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EDITORIAL

Trochanteric area pain, the result of a quartet of bursal inflammation

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Abstract

Bursitis is quite responsive to therapeutic intervention, once the afflicted area is accurately identified. This is especially notable for some hip complaints. Patients' use of the term "hip" can relate to anything from the low back to groin to lateral thigh pain. Trochanteric area surface localization of "hip" pain may afford an opportunity for immediate cure. Effectiveness of therapeutic intervention is predicated upon injection of not one or two, but all four peri-trochanteric bursa with a depot (minimally water-soluble) corticosteroid. The term trochanteric bursitis suggests that the inflammation is more focal than what is clinically observed. While easier to express, perhaps it is time to refer to inflammation in this area, naming all four affected bursae.

Key words: Trochanter; Bursitis; Bursa; Hip; Injection; Corticosteroids; Dexamethasone; Triamcinolone

Core tip: The designation hip pain requires localization to identify effective treatment. Once tenderness is localized to the area of the greater trochanter, it is quite amenable to treatment. However, there are four bursa represented and injection of only one usually does not resolve the problem. Injection of all four with a corticosteroid that is minimally water soluble is required.

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HIP PAIN

Bursitis is quite responsive to therapeutic intervention, once the afflicted area is accurately identified. This is especially notable for some hip complaints. Patients' use of the term "hip" can relate to anything from the low back to groin to lateral thigh pain[1-6]. The affected area is typically identified by where the patient points. Lateral thigh localization suggests involvement of bursae in the vicinity of the greater trochanter[7-15]. Pain on external rotation with abduction is highly suggestive of the diagnosis. Direct palpation of the greater trochanter is usually diagnostic, although slipping ilial-tibial band syndrome must be considered[15] and of course, the bursae may rarely be infected (*e.g.*, tuberculosis)[16].

Non-operative orthopedics is a field in which results are typically expected in days (more commonly weeks or months) rather than producing the gratification of immediate and safe resolution of the problem that is so commonly the result of surgical intervention. One diagnosis that I find especially rewarding is that of involvement of peri-trochanteric bursae in individuals with "hip" pain. Such pathology has a female predominance. It is present unilaterally in 15% of women, 8.5% of men; bilaterally, in 6.6% of women, 1.9% of men[17,18]. It is rewarding to both physician and patient, as it is especially responsive to injection of the appropriate bursae with triamcinolone and lidocaine[19-23]. The lidocaine gives immediate relief of patient symptoms, confirming the diagnosis, while the triamcinolone provides lasting relief. It is performed with a 22 gauge spinal (3-1/2 inch) needle and is sometimes performed under radiological guidance[24]. This injection provides a depot corticosteroid effect, in contrast to the time-limited effect of dexamethasone, whose water solubility results in rapid systemic, rather than localized distribution. Passive movement of the hip through full range of motion subsequent to injection is critical to assure mobilization of the steroid throughout the bursae[25]. This intervention is usually effective, even when it is a post-surgical event or in the presence of a leg length discrepancy[26-28], although presence of lower extremity osteoarthritis reduces effectiveness[18].

A recent article[29] questioned the efficacy of such injection therapy. However, the identified treatment approach was flawed in its injection of only one or two bursa(e), a common approach[30]. I too found disappointing results with that approach. However, there are actually four significant bursae in that location: gluteus medius, gluteus minimus, subgluteus medius and subgluteus minimus bursae[31].

Retrospective assessment of the last 50 individuals in my practice in whom all four bursae were injected revealed immediate elimination of pain in 49. Pain relief persisted more than 6 mo in 47 individuals. Two individuals had recurrent "hip" pain 3 mo after the initial injections. Their pain responded to repeat injection of the four bursae and they have been pain free since. Involvement of bursae was often (30 instances) bilateral. Because of insurance company limitations, unilateral injections were initially performed, with plan to inject the contralateral the following week. An unexpected observation was resolution of pain in the contralateral bursa, as well as in those injected. Given the effect of bursitis on gait[32,33], perhaps injection of the most symptomatic side eliminated the mechanical effect of altered gait. That may have allowed the contralateral side to heal. A systematic effect of the injected depot corticosteroid is unlikely, as injection of the above-named peri-trochanteric bursae did not affect concurrent anserine bursitis (which itself is extremely responsive to injection of a depot corticosteroid), nor did it affect concurrent bicipital or supraspinatus tendonitis. As injection of all four bursae is so effective, the role for diagnostic studies (*e.g.*, magnetic resonance imaging) seems an unnecessary expense[34-37].

It is intriguing that so many exotic approaches (*e.g.*, shock wave therapy and even surgery) to this problem have been pursued[38-48], when a simple injection approach is so frequently and fully effective. Non-steroidal anti-inflammatory drugs may reduce discomfort[49], but have significant systemic effects and do not resolve the underlying inflammation. Injection of only one or two of the four bursae results in partial, but statistically significant pain relief[8]. Comparison with elimination of pain in 98% of afflicted individuals by injection of all four bursae suggests the latter provides a greater opportunity for clinical benefit. The term trochanteric bursitis suggests that the inflammation is more focal than what is clinically observed. While easier to express, perhaps it is time to refer to inflammation in this area, naming all four affected bursae (*i.e.*, gluteus medius, gluteus minimus, subgluteus medius and subgluteus minimus bursitis).

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EDITORIAL

Mechanical solution for a mechanical problem: Tennis elbow

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Abstract

Lateral epicondylitis is a relatively common clinical problem, easily recognized on palpation of the lateral protuberance on the elbow. Despite the "itis" suffix, it is not an inflammatory process. Therapeutic approaches with topical non-steroidal anti-inflammatory drugs, corticosteroids and anesthetics have limited benefit, as would be expected if inflammation is not involved. Other approaches have included provision of healing cytokines from blood products or stem cells, based on the recognition that this repetitive effort-derived disorder represents injury. Noting calcification/ossification of tendon attachments to the lateral epicondyle (enthesitis), dry needling, radiofrequency, shock wave treatments and surgical approaches have also been pursued. Physiologic approaches, including manipulation, therapeutic ultrasound, phonophoresis, iontophoresis, acupuncture and exposure of the area to low level laser light, has also had limited success. This contrasts with the benefit of a simple mechanical intervention, reducing the stress on the attachment area. This is based on displacement of the stress by use of a thin (3/4-1 inch) band applied just distal to the epicondyle. Thin bands are required, as thick bands (*e.g.*, 2-3 inch wide) simply reduce muscle strength, without significantly reducing stress. This approach appears to be associated with a failure rate less than 1%, assuming the afflicted individual modifies the activity that repeatedly stresses the epicondylar attachments.

Key words: Epicondylitis; Tennis elbow; Adaptive equipment; Mechanical overload; Elbow; Inflammation

Core tip: Lateral epicondylitis is a mechanical problem with a mechanical solution. While there have been many approaches, some quite exotic, to this phenomenon, there is a very effective non-invasive treatment: application of a 3/4-1 inch forearm band just below the elbow, of course associated with modification of the activity that is stressing the epicondylar attachments.

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CHARACTER OF LATERAL EPICONDYLITIS

Popularly referred to as tennis elbow, lateral epicondylitis is a relatively common clinical problem[1,2] that has apparently confounded many attempts at its resolution. Easily recognized on induced pain/replication of symptoms by palpation of the lateral protuberance on the elbow, the term lateral epicondylitis identifies a disorder localized to that lateral epicondyle. The "itis" suffix in the term epicondylitis is misleading. Histological evaluation does not support categorizing it as an inflammatory process[3-5]. Microscopic examination actually reveals angiofibroblastic and mucoid degeneration, attributed to mechanical overloading[3]. Indeed, ultrasound evaluation reveals mechanical damage to tendons[6-9].

ANALGESIC AND ANTI-INFLAMMATORY INTERVENTION

The multitude of approaches to management of a clinical problem suggests either that it is quite responsive to intervention or that the optimal approaches have yet to be identified. Many of the approaches to treatment of lateral epicondylitis seem to be predicated on the subsequently falsified hypothesis that the epicondylitis represented an inflammatory process[3-9]. These attempts have included use of oral or topical non-steroidal anti-inflammatory drugs[10-12], injections[13] of corticosteroids[10,13-20], anesthetics (*e.g.*, bupivacaine)[21] or even botulinum toxin[22] injection, none of which have had documented long-term clinical benefit[3]. Simply treating the pain symptom with analgesics has also provided inadequate relief[10,11,21,23].

INJURY-PREDICATED INTERVENTION

Based on recognition that epicondylitis represents an injury, another approach has been to inject autologous blood[24-27] or platelet-rich plasma[3,18,21,24,28,29]. This is predicated on the hypothesis that these injections provide growth factors, which stimulate healing. Similarly, skin-derived stem cells have been injected with this goal[30]. The enthesitis (irritation of tendon insertions) occasionally leads to calcification/ossification of those attachments. Speculation that the ossification/calcification process is the source of pain, radiofrequency[31] and shock wave[32,33] treatments have also been pursued. Surgical approaches have included percutaneous tenotomy and arthroscopic approaches[23,26,34-39].

PHYSIOLOGIC APPROACHES

More physiologic approaches have included physiatric/physical therapy techniques including manipulation, therapeutic ultrasound, phonophoresis, iontophoresis, acupuncture and exposure of the area to low-level laser[11,19,38,40-43]. An intriguing approach has been dry needling[25,34]. This is especially remarkable, as the lateral epicondyle has been listed[44], I believe erroneously[45], as a fibromyalgia trigger point and needling has been utilized as an approach to treatment of fibromyalgia[46]. The efficacy of all these approaches has been limited[3,13-16,25,28,29,38,47]. The study by Creaney *et al*[25] showed statistically significant clinical improvement in 60%-72%, but not complete relief. This is a greater response than with other approaches, but none identify complete resolution.

MECHANICAL INTERVENTION

The efficacy of these variably invasive approaches contrasts with a simple mechanical intervention. The irritation that appears to be the source of the pain derives from stresses produced by the muscles which attach to the lateral epicondyle[48]. Reducing the stress on the attachment area seems a reasonable approach. Logically, a band applied to the forearm, just distal to the elbow, would be expected to reduce stress on muscle attachment to the epicondyle, and it does. Early attempts to utilize this approach, however, were only marginally effective, because commercially available bands have an unintended effect. Those several inch wide bands only reduced effective muscle strength. The reduced available muscle power did reduce stress on the epicondyle, but did so inadequately and use of such armbands was less effective than immobilization of the elbow[12]. The latter, of course, results in muscle atrophy and loss of strength.

My personal approach has been to utilize Velcro bands of 0.75 to 1 inch in width and to assure their application 1 inch below the epicondyle. That position is critical. Such placement has no effect on muscle strength, but displaces the stresses on the epicondyle, such that it was now at the site of the band and thus distal to the epicondyle. Pain was immediately reduced and eliminated within several weeks. Patients were advised to wear the bands continually, except when sleeping, and to continue their use for two weeks beyond their perception of any residual elbow pain. Recurrences have responded equally well, once the activity responsible for the epicondyle stress is modified. I have had only 5 patients who have not responded (with complete resolution of elbow symptoms) in the three decades that I have utilized this approach. That represents less than 1% failure rate, and that was in individuals who would or could not modify the activity[2,42,49,50] that was repeatedly stressing the epicondylar attachments.

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EDITORIAL

Use of intercostal nerves for different target neurotization in brachial plexus reconstruction

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Abstract

Intercostal nerve transfer is a valuable procedure in devastating plexopathies. Intercostal nerves are a very good choice for elbow flexion or extension and shoulder abduction when the intraplexus donor nerves are not available. The best results are obtained in obstetric brachial plexus palsy patients, when direct nerve transfer is performed within six months from the injury. Unlike the adult posttraumatic patients after median and ulnar nerve neurotization with intercostal nerves, almost all obstetric brachial plexus palsy patients achieve protective sensation in the hand and some of them achieve active wrist and finger flexion. Use in combination with proper muscles, intercostal nerve transfer can yield adequate power to the paretic upper limb. Reinnervation of native muscles (*i.e.*, latissimus dorsi) should always be sought as they can successfully be transferred later on for further functional restoration.

Key words: Intercostal nerve; Brachial plexus reconstruction; Reinnervation; Root avulsion

Core tip: Intercostal nerves are a very good choice for elbow flexion or extension and shoulder abduction when the intraplexus donor nerves are not available. Use in combination with proper muscles, intercostal nerve transfer can yield adequate power to the paretic upper limb. Reinnervation of native muscles (*i.e.*, latissimus dorsi) should always be sought as they can successfully be transferred later on for further functional restoration.

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INTRODUCTION

Nerve transfer or neurotization procedure can provide a useful function in cases of brachial plexus palsy with global spinal nerve root avulsion or irreparable proximal lesion. During a neurotization procedure a healthy donor nerve is separated from its territory, and its proximal stump is then connected directly or *via* a nerve graft to the distal stump of an injured nerve or implanted directly into a more critical denervated muscle target.

Sacrificing a donor nerve must be worthwhile. More specifically, the function gained has to be of greater value than the function lost and the donor nerve must contain adequate number of motor fibers to affect target reinnervation. Additionally, sufficient brain plasticity must take place to affect the restored function. These principles are operable in cases when intercostal nerves are used to neurotize different targets.

Yeoman *et al*[1] first in 1963 transferred several intercostals nerves into the musculocutaneous nerve using the

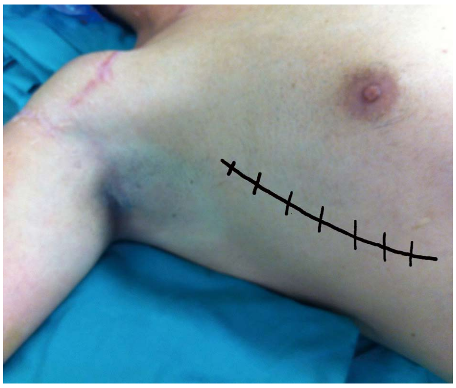

Figure 1 A curved incision starts at the anterior axillary line at the level of the upper chest and extents caudally towards the midline of the abdomen at the level of the umbilicus, depending on the number of intercostals nerves to be harvested.

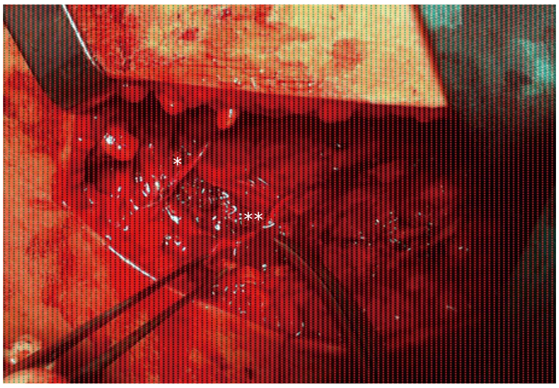

Figure 2 The motor branch is identified on top of the innermost intercostal muscle and dissected from the costochondral junction anteriorly to the posterior axillary line posteriorly. The intercostal nerves are passed to the axilla through a subcutaneous tunnel so they can be sutured to the recipient nerve. Note the intercostal nerve 5 (*) and the intercostal nerve 6 (**) after their dissection and mobilization.

ulnar nerve as a graft. This technique was modified and further developed by Kotani *et al*[2] and Tsuyama *et al*[3] ten years later. The pioneers in brachial plexus surgery such as Millesi, Narakas, Celli, Morelli, Terzis, and Gu commonly used intercostal nerve transfer for brachial plexus reconstruction[4-13].

ANATOMY AND PHYSIOLOGY OF THE INTERCOSTAL NERVES

Intercostal nerves are the ventral primary rami of spinal nerves T1 to T11. The ventral primary ramus of T12 spinal nerve is the subcostal nerve. T1 takes part in the brachial plexus and T12 does not actually occupy an intercostal space. Therefore 10 thoracic nerves from T2 to T11 constitute the anterior branch of intercostal nerves. In the intercostal space there are three muscular layers: (1) external intercostal muscle; (2) internal intercostal muscle; and (3) the innermost intercostal muscle. The upper intercostal nerves (T3, T4, T5 and T6) run parallel to their ribs in between the middle and innermost intercostal muscles, while the lower intercostal nerves (T7, T8, T9, T10 and T11) lie superficial either to transversus thoracic or transversus abdominis muscles.

There are some anatomic differences between the intercostal nerves. The first intercostal nerve is a tiny ramus of the first thoracic nerve and runs along the lower margin of the first rib. This is a purely sensory nerve and travels towards the sternum to innervate the skin near the midline. The second intercostal nerve has a large sensory lateral branch that innervates the skin in the anterior portion of the axilla and forms a connection with the medial cutaneous nerve of the arm. Furthermore, this nerve, because of its very high location is not accessible for neurotization. The anterior portion of the second and third intercostal nerves runs deep to the external intercostal muscle under the rib margin. The fourth intercostal nerve is slightly thinner than the third, its sensory component supplies the skin of the nipple-areolar area, and must be avoided for harvesting. Intercostal nerves from the 7 to the 11 supply muscles and skin of the anterior abdominal wall and theoretically will carry on higher number of axons than the upper intercostal nerves.

