brace, another duration of bracing, or no bracing. Bracing does not provide any benefit and is not necessary. Accelerated rehabilitation has shown no deleterious effects, and it is likely safe for patients to begin immediate postoperative weight-bearing, move the knee from 0 to 90 of flexion, and perform closed-chain strengthening exercises.

Eccentric quadriceps muscle strengthening and isokinetic hamstring muscle strengthening were safely incorporated three weeks after surgery; they may be safe sooner, but further research is needed.

Neuromuscular exercises are not likely to harm patients; however, their impact was small, making them unlikely to yield large improvements in outcomes or help patients return to sports faster.

Neuromuscular exercises should not be performed to the exclusion of strengthening and range-of-motion exercises.

The studies presented in this paper focused on improving rehabilitation following ACL reconstruction, with a goal of safely allowing expeditious return of mobility, strength, and ultimately sport participation.

However, few studies measured the ability to return to sports and its timing following the interventions. The availability of such data could strengthen the conclusions of studies and should be considered in future research. Despite the large number of randomized trials, further investigations of the timing of rehabilitation and supplemental rehabilitation exercises are needed to continue to improve the care and function of patients following ACL reconstruction.

CONCLUSIONS

Following ACL reconstruction, patients often exhibit deficits in muscle strength, activation, power, postural stability, and biomechanical alterations. These factors negatively impact the psychological aspect, and decreased mobility increases the risk of re-injury.

This study confirmed that proprioceptive and balance exercises improve postural stability during the initial rehabilitation phase following ACL reconstruction. It was also confirmed that there are no contraindications for neuromuscular exercises, which can be safely used in patients who have undergone ACL surgery. At the final assessment, it was noted that all patients who used proprioceptive exercises fully regained muscle strength and joint mobility, resolving intra-articular bleeding. Regarding pain, 80% of patients experienced complete relief, while 20% had partial improvement.

It was observed that while proprioceptive rehabilitation is crucial, it alone does not complete knee joint rehabilitation. It is important to find a balance between proprioceptive exercises and strength training exercises.

The study results show that muscle strength is a significant factor that enhances knee joint performance during sports activities, reducing the risk of repeated injury. By incorporating proprioceptive exercises that specifically stimulate movement gestures, as well as external and internal stimuli that athletes encounter daily during activity, an optimal biomechanical function of the knee joint can be achieved. For example, Patient 1 was recommended to resume running on soft terrain after 3 months post-surgery and to restart sports activity after 5 months, given the good muscle strength, joint mobility, and knee stability.

Good proprioception and knee joint stability help reduce stride length, especially in backward walking. Although this type of walking is infrequent, it helps understand motor control during walking.

Based on the analysis of clinical cases, the following conclusions were drawn:

- proprioceptive rehabilitation is highly important during the rehabilitation phase as it improves motor control, postural stability, and movement sensitivity and reduces the risk of re-injury;
- proprioceptive rehabilitation does not shorten the return-to-sport time, so it is recommended to combine these exercises with strength and ROM exercises;
- proprioceptive rehabilitation aids in the recovery of stabilizing reflexes, facilitating functional recovery of the knee to its pre-trauma state;
- proprioceptive rehabilitation helps modify muscle strength, proving effective in managing repetitive injuries and preventing subsequent trauma.

All these factors enable patients to regain the necessary stability, strength, and proprioceptive sensitivity, thereby reducing the risk of new injuries to the knee joint.

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Case Study

DURAL ECTASIA WITH BONE SCALLOPING AND CERVICAL MENINGOCELE: A PREDICTIVE SIGN OF NEUROFIBROMATOSIS TYPE 1

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ABSTRACT

Neurofibromatosis (NF) is a group of rare genetic disorders characterized by the formation of benign tumors, predominantly neurofibromas, along the peripheral and central nervous system, as well as in other mesodermal and ectodermal tissues. The main clinical forms of NF include NF type 1 (NF1), NF type 2 (NF2), and schwannomatosis, each with specific genetic and phenotypic characteristics. NF1, the most common form, has an incidence of 1 in 3,000 live births and is associated with mutations in the NF1 gene on chromosome 17, responsible for the production of neurofibromin. This protein regulates the RAS-MAPK signaling pathway. Aberrant activation of this pathway leads to uncontrolled cellular proliferation, with clinical manifestations such as café-au-lait spots, neurofibromas, optic gliomas, and skeletal dysplasias.

KEYWORDS: *neurofibromatosis, neurofibromas, NF, schwannomatosis, mutation, chromosome*

INTRODUCTION

Neurofibromatosis 2 (NF2) has an incidence of approximately 1 in 25,000 individuals and is caused by mutations in the NF2 gene on chromosome 22, responsible for merlin, a tumor suppressor protein. Loss of merlin function is associated with schwannomas and meningiomas, with a 90% prevalence of bilateral vestibular schwannomas, leading to an increased risk of deafness and postural instability (1-13). Schwannomatosis is the rarest form of the disease, characterized by the presence of schwannomas along peripheral nerves, which can cause neuropathic symptoms such as chronic pain, often associated with mutations in the SMARCB1 and LZTR1 genes (3, 11, 12).

Early diagnosis of neurofibromatosis (NF) is of fundamental importance for the management of the disease and for the mitigation of the risk of associated complications. Imaging plays a crucial role, allowing not only the monitoring of tumor growth but also the timely identification of any complications (14). When analyzing localized portions of the body, different imaging modalities should be used. Magnetic resonance imaging (MRI) is recommended for the characterization of intracranial or spinal lesions, while computed tomography (CT) represents a secondary choice. For the preliminary evaluation of skeletal lesions, the use of radiography (XR) is indicated. Furthermore, ultrasonography is

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a useful option for evaluating superficial lesions and for characterizing peripheral and intra-abdominal nerve tumors (14, 15).

In situations where it is necessary to analyze the entire body, methods such as whole-body MRI are used, which allows a global evaluation of the growth pattern and extension of the peripheral nerve sheath tumor (PNST). Positron emission tomography with fluorodeoxyglucose (FDG PET) or CT is used as a tool for differential diagnosis, proving particularly useful in the evaluation of potential malignant transformation, as in the case of malignant peripheral nerve sheath tumor (MPNST) (14, 15).

In recent years, innovative therapeutic approaches, such as MEK kinase inhibitors, have demonstrated efficacy in reducing tumor volume in patients with NF1 (16). Despite these advances, the management of NF remains complex, due to phenotypic variability and unpredictability of disease progression.

Currently, there are no standardized protocols for imaging NF. Diagnostic strategies may vary depending on the type of NF and the presence of clinical symptoms (15-17). This variability represents a significant obstacle to progress in research and technology, making NF a particularly complex disease to diagnose. It is, therefore, imperative to follow standardized protocols based on empirical evidence derived from clinical practice to improve patient management and therapeutic outcomes. The present study aims to illustrate a clinical case of neurofibromatosis type I (NF1) in which the efficacy of the diagnostic sequences employed led to an accurate diagnosis, highlighting the importance of a systematic and targeted diagnostic approach.

CASE STUDY

SD, male, born October 2005, presents to clinical attention due to neck pain; this was the reason why the doctor requested a cervical MRI, which revealed the presence of ectasia of the dura mater, that is, an enlargement of the dural sac, such as to determine posterior vertebral bone scalloping associated with herniation of the nerve root sheaths with the formation of cervical meningoceles at the C5-C7 passage on the left hemiside, (Fig 1A-C, Fig. 2A, B), this picture enters into the differential diagnosis with Marfan syndrome and Ehlers-Danlos syndrome.