An intercostal nerve contains no more than 1200-1300 myelinated fibers and only 40% of them are motor fibers. Freilinger *et al*[14] studied the motor fiber content in the six, seventh and eight intercostal nerves and found a relatively constant level between 30% and 40% in the six intercostal nerve. The highest percentage (40%) was reached just after the lateral cutaneous branch had left the main trunk. Each intercostal nerve innervates multifunctional muscles and affects the respiratory function and posture including trunk flexion-extension and rotation. After intercostal nerve transfer to a given muscle, central motor programs responsible for respiration and posture will be connected to the innervated muscle. Initially, the function will occur only after voluntary respiratory effort, but with time voluntary control over the restored function will be achieved. These changes of control imply central adaptation, involving rearrangement of motor programs for a given muscle function and respiration[15].

During nerve transfer procedure, there is always a great risk of wasting transferred motor nerve fibers into inappropriate channels. For this reason, the distal site of coaptation must be as close as possible to the entry point of the motor nerve into the muscle target. This requires harvesting greater length of the donor nerve (Figures 1 and 2). However, the more the dissection proceeds distally, the lower the available number of motor fibers in the intercostal nerve.

To avoid an interposed nerve graft, Celli *et al*[4] suggested dissection of the intercostal nerve from its origin in the back and tracing it anteriorly for a length of 30-40 cm. Morelli *et al*[8], in order to maintain the maximal number of motor fibers, suggested transection of the intercostal nerve close to its origin followed by lengthening with a long intermediate nerve graft to reach the target.

INDICATIONS

Intercostal nerves can be used for primary nerve repair

Table 1 Intraoperative scoring system used to estimate the severity score

Score	Description of lesion
0	Avulsion
1	Rupture/avulsion
2	Rupture
3	Rupture/traction
4	Traction
5	Normal

in early or in late cases when free muscle transfer is indicated. The primary nerve transfer contains direct coaptation with single muscle target (musculocutaneous nerve, axillary nerve, triceps branch, and direct coaptation with nerves of multiple muscle targets (ulnar and median nerves); However, innervation of muscle targets for muscle transfer contains (1) neurotization of long thoracic nerve for stabilization of scapula and shoulder abduction; (2) neurotization of the thoracodorsal nerve and using in a second stage the latissimus dorsi muscle as pedicle flap for restoration of elbow flexion or extension; and (3) neurotization of free muscles transferred for shoulder, elbow, or hand reanimation. In patients with history of rib fractures, chest tube placement, or thoracotomy appropriate electrodiagnostic studies of intercostal nerves involved should be performed preoperatively.

DATA ANALYSIS

Brachial plexus palsy with multiple root avulsion is a devastating injury due to paucity of proximal motor donors. The only alternative for restoration of useful function is the use of neurotization procedures. However, the available donor nerves for transfer are few.

Yeoman *et al*[1] first described intercostal nerve transfer for brachial plexus reconstruction. Subsequently, several authors have reported their experience with intercostal nerve transfer[4,16-29]. In order to restore maximum function of the arm, as many intercostal nerves as possible are harvested and transferred. However, the optimal number of intercostal nerves used for nerve transfer remains controversial. Nagano *et al*[26] showed 70% good to excellent results using two intercostal nerves for musculocutaneous nerve neurotization. Chuang *et al*[17] reported higher success rate when they used three intercostal nerves. Kawai *et al*[23] supported that at least two intercostal nerves are needed to achieve useful elbow flexion, but using more than two intercostal nerves the results were not significantly better than those obtained when only two intercostal nerves were used.

There is a controversy on which intercostal nerves are the best for transfer. For brachial plexus reconstruction purposes, nine intercostal nerves are available: T3 through T11. Chuang *et al*[17] in their series showed no difference in the functional outcomes after using upper *vs* lower intercostals.

Different series have advocated the advantages of direct method of intercostal nerve coaptation without tension to the recipient nerve *vs* using nerve graft[10,20,25,27,30-33]. None of the patients in series of Friedman *et al*[20] who had interposed nerve graft between the transferred intercostal nerve and the musculocutaneous nerve obtained useful elbow flexion. Sedel[34] reported useful elbow flexion in five out of nine patients using nerve grafts. Songcharoen[28] showed muscle grading 3 or more in 65% of patients after intercostal to musculocutaneous nerve transfer (Table 1). Probably, when direct nerve repair is utilized, the distance to the target is shorter, and the regenerating axons pass through only one coaptation site instead of two when nerve graft has been used.

In late brachial plexus cases, when native muscle targets have been wasted, free muscle transfer innervated by intercostal nerves seem to be a viable procedure[16,18,35-39]. When planning a muscle transfer for upper extremity reanimation, in order to obtain the maximum result it is imperative to choose the correct muscle for needed function. Due to the greater power demands needed for proximal joint animation, free latissimus dorsi, rectus femoris or vastus lateralis muscles should be used for elbow flexion restoration, and the use of free gracilis muscle should be limited to hand reanimation.

The overall results after intercostal nerve transfer differ in many series. Chuang *et al*[17] showed that 67% of patients obtained a muscle strength of grade 4 or higher after intercostal to musculocutaneous nerve neurotization. Ruch *et al*[40] reported that 47% of patients obtained good or excellent results after musculocutaneous nerve neurotization with intercostal nerve transfer. Krakauer *et al*[24] showed that 6 out of 8 patients achieved a muscle grading of 3 or more after musculocutaneous nerve neurotization with intercostal nerves. Malessy *et al*[30] reviewed intercostal to musculocutaneous nerve transfers in adult patients performed in 6 different centers and found that a grade of 3 or more was achieved in 78% of the cases. Kawai *et al*[23] showed a muscle grading of +3 or more in 42% of patients after intercostal to musculocutaneous nerve transfer. Kawabata *et al*[41] reported his experience with intercostal nerve transfer in obstetric brachial plexus palsy patients and found that 84% of their patients achieved a muscle power of grade 4. Terzis *et al*[12] showed excellent results (M4 to M5-) in 5 out of 6 obstetric brachial plexus palsy patients when using intercostal to musculocutaneous nerve transfer and excellent result in 5 out of 11 patients when intercostal nerves were used for triceps nerve reinnervation[12].

Restoration of protective sensation it is imperative to maximize the upper extremity function. Kotani *et al*[2] reported limited recovery of sensibility in 11 out of 15 cases treated with intercostal nerve transfer for sensory restoration of the hand. Millesi[7,25] showed recovery of protective sensation in 15 out of 18 patients. Kawai *et al*[23] reported superficial pain recovery and some touch sensation in 5 out of 13 cases. Ihara *et al*[21] stated that intercostal nerve neurotization of the median nerve provided some touch sensation in 12 out of their 15 cases but no two-point discrimination was recorded. Doi *et al*[37] showed tactile gnosis after intercostal nerve transfer to the ulnar nerve in all their patients. Terzis *et al*[12] reported complete recovery of protective sensation and active wrist and finger flexion after intercostal to ulnar and/or median nerve neurotization in obstetric brachial plexus palsy patients.

CONCLUSION

Intercostal nerve transfer is a valuable procedure in devastating plexopathies. Intercostal nerves are a very good choice for elbow flexion or extension and shoulder abduction when the intraplexus donor nerves are not available. The best results are obtained in obstetric brachial plexus palsy patients, when direct nerve transfer is performed within six months from the injury. Unlike the adult posttraumatic patients after median and ulnar nerve neurotization with intercostal nerves, almost all obstetric brachial plexus palsy patients achieve protective sensation in the hand and some of them achieve active wrist and finger flexion. Use in combination with proper muscles, intercostal nerve transfer can yield adequate power to the paretic upper limb. Reinnervation of native muscles (*i.e.*, latissimus dorsi) should always be sought as they can successfully be transferred later on for further functional restoration.

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EDITORIAL

Cervical adjacent segment pathology following fusion: Is it due to fusion?

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Abstract

Adjacent segment pathology affects 25% of patients within ten years of anterior cervical diskectomy and fusion (ACDF). Laboratory studies demonstrate fused segments increase adjacent level stress including elevated intradiscal pressure and increased range of motion. Radiographic adjacent segment pathology (RASP) has been associated to ACDF in multiple statistically significant studies. Randomized controlled trials (RCTs) comparing anterior cervical discectomy and arthroplasty (ACDA) and ACDF have confirmed ACDF accelerates RASP. The question of greatest clinical interest is whether ACDA, artificial disc surgery, results in fewer adjacent level surgeries than ACDF. Current RCT follow up results reveal only non statistically significant trends favoring ACDA yet the post operative periods are only two to four years. Statistically significant increased RASP in ACDF patients however is already documented. The RCT patients' average ages are in the mid forties with an expected longevity of up to forty more years. Early statistically significant increased RASP in the ACDF patients supports our prediction that given sufficient follow up of ten or more years, fusion will lead to statistically significant higher rate of adjacent level surgery compared to artificial disc surgery.

Key words: Cervical; Diskectomy; Fusion; Arthroplasty; Adjacent; Degeneration

Core tip: Cervical artificial disc surgery has brought the expectation of a lower rate of adjacent segment pathology. Randomized controlled trials (RCTs), currently have only two to four years follow ups and the results regarding adjacent segment surgery indicate only non statistically significant trends favoring the anterior cervical discectomy and arthroplasty (ACDA). Higher rates of radiographic adjacent level pathology, after anterior cervical diskectomy and fusion (ACDF) is already documented. We predict that as the RCT average age mid forty-year-old patients continue to their almost forty year expected longevity, adjacent level surgery rates after ACDF will also increase in comparison to the ACDA patients.

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ADJACENT SEGMENT PATHOLOGY

The advent of anterior cervical discectomy and arthroplasty (ACDA) has brought the expectation of reduced adjacent level disease that may lead to additional surgery[1,2]. Randomized control trials (RCT), conducted in the United States for a variety of cervical artificial discs have a control arm consisting of anterior cervical discectomy and fusion (ACDF). Thus, these studies may give definitive answers to the much discussed and debated question; Does fusion surgery lead to adjacent segment pathology?

Adjacent segment pathology (ASP) is a serious problem after ACDF. Hilibrand *et al*[3] reported that 25% of patients experienced symptomatic clinical ASP (CASP) within ten years of ACDF. Fused cervical segments have been documented to increase adjacent level stress in multiple ways including: increased pressure and increased range of motion[4-9].

Radiographic adjacent segment pathology (RASP), has been linked to ACDF in multiple statistically significant studies[10]. Baba *et al*[11] reported 25% new spinal stenosis adjacent to ACDF. Gore *et al*[10] reported 25% new and 25% progression of degenerative disc changes at adjacent segments within five years of ACDF. Goffin *et al*[12] reported that 92% of patients developed RASP within five years of ACDF. They concluded that RASP was correlated also to CASP as an independent effect above the natural history of cervical degenerative disc disease. Not all randomized RCTs looked at RASP but those that have, confirmed that ACDF accelerates RASP. Coric *et al*[13] found much less RASP after the artificial disc compared to fusion. At two year follow-up, 24.8% of ACDF patients compared to 9% of ACDA had RASP with very high statistical significance, (P = 0.0001). Beaurain *et al*[14] for the Moby-C RCT, also at two year follow-up 34.6% RASP with ACDF compared to 17.5% after ACDA. Looking at all the available data, most will agree that there is an overwhelming and robust evidence for increased RASP with ACDF as opposed to ACDA.

But does fusion lead to more adjacent level surgeries than an artificial disc? Currently published and/or available data from RCTs show a trend, albeit statistically insignificant, towards increased ASP surgeries[1]. Most current RCT reports have only a two year follow up and not surprisingly there is no statistically significant difference between ACDF and ACDA with respect to CASP. Two, or even four year follow ups are too short a time when dealing with DDD that may take decades to become symptomatic. Most of the RCT patients were in their 40’s and they are expected to live 30 or 40 more years. The increased RASP and the trend of increased CASP in the ACDF patients portend what is obvious. Cervical fusion accelerates adjacent segment pathology and will lead to increased adjacent segment surgery. We predict that given sufficient length of follow-up (at least 10 years), fusion will lead to statistically significant increased rate of adjacent level surgery as opposed to artificial disc.

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MINIREVIEWS

Orthopaedic perspective on bone metastasis

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Abstract

The incidence of cancer is increasing worldwide, with the advent of a myriad of new treatment options, so is the overall survival of these patients. However, from an orthopaedic perspective, there comes the challenge of treating more patients with a variety of metastatic bone lesions. The consequences of such lesions can be significant to the patient, from pain and abnormal blood results, including hypercalcemia, to pathological fracture. Given the multiple options available, the treatment of bone metastasis should be based on a patient-by patient manner, as is the case with primary bone lesions. It is imperative, given the various lesion types and locations, treatment of bone metastasis should be performed in an individualised manner. We should consider the nature of the lesion, the effect of treatment on the patient and the overall outcome of our decisions. The dissemination of primary lesions to distant sites is a complex pathway involving numerous cytokines within the tumour itself and the surrounding microenvironment. To date, it is not fully understood and we still base a large section of our knowledge on Pagets historic "seed and soil" theory. As we gain further understanding of this pathway it will allow us develop more medical based treatments. The treatment of primary cancers has long been provided in a multi-disciplinary setting to achieve the best patient outcomes. This should also be true for the treatment of bone metastases. Orthopaedic surgeons should be involved in the multidisciplinary treatment of such patients given that there are a variety of both surgical fixation methods and non-operative methods at our disposal.

Key words: Bone metastases; Diagnosis; Pathophysiology; Surgical treatment, Medical treatment

Core tip: This paper discusses the pathophysiology and patient implications of bone metastasis. We aim to describe the orthopaedic input into the management of this condition, especially in a multi-disciplinary setting. We believe that orthopaedics do not have a significant enough involvement in the treatment of long bone metastasis, although from this paper we feel we have many options to offer. The future of metastasis treatment may be targeted at the molecular level but current management options do require an understanding of musculoskeletal oncology to obtain best patient outcomes through operative and non-operative means.

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INTRODUCTION

The American Cancer Society estimates that 1.64 million cases of cancer will be diagnosed in the United States in 2012[1]. Approximately 50% of these cases involve tumours of the breast, prostate, lung, kidney and thyroid. These tumours commonly metastasize to bone and account for 80% of all skeletal metastases[2]. This compares to an estimated 2890 cases of primary bone tumours that will be diagnosed during the same period[1]. These figures emphasize the importance of being able to recognise, investigate, manage and intervene appropriately in the course of metastatic disease in order to preserve function and quality of life while minimizing complications.

The microenvironment associated with bone is ideal for tumour progression. Bone is a highly vascular mineral which produces adhesion molecules and is a source of angiogenic and bone resorbing molecules, all of which are conducive to the spread and development of tumours[3,4]. It also contains immobilised growth factors, which, when released, further enhance tumour cell proliferation[3,5].

Earliest evidence of skeletal metastases dates from 400 BC[6]. The term "metastasis" was first used by Hippocratic physicians, is of Greek origin and means the "change in the seat of a disease".

Throughout the 19th century, further investigation was carried out to elicit the mechanism behind the development of metastases. This era gave rise to pagets "seed and soil" theory, which postulated that tissues ("soil") receiving tumour cells could either be congenial or hostile[7]. The preferential development of bone metastases first postulated by Stephen Paget in 1889 noted that "in a cancer of the breast the bones suffer in a special way, which cannot be explained by any theory of embolism alone". Hence he proposed the widely acknowledged "seed and soil hypothesis". Circulating disseminated cancer cells activate bone to provide the ideal "soil" in which the aforementioned "seeds" can grow.

Others explained metastases on a purely stochastic basis[8]. It is now accepted that both methods occur, approximately 60% of metastatic sites can be predicted on a purely haematological and/or lymphatic route basis, the remainder of metastases involve intricate interactions between the tumour and host sites at the cellular and molecular level.

The identification of bone metastases is a significant development for patients. Their treatment can change completely as does their outcome. Not only can this news have a physical effect on patients' lives but also an emotional effect. As the treatment of metastatic disease is multidisciplinary in nature, it is imperative that orthopaedic surgeons are involved at an early stage and not just following pathological fracture or the development spinal stenosis.

DIAGNOSIS

Bone metastases and their associated complications (bone pain, pathological fractures, spinal cord compression, loss of independence and mobility and abnormal electrolytes) are the major morbidities associated with advanced disease and the symptoms with which patients will present[9].

The critical aspect in the investigation of a patient with potential metastases involves recognition of the above symptoms as possible progression of the primary tumour to bone. Imaging has an important role in the detection, diagnosis, prognostication, treatment planning, and follow-up monitoring of bone metastases.

Despite the relative insensitivity of plain radiographs in detecting small or early metastases, initial investigations should always include plain radiography. The presence of sclerosis or osteolysis on the X-ray can aid in diagnosis of the metastatic lesion, with sclerosis typically indicating a prostatic lesion and osteolytic lesions secondary to a breast primary[9,10].

Technetium-99m (99mTc) bone scintiscanning (*i.e.*, radionuclide bone scanning) is the most cost-effective and widely available whole-body screening test for the assessment of bone metastases. Combined analysis with plain radiography and 99mTc bone scintiscans improves diagnostic accuracy in detecting bone metastases and assessing the response to therapy[10].

Computed tomography (CT) scanning is an invaluable modality in those cases where bone scan confirms a focal abnormality but plain radiography cannot confirm any metastases. All bony metastatic lesions are depicted well on CT, including those of an osteoblastic, osteolytic and mixed nature.

Despite the expensive nature of the modality, magnetic resonance imaging (MRI) is very sensitive in the detection of metastases. Although some studies have suggested whole body MRI as a possible alternative to 99mTc bone scanning in the skeletal evaluation of bone metastases, this would be an impractical and expensive choice. MRI is primarily used in the evaluation of vertebral metastases for spinal cord compression or soft tissue involvement[11].

Histological diagnosis of metastases can be obtained from core biopsy of the effected bone, or CT guided biopsy should the former prove difficult. Alternatively, in the case of a patient presenting with a pathological fracture in the setting of known metastases, bone reamings at the time of surgical fixation can also be histologically analysed for the presence of circulating tumour cells.

MECHANISM OF METASTATIC LESION FORMATION

Metastasis involves a number of complex cell-cell interactions that ultimately leads to the development and growth of cancer cells in a distant visceral or bony site. Cells from the primary tumour must detach and extravasate. Following this they must migrate through the endothelium into the surrounding blood vessels, attach to the endothelium of a distant site after surviving the turbulent arterial blood supply, then migrate through the endothelium and extracellular matrix of the distant organ. Finally these circulating tumour cells must develop in the distant organ and facilitate the growth of further cancer cells[12].

The capacity to enter the circulation requires that neoplastic cells must have intrinsic properties that facilitate this process. The tumour cell must have the ability to induce neovascularization and be capable of crossing from the tumour stroma to the vasculature by invading the basement membrane of the vascular endothelium[13]. This process is facilitated by cell adhesion molecules (CAMs). Several categories of CAMs exist, including intercellular adhesion molecules (ICAMs), selectins and cadherins[14,15].

Once in the circulation, embolization of the tumour

Table 1 Mirels classification of metastatic bone lesions

Variable	Score		
	1	2	3
Site	Upper limb	Lower limb	Peritrochanter
Pain	Mild	Moderate	Functional
Lesion	Blastic	Mixed	Lytic
Size	< 1/3	1/3-2/3	> 2/3

cell is facilitated by adhesion to P- and L-selectins, located on platelets and leucocytes respectively. Adhesion to the endothelium of the metastatic tissue is mediated *via* E-selectin. Upon adhesion, an integrin signalling pathway is initiated, the net result of which is up-regulation of both the anti-apoptotic machinery and proteolytic activity in the microenvironment, thus facilitating the extravasation of tumour cells out of the circulation, and their invasion into the host tissue[16].

Disseminated tumour cells also contain integrins, a transmembrane receptor family which allows their attachment to several peptide sequences present on certain bone matrix proteins. These cell-surface molecules are involved in signal transduction and have been implicated in the mediation of cell migration, differentiation and apoptosis. Many studies have shown the correlation of increased integrin expression with malignant potential[17].

While our understanding of the molecular mechanisms of metastases has improved significantly since the earliest observations of Billroth[18], we remain ignorant of the intricacies of metastases. Selective therapeutic agents targeted exclusively at metastatic cells have yet to be developed[19] and much remains to be discovered about the critical determinants of metastatic process. However, the accelerated advances in the fields of molecular biology and genetics augurs well for the future.

TREATMENT OPTIONS FOR SKELETAL METASTASES

Bisphosphonates

Current medical options for the treatment of bone metastases primarily involves the use of bisphosphonates[20]. These are potent inhibitors of osteoclast activity and bone resorption and are widely used in both metabolic bone disease and metastatic disease. The mechanism of action of bisphosphonates targets the key stage of metastatic development where the disseminated circulating tumour cell stimulates further bone resorption. The disruption of this interaction, for either a palliative or preventative means, decreases the amplification of the metastatic process.

More recent studies have investigated the direct anti-tumour effects of bisphosphonates. It is believed that along with their inhibition of bone resorption, bisphosphonates may induce apoptosis of certain disseminated cancer cells, such as breast cancer cells. Furthermore, it is now believed from *in vivo* studies that bisphosphonates alter the properties of adhesion molecules in the bone matrix thus inhibiting the direct attachment of circulating tumour cells to the bone microenvironment[12,20]. However, despite their benefits in the treatment of symptomatic metastatic disease, they have not improved survival in patients with bone metastases[20].

Table 2 Capanna classification, classification according to tumour type

Classification according to tumour type	
Class 1	Solitary metastatic lesion
	Primary with good prognosis
	Interval after primary over 3 years
Class 2	Pathological fracture at any site
Class 3	Impending fracture in a major weight bearing bone
Class 4	Osteoblastic lesions at all sites
	Osteolytic or mixed lesions in non-structural bones
	Osteolytic lesion with no impending fracture in major weight-bearing bone
	Lesions of the iliac wing, anterior pelvis or scapula

Surgery

There is no strict rationale governing the surgical management of skeletal metastases. Clinical, medical, radiological and surgical factors, coupled with the inherent biology of the primary tumour all contribute to the decision making process. Furthermore, surgery in the setting of metastatic disease requires reliable data about patient survival and quality of life[21]. Earliest recommendations were simple and called for surgical intervention in the clinical scenario where fractures were "predicable"[22], the idea that the patient should have a reasonable life expectancy before considering surgery is relatively new[23].

Protocols for the treatment of bone metastases of the appendicular skeleton have been published. Mirels described a weighted scoring system in an attempt at quantifying the risk of sustaining a pathological fracture[24] and consequently the relative urgency for orthopaedic surgical intervention (Table 1). Mirels' system remains in wide use today despite the recent introduction of newer protocols[25]. The newer system describes the guidelines to surgical indications, types of surgery and recommended implants. Capanna classifies all patients with bony metastases into 4 categories (Table 2). Patients accumulate a representative numerical value for their metastatic lesion depending on figures awarded for potential survival (Table 3), the size of the lesion, the biomechanics of the bone involved and the potential response to adjuvant therapy. This dictates the recommended surgical intervention and the prosthetic implant to be used (Table 4).

However, despite involved classification systems and resultant surgical recommendations, each case of metastatic disease warrants treatment on an individual basis. Huge strides have been made in the techniques of surgical management for achieving secure fixation of pathological fractures despite what is often extensive bony destruction[26,27]. The use of internal fixation devices and prostheses along with methyl methacrylate has greatly assisted the orthopaedic surgeon in managing

Table 3 Capanna classification, potential survival

Survival	Sources of metastasis
< 1 yr (1 point)	Unknown Primary
	Melanoma
	Lung
	Pancreas
	Thyroid (undifferentiated)
	Stomach
1-2 yr (3 points)	Colon
	Breast (not responding to adjuvants)
	Liver
	Uterus (responding to adjuvants)
> 2 yr (6 points)	Thyroid (differentiated)
	Myeloma
	Lymphoma
	Breast (responding to adjuvants)
	Rectum
	Prostate
	Kidney

Table 4 Capanna classification, recommended surgical procedure and prosthetic type

Survival	Biomechanics	Size defect	Response to adjuvant therapy
< 1 yr = 1 pts	Tibia = 1pt	Small (1/3) = 1 pt	Yes = 0
1-2 yr = 3 pts	Femur, humerus = 2 pts	Large (1/2) = 2 pts	No = 3
> 2 yr = 6 pts	Subtrochanteric, supracondylar = 3 pts	Defective or pathological fracture = 3 pts	
	< 5 points =	Minimal or simple osteosynthesis	
	5-10 points =	Reinforced osteosynthesis	
	10-15 points =	Megaprosthesis or intercalary spacer	

pathological fractures. Despite improved fixation, healing of pathological fractures remains a challenge, overall 35% of pathological fractures can be expected to heal in 6 mo[28], highest healing rates are seen with multiple myeloma (67%) and the lowest rates were seen with lung carcinoma (0%).

It is imperative that whatever fixation device is used the construct should be durable enough to reliably last the remainder of the patient's life expectancy[29] and it is our recommendation that the entire diseased bone be stabilised at one operative sitting (Figure 1).

Although the general orthopaedic surgeon will commonly deal with pathological fractures in their day to day practice, we are commonly referred patients with spinal metastases. As with any patient, a complete history and examination is necessary, including a thorough neurological examination. Radiology should include an MRI to assess spinal cord compression and the extent of spinal metastases. Neurological status may necessitate urgent decompression with stabilisation of the adjacent vertebrae. However, prior to major surgery, it is important to liaise with the patients' oncology service to ascertain overall outcome. In palliative cases, radiotherapy may be

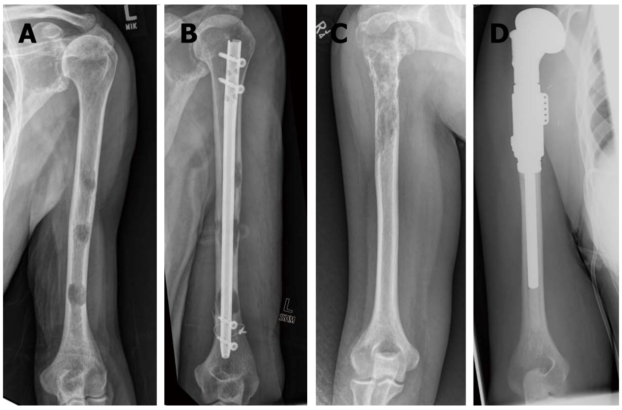

Figure 1 Different fixation methods for metastases of the humerus. A, B: Show the pre and post-operative X-rays of a 71-year-old male with painful metastatic lesions secondary to renal cell carcinoma. The humerus was stabilized using a locked intramedullary nail with a prophylactic distal cerclage wire, excellent pain relief was achieved; C, D: Show the pre and post-operative status of a 40-year-old female with painful metastatic breast carcinoma. The painful lesion was excised and replaced with an endoprostheses, good symptomatic relief was achieved.

an option, if the patient is medically unfit to undergo and survive spinal surgery.

Radiotherapy

The indications to treat bone metastases with radiation therapy include pain, risk of pathological fracture and spinal cord compression. The goals of radiation therapy are to palliate pain, decrease the use of narcotic analgesics, improve ambulation and restore function and prevent complications of pathological fracture.

External-beam radiation is the most common treatment and remains the cornerstone of palliative treatment with hundreds of thousands of patients undergoing treatment each year in the United States. Radiotherapy for bone metastases attempts to exploit the radiosensitivity characteristics inherent to tumour cells such as significant vascularization, high rates of proliferation and non-differentiation[30]. The exact mechanism of action of radiation therapy is unknown and remains speculative[31]. It was only recently that animal models established that radiation had its effect on tumour cells and that the benefit did not accrue from an indirect effect on the peripheral surrounding normal cells[32,33].

Clinically, several choices exist regarding the use of radiation therapy for bone metastases. Opinions differ on the best regimen for each patient, the most suitable radiation dosage, the appropriate adjuvant therapies and their timings and the best delivery mechanism.

The radiation therapy oncology group (RTOG) conducted a prospective randomized trial (RTOG 74-02)[34]. Patients with a solitary metastasis were randomized to receive 2000 cGy using 4 Gy fractions delivered over a short 5-day period or 4050 cGy delivered using 2.7 Gy fractions over a 3 wk period. There was no significant difference in outcomes measured by pain relief. Similar results were seen in patients with multiple metastases who were randomized to receive 3000 cGy in 10 fractions over 2 wk or 1500 cGy in 5 fractions over 1 wk or 2000 cGy in 5 fractions over 1 wk or 2500 cGy in 5 fractions over 1 wk.

Since the RTOG trial[34] there have been several trials evaluating dose fractionation schemes[34,35] with no schedule or dose demonstrating significantly better outcome. Single-fraction radiotherapy has been advocated as a cost effective way to palliate bony metastases. A single dose of 8 Gy has been shown to have significantly better response rates when compared to a single dose of 4 Gy[36]. When a single dose regimen was compared to a multi-fraction regimen (20 Gy/5 fractions or 30 Gy/10 fractions), no differences were noted in time to symptomatic improvement, time to complete pain relief or time to first increase in pain up to 12 mo post-treatment[37].

It is now accepted that accelerated regimens may be appropriate in certain clinical settings for instance if the life expectancy is less than 3 years or where social circumstances decree that the patient cannot return on a daily basis. A protracted course may be more appropriate where the disease is more indolent or where the patient has a good performance status with a longer life expectancy or a solitary bone metastasis where the primary is well controlled[38].

Chemotherapy

The decision to use chemotherapy for the management of bone metastases relies on several factors. Firstly, the histology of the tumour must be known and secondly, it is important to know whether the patient has previously received chemotherapy because even the most chemosensitive tumours, such as lymphomas, are frequently resistant on relapse[38].

Certain tumours are considered highly chemosensitive. Such tumours frequently respond rapidly and often chemotherapy results in a significant reduction in the tumour burden. Complete or near complete remissions can be seen in certain chemosensitive tumours. Highly chemosensitive bone tumours may be considered for a trial of chemotherapy unless the involved bone is mechanically unstable.

Chemotherapy should rarely be considered for the management of metastatic tumours if the primary tumour is not chemoresponsive or chemosensitive. Response rates for these tumour types are so low that responses are considered anecdotal and it is reasonable to consider the tumour to have no effective chemotherapy.

CONCLUSION

Unfortunately the incidence of primary tumours is increasing, with that comes the challenge of dealing with metastatic disease. An individualised approach is recommended for each patient, taking into account the nature and biology of the primary lesion, life expectancy and the most appropriate surgical option. An increased understanding of the biology of the metastatic process may produce new treatment options to arrest this pathway at a variety of positions. Surgical management relies upon basic principles, but also on a fundamental knowledge of the nature of bone metastases.

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BRIEF ARTICLE

Errors in visual estimation of flexion contractures during total knee arthroplasty

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Abstract

AIM: To quantify and reduce the errors in visual estimation of knee flexion contractures during total knee arthroplasty (TKA).

METHODS: This study was divided into two parts: Quantification of error and reduction of error. To quantify error, 3 orthopedic surgeons visually estimated preoperative knee flexion contractures from lateral digital images of 23 patients prior to and after surgical draping. A repeated-measure analysis of variance was used to compare the estimated angles prior to and following the placement of the surgical drapes with the true knee angle measured with a long-arm goniometer. In an effort to reduce the error of visual estimation, a dual set of inclinometers was developed to improve intraoperative measurement of knee flexion contracture during TKA. A single surgeon performed 6 knee extension measurements with the device during 146 consecutive TKA cases. Three measurements were taken with the desired tibial liner trial thickness, and 3 were taken with a trial that was 2 mm thicker. An intraclass correlation coefficient (ICC) was calculated to assess the test-retest reliability for the 3 measurements taken with the desired liner thickness, and a paired t test was used to determine if the knee extension measurements differed when a thicker tibial trial liner was placed.

RESULTS: The surgeons significantly overestimated flexion contractures in 23 TKAs prior to draping and significantly underestimated the contractures after draping (actual knee angle = 6.1° ± 6.4°, pre-drape estimate = 6.9° ± 6.8°, post-drape estimate = 4.3° ± 6.1°, P = 0.003). Following the development and application of the measurement devices, the measurements were highly reliable (ICC = 0.98), and the device indicated that 2.7° ± 2.2° of knee extension was lost with the insertion of a 2 mm thicker tibial liner. The device failed to detect a difference in knee extension angle with the insertion of the 2 mm thicker liner in 9/146 cases (6.2%).

CONCLUSION: We determined the amount of error associated with visual estimation of knee flexion contractures, and developed a simple, reliable device and method to improve feedback related to sagittal alignment during TKA.

Key words: Extension; Knee; Arthroplasty; Flexion contracture

Core tip: Fixed flexion contractures of even 1° have been reported to result in inferior outcomes after total knee arthroplasty. Despite the importance of correcting flexion deformities during surgery, the knee angle is often estimated visually. We developed an intraoperative measurement device that was highly reliable (intraclass correlation coefficient = 0.98) and was able to detect a loss of knee extension with the placement of a 2 mm thicker trial polyethylene liner in 93.8% of cases.

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INTRODUCTION

During total knee arthroplasty (TKA), surgeons often visually evaluate the angle of knee extension when determining if additional soft tissue releases or bony resection are required to correct flexion contractures. However, with the knee draped and tourniquet inflated, errors in the estimation of knee extension angle may occur as the surgeon can no longer visualize the location of the hip joint. The purposes of this two-part study were to (1) determine the effect of surgical draping and tourniquet inflation on visual estimation of knee flexion contractures, and (2) develop and evaluate an inexpensive manual tool to provide surgeons with accurate and reliable measures of knee extension angle during TKA.

Figure 1 Intraoperative use of the knee flexion contracture measuring device.

MATERIALS AND METHODS

Patients electing to undergo primary TKA (n = 23, age = 64.5 ± 10.9 years, body mass index = 32.2 ± 5.9 kg/m^2) volunteered to participate in this IRB-approved study designed to better understand the magnitude of errors in visual estimation of knee flexion contractures during TKA. Once the patient had been anesthetized and in a supine position, a member of the surgical team lifted the operative limb into 20°-30° of hip flexion with the foot rotated so that the second toe was pointed towards the ceiling in order to neutrally align the knee. The preoperative knee flexion contracture was then measured using a long-arm goniometer prior to the placement of surgical draping and tourniquet. Digital photographs of the lateral aspect of the surgical limb were taken prior to and after the placement of standard surgical drapes and inflation of the tourniquet. The camera location for all of the photographs was perpendicular to the operative leg and consistently placed 183 cm from the table. The knee was centered within the camera's field of view, and the hip, knee, and ankle were fully visible prior to draping, after the knee had been partially draped, and after the knee had been fully draped and the tourniquet inflated.