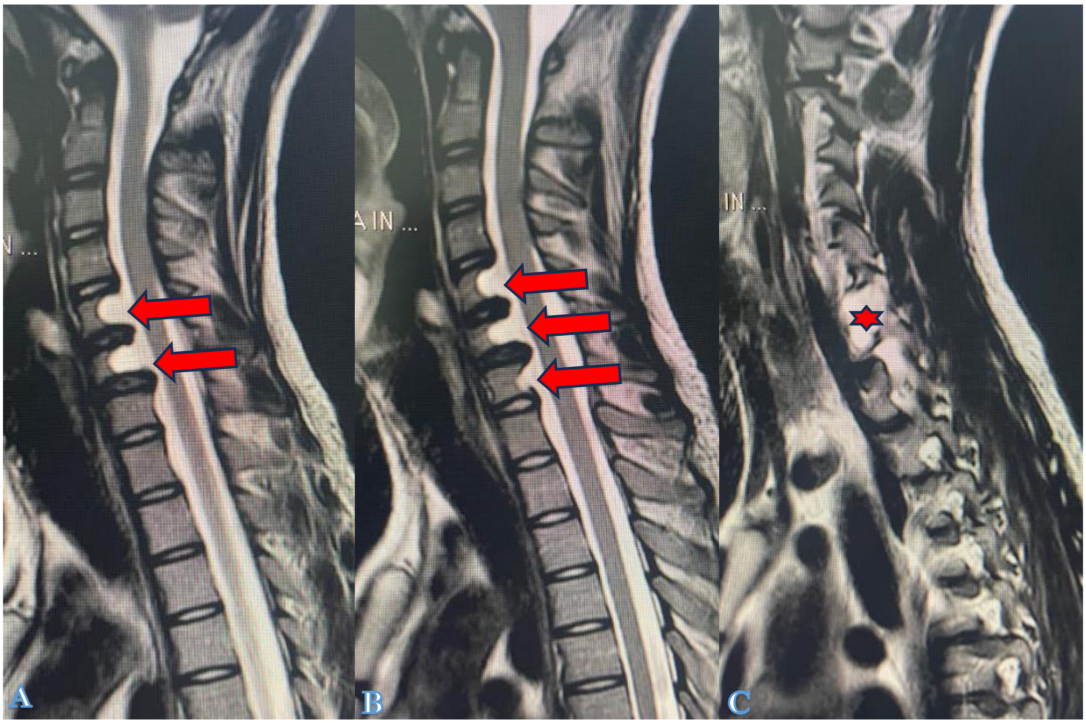

Fig. 1. ***A-C****): Sagittal MRI T2; posterior vertebral bone scalloping of C5, C6, C7* ***(arrows)*** *and left meningocele at C6-C7 (*).*

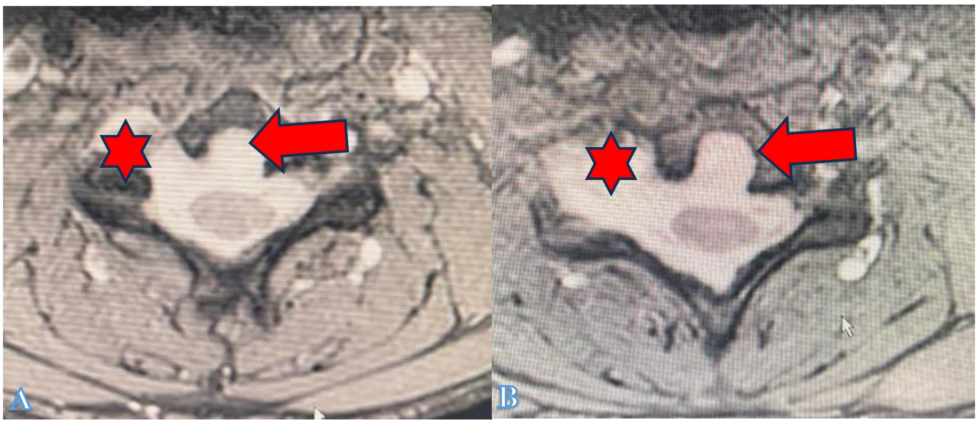

Fig. 2. ***A, B***)*: Axial T2 MRI; posterior vertebral bone scalloping of C5, C6, C7 (****arrows****) and left meningoceles at C5-C6 and C6-C7 (*********).*

In light of these findings, to reach a diagnosis of the nature of the disease, the investigations are completed with an MRI of the brain and an ultrasound of the subcutaneous soft tissues of the lateral cervix.

Brain MRI allows us to appreciate the presence of four focal areas of altered signal intensity at the subtentorial level with cerebellar localization, compatible with UBO (unidentified bright objects). These areas appear characterized by signal hyperintensity in T2 and Flair sequences that do not exert mass effect on adjacent structures (Fig. 3A, B) and do not show enhancement after intravenous administration of contrast medium (Fig. 4).

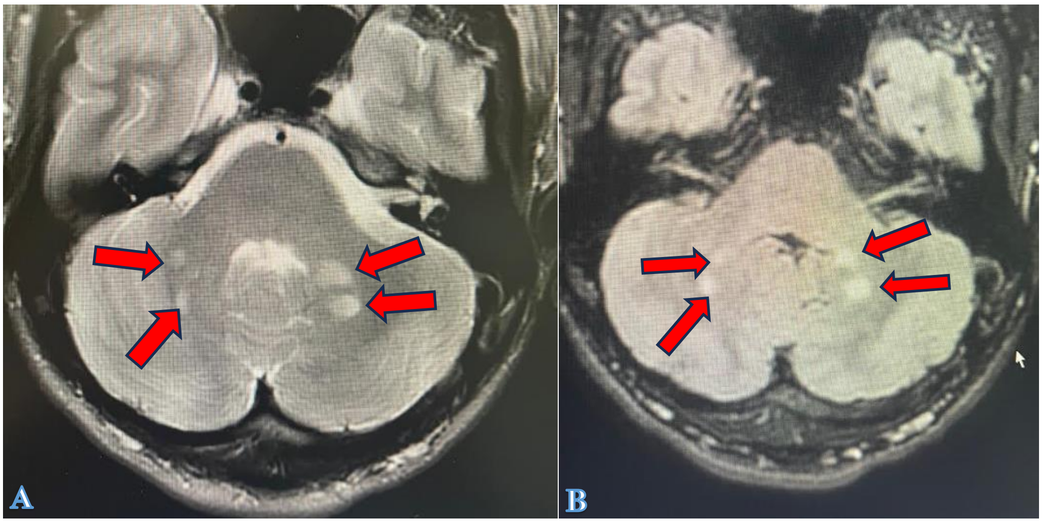

Fig. 3. ***A***)*: Axial T2 MRI;* ***B***)*: Flair; focal areas of altered signal intensity at the infratentorial level with cerebellar localization, compatible with UBO (****arrows****).*

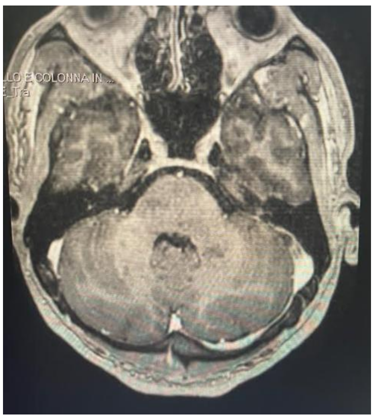

Fig. 4. *Axial MRI after intravenous contrast medium administration: there is no enhancement of the lesions.*

Therefore, by adding the results of the cervical and encephalic MRI investigations, we tend towards a possible diagnosis of NF1, which is also confirmed by the support of the ultrasound investigation of the subcutaneous soft tissues of the lateral carpi, which allows us to appreciate the presence of some small subcutaneous neurofibromas.

DISCUSSION

NF1 is a well-documented genetic condition, but its clinical presentation can vary significantly, making it possible to make late or incorrect diagnoses. In the case presented, neck pain was the only initial clinical manifestation, a symptom that is not always directly and immediately associated with NF1. This situation highlights the importance of accurate diagnosis, considering that initial symptoms may be atypical and overlap with those of other musculoskeletal or neurological pathologies. Targeted MRI revealed significant findings, such as dural ectasia and the presence of meningoceles, information that directed the diagnosis toward a more complex condition.