Three board-certified orthopedic surgeons individually estimated the degree of knee flexion contracture from each of the photographs. The order of the resulting 69 images was randomized and the surgeons were blinded to their previous responses as well as the responses of the other surgeons.

The aforementioned results demonstrated a need to reduce the risk of uncorrected flexion contractures by providing surgeons with more accurate and reliable methods to measure knee flexion contractures during TKA. A simple, inexpensive tool that consisted of two inclinometers, both of which featured a freely moving angle indicator arm with an inferior counterweight, was developed with an inferior counterweight was developed (Biomet, Warsaw, IN, United States). After placement of the trial components, the inclinometers were used to measure the resulting degree of flexion contracture. The tibial inclinometer was designed to slide over the handle of the tibial trial inserter, and a set screw was tightened to ensure that it was properly fixed to the handle of the inserter. A drill pin was then inserted into the femoral trial, and the femoral inclinometer was placed on the drill pin (Figure 1). As the leg was positioned in approximately 30° of hip flexion, the degree of knee flexion contracture was measured as the difference between the 2 angles indicated on the tibial and femoral inclinometers. Simply put, if the two inclinometers were divergent when viewing from the lateral aspect of the knee, then full extension had not been achieved whereas if the two inclinometers were convergent, then the knee was in hyperextension. Full extension (0°) was present if the two were parallel.

The resulting value was the combination of the angular difference between the femur and tibia, but also included the relative degree of flexion or extension of the femoral component and the degree of posterior slope of the proximal tibial cut (Figure 2). For example, a surgeon performing cruciate-retaining TKA preferred to make the proximal tibial cut with 3° of posterior slope. If in this example the femoral component was properly aligned in the sagittal plane (neither flexed nor extended), then the difference between the study device's two inclinometers would be -3° (the two pins would be convergent indicating hyperextension). The knee itself; however, would truly be in full extension (0°) as the 3° posterior slope of the tibial component would create the appearance of hyperextension.

Statistical analysis

To evaluate the errors of visual estimation, a repeated-measure analysis of variance was used to compare the estimated angles prior to and following the placement of the surgical drapes and tourniquet inflataion with the preoperative flexion contracture measured with the long-arm goniometer. To evaluate the efficacy of the novel device, we assessed the consistency of measurement and the ability to detect a change in angle. A single surgeon performed 6 knee flexion contracture measurements with the study device during 146 TKA procedures (141

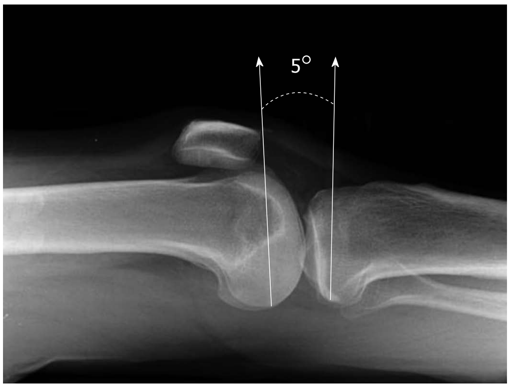

Figure 2 The effect of posterior slope of the proximal tibial cut on the measurements with the study device. If the femoral and tibial components were both placed perpendicular to the long axis of each bone as pictured, then the study device would indicate the presence of a 5° flexion contracture. However, if the proximal tibia was cut with 5° of posterior slope, it would give the false impression that full extension had been achieved as the two inclinometers would be parallel.

patients). Three of the measurements were made with the intended polyethylene thickness, and 3 measurements were taken with the insertion of a trial liner that was 2 mm thicker than the intended liner. An intraclass correlation coefficient (ICC) was calculated to assess the test-retest reliability for the 3 repeated flexion contracture measurements. To evaluate ability to detect a change in knee angle, we compared the measurements with the 2 different liner thicknesses using a paired *t* test. All statistical analyses were performed using SPSS Statistics version 20 (IBM, Armonk, NY, United States).

RESULTS

Prior to draping, the surgeons significantly overestimated the degree of flexion contracture but significantly underestimated the degree of contracture after draping (goniometric measurement = 6.1° ± 6.4°, pre-drape visual estimate = 6.9° ± 6.8°, post-drape visual estimate = 4.3° ± 6.1°, $P = 0.003$).

When evaluating the novel intraoperative measurement device, the measurements were highly reliable (ICC = 0.98), and the device indicated that 2.7° ± 2.2° of knee extension was lost with the insertion of a 2 mm thicker tibial liner. The device failed to detect a difference with the insertion of the 2 mm thicker liner in 9/146 cases (6.2%).

DISCUSSION

The purposes of this two-part study were to determine the effect of surgical draping and tourniquet inflation on visual estimation of knee flexion contractures, and develop and evaluate an inexpensive manual tool to provide surgeons with accurate and reliable measures of knee extension angle during TKA. It was evident after Part I of this study that the ability to correctly estimate the degree of extension during TKA becomes more difficult when the knee is draped.

On average, the three study surgeons visually estimated the knee extension angle to be 2.6° less when the knee was draped compared to estimates made prior to draping. This highlights the need for an intraoperative technique that allows more accurate evaluation of sagittal alignment to avoid fixed flexion contractures. Postoperative flexion contractures of even 1° may negatively affect clinical outcomes[1-6]. By limiting a patient's ability to properly accept weight during gait, flexion contractures cause patients to walk with a bent-knee gait, increasing contact forces in the patellofemoral joint of the involved knee[7,8]. Furthermore, postoperative flexion contractures have been demonstrated to create mechanical overloading of the contralateral knee during gait, potentially contributing to the progression of osteoarthritis in the contralateral knee[9]. As such, great care should be taken to properly correct flexion contractures during TKA.

The novel device used in this study provided a consistent method to intraoperatively measure knee flexion contractures without the added expense or operative time associated with computer-assisted navigation or other electronic sensors.

COMMENTS

Background

Fixed flexion contractures of even 1° have been reported to result in inferior outcomes after total knee arthroplasty (TKA). Despite the importance of correcting flexion deformities during surgery, the knee angle is often estimated visually.

Research frontiers

When visually estimating knee flexion contractures, surgeons significantly underestimated the contractures after draping.

Innovations and breakthroughs

The authors developed an intraoperative measurement device that was highly reliably and was able to detect a loss of knee extension with the placement of a 2 mm thicker trial polyethylene liner in 93.8% of cases.

Applications

The simple, inexpensive device used in this study may allow surgeons to more consistently correct flexion deformities during TKA.

Peer review

This is a well done, interesting paper, presenting strong data.

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BRIEF ARTICLE

Biomechanical characteristics of bone in streptozotocin-induced diabetic rats: An *in-vivo* randomized controlled experimental study

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Abstract

AIM: To investigate the *in vivo* effects of type I diabetes on the mechanical strength of tibial bone in a rodent model.

METHODS: The biomechanical effect of diabetes on the structural integrity of the tibia in streptozotocin induced diabetic Wistar rats was analysed. Induction of diabetes was achieved by an intra-peritoneal injection and confirmed by measuring serial blood glucose levels (> 150 mg/dL). After 8 wk the tibiae were harvested and compared to a control group. Biomechanical analysis of harvested tibiae was performed using a three-point bending technique on a servo hydraulic MTS 858 MiniBionix frame. Maximum force applied to failure (N), stiffness (N × mm) and energy absorbed (N/mm) were recorded and plotted on load displacement curves. A displacement control loading mode of 1 mm/min was selected to simulate quasi-static loading conditions. Measurements from load-displacement curves were directly compared between groups.

RESULTS: Fourteen streptozotocin induced diabetic Wistar rats were compared against nineteen non-diabetic controls. An average increase of 155.2 g in body weight was observed in the control group compared with only 5 g in the diabetic group during the experimental study period. Levels of blood glucose increased to 440.25 mg/dL in the diabetic group compared to 116.62 mg/dL in the control group.The biomechanical results demonstrate a highly significant reduction in the maximum load to failure from 69.5 N to 58 N in diabetic group compared to control (P = 0.011). Energy absorption to fracture was reduced from 28.2 N in the control group to 23.5 N in the diabetic group (P = 0.082). No significant differences were observed between the groups for bending stiffness.

CONCLUSION: Streptozotocin-induced diabetes in rodents reduces the maximum force and energy absorption to failure of bone, suggesting a predisposition for fracture risk.

Key words: Streptozotocin; Rodent; Bone; Biomechanics

Core tip: The bones of streptozotocin-induced diabetic Wistar rats are more fragile with reduced toughness, characterized by a reduction in the capacity to absorb energy and with lower forces required to induce fracture in comparison to those in the control group. Our findings confirm previous studies and lend weight to the literature describing the detrimental relationship between the mechanical properties of bone subjected to diabetes mellitus. Further research needs to be conducted to ascertain whether uncontrolled diabetes in a human population affects the structural and biomechanical properties of bone.

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INTRODUCTION

Bone is a composite of organic collagen and inorganic crystalline hydroxyapatite. Bone loss in diabetes mellitus (DM) has been attributed to metabolic abnormalities, abnormal calcium concentration within cells, and high blood glucose levels[1]. DM interferes with the formation of the collagen network, therefore affecting the biomechanical integrity of bone. Any basis for reduction in bone integrity and material strength has yet to be accurately defined. A lack of insulin in *in vitro* experiments results in a reduction in ossification and calcification and a reduction in cartilage formation[2]. Furthermore, in rat studies the proliferation of osteoblasts and nucleotide synthesis[3,4] *in vitro* are associated with insulin binding through expression of insulin receptors[5]. Production of advanced glycation end products has also been implicated in the reduction of bone material strength in diabetes, through the non-enzymatic cross-linking of collagen[6,7]. Despite molecular evidence for this theory, mechanical data on the effect of diabetes on bone remain conflicting and sparse.

Clinical and experimental studies demonstrate that diabetes is associated with molecular and cellular changes with resultant alterations to bone physiology[8]. Patients with type 1 DM have been observed to exhibit a disproportionately high risk of fracture with reduced bone mass, leading to speculation that diabetic bone has reduced strength[9,10]. Furthermore studies indicate that diabetes exerts a similar effect on bone to that observed in the normal ageing process, with a predisposition to fracture susceptibility, delayed union and osteoporosis[11]. The biomechanical properties of bone in diabetes have been poorly addressed in the literature with conflicting results. Fleischli *et al*[12] demonstrated no differences in the material properties of human metatarsal bones when comparing younger diabetics to older non-diabetic donors. In a subsequent study on cadaveric human tibiae no significant differences were demonstrated between diabetic and non-diabetic specimens[13]. Animal studies suggest a reduction in bone mineral density as a direct consequence of DM. This is exhibited by bone loss in trabecular bone and failure to accrue cortical bone due to premature cessation of growth[14]. Further biomechanical experimental animal studies have demonstrated either increased stiffness[9,15] or reduced stiffness[16-18]. These variances are confusing but may be accounted for due to a number of factors. Stiffness as an indicator of overall bone strength alone is not the only significant biomechanical factor that can be affected by diabetes. Taken in isolation, changes in stiffness may be a consequence of a reduction in total whole bone strength. Any decoupling of stiffness or strength as a ratio may account for the reported differences observed in studies. Changes to strength may not only be an effect of the material strength of the tissues but also a consequence of differences in the size and shape of the bone being tested. Furthermore, the length of time that the rats were exposed to a diabetic state may also account for differences in results.

The aim of the current study is to examine and quantify the mechanical behavior of bone in streptozotocin-induced diabetic rats compared to normal controls.

MATERIALS AND METHODS

Animal model

The experimental protocol was ethically approved by the General Directorate of Veterinary Services (license No: K/7559/29-10-09) and by the Bioethics Committee of University of Athens Medical School, Hellas. The study was conducted in accordance with Hellenic legislation for experimental animal studies (P.D.160/91) and in compliance with European Union law (86/609/EEN.2015/92) and the Convention on Vertebrate Animals Protection for experimental or other scientific purposes (123/1986). Forty male Wistar rats aged 3 mo, weighing between 200-300 g were supplied by the Institute Pasteur. Wistar rats represent a close homology to the human type 1 DM phenotype, demonstrating comparable genetic and physiological characteristics. All animals had free access to food and water. Animals were randomly assigned to a control (C) or diabetic (D) group. Those assigned to the D group were induced to a diabetic state by an intra-peritoneal injection of streptozotocin at a dose of 55 mg/kg body weight. Streptozotocin is an agent known to be specifically toxic to the beta cells in the islets of Langerhans in the pancreas. The mechanism of action is thought to be mediated by alkylation of DNA bases, resulting in reduction of nicotinamide adenine dinucleotide. This, therefore, eliminates production of insulin and induces a hyperglycaemic state. After 1 wk, body weight estimation,

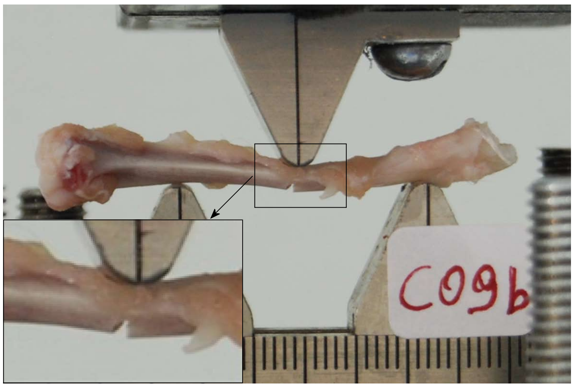

Figure 1 Mini-Bionix Frame with application of three-point bending at the mid diaphysis.

and glucose blood sampling was conducted to determine animals in a hyperglycemic state, defined as blood sugar > 150 mg/dL. Twenty-six animals were originally induced with streptozotocin to a diabetic state. Seven out of those 26 animals were excluded from the study (3 died and 4 did not respond) leaving 19 animals in the D group. The diabetic state was defined as polyuria and minimal weight gain post streptozotocin injection. Fourteen rats remained in the C group and compared with the 19 rats in the D group. Eight weeks after induction of diabetes, the animals were euthanized according to the Convention on Vertebrate Animals Protection for experimental scientific purposes (123/1986) using isoflurane gas and sodium-pentobarbital. Tibial bones were carefully dissected of soft tissue from each animal in each group, isolated and harvested for mechanical testing.

Biomechanical testing

Biomechanical analysis was performed by three-point bending mechanical tests. The experiments were conducted using a servo hydraulic MTS 858 Mini Bionix frame (MTS Systems, Eden Prairie, MN, United States). Tibiae were placed horizontally on the frame on rounded edges at a distance of 24 mm. Attention was paid to ensure all the specimens were placed in exactly the same manner with regards to position and orientation in an effort to minimize variability. The load was applied at the mid-shaft of the diaphysis using a punch with a rounded notch (Figure 1). The displacement control loading mode was selected. The rate of the imposed displacement was selected as 1 mm/min in an effort to simulate quasi-static loading conditions. The displacement was imposed continuously until fracture. The load-displacement curves and the maximal load at fracture in Newtons (N) were recorded. Failure was defined and observed by a propagation of an almost vertical fracture starting almost universally at the lower cortical bone surface. This is expected in bending tests of a brittle material because of the relatively lower tensile strengths compared to the respective opposite compressive strength.

Maximum force applied to failure (N), stiffness (N × mm) and energy absorbed (N/mm) were recorded and plotted on load-displacement curves. The maximum load is represented by the maximum compressive force applied until fracture. Deformation (strain) was defined as the degree of transverse displacement at the loading point. The initial non-linear curve corresponds to the adaptation of the specimens on the rounded edges of the loading device. The almost perfectly linear portion represents the linear elastic behavior of the tissue and the slope is equal to the stiffness. The nonlinear portion corresponds to the non-elastic (plastic) behavior of the tissue.

Statistical analysis

Statistical analysis on the groups was conducted using analysis of variance. An overall P value of < 0.05 was considered to be statistically significant.

RESULTS

Weight and glucose measurements

Table 1 demonstrates weight measurements and glucose measurements of both groups over the experimental study period. An average increase of 155.2 g in body weight was observed in the C group compared with only 5 g in the D group during the experimental study period. Levels of blood glucose increased to 440.25 mg/dL in the D group compared to 116.62 mg/dL in the C group.

Biomechanical analysis

Table 2 summarizes the differences in maximum force to failure, stiffness and energy-absorbed values recorded between the two groups. Maximal load to failure in C was 69.5 ± 10.3 N (mean ± SD) compared with a reduction to 58 ± 13.2 N (mean ± SD) in the D group. This demonstrated a statistically significant difference (P = 0.011). Stiffness measurements demonstrated no significant differences between the two groups. A statistically significant reduction (P = 0.019) was observed in measurements for energy absorption from 28.2 ± 5 N in the control group to 23.5 ± 5.6 N in the D group.

DISCUSSION

Our experimental randomized controlled study demonstrated the effect of diabetes on bone strength.

The literature on the association between bone strength and fracture risk in DM remains weak. The bone changes directly observed in DM can be attributed to a multitude of interrelated factors. Both the material and geometric properties of bone are implicated in influencing mechanical strength. Macroscopic structure (size and shape), architecture (cortical and cancellous components) and the bone substance (organic and inorganic components) are all influenced by DM. Furthermore, changes in collagen, elastin and proteoglycan concentrations, formation of advanced glycation end products and the orienta-

Table 1 Weight and blood glucose comparison between groups

	Prior to induction		One weekpost-induction		Ateuthanasia	
	C group	D group	C group	D group	C group	D group
Weight (g)	263.5	272.5	367	284.7	418.7	277.5
Glucose (mg/dL)	135.5	128.5	121.37	359.37	116.62	440.25

C group: Control group; D group: Diabetic group.