The finding of infratentorial UBOs in correspondence with the cerebellar hemispheres in brain MRI further supported the diagnosis of NF1, as this finding is well-known and frequently associated with this pathology. Finally, the presence of subcutaneous neurofibromas, documented by ultrasound, completed the clinical picture, highlighting the importance of performing multimodal investigations for an accurate diagnosis. The systematic approach that led to the diagnosis is in line with current recommendations for managing NF1, in which early identification of lesions and associated complications is crucial for timely therapeutic intervention.

Furthermore, the phenotypic variability in patients with NF1 requires continuous monitoring and adaptation of diagnostic and therapeutic strategies. The implementation of standardized protocols based on consolidated evidence can improve not only diagnostic accuracy but also long-term clinical outcomes.

CONCLUSIONS

The clinical case analyzed demonstrates the importance of an accurate diagnostic evaluation of NF1, highlighting how common symptoms, such as neck pain, can mask more serious conditions. The combined use of imaging techniques, such as MRI and ultrasound, has proven to be essential for the timely and accurate identification of the pathology.

This study highlights the need to develop standardized and appropriate imaging protocols that can guide clinicians and radiologists in the early diagnosis of NF1 and in managing associated complications. Early identification of visceral alterations and predisposition to develop malignancies require regular surveillance and timely therapeutic intervention.

In conclusion, a systematic and targeted diagnostic approach is essential not only to confirm the diagnosis of neurofibromatosis but also to improve the overall management of patients and to optimize long-term therapeutic outcomes. Future research should focus on the definition of practical guidelines for monitoring and treatment of NF1 based on scientific evidence and consolidated clinical experience.

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Review

THE IMPACT OF CARPAL TUNNEL SYNDROME IN DENTAL PRACTICE: A MINI-REVIEW

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ABSTRACT

The prevention of musculoskeletal disorders (MSDs) is a topical issue among dental professionals. Carpal tunnel syndrome (CTS), the most common disabling hand disorder, appears to have a high incidence in dental practitioners. This review critically examines the literature on CTS, focusing on its epidemiology, risk factors, diagnosis, and treatment. Preventive strategies and measures are also discussed to mitigate the risk of CTS among dental healthcare personnel. It is crucial for clinicians to possess a comprehensive understanding of ergonomics and to develop an acute awareness of their own body. The ability to modify inappropriate, harmful postures in order to prevent the onset of MSDs should be as fundamental as providing quality dental care.

KEYWORDS: *CTS, carpal tunnel syndrome, wrist pain, preventive measures, injury*

INTRODUCTION

Musculoskeletal disorders (MSDs) represent a significant occupational health issue in the dental profession. The prevalence of general musculoskeletal pain has been reported to range between 64% and 93%. During clinical practice, Hayes et al. found that dentists experienced the most significant prevalence of pain in the back (36.3-60.1%) and neck regions (19.8-85%), whereas for dental hygienists, the most common areas affected were the hand and wrist (60-69.5%) (1). Carpal tunnel syndrome (CTS) represents the most prevalent disabling disorder affecting the hand, and dental practice appears to be associated with an increased risk (2).

The carpal tunnel (CT) is an osteofibrous canal in the volar wrist. This structure offers attachment for the thenar and hypothenar muscles and acts as a restraint for the bowstringing of the extrinsic flexor tendons. The carpal bones and the transverse carpal ligament (or flexor retinaculum) delineate the floor (the carpal arch) and the roof of the CT space. The flexor retinaculum is about 3-4 cm wide and takes insertion into the scaphoid tuberosity, the trapezium, the pisiform, and the hook of the hamate. The CT contains 9 tendons and one nerve: the flexor pollicis longus, the four flexor digitorum superficialis, the four flexor digitorum profundus, and the median nerve (Fig. 1). As a natural consequence, any condition

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that will lead to an increase of the volume of such structures can cause compression of the median nerve. The median nerve gives sensory branches to the thumb, index, middle, and half of the ring fingers (Fig.1). Given that the palm of the hand is supplied by a sensory cutaneous branch of the median nerve, which arises proximally to the flexor retinaculum and remains superficial, this area is not affected by changes of pressure within the CT. The flexor carpi radialis tendon, and the palmaris longus tendon are other important structures that travel outside the CT but are in close contact with it (3) (Fig. 1).

This review aims to critically analyze the available scientific literature and synthesize the most reliable evidence on the epidemiology, diagnosis, and treatment of CTS. In addition, several strategies are proposed to prevent or reduce related symptomatology.

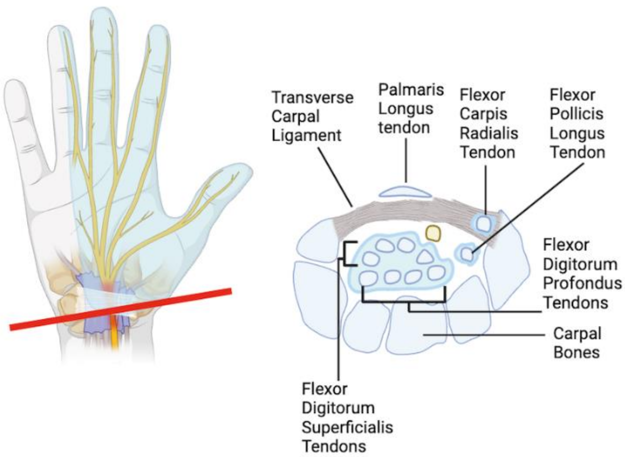

Fig. 1. *Cross section of CT area. The yellow spot represents the Median nerve responsible for the cutaneous innervation of the thumb, index, middle, and half of the ring fingers.*

MATERIALS AND METHODS

By conducting an electronic search on the MEDLINE bibliographic database (Pubmed), 202 articles with a time span from 1983 to 2024 were selected using the following algorithms: "Carpal Tunnel Syndrome" AND ("dental" OR "dentistry"). Titles and abstracts of articles were subjected to an initial selection process considering relevance, type of study, and population considered. References of selected studies were also scanned to retrieve other eligible studies.

DISCUSSION

CTS appears to be the most common peripheral mononeuropathy reported between 30 and 50 years of age (4, 5). Several studies show that approximately 3.8 % of the population complaining of pain, numbness, and tingling in their hands may have CTS(6). Such a syndrome seems to be more frequent in women than in men (7) (prevalence rate of 9.2% vs 6 %) and is associated with moderate/heavy manual work (4), such as dental practice.

The incidence of CTS and MSDs among dental healthcare personnel is relatively high. A meta-analysis conducted by Chenna et al. (8) reported that potentially 1 out of 7 dental practitioners may be affected by CTS. Although this syndrome is widely known, its etiology is not clearly defined.

Prolonged wrist flexion or extension, repetitiveness of certain movements (9), forceful executions, mechanical stress, poor posture, and vibration exposure appear to be some of the main risk factors involved in the genesis of the condition, particularly in the dental health care personnel (10). Medical risk factors include extrinsic factors, intrinsic factors, conditions that can alter the contour of the tunnel, and neuropathic factors. Extrinsic factors, such as pregnancy, menopause, obesity, renal failure, hypothyroidism, the use of oral contraceptives, or congestive heart failure, can increase the volume within CT, eliciting the syndrome. Intrinsic factors within the nerve, such as tumors or tumor-like lesions, and other extrinsic factors that can directly alter the contour of the tunnel (i.e., the aftermath of fractures of the distal radius and/or posttraumatic arthritis) represent additional causative factors that should be taken into account. Neuropathic factors, especially diabetes, also have an important role in the onset of the condition, affecting the nerves without increasing the interstitial pressure (11).

A mixture of mechanical trauma and ischemic injury to the median nerve is thought to be fundamental for the pathogenesis of CTS (12). Experimental studies have reported that neural dysfunction is directly proportional to the duration and magnitude of pressure (13). In addition, chronic compression can lead to fibrosis and adhesion of the nerve to the surrounding tissues. This condition inevitably leads to nerve traction during wrist flexion and extension, allowing the tethered median nerve test to be used as a diagnostic tool for chronic CTS (11).