Table 2 Summary of biomechanical data (mean ± SD)

	Max force (N)	Stiffness (N × mm)	Energy (N/mm)
Diabetic group	58.0 ± 13.2	101.1 ± 30.2	23.5 ± 5.6
Control group	69.5 ± 10.3	118.4 ± 23.0	28.2 ± 5.0
P value	0.011	0.082	0.019

tion of collagen fibers are all important determinants of mechanical integrity, which are also affected.

In our study, we aimed to directly quantify whether an uncontrolled diabetic state directly alters the mechanical properties of appendicular long bone of tibiae, to add to the quality of published evidence that DM adversely affects bone quality. Immature rodents were used in an attempt to mimic the presentation of DM in humans, which typically occurs prior to skeletal maturity. Wistar rats were selected for the animal model as this genotype represents a close homology to DM in humans. We observed statistically significant changes in the D group, with reductions in maximum force and energy absorbed to failure demonstrating that the DM alters mechanical properties after as little as 8 wk. Interestingly, in our study we found no statistically significant differences in stiffness between C and D groups. Reported information on stiffness is conflicting in the literature, with some demonstrating increased[9] and other decreased values[16,18]. These variances are confusing but may be accounted to a number of factors. Stiffness as an indicator of overall bone strength alone is not the only significant biomechanical factor that can be affected by diabetes. Taken in isolation, changes in stiffness may be a consequence of a reduction in total bone strength. Any decoupling of stiffness or strength as a ratio may account for the reported differences observed in studies. The changes to strength therefore may not only be an effect of material strength of the tissues but also as a consequence of differences in the size and shape of the bone being tested. When values for stiffness are normalized against the geometry and structural shape of the bone, these differences in stiffness can be accounted for.

A number of experimental rodent studies exist documenting the biomechanical effects of bone in streptozotocin induced DM. These studies exhibit various experimental protocols. To our knowledge, eight studies exist evaluating bone mechanics using a type 1 diabetic model in rodent studies[9,14-16,19-22]. All these studies exhibit differences in their methodology, specifically duration of induced DM, species of rodent and diabetogen used to initiate DM. However, despite their differences these studies consistently demonstrate reductions in ultimate force to failure in the D groups, in keeping with the result of our study. The three studies which report on values for energy to failure[15,16,22] all demonstrate a reduction in energy to failure in the diabetic groups, in keeping with our analysis.

Our findings lend weight to the argument that DM (in a type 1 DM rodent model) reduces the mechanical behavior of bone. However, the changes that occur are probably not only to be result of changes in mechanical properties but are probably also due to inherent detrimental changes which occur in the structural material properties. This theory has been confirmed in a mouse model where significant differences were observed in the strength-structure relationship, with reductions to the tissue mineral density of bone in DM, which became apparent after only 10 wk[23].

Our experimental model subjected the D group of rats to uncontrolled levels of hyperglycaemia. This experimental protocol represents a scenario, which would only be representative of the small proportion of the human DM population who poorly control their blood glucose levels. It is likely be that our experimental model represents a worse case scenario. Conversely the duration that the rats were exposed to an uncontrolled hyperglycaemic state was only 8 wk. This is unlikely to represent the chronic human diabetic state. It is possible that subjecting the animals to a longer period of hyperglycaemia would cause further deterioration in the material properties of bone. This has been confirmed by Nyman *et al*[23] in a mouse model exposed to DM for up to 18 wk, in which further deterioration in mechanical properties was observed with longer exposure.

There are several limitations to our study. Firstly the duration of induced DM was only 8 wk, which may not be representative of the changes that occur chronically. It could be postulated that any effects on mechanical properties could be under-estimated and the further detrimental changes could have occurred if DM was allowed to continue. The experimental model also represents a scenario where DM remains unchecked with hyperglycemia allowed to develop without control. This model is unlikely to be representative of a clinical scenario where DM is treated and therefore represents a worse case presentation. Furthermore, this study did not investigate the effects of DM on bone structure and architecture. No histomorphometric analysis was conducted to investigate whether the mechanical changes to the material observed, exhibited correlation to bone quality.

Although the pathogenesis of osteopenia in diabetes is a poorly understood phenomenon, decreased bone formation, mineralization and absorption seem to be associated with inferior mechanical properties of bone turnover in diabetes. These changes may be not so frequently observed in humans, as most people do not allow serum glucose levels to go unchecked and manage DM with strict administration of insulin therapy. Significant changes to bone biomechanics may, therefore, only be representative of a small cohort of human diabetics who have long-standing prolonged disease which is resistant to or poorly controlled by insulin therapy.

The bones of streptozotocin-induced diabetic Wistar rats are more fragile with reduced toughness characterized by a reduction in the capacity to absorb energy and with lower force required to induce fracture, in comparison to those in the control group. Our findings confirm previous studies and add weight to the literature investigating the detrimental relationship between the mechanical properties of bone subjected to DM.

COMMENTS

Background

Clinical and experimental studies demonstrate that diabetes is associated with molecular and cellular changes with resultant alterations to bone physiology. Patients with type 1 diabetes mellitus (DM) have been observed to exhibit a disproportionately high risk of fracture with reduced bone mass, leading to speculation that diabetic bone has reduced strength. The resultant biomechanical changes and properties of bone in DM have been poorly addressed in the literature with conflicting results.

Research frontiers

Experimental studies demonstrating alterations to physiology and structural changes to bone in DM is sparse and conflicting. Uncontrolled DM has been suggested to result in detrimental biomechanical properties of bone. Furthermore, studies indicate that diabetes exerts a similar effect on bone to that observed in the normal ageing process, with a predisposition to fracture susceptibility, delayed union and osteoporosis.

Innovations and breakthroughs

This study lends weight to the literature that an uncontrolled DM state in a rodent population induced by streptozotocin results in reduction in the biomechanical properties of bone, specifically with reduction in ultimate strength to failure and capacity to absorb energy.

Applications

By understanding how an uncontrolled diabetic state detrimentally alters bone biomechanics, future strategies to target diabetic patients may result in better bone health and reduction in osteoporosis and fracture risk.

Terminology

Wistar rats represent a close homology to the human type 1 DM phenotype, demonstrating comparable genetic and physiological characteristics. Thus, they likely to be the closest animal model representative of an uncontrolled diabetic state in humans.

Peer review

The authors examined the effects of an induced DM state and its relationship to the biomechanical properties of bone. Results revealed decreased bone quality and reduction in energy absorbing capacity. The results are interesting and may represent a close homology to the effects seen in the bone health of patients who have DM.

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BRIEF ARTICLE

Olecranon anatomy: Use of a novel proximal interlocking screw for intramedullary nailing, a cadaver study

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Abstract

AIM: To define the optimum safe angle of use for an eccentrically aligned proximal interlocking screw (PIS) for intramedullary nailing (IMN).

METHODS: Thirty-six dry cadaver ulnas were split into two equal pieces sagitally. The following points were identified for each ulna: the deepest point of the incisura olecrani (A), the point where perpendicular lines from A and the ideal IMN entry point (D) are intersected (C) and a point at 3.5 mm (2 mm safety distance from articular surface + 1.5 mm radius of PIS) posterior from point A (B). We calculated the angle of screws inserted from point D through to point B in relation to D-C and B-C. In addition, an eccentrically aligned screw was inserted at a standard 20° through the anterior cortex of the ulna in each bone and the articular surface was observed macroscopically for any damage.

RESULTS: The mean A-C distance was 9.6 mm (mean ± SD, 9.600 ± 0.763 mm), A-B distance was 3.5 mm, C-D distance was 12.500 mm (12.500 ± 1.371 mm) and the mean angle was 25.9° (25.9° ± 2.0°). Lack of articular damage was confirmed macroscopically in all bones after the 20.0° eccentrically aligned screws were inserted. Intramedullary nail fixation systems have well known biological and biomechanical advantages for osteosynthesis. However, as well as these well-known advantages, IMN fixation of the ulna has some limitations. Some important limitations are related to the proximal interlocking of the ulna nail. The location of the PIS itself limits the indications for which intramedullary systems can be selected as an implant for the ulna. The new PIS design, where the PIS is aligned 20° eccentrically to the nail body, allows fixing of fractures even at the level of the olecranon without disturbing the joint. It also allows the eccentrically aligned screw to be inserted in any direction except through the proximal radio-ulnar joint. Taking into consideration our results, we now use a 20° eccentrically aligned PIS for all ulnas. In our results, the angle required to insert the PIS was less than 20° for only one bone. However, 0.7° difference corresponds to placement of the screw only 0.2 mm closer to the articular surface. As we assume 2.0 mm to be a safe distance, a placement of the screw 0.2 mm closer to the articular surface may not produce any clinical symptoms.

CONCLUSION: The new PIS may give us the opportunity to interlock IMN without articular damage and confirmation by fluoroscopy if the nail is manufactured with a PIS aligned at a 20.0° fixed angle in relation to the IMN.

Key words: Interlocking screw; Intramedullary nailing; Ulna fracture; Ulna anatomy

Core tip: Limitations of intramedullary nailing (IMN) of the ulna, which make IMN a secondary choice, include problems experienced at the proximal interlocking screw (PIS). A new PIS system may solve most common problems with an eccentrically aligned screw. This new PIS system may be very advantageous if the fluoroscopy time, operation time and the need for additional incision in other systems is considered. However, the screw must be designed at a safe angle to have these advantages. According to our results, a 20.0° is the optimum angle of alignment for this screw.

Küçükdurmaz F, Saglam N, Ağır İ, Sen C, Akpınar F. Olecranon anatomy: Use of a novel proximal interlocking screw for intramedullary nailing, a cadaver study. *World J Orthop* 2013; 4(3): 130-133 Available from: URL: http://www.wjgnet.com/2218-5836/full/v4/i3/130.htm DOI: http://dx.doi.org/10.5312/wjo.v4.i3.130

INTRODUCTION

Intramedullary nailing (IMN) of the forearm has gained much popularity but still has some technical limitations, especially in relation to IMN of the ulna[1,2]. The proximal interlocking screw (PIS) is one of the critical steps in IMN of the ulna. Location of the PIS limits the indications for which IMN of the ulna can be used with currently available IM systems. IM systems are useless in fractures where the olecranon is involved. In addition, IM systems may be insufficient in proximal ulna fractures and may require extra caution to avoid damage to the articular surface when placed around the olecranon[1,2]. Currently available IMN systems of the ulna have the same inherent problems as all IMN, requiring an extra incision for the interlocking screw and prolonged radiation exposure of the surgical team because of the use of fluoroscopy.

A newly developed PIS system[3] solves these problems with an eccentrically aligned PIS (Figure 1) which is inserted through a hole located at the proximal tip of the nail.

In this *in vitro* study, we aim to identify the optimum angle of the eccentrically aligned PIS to the IMN in relation to the olecranon articular surface.

MATERIALS AND METHODS

Ulna bones of 36 dry bony cadavers were used. The proximal parts of the ulnas were split sagitally into two equal pieces. The deepest point of the incisura olecrani (A) was identified for each ulna. A horizantal line was drawn longitudinally at the middle of the medulla and a vertical line was drawn from point A perpendicular to this line. The point where these lines intersected (C) and the ideal IMN entry point (D) were also identified for each ulna. Then a point (B) was identified, located on the A-C line and 3.5 mm posterior to point A. 3.5 mm is the sum safe distance from the articular surface (2 mm) and the radius of PIS (1.5 mm) (Figure 2). Then, we calculated the angles of the screws when inserted from point D through to point B using the following formula: tanα = B-C/C-D (Figure 2).

Figure 1 Eccentrically aligned proximal interlocking screw.

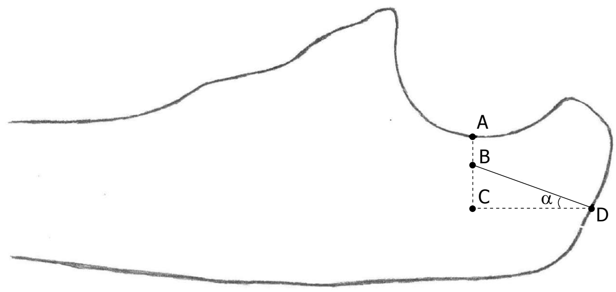

Figure 2 Olecranon anatomy, related to a novel proximal interlocking screw for intramedullary nailing. A: Deepest point of the incisura olecrani; B: The point, which is 3.5 mm posterior to A point and targeted during insertion of the proximal interlocking screw; C: The point where the line from the middle of the medulla and the line perpendicular to point A intersect; D: Ideal entry point for intramedullary nail.

In addition, taking into consideration the measured angles, a screw alligned eccentrically in relation to the IMN was inserted at a standard 20° through the anterior cortex of the ulna in each bone as a PIS and the articular surface was observed macroscopically for any damage.

RESULTS

The mean A-C distance was 9.600 mm (range 8.500-11.000 mm, SD = 0.763 mm). The mean A-B distance was 3.5 mm for each ulna. The mean C-D distance was 12.500 mm (range 10.000-14.600 mm, SD = 1.371 mm). The mean angle was 25.9° (range 19.3°-29.2°, SD = 2.0°) (Table 1). Lack of articular damage was observed macroscopically for each bone after the 20.0° eccentrically aligned screws were inserted.

DISCUSSION

Intramedullary nail fixation systems have well known biological and biomechanical advantages for osteosynthesis. However, in addition to these well-known advantages, intramedullary nail fixation of the ulna has some limitations[1,2]. Some important limitations are related to the PI of the ulna nail. The location of the PIS itself limits the indications for which intramedullary systems can be selected as an implant for the ulna.

Table 1 The A-C distance, C-D distance and angle for each ulna

Ulna No.	A-C distance (mm)	C-D distance (mm)	Angle (°)
1	9.7	11.2	24.9
2	9.4	13.8	23.1
3	9.0	12.0	24.6
4	8.5	14.3	19.3
5	8.9	13.4	21.9
6	11.0	14.6	27.2
7	10.1	13.6	25.9
8	10.4	12.4	29.1
9	11.0	13.4	29.2
10	11.0	14.6	27.2
11	9.0	11.7	25.2
12	8.7	10.6	26.1
13	10.2	14.0	25.6
14	10.5	13.2	27.9
15	9.3	12.9	24.2
16	9.8	12.4	26.9
17	10.0	14.5	24.1
18	9.5	12.8	25.1
19	9.5	12.7	25.3
20	8.8	10.7	26.3
21	10.1	13.5	26.0
22	11.0	14.5	27.3
23	9.0	10.7	27.2
24	9.6	12.1	26.7
25	9.9	12.5	27.1
26	8.7	11.3	24.7
27	8.9	10.2	27.9
28	10.8	13.6	28.2
29	9.0	11.0	26.6
30	9.0	10.6	27.4
31	8.9	10.1	28.1
32	8.6	12.5	22.2
33	9.3	12.7	24.5
34	10.1	13.1	26.7
35	9.8	12.4	26.9
36	8.7	10.0	27.4
Total, mean ± SD	9.600 ± 0.763	12.500 ± 1.371	25.9 ± 2.0
(range)	(8.500-11.000)	(10.000-14.600)	(19.3-29.2)

Intramedullary fixation systems are inadequate for fractures of the proximal ulna especially if the olecranon is involved. There is usually not enough bone stock to put a PIS into proximal fractures even if the fracture is slightly distal to the olecranon[4]. If the fracture is to the proximal part of the ulna or at the level of the olecranon, the screw should be inserted perpendicular or oblique to the articular surface[5-7]. This requires the selection of a PIS to avoid disturbing the joint, and this may not provide adequate stability. Moreover, there may be irritatation of the ulnar nerve if the PIS is aligned parallel to the articular surface of the olecranon[5]. Gehr and Friedl developed an intramedullary device for olecranon fractures, although this device cannot be used for segmental fractures, which also involve distal fractures, and they reported ulnar nerve irritation. The new PIS design allows the fixing of fractures even at the level of the olecranon without disturbing the joint when the PIS is aligned 20.0° eccentrically to the nail body. It also allows the eccentrically aligned screw to be inserted in any direction except through the proximal radio-ulnar joint.

Radiation exposure tends to be underestimated by surgeons[8,9]. Proximal interlocking always requires fluoroscopic confirmation. Currently available intramedullary nails for the ulna require quite long fluoroscopy time, even up to 150 min[7]. By contrast, with the new PIS system floroscopy usage is optional, provided preoperative measurements are done properly.

The PIS usually requires an additional incision[6,10,11]. In the new PIS system, the screw is inserted from the proximal tip of the nail. There is no need for an additional incision for PI other than the incision used for insertion of the IM nail, which means no additional soft tissue damage.

An eccentrically aligned PIS with a fixed angle may provide important advantages. The angle between the nail and screw has critical importance to the articular surface of the olecranon.

Taking into consideration our results, we use a 20° eccentrically aligned PIS for all ulnas by. In our results, the angle required to send the PIS was less than 20° (19.3°) for only one bone (No. 4). However, 0.7° difference corresponds to placement of screw only 0.2 mm closer to the articular surface. As we assume 2.0 mm to be a safe distance, a 0.2 mm closer placement of the screw to the articular surface may not produce any clinical symptoms. Moreover, as far as we know, there are no previous studies which have considered the safe distance between the screw and the articular surface of the olecranon. As a result, the lack of macroscopic articular surface damage in case 4, like all others, may be evidence of the safety of this system.

As a result, this new PIS system may be very advantageous if the fluoroscopy time, operation time and the need for additional incision compared to other systems is considered. However, the screw must be positioned at a safe angle to have these advantages. According to our results, a 20° is the optimum angle of alignment for the screw.

COMMENTS

Background

Intramedullary nail fixation systems have well known biological and biomechanical advantages for osteosynthesis. Limitations of intramedullary nailing (IMN) of the ulna, which makes IMN a secondary choice, includeproblems experienced at the proximal interlocking screw (PIS).

Research frontiers

Location of the PIS limits the indications for use of IMN of the ulna in currently available intramedullary systems. A new PIS system may solve most common problems with an eccentrically aligned screw. The purpose of this *in vitro* study was to define the optimum safe angle of eccentrically aligned PIS for IMN.

Innovations and breakthroughs

İntramedullary systems may be insufficient in proximal ulna fractures and may require extra caution not to damage the articular surface when placed around the olecranon. Currently available IMN systems of the ulna have the same inherent problems as all IMN, requiring an extra incision for the interlocking screw and prolonged radiation exposure of the surgical team because of the use of fluoroscopy. The new PIS may give the authors the opportunity to interlock the IMN without articular damage and confirmation by fluoroscopy if the nail is manufactured with a PIS aligned at a 20° fixed angle in relation to the IMN.

Applications

The new PIS design allows fixing fractures even at the level of the olecranon without articular damage and confirmation of fluoroscopy.

Terminology

Intramedullary nailing: A rod of metal, or other material for fixation of fragments of fractured bones, in this study for ulna fractures. Interlocking screw: A screw which passes through the IMN perpendicular to its long axis and prevents the nail to migrate or rotate within the bone.

Peer review

This new PIS system may be very advantageous if the fluoroscopy time, operation time and the need for additional incision at other systems is considered. However, it must be designed at a safe angle to have these advantages. According to these results, 20° is the optimum angle of alignment for this screw.

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BRIEF ARTICLE

Comparison of straight median sternotomy and interlocking sternotomy with respect to biomechanical stability

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Abstract

AIM: To increase the stability of sternotomy and so decrease the complications because of instability.

METHODS: Tests were performed on 20 fresh sheep sterna which were isolated from the sterno-costal joints of the ribs. Median straight and interlocking sternotomies were performed on 10 sterna each, set as groups 1 and 2, respectively. Both sternotomies were performed with an oscillating saw and closed at three points with a No. 5 straight stainless-steel wiring. Fatigue testing was performed in cranio-caudal, anterio-posterior (AP) and lateral directions by a computerized materials-testing machine cycling between loads of 0 to 400 N per 5 s (0.2 Hz). The amount of displacement in AP, lateral and cranio-caudal directions were measured and also the opposing bone surface at the osteotomy areas were calculated at the two halves of sternum.

RESULTS: The mean displacement in cranio-caudal direction was 9.66 ± 3.34 mm for median sternotomy and was 1.26 ± 0.97 mm for interlocking sternotomy, $P < 0.001$. The mean displacement in AP direction was 9.12 ± 2.74 mm for median sternotomy and was 1.20 ± 0.55 mm for interlocking sternotomy, $P < 0.001$. The mean displacement in lateral direction was 8.95 ± 3.86 mm for median sternotomy and was 7.24 ± 2.43 mm for interlocking sternotomy, $P > 0.001$. The mean surface area was 10.40 ± 0.49 cm^2 for median sternotomy and was 16.8 ± 0.78 cm^2 for interlocking sternotomy, $P < 0.001$. The displacement in AP and cranio-caudal directions is less in group 2 and it is statistically significant. Displacement in lateral direction in group 2 is less but it is statistically not significant. Surface area in group 2 is significantly wider than group 1.

CONCLUSION: Our test results demonstrated improved primary stability and wider opposing bone surfaces in interlocking sternotomy compared to median sternotomy. This method may provide better healing and less complication rates in clinical setting, further studies are necessary for its clinical implications.

Key words: Median sternotomy; Interlocking stenotomy; Stability; Osseos healing; Biomechanics

Core tip: Sternal healing after median sternotomy can be compromised by an unstable closure. In this *in vitro* study, we found that the biomechanical characteristics of the median interlocking sternotomy were superior to those of the straight median sternotomy. The zigzag cuts made the sternotomy line significantly more stable and provided more surface area

for bony healing. These improved features are highly associated with improved bony healing. We believe that the interlocking sternotomy will decrease the complications associated with sternotomy in clinical basis by providing a better bony healing.

Küçükdurmaz F, Ağır İ, Bezer M. Comparison of straight median sternotomy and interlocking sternotomy with respect to biomechanical stability. *World J Orthop* 2013; 4(3): 134-138 Available from: URL: http://www.wjgnet.com/2218-5836/full/v4/i3/134.htm DOI: http://dx.doi.org/10.5312/wjo.v4.i3.134

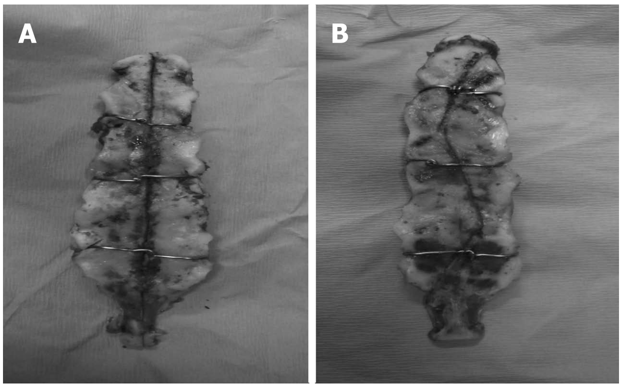

Figure 1 Sternotomy. A: Fixated median straight sternotomy, anterior view; B: Fixated interlocking sternotomy, anterior view.

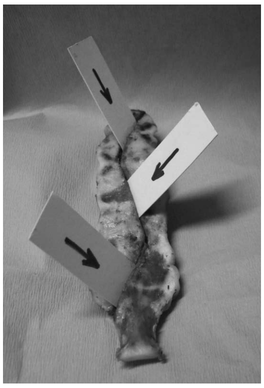

Figure 2 Sternotomy planes of interlocking sternotomy. Each zigzag osteotomy line was perpendicular to the previous line in the axial plane, which are showed with arrows.

INTRODUCTION

Median sternotomies are the most commonly performed osteotomy in the world[1]. Sternotomy is the best transsternal approach for accessing lesions localized to the vertebral bodies of the upper thoracic spine[2,3], and it is a standard incision for thoracic and cardiac surgery.

Despite the popularity of median sternotomy, complications such as nonunion, persistent pain, and infection occur in 0.3% to 5% of cases and are associated with a 14% to 47% mortality rate if mediastinitis supervenes[4]. The morbidity, mortality, and expenses associated with these complications continue to make their prevention and treatment of great importance.

The continuous motion between the halves of the divided sternum resulting from the lack of immobilization causes postoperative sternal instability[5], which is the most important factor in postoperative morbidity and mortality. Providing greater stability[3,4,6] and promoting primary osseous healing is crucial for preventing these complications[7-11].

More than 40 different techniques have been described for closing median sternotomy[12-16]. The biomechanical characteristics of different sternal closures may substantially improve sternotomy reduction and stability[17-19]. In particular, interlocking sternotomy appears to offer better stability and greater surface area for bone healing than other techniques. However, the biomechanical characteristics of this technique have not been assessed. Accordingly, in this experimental study, we compared the biomechanical characteristics of interlocking sternal closure with those of straight sternal closure in a study of sheep sterna.

MATERIALS AND METHODS

We obtained sterna freshly isolated from the sterno-costal joints of the ribs of 20 sheep (Ovis ammon aries) in same age and weight from slaughterhouse. We had institutional ecthical approval from Marmara University ethical committee. Median straight (Figure 1A) and interlocking (Figure 1B) sternotomies were performed on 10 sterna each.

Sternotomy procedure

Interlocking sternotomy was created with 3 zigzag osteotomy lines approximately 150 degrees to each other in the coronal plane. Each osteotomy line was perpendicular to the previous line in the axial plane (Figure 2). Median sternotomy was performed as a straight osteotomy line in the cranio-caudal (CC) direction. We measured the dimension of the cut surface and simply calculated the area of surface for interlocking sternotomy and median sternotomy.

Both sternotomies were performed with an oscillating saw and closed at three points with No. 5 straight stainless-steel wiring (Figure 1). The wire tension during closure is done by free hand, with 5 times twisting the wire for each suture.

The sterna were attached to custom fixtures designed to produce displacement in one of three directions: (1) CC shear; (2) anterio-posterior (AP) shear; and (3) lateral (distraction) shear. The test was done in CC, AP and distraction directions sequentially. The fixtures designed to have 3 grasping jigs in 3 directions like the *x*, *y* and *z* dimensions.

Biomechanical testing

Fatigue testing was performed by a computerized materials-testing machine (High Capacity 8802, Instro, Norwood, MA, United States). The sterna were attached (Figure 3) to custom fixtures designed to produce dis-

Table 1 Biomechanical characteristics of median sternotomies in fresh sheep sterna 4 d after surgery

Characteristic	Median straight sternotomy (n = 8), mean (range)	Median interlocking sternotomy (n = 8), mean (range)	Difference (95%CI)
CC displacement, mm	9.66 ± 3.34 (5.24 to 15.35)	1.26 ± 0.97 (0.3 to 2.8)	6.08 to 10.71 $P < 0.001$
AP displacement, mm	9.12 ± 2.74 (5.48 to 14.78)	1.20 ± 0.55 (0.3 to 2.5)	6.06 to 9.77 $P < 0.001$
Lateral displacement, mm	8.95 ± 3.86 (5.1 to 17.1)	7.24 ± 2.43 (3.26 to 11.11)	-1.32 to 4.74 $P > 0.001$
Surface area, cm²	10.40 ± 0.49 (9.6 to 10.9)	16.8 ± 0.78 (15.3 to 18.3)	-7.01 to 5.78 $P < 0.001$

CC: Cranio-caudal; AP: Anterio-posterior.

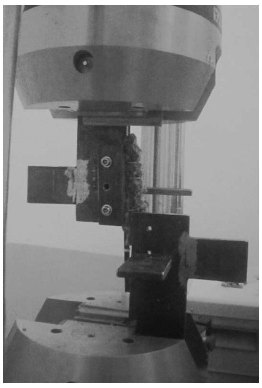

Figure 3 The sterna were attached to custom fixtures designed to produce displacement in one of three directions.

placement in one of three directions: (1) CC shear; (2) AP shear; and (3) lateral (distraction) shear. The displacement between the halves of the sternum was measured and recorded automatically by the testing device.

Fatigue testing was performed by cycling between loads of 1 and 400 N per 5 s (0.2 Hz) for 60 cycles of distraction and release. One sterna in each group was distracted for 180 cycles. The test was ended if the wires were torn from the bone or if the bone broke.

Statistical analysis

Mean displacement was measured after completion of distraction in all three directions and was compared between the two groups with Student's t test for independent groups. The data conformed to the assumptions of the t test, and all tests were two-tailed. Alpha was set at 0.05. The "SPSS 16.0" statistical software program was used in the analyses was used.

RESULTS

Two sterna in each group broke during the calibration of the testing machine so they were excluded from analyses. Fractures were related to fixation apparatus not related to test, and after the fractures it was revised and test began from the beginning. Displacement in all directions was smaller in the interlocking sternotomies (Table 1).

The mean displacement in CC direction was 9.66 ± 3.34 mm for median sternotomy and was 1.26 ± 0.97 mm for interlocking sternotomy, $P < 0.001$. The mean displacement in AP direction was 9.12 ± 2.74 mm for median sternotomy and was 1.20 ± 0.55 mm for interlocking sternotomy, $P < 0.001$. The mean displacement in lateral direction was 8.95 ± 3.86 mm for median sternotomy and was 7.24 ± 2.43 mm for interlocking sternotomy, $P > 0.001$. The mean surface area was 10.40 ± 0.49 cm² for median sternotomy and was 16.80 ± 0.78 cm² for interlocking sternotomy, $P < 0.001$. The displacement in AP and cranio-caudal directions is less in group 2 and it is statistically significant. Displacement in lateral direction in group 2 is less but it is statistically not significant. Surface area in group 2 is significantly wider than group 1.

DISCUSSION

Normal breathing, coughing, and movement apply pressure to the sternum, creating a combination of lateral displacement forces and anterior-posterior shear and cranial-caudal shear[20]. After sternotomy, these forces can interfere with bony healing and cause serious complications[21-23]. An unstable sternotomy can increase postoperative sternal pain, which can lead to atelectasis and pneumonia, secondary to a decreased inspiratory effort[9]. Other serious complications related to instability include sternal dehiscence, deep sternal infection, fulminant medistinitis, osteomylelitis, and chronic sternal instability[4,24-26]. These complications are associated with a 14% to 47% mortality rate[4]. Providing a more stable osteotomy and improving sternal osteosynthesis is the best way to prevent these complications[3,4,27,28].

More than 40 different techniques with various materials have been described for sternal closure[12-16]. Most techniques revolve around a different pattern of wire cerclage, rigid plate fixation, or various non-rigid methods of closure[29-36]. The techniques those provide more rigid fixation are associated with relatively fewer wound infection and even mortality[3]. However, one has to consider the movements of sternal halves at AP and CC directions. Current methods provide sufficient lateral stability, but does not provide adequate AP and CC stability[20]. Due to this three dimensional movement of sternum during physiological activities, providing stability in AP and CC directions is important as well as stability in lateral direction.

The sternal fixation with using plate and screw provides relatively more stability in AP and CC directions. However, this method has some serious disadvantages[3]. Drilling into the sternum increases the obvious risks to the heart and bypass conduits[3], and the costs of plate fixation are about 10 times higher than those of wire fixation[6]. In addition, the screw holes closest to the midline tend to break through the adjacent bone[6]. That is why the plate and screw fixation does not gain popularity. Also, in an *in vitro* study, Saito *et al*[35] compared wire fixation with wire fixation plus an intrasternal pin. The intrasternal pin was presented, as a technical modification required increasing stiffness in the AP and CC directions. Intrasternal pin fixation did provide significantly more stability than did wire fixation alone. However, the clinical application of this technique is not reported yet.

Current methods aiming to increase the stability of sternotomy are focused on different implants and configuration of suturing with wire. On the other hand, it is well known that, improving the stability of an osteotomy line can be increased by selecting the correct osteotomy technique[37,38]. In our study, we focused on decreasing AP and CC interfragmentary motion at the same time by changing the configuration of the osteotomy line itself. In our literature search we determined, two clinical studies have shown that the stability of the sterna can be increased by the sternotomy configuration itself. Joshi *et al*[36] performed a lazy-S-shaped sternotomy, which minimized post-operative pain, was also associated with better respiratory function, and reduced rates of sternal dehiscence and mediastinitis. Lee *et al*[39] performed curvilinear paramedian sternotomy and found this technique ensuring precise open reduction and internal fixation. These results may indicate that the changing the sternotomy technique prevents CC motion, on the other hand, these sternotomy techniques still does not prevent the AP motion.

In our study, we focused on decreasing AP and CC interfragmentary motion at the same time by changing the configuration of the osteotomy line itself. The interlocking osteotomy created an inherently more stable closure that was less affected by displacement and shear forces and that provided a greater mean surface area than that provided by straight sternotomies. Although the interlocking sternotomy indirectly reduced lateral displacement, the amount of displacement was not statistically significant.

Increasing the opposing surface areas of an osteotomy is important for primary bone healing[36]. The interlocking sternotomy maximizes the opposing surfaces of the sternal halves. By preventing the slippage of sternal ends in the AP and CC directions, the interlocking sternotomy ensures appropriate approximation during closing and should substantially improve the osseous healing.

In this *in vitro* study, we found that the biomechanical characteristics of the median interlocking sternotomy were superior to those of the straight median sternotomy. The zigzag cuts made the sternotomy line significantly more stable and provided more surface area for bony healing. Our method does not require any extra equipments or implants. The wires are used as fixation material, already employed and the surgeons are familiar with. Also this technique does not require surgeons to make great changes in their routine practice. It is possible to make this sternum incision with sternotomy saws in routine use. We believe that the interlocking sternotomy provide a significantly more stable sternotomy without extra costs. Although no clinical or animal experiment study has been performed with interlocking sternotomy, our biomechanical study may be evidence of superiority in primary osseos healing if interlocking sternotomy is performed in clinical practice.

COMMENTS

Background

The continuous motion between the halves of the divided sternum resulting from the lack of immobilization causes postoperative sternal instability, which is the most important factor in postoperative morbidity and mortality. Providing greater stability and more surface area promoting primary osseous healing is crucial for preventing these complications.

Research frontiers

Interlocking sternotomy appears to offer better stability and greater surface area for bone healing than other techniques. However, the biomechanical characteristics of this technique have not been assessed. In this study, authors compared the biomechanical characteristics of interlocking sternal closure with those of straight sternal closure in a study of sheep sterna and compared the surface area of two osteotomies.