Symptoms vary according to the severity of the neuropathy. A general reduction in grip strength and hand function with pain, unpleasant tingling, or numbness in the palmar aspect of the thumb, index, median, and radial aspect of the ring finger are the main symptoms reported, which tend to be worse at night. Most CTS patients report flicking the affected wrist as an effective maneuver to reduce pain and discomfort (14).

Patients may experience atypical signs of CTS, such as pain in the shoulder (15), forearm, or numbness in the third finger only (16). In a latent form, referred to as “dynamic CTS”, symptoms may be transient, and the condition is directly triggered by stressful movements (17).

In CTS, both the somatic (sensory and motor) and sympathetic fibers are affected by the compression. However, unmyelinated sympathetic fibers are thought to be more resistant to mechanical or ischemic injury than myelinated, somatic ones. This may be the possible explanation for the reported poor involvement of the sympathetic system in CTS (18).

Interestingly, in a large multicenter Italian study, patients with a more severe disease reported less severe symptoms but more important functional hand limitations than patients with mild, moderate CTS. Although it may appear contradictory, the worsening of functionality and improvement of symptoms can be explained according to the intuitive effect of the reduction in nerve fiber function (19).

The diagnosis of CTS is based on specific clinical findings and electrodiagnostic evaluation, which are necessary to distinguish it from other focal neuropathies of the upper extremities, such as cervical radiculopathy, ulnar neuropathy at the elbow, proximal median neuropathy (especially at the level of the pronator teres) and brachial plexopathy as well as Thoracic Outlet Syndrome (TOS) and Central Nervous System (CNS) disorders (multiple sclerosis, small cerebral infarction) (20, 21).

The symptom questionnaires, such as the hand diagram by Katz and Stirrat (22) or the CTS diagnostic scale adopted by Kamath and Stothard (23), based on self-reported symptoms of patients, may have high reliability. Still, their main limitation is based on the subjective component.

Based on clinical observation, since the abductor pollicis brevis is innervated by the median nerve and located superficially on the radial aspect of the thenar mass, the presence of thenar atrophy with symptoms may be sufficient to confirm the presence of moderate to severe CTS (24). Phalen’s and Tinel’s tests are the most common provocative tests used to diagnose the condition. In Phalen’s test, the patient is asked to flex the wrist and hold it in this position for 60 seconds. Pain or paraesthesia in the distribution of the median nerve represents a positive response (25) with reported sensitivity and specificity values in the range of 68% and 73%, respectively (26).

The Tinel test seems more specific than sensitive (77% vs 50%) (26). It is performed by tapping over the volar surface of the wrist; tangling or electric shocks in the area innervated by the median nerve represent the response of regenerating nerve fibers, which are more susceptible to triggers.

Similar values of sensitivity and specificity (48% vs 76%) were reported by the tethered median nerve stress test, which elicits a response hyperextending the index finger (and wrist) by pressing on the distal end with the forearm supinated (26). However, as the test assesses the presence of adhesion between the nerve and the flexor tendons, it may not be as effective in detecting the acute phases of CTS, and the general trend is to consider it more as an etiological test rather than a routine diagnostic test (26).

Other clinical signs and provocative tests have been described; however, according to Mondelli et al., none appear to be relevant on their own (27). To overcome these limitations, specific diagnostic algorithms, based on the integration of symptoms, signs, and diagnostic tests, were proposed by some authors to determine the likelihood of carpal tunnel syndrome (11).

In addition, clinical neurophysiological assessments using tests such as the vibrometry threshold, current perception, Semmes-Weinstein monofilament, tactile sensitivity, and two-point discrimination test are described in the literature. However, such diagnostic analyses generally require skill in both administration and interpretation of results (11).

Nerve Conduction Studies (NCS), in which the conduction across the nerve is assessed by surface electrodes, represent the gold standard for confirming a suspected CTS clinical condition. In addition, such exams can provide critical information on the severity of the neuropathy, on prognosis, and helpful insight to eventually assess alternate or associated diagnoses (e.g., ulnar neuropathy, cervical radiculopathy, brachial plexus lesion, or generalized polyneuropathy). On the other hand, the reported invasiveness, costs, and relatively high false-negative rate (up to 30%) of such examinations have prompted clinicians to develop more practical and less invasive evaluative methods (28-30).