Innovations and breakthroughs

More than 40 different techniques with various materials have been described for sternal closure. The techniques those provide more rigid fixation are associated with relatively fewer wound infection and even mortality. Current methods provide sufficient lateral stability, but do not provide adequate anterio-posterior (AP) and cranio-caudal (CC) stability. Interlocking sternal closure provide stability in AP, CC and in lateral direction and more surface area.

Applications

Authors believe that the interlocking sternotomy provide a significantly more stable sternotomy and more surface area for bony healing so decreasing the complications without extra costs.

Terminology

The interlocking sternotomy is a zigzag cut in three dimension. CC movement is a movement of one half of sternum superior while the other half inferior.

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The sterna were attached to custom fixtures designed to produce displacement in one of three directions: (1) CC shear, (2) AP shear, and (3) lateral (distraction) shear. The displacement between the halves of the sternum was measured and recorded automatically by the testing device. The zigzag cuts made the sternotomy line significantly more stable and provided more surface area for bony healing.

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BRIEF ARTICLE

Relationship of knowledge about osteoporosis with education level and life habits

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Abstract

AIM: To assess possible relationships of knowledge and related factors with educational level and osteoporosis-related life habits.

METHODS: This was a cross sectional study conducted on 268 women (⩾ 35 years old) from June 2011 to August 2011. The sample collection was done in outpatient clinics in three university hospitals in Isfahan, Iran. We used a demographic questionnaire containing questions that evaluated osteoporosis-related life habits, including exercise, smoking, intake of calcium and vitamin D supplements and so on. We also used the Osteoporosis Knowledge Assessment Tool to measure osteoporosis knowledge of women.

RESULTS: The mean level of knowledge about awareness of osteoporosis, its risk factors and preventive factors were 56, 55 and 22, respectively. The relationship of education level and awareness of osteoporosis, its risk factors and preventive factors was significant, with R = 0.76, R = 0.73 and R = 0.83, respectively (P < 0.001). The relationship of education level and osteoporosis-related life habits was not significant (R = 0.03 and P = 0.56). The relationship of osteoporosis-related life habits and awareness of osteoporosis and its risk factors was significant, with R = 16%, P = 0.006 and R = 16%, P = 0.008, respectively, but the relationship of osteoporosis-related life habits and preventive factors was not significant (R = 0, P = 0.99).

CONCLUSION: Iranian women with a higher education level have significantly better knowledge about osteoporosis than women with a lower educational level but they do not use this knowledge in their life.

Key words: Osteoporosis; Knowledge; Education; Life habits; Relationship

Core tip: Osteoporosis, a serious health problem that diminishes quality of life, is a systemic skeletal disorder, characterized by reduction in bone mass, increasing bone fragility and fracture risk. Iranian women with a higher education level have significantly better knowledge about osteoporosis than women with a lower educational level but they do not use this knowledge in their life.

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INTRODUCTION

Osteoporosis, a serious health problem that diminishes quality of life, is a systemic skeletal disorder, characterized by reduction in bone mass, increasing bone fragility and fracture risk[1,2]. It has often been viewed as a disease affecting women[3]. Approximately 40%-50% of women sustain osteoporotic fractures in their lifetime[1,2]. The progress of decrease in bone mass is typically asymptomatic but in many women is manifested with clinical presentations, including acute back pain, fragility fractures (hip, vertebra, proximal femur and tibia), compression of mid-thoracic and upper lumbar vertebrae and progressive deformation of the spinal column that leads to limited back mobility and reduction in height[4-7]. Based on bone mineral density (BMD) testing, the World Health Organization (WHO) clinically defines osteoporosis by a BMD T-score ≥ 2.5 SD below the mean bone mass density in healthy, young normal women[8,9].

Many risk factors for osteoporosis have been identified: female sex, with a prevalence 4 times that of men; Asiatic and Caucasian races; old age, with a high percentage of osteoporosis among women over 70 years old; a family history of osteoporosis or fragility fractures; low body weight (less than 51.8 kg); premature menopause (menopause before 45 years of age); nulliparity; prolonged lactation; prolonged amenorrhea unrelated to menopause; inadequate consumption of a diet containing calcium and vitamin D; poor intestinal absorption of calcium; lactose intolerance; excessive caffeine and alcohol consumption; smoking; sedentary lifestyle; and prolonged treatment with thyroid hormones, glucocorticoids, anticonvulsants, aluminum antacids and anticoagulants[1,10].

The most important preventive habits are weight-bearing exercises (*e.g.*, going up and down stairs, jogging, aerobics, swimming and isometrics, for at least 30 min daily), diet or supplements containing adequate levels of calcium and vitamin D, and absence or cessation of smoking and moderate or less alcohol and caffeine consumption[7,11]. A study in the United States revealed that a high proportion of women were unaware of the association between cigarette smoking and osteoporosis[12].

Physical activities continue to stimulate increases in bone diameter throughout the lifespan. These exercise-stimulated increases in bone diameter diminish the risk of fractures by mechanically counteracting the thinning of bones and increases in bone porosity. Exercise should be dynamic, exceed a threshold intensity and strain frequency, be relatively brief but intermittent, and also be supported by unlimited nutrient energy and adequate calcium and vitamin D3 supplements[13].

A study of American women (≥ 25 years) showed that knowledge about osteoporosis was limited[14]. Although calcium intake was sufficient in most cases, the amount and type of physical activity was not enough for their age. Other studies of Caucasian and African-American women found that most had heard about osteoporosis but few women had adequate exercise or the recommended intake of calcium per day[15,16]. Another study in Australia showed that Asian women living in Australia also had a low calcium intake (< 800 mg/d) and their knowledge about osteoporosis was limited[17]. A study in Mexico of women aged 50-59 years showed that about 90% of subjects had knowledge about the relationship of menopause and osteoporosis but most subjects were not aware of other risk factors and incorporated life habits that increase the risk of osteoporosis[18]. Two studies of women of Hispanic origin in the United States have shown different results. One study found that more than 37% of women had habits preventing osteoporosis, including taking calcium supplements and getting enough physical exercise. It was mostly attributed to prior health education, knowledge about osteoporosis and bone-mass evaluations offered by healthcare services[19]. The other study of both Hispanic and African-American women found that most women in both groups had little knowledge of behaviors that increase and maintain bone mass, less than 50% of women had regular physical exercise, and less than 10% had adequate calcium intake[20]. Bisphosphonates are antiresorptive drugs widely used to treat osteoporosis. Denosumab 60 mg subcutaneously every 6 mo is an approved treatment for women with postmenopausal osteoporosis (PMO) who are at high risk for fracture[21,22].

In this study, we aimed to assess the possible relationships of the level of knowledge and related factors with educational level and osteoporosis-related life habits (including exercise, calcium and vitamin D intake) among Iranian women aged ≥ 35 years.

MATERIALS AND METHODS

Ethics

This work was carried out in accordance with the Declaration of Helsinki (2000) of the World Medical Association and was approved ethically by Al-Zahra University Hospital Trust (988/1.786). All patients provided informed written consent.

Patients and settings

This was a cross sectional study conducted on 268 women (≥ 35 years old) from June 2011 to August 2011. The sample collection was done in outpatient clinics (except orthopedic and rheumatology) in three university hospitals in Isfahan, Iran.

We used a demographic questionnaire containing questions that evaluated osteoporosis-related life habits (including exercise, smoking, daily consumption of milk,

Table 1 Relationship of level of knowledge about osteoporosis with education level and related life habits with a Persian version of the osteoporosis knowledge assessment tool

	Awareness of osteoporosis	Risk factors	Preventive factors	Osteoporosis-related life habits
Education level	R = 0.76/ P < 0.001	R = 0.73/ P < 0.001	R = 0.83/ P < 0.001	R = 0.03/ P = 0.56
Osteoporosis-related life habits	R = 16/ P = 0.006	R = 16/ P = 0.008	R = 0/ P = 0.99	

intake of calcium and vitamin D supplements, usage of certain drugs such as contraceptives and exposure to sunlight) and the Osteoporosis Knowledge Assessment Tool (OKAT), an instrument to measure knowledge about osteoporosis of women[23]. The Persian version of the OKAT was tested in a pilot study and 10 adult women filled out a scale for "cognitive debriefing" which was evaluated by four orthopedic surgeons for a "clinician's review"[24].

Statistical analysis

We used Cronbach's alpha to evaluate the internal consistency of OKAT, which was 77%. To evaluate education level, Spearman's correlation was used. Pearson's correlation was applied to determine the relationship of the level of knowledge and osteoporosis-related life habits. $P < 0.05$ was considered as significant. SPSS for Windows, Version 16.0, was used for statistical analyses.

RESULTS

The study involved 268 adult women older than 35 years. Ninety seven percent were married and 94.8% of them did not have other diseases (4% had thyroid disease, 2.6% had diabetes and 2.2% had other diseases). Regarding the education level, 68.6%, 16.4% and 15% of participants had the education level below high school diploma, high school diploma, and academic education, respectively. Nonsmokers comprised 97.4% of the sample. Ninety five point nine percent of women did not exercise regularly. Among the women in the study, 41% had at least 30 min exposure to sunlight every day. Ninety seven point six percent and 98.2% of participants had no intake of calcium and vitamin D supplements, respectively. Only 19.8% regularly consumed daily milk. Forty percent of women were post-menopausal, of whom just 1.3% have received replacement hormone therapy. Ninety eight point five percent of women in our study did not undergo any assessments to evaluate osteoporosis. Sources of their information were television (40%), radio (27%), books (14%), newspapers (11%) and other people (8%).

The mean level of knowledge about osteoporosis, its risk factors and preventive factors were 56, 55 and 22, respectively. Thus, mean level of knowledge about osteoporosis was 44.3 in total. Means were calculated between "0 to 100". The relationship of education level and awareness of osteoporosis, its risk factors and preventive factors was significant with R = 0.76, R = 0.73 and R = 0.83, respectively ($P < 0.001$). The relationship of education level and osteoporosis-related life habits was not significant (R = 0.03 and $P = 0.56$). The relationship of osteoporosis-related life habits and awareness of osteoporosis and its risk factors was significant with R = 16, $P = 0.006$ and R = 16, $P = 0.008$, respectively, but the relationship of osteoporosis-related life habits and preventive factors was not significant (R = 0, $P = 0.99$) (Table 1).

DISCUSSION

Women's knowledge about osteoporosis was poor or limited among our subjects; therefore, health educational programs and health services regarding osteoporosis are necessary. This finding is consistent with previous studies in Taiwan, Brazil, Australia and the United States[14,23,25,26]. In contrast, a study in Sweden showed that performing a general intervention program concerning the knowledge of osteoporosis in participants is not effective[27].

We found that there was a significant relationship of level of knowledge and education but the relationship of education level and osteoporosis-related life habits was not significant. The relationship of osteoporosis-related life habits and awareness of osteoporosis and its risk factors was significant but there was no significant relationship of osteoporosis-related life habits and preventive factors. The present results show that Iranian women with a higher education level have significantly better knowledge about osteoporosis than women with a lower educational level, similar to Chinese women in Singapore and Salvadoran women in Brazil[26,28], but they do not use this knowledge in their life. For instance, among women of our study which included participants with a high education level, 95.9% did not exercise regularly, 97.6% and 98.2% did not have an adequate intake of calcium and vitamin D supplements and only 19.8% had regular daily milk. So, similar to studies in Australia and Brazil, intake of calcium in our study was low[17,26]. This was in contrast to the study of Terrio *et al*[14] in the United States in which the intake of calcium was sufficient in most cases.

It indicates the importance of skin sun exposure in order to raise serum vitamin D levels. We can conclude that Iranian women's knowledge about osteoporosis does not lead to improving the preventive habits of osteoporosis and, with regards to the absence of a significant relationship between education level and osteoporosis-related life habits, in addition to increasing women's knowledge, we must change osteoporosis-related life habits, together with women's diet and behavior patterns. Therefore, we should provide better programs for the evaluation of osteoporosis, establish continuous teaching programs, and prepare more appropriate educational materials for osteoporosis and improve specific health messages in public media.

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COMMENTS

Background

Osteoporosis, a serious health problem that diminishes quality of life, is a systemic skeletal disorder, characterized by reduction in bone mass, increasing bone fragility and fracture risk.

Research frontiers

Osteoporosis, a serious health problem that diminishes quality of life, is a systemic skeletal disorder, characterized by reduction in bone mass, increasing bone fragility and fracture risk. In this study, the authors assessed possible relationships of the level of knowledge and related factors with educational level and osteoporosis-related life habits (including exercise, calcium and vitamin D intake) among Iranian women aged ⩾ 35 years.

Innovations and breakthroughs

Iranian women's knowledge about osteoporosis does not lead to improving the preventive habits of osteoporosis and, with regards to the absence of a significant relationship between education level and osteoporosis-related life habits, in addition to increasing women's knowledge, osteoporosis-related life habits, together with women's diet and behavior patterns must change. Therefore, better programs for the evaluation of osteoporosis should be provided, continuous teaching programs established, and more appropriate educational materials for osteoporosis and improved specific health messages in public media should be prepared.

Applications

By understanding how knowledge about osteoporosis leads to improving the preventive habits of osteoporosis, this study may represent a future strategy for improving women's knowledge about osteoporosis.

Peer review

The authors examined women's knowledge about osteoporosis and demonstrated that it does not lead to improving the preventive habits of osteoporosis and, with regards to the absence of a significant relationship between education level and osteoporosis-related life habits, in addition to increasing women's knowledge, the authors must change osteoporosis-related life habits, together with women's diet and behavior patterns. Therefore, the authors should provide better programs for the evaluation of osteoporosis, establish continuous teaching programs, and prepare more appropriate educational materials for osteoporosis and improve specific health messages in public media.

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META-ANALYSIS

Ponseti method compared with soft-tissue release for the management of clubfoot: A meta-analysis study

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Abstract

AIM: To compare the functional outcomes of patients who underwent open surgery *vs* Ponseti method for the management of idiopathic clubfoot and to determine whether correlations exist between functional outcome and radiographic measurements.

METHODS: A meta-analysis of the literature was conducted for studies concerning primary treatment of patients with idiopathic clubfoot. We searched PubMed Medline, EMBASE, and the Cochrane Library databases from January 1950 to October 2011. Meta-analyses were performed on outcomes from 12 studies. Pooled means, SDs, and sample sizes were either identified in the results or calculated based on the results of each study.

RESULTS: Overall, 835 treated idiopathic clubfeet in 516 patients were reviewed. The average follow-up was 15.7 years. Patients managed with Ponseti method did have a higher rate of excellent or good outcome than patients treated with open surgery (0.76 and 0.62, respectively), but not quite to the point of statistical significance (Q = 3.73, P = 0.053). Age at surgery was not correlated with the functional outcome for the surgically treated patients (r = -0.32, P = 0.68). A larger anteroposterior talocalcaneal angle was correlated with a higher rate of excellent or good outcomes (r = 0.80, P = 0.006). There were no other significant correlations between the functional and radiographic outcomes.

CONCLUSION: The Ponseti method should be considered the initial treatment of idiopathic clubfeet, and open surgery should be reserved for clubfeet that cannot be completely corrected.

Key words: Idiopathic clubfoot; Congenital talipes equinovarus; Ponseti method; Surgical release; Ponseti-Laaveg score

Core tip: This study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. Although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

Lykissas MG, Crawford AH, Eismann EA, Tamai J. Ponseti method compared with soft-tissue release for the management of clubfoot: A meta-analysis study. *World J Orthop* 2013; 4(3): 144-153 Available from: URL: http://www.wjgnet.com/2218-5836/full/v4/i3/144.htm DOI: http://dx.doi.org/10.5312/wjo.v4.i3.144

INTRODUCTION

During the second half of the twentieth century, the primary treatment of idiopathic clubfoot has ranged from gentle manipulations to aggressive surgical treatment. Surgical management predominated because it was considered as a method that could obtain full and lasting correction. Over time and based on long-term follow-up studies surgeons realized that the results of surgical intervention are unpredictable[1-3]. Extensive soft-tissue releases can result in scarring which may lead to stiffness, recurrent deformity, and pain[4]. It was this observation along with the promising results of the Ponseti method[5,6] that shifted treatment of idiopathic clubfoot towards a more conservative approach consisting of manipulations and serial casting, and frequently minimal invasive surgery. Open surgery is usually reserved for more severe cases that failed serial casting. However, even in these cases, current surgical procedures are less aggressive than procedures performed three decades ago.

Although there are a plethora of studies that have assessed the functional and radiographic outcomes following different treatment protocols, there are only a few studies that directly compare open surgery and Ponseti method for the management of idiopathic clubfoot[1,7-9]. This can be mainly attributed to variable and simplistic grading systems for scoring the severity of the deformity as well as the differing evaluation systems for assessing outcomes. Only one study in the current literature prospectively compares surgical management and Ponseti method, but there are no prospective randomize controlled trials[7].

The present meta-analysis aims to address two topics. The main purpose is to compare the functional outcomes between patients undergoing open surgery *vs* Ponseti method for the treatment of idiopathic clubfoot. A secondary aim is to determine if functional outcomes and radiographic measurements correlate.

MATERIALS AND METHODS

Literature search

A meta-analysis of the literature was conducted for studies concerning management of patients with idiopathic clubfoot with either soft-tissue release or Ponseti method. The search was performed with use of the following electronic bibliographic databases: Medical Literature Analysis and Retrieval System online (PubMed Medline), Excerpta Medica Database (EMBASE), and The Cochrane Library. The medical subject headings or text words utilized included: "clubfoot", "congenital talipes equinovarus", "soft-tissue release", "surgery", and "Ponseti method". The bibliographies of the retrieved articles as well as the "related articles" option in PubMed Medline were also searched to assess for potentially inclusive papers that were missed by the initial search.

Criteria for eligibility

Since several methods and systems have been used to describe the functional and radiographic outcome of patients treated with open surgery or Ponseti method, we performed an initial search to identify the most commonly used functional scores and radiographic parameters. These included: Laaveg-Ponseti score (Figure 1)[5], anteroposterior talocalcaneal angle (TCA-AP), lateral talocalcaneal angle (TCA-LT), anteroposterior talus-first metatarsal angle (TMT-AP), lateral talus-first metatarsal angle (TMT-LT), anteroposterior calcaneus-fifth metatarsal angle (CMT-AP), lateral first-fifth metatarsal angle (MTT-LT), and talocalcaneal index (TCI) (Figure 2). The Laaveg-Ponseti score is a 100-point evaluation system with scores between 90 and 100 considered as excellent, 80 and 89 as good, 70 and 79 as moderate, and below 70 as poor. According to our initial search of the literature, this was the most commonly used functional score in patients who underwent soft-tissue release or Ponseti method from its description in 1980 until today. In contrast to other systems, it can be used to study the correlation between the functional outcome and radiographic measurements since it relies only on clinical aspects, not including any radiographic parameters[10].

Based on the initial search findings, studies selected for the analyses were original studies fulfilling the following eligibility criteria: (1) assess idiopathic clubfoot; (2) assess primary treatment of idiopathic clubfoot; (3) use the functional evaluation score of Laaveg-Ponseti; (4) use of at least three of the radiographic outcome measures found to be the most commonly used in the literature and described above; (5) evaluate more than ten feet; (6) evaluate human subjects; and (7) was published from January 1950 through October 2011.

Potentially inclusive papers were manually reviewed and were discussed among the authors, and a decision was made regarding inclusion. If there was any disagreement among authors regarding the inclusion of an article, the senior author made the final decision.

Extraction of data

Data were carefully extracted and computerized on the following variables from those published articles that meet our inclusion criteria: (1) radiographic findings at final follow-up (main outcome variable); (2) Laaveg-Ponseti score at final follow-up (main outcome variable); (3) time period during which the procedure was performed; (4) duration of follow-up; (5) number of patients/feet; (6) unilateral or bilateral involvement; (7) sex of the patient; (8) age at treatment; (9) level of evidence; (10) publication year; and (11) authors' names.

Statistical analysis

Due to the possibility of variation between studies, the more conservative, random-effects model was selected over a fixed-effects model. Random effects models account for both within-study and between-study variation and are more preferable when assessing observational studies. Pooled means, SDs, and sample sizes were either identified in the results of each study or calculated based

Category	Points
Satisfaction (20 points)	
I am	
(1) very satisfied with the end result	20
(2) satisfied with the end result	16
(3) neither satisfied nor unsatisfied with the end result	12
(4) unsatisfied with the end result	8
(5) very unsatisfied with the end result	4
Function (20 points)	
In my daily living, my club foot	
(1) does not limit my activities	20
(2) occasionally limits my strenuous activities	16
(3) neither satisfied nor unsatisfied with the end result	12
(4) usually limits my strenuous activities	8
(5) limits me in walking	4
Pain (30 points)	
My club foot	
(1) is never painful	30
(2) occasionally causes mild pain during strenuous activities	24
(3) usually is painful after strenuous activities only	18
(4) is occasionally painful during routine activities	12
(5) is painful during walking	6
Position of heel when standing (10 points)	
My club foot	
Heel varus, 0° or some heel valgus	10
Heel varus, 1°-5°	5
Heel varus, 6°-10°	3
Heel varus, greater than 10°	0
Passive motion (10 points)	
Dorsiflexion	1 point per 5°
Total varus-valgus motion of heel	1 point per 10°
Total anterior inversion-eversion of foot	1 point per 25°
Gait (10 points)	
Normal	6
Can toe-walk	2
Can heel-walk	2
Limp	-2
No heel-strike	-2
Abnormal toe-off	-2

Figure 1 Functional rating system for clubfoot. Reproduced from by Laaveg *et al*[5].

Figure 2 Radiographic parameters most commonly measured on plain films. Anteroposterior (A) and lateral (B) standing foot radiographs of a patient with clubfoot showing the anteroposterior talocalcaneal angle (a), anteroposterior calcaneus-fifth metatarsal angle (b), anteroposterior talus-first metatarsal angle (c), lateral talocalcaneal angle (d), lateral talus-first metatarsal angle (e), and lateral first-fifth metatarsal angle (f).

on the results. Effect sizes with 95%CI were calculated using the mean and SE for each study. Subgroup analyses were performed in order to compare the Ponseti method and surgical treatment studies on all outcome measures. Variability between treatment types was assessed with Cochran's Q statistic, which measures the presence or absence of heterogeneity between studies based on a χ^2 distribution. It is calculated as the weighted sum of squared differences between individual study effects and pooled effects across studies. The I^2 index was also calculated as a measure of the extent of heterogeneity between studies. Larger Q and I^2 values indicate

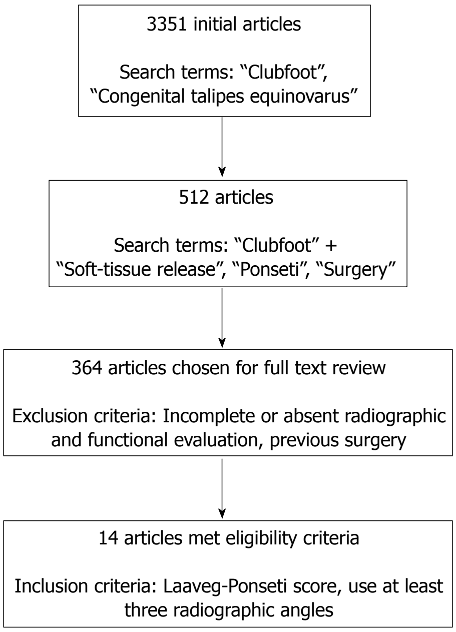

Figure 3 Flow chart summary of the literature.

greater variability. The number of feet with good or excellent outcomes on the Laaveg-Ponseti scale was also compared to the number of feet with poor or fair outcomes using event rates of successful outcomes rather than effect sizes.

Meta-analyses were performed using the Comprehensive Meta-Analysis software (2.0, Bio-Stat, Englewood, NJ, United States). A *P* value of 0.05 or less was considered as statistical significant.

RESULTS

Literature search

Based on the title and the abstract, the initial electronic search yielded 512 articles as potentially eligible. After obtaining the full text of 364 articles, a total of fourteen articles were found to fulfill the inclusion criteria[1,3,5,6,9-18]. Two studies were excluded because the measures were in terms of medians and ranges, and thus, effect sizes could not be calculated[9,18]. A flow chart summary of the literature search is shown in Figure 3.

Meta-analyses were performed on outcomes from 12 studies[1,3,5,6,10-17]. Nine studies evaluated functional and radiographic outcome following soft-tissue release, two studies after Ponseti method, and one study compared outcomes in patients who underwent Ponseti method or open surgery for the management of idiopathic clubfoot. Three studies were therapeutic level of evidence Ⅲ studies[1,3,13]. The rest of the studies were observational level of evidence Ⅳ case series[5,6,10-12,14-17].

In summary, 835 treated idiopathic clubfeet in 516 patients were reviewed. Among these patients, 369 patients (611 feet) were treated with soft-tissue release and 147 patients (224 feet) were managed with the Ponseti method. The male-to-female ratio was 2.5:1. The unilateral-to-bilateral involvement ratio was 1.25:1. The mean age at initiation of treatment was 8.8 ± 4.8 mo. The average follow-up was 15.7 ± 10.8 years. The minimum follow-up was one year and the maximum 42 years.

Functional outcome

At the final follow-up, functional outcomes, as measured with the Laaveg-Ponseti score, did not differ between patients treated with Ponseti method and patients treated with soft-tissue release (86.3 and 82.0, respectively, Q = 0.45, P = 0.50) (Table 1). However, when compared categorically, patients managed with Ponseti method did have a higher rate of excellent or good outcome than patients treated with open surgery (0.76 and 0.62, respectively), but not quite to the point of statistical significance (Q = 3.73, P = 0.053) (Figure 4, Table 1).

For all patients studied, a longer length of follow-up was correlated with worse functional outcomes (r = -0.82, P = 0.023). Age at surgery was not correlated with functional outcome for patients treated with open surgery (r = -0.32, P = 0.68).

Radiographic outcome

The radiographs taken at the time of the final follow-up did not show any significant differences between patients treated with manipulation and serial casting (Ponseti method) and patients treated with soft-tissue release regarding the TCA-AP (15.8° and 18.9°, respectively) (Q = 2.09, P = 0.15), TCA-LT (29.9° and 26.6°, respectively) (Q = 0.33, P = 0.57), TCI (45.7° and 46.1°, respectively) (Q = 0.002, P = 0.96), and the TMT-AP angles (0.96° and 6.04°, respectively) (Q = 0.55, P = 0.11) (Table 2).

Statistically significant differences were noted between patients managed with the Ponseti method and patients treated with open surgery in TMT-LT (5.51° and 12.08°, respectively) (Q = 10.74, P = 0.001), MTT-LT (15.4° and 25.2°, respectively) (Q = 10.48, P = 0.001), and CMT-AP angles (-6.49° and 3.86°, respectively) (Q = 16.12, P < 0.001) (Table 3).

Heterogeneity in outcomes

For the Laaveg-Ponseti score and all radiographic measurements, except TCA-LT, greater variability was recorded in patients who underwent open surgery compared with patients managed with the Ponseti method, as indicated by the higher Q values and I^2 values (Table 4).

Correlations between functional outcome and radiographic measurements

A larger TCA-AP angle was correlated with a higher rate of excellent or good outcomes (r = 0.80, P = 0.006). Functional outcomes were not significantly correlated with MTT-LT (r = -0.80, P = 0.20), TMT-AP (r = -0.80, P = 0.20), and TCA-AP (r = 0.70, P = 0.19) angles or the TCI (r = -0.30, P = 0.62) (Table 5).

DISCUSSION

Idiopathic clubfoot is a complex three dimensional deformity with an incidence of between 0.64 and 6.8 per

Table 1 Comparison of Laaveg-Ponseti score between patients treated with the Ponseti method and surgically managed patients

Studies	Level of evidence	Mean follow-up (yr)	Time period of procedure	Patients (*n*)	Feet (*n*)	Laaveg-Ponseti score mean (95%CI)	Excellent/good Laaveg-Ponseti rating rate (95%CI)
All Treatments				500	810	86.2 (84.2-88.2)	0.73 (0.67-0.78)
Ponseti method				147	224	86.3 (84.2-88.3)	0.76 (0.69-0.81)
Ippolito *et al*[1]	III	19	1979-1984	32	49	85.4 (83.9-86.9)	0.78 (0.64-0.87)
Laaveg *et al*[5]	III	18.8	1950-1967	70	104	87.5 (85.3-89.7)	0.74 (0.65-0.82)
Cooper *et al*[6]	IV	34	1950-1967	45	71	-	0.78 (0.63-0.88)
Soft-tissue release				353	586	82.0 (69.5-94.5)	0.62 (0.48-0.74)
Ippolito *et al*[1]	III	25	1973-1977	32	47	74.7 (71.4-78.0)	0.43 (0.29-0.57)
Dobbs *et al*[3]	III	31	1972-1979	45	73	65.3 (62.9-67.7)	0.33 (0.23-0.44)
Fridman *et al*[10]	IV	6.4	1986-2003	50	71	86.9 (84.1-89.6)	0.80 (0.69-0.88)
Schuh e *et al*[11]	IV	4.5	1986-2000	86	130	95.6 (94.0-97.2)	-
Singh *et al*[12]	IV	13.8	1980-1996	18	33	-	0.82 (0.65-0.92)
Prasad *et al*[13]	IV	-	-	30	50	-	0.58 (0.44-0.71)
Munshi *et al*[14]	III	3.5	-	-	50	87.3 (83.1-91.5)	0.78 (0.65-0.87)
Herbsthofer *et al*[15]	IV	6.7	1984-1994	38	62	-	0.47 (0.35-0.59)
Abulsaad *et al*[16]	IV	3.9	2000-2004	54	70	-	0.69 (0.57-0.78)
Difference between treatments						$Q = 0.45$, $P = 0.50$	$Q = 3.73$, $P = 0.053$

Treatment type	Study	Year	Statistics: Event rate	Lower limit	Upper limit	*Z*	*P*
Ponseti Method	Ippolito *et al*[1]	2003	0.78	0.64	0.87	3.62	< 0.001
Ponseti Method	Cooper *et al*[6]	1995	0.78	0.63	0.88	3.49	< 0.001
Ponseti Method	Laaveg *et al*[5]	1980	0.74	0.65	0.82	4.69	< 0.001
Ponseti Method			**0.76**	**0.69**	**0.81**	**6.85**	**< 0.001**
Soft Tissue Release	Ippolito *et al*[1]	2003	0.43	0.29	0.57	-1.02	0.31
Soft Tissue Release	Singh *et al*[12]	2005	0.82	0.65	0.92	3.33	0.001
Soft Tissue Release	Prasad *et al*[13]	2009	0.58	0.44	0.71	1.13	0.26
Soft Tissue Release	Herbsthofer *et al*[15]	1998	0.47	0.35	0.59	-0.51	0.61
Soft Tissue Release	Fridman *et al*[10]	2007	0.80	0.69	0.88	4.71	< 0.001
Soft Tissue Release	Dobbs *et al*[3]	2006	0.33	0.23	0.44	-2.87	0.004
Soft Tissue Release	Abulsaad *et al*[16]	2008	0.69	0.57	0.78	3.03	0.003
Soft Tissue Release	Munshi *et al*[14]	2006	0.78	0.65	0.87	3.71	< 0.001
Soft Tissue Release			**0.62**	**0.48**	**0.74**	**1.66**	**0.097**
Combined			**0.73**	**0.67**	**0.78**	**6.78**	**< 0.001**

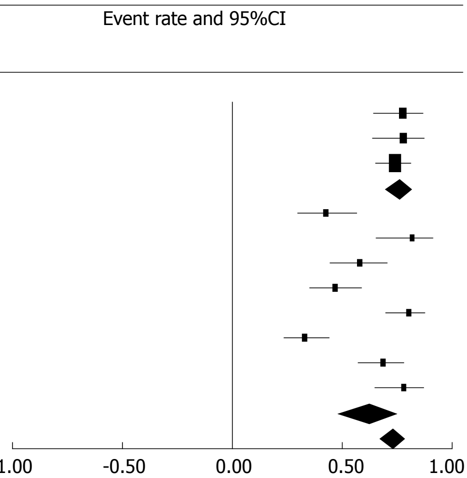

Figure 4 Success rate of Ponseti method *vs* soft-tissue release for clubfoot management based on Laaveg-Ponseti score.

1000 live births[19]. Pathogenesis of idiopathic clubfoot remains obscure, but there is increased evidence for a multifactorial etiologic model. Both genetic and environmental factors have been implicated. Muscle growth impairment[20,21], primary germ plasm defect in the talus[22], vascular anomalies[23-25], medial retraction fibrosis[26], and intrauterine factors[19], such as oligohydramnios, placental insufficiency, drugs, infective pathogens, and amniocentesis prior to the eleventh week[27], have been proposed as potential etiologic factors in the pathogenesis of idiopathic clubfoot. Studies have shown that the deformity has a heritable factor, but is not inherited in a simple autosomal dominant or recessive mendelian fashion[28-32]. Although there is no evidence to support sex linkage, males are affected more commonly than females in all ethnic groups. The reported male-to-female ratio is 2.5:1[33]. This is in accordance to our findings. The male-to-female ratio in 516 patients with idiopathic clubfoot reviewed in our study was 2.5:1. We also recorded a unilateral-to-bilateral involvement ratio of 1.25:1.

The success rates in different series are difficult to compare because of variation in severity of the deformity between study groups and, more importantly, absence of common assessment protocols. In the present meta-analysis, in an effort to use a "common language" between patients treated with open surgery or Ponseti method, we used the subjective assessment method published by Laaveg *et al*[5]. It is based on functionality, presence of pain, foot and ankle range of motion, and patient's satisfaction. In contrast to other systems, it can be used to study the correlation between the functional outcome and radiographic measurements since it relies only on clinical aspects, not including any radiographic parameters[15]. Although it may have been interesting to compare outcomes based on the degree of deformity prior to treatment, only five of the 12 studies included in this meta-analysis evaluated clubfeet at birth. Even in these few studies, the system used deferred, and a comparison in terms of severity of the deformity was not possible. It should also be noted that this study has the disadvantages

Table 2 Comparison of anteroposterior talocalcaneal angle, lateral talocalcaneal angle, and talocalcaneal index between patients treated with the Ponseti method and surgically managed patients

Studies	Patients	Feet