Ultrasound is a useful method for assessing the median nerve cross-sectional area at various levels of the CT. Cross-sectional areas in CTS patients were shown to be significantly wider than those in healthy controls. However, due to the lack of standardization and a plethora of proposed cut-off values, wide ranges of sensitivity and specificity of such diagnostic methods have been reported (31). Since some studies have shown that non-pathological median nerve area is the same at the wrist and in the forearms (32), a direct comparison between the areas of the nerve within these structures (33) or the determination of a "swelling ratio" (34) have been proposed by some author to reduce the discrepancies. Ultrasound elastography has been shown to be an effective tool for overcoming these limitations.

Orman et al., evaluating the mean tissue strain in CTS patients, reported that it was significantly lower than in healthy controls, with the median nerve stiffer and less elastic (35). Strain elastography provided reliable cut-off strain ratios with high sensitivity and specificity values.

The same trend was found using shear wave elastography (36, 37), where an excellent accuracy in differentiating patients with and without CTS was reported in analyzing the median nerve stiffness cut-offs (37). However, these examinations do not seem to provide a clear relationship with the severity of the disease (38, 39). Despite these limitations, elastography, particularly the shear wave, has proved to be a valuable tool for diagnosing the condition and overcoming the limitations of conventional ultrasound.

Magnetic resonance imaging (MRI) can also be used in limited cases to determine the site of nerve entrapment after failed surgical procedures, for differential diagnosis in cases of vague symptoms, and to confirm the presence of space-occupying lesions (e.g., fibrolipomatous hamartoma of the median nerve (40, 41).

Treatment

Treatment of CTS is based on severity, staging of the pathology, and patient's preferences. Mild or moderate symptoms can be generally treated by non-surgical procedures such as splinting, acupuncture, steroid injections (42), vitamins B6 and B12, non-steroidal anti-inflammatory drugs (NSAIDs), ultrasound, yoga, or carpal bone mobilization (4). However, even though they can significantly relieve CTS symptoms in the short term, the durability of such beneficial effects is hardly determinable in the long term (43).

Marshall et al. reported that steroid injections produced a more significant clinical improvement in symptoms one month after the injections compared with placebo (44). However, the effects appeared to be transient, and no significant symptom relief was observed beyond one month (44). When conservative treatment fails, surgery is indicated (41). Surgical treatment is considered more effective than non-surgical treatment, especially when compared with splinting (45). With both an endoscopic or an open technique, the transverse carpal ligament is divided to increase the space and relieve pressure in the CT.

Open procedures have been shown to be effective in almost all patients (from 70 % up to 90%) with excellent long-term results (46). The endoscopic procedures, even if the technique is well performed (47), seem to have more drawbacks and a higher risk of nerve damage related to the insertion of the cannula in the CT (especially in the case of adherence) (41).

Preventive strategies

By analyzing the reported evidence, maintaining a neutral position with the forearms and wrist in a straight line is the most effective preventive measure, as it prevents increased pressure in the CT and reduces the risk of injury. The selection of larger, round-tapered, and lighter instruments with multiple accentuated angles or long terminal shanks can reduce muscle workload and pinch force (48). Rather than employing a 'one-size-fits-all' approach, the instrument design should be tailored to the operator (49). Owing to its ability to increase blood flow, inter-procedural stretching, turning the palm upward while slowly extending the elbow, is another reliable method for relieving symptoms and preventing injury (50).

CONCLUSIONS

The prevention of MSDs such as CTS is a topical issue in dentistry. Some preventive measures can be highlighted and recommended. CTS can be prevented by tailoring instruments and adopting a proper inter-procedural stretching plan. It is essential for clinicians to have a comprehensive understanding of ergonomics and develop an acute awareness of his or her own body. Being able to adjust inappropriate, harmful postures to prevent the onset of MSDs should be as fundamental as providing quality dental care.

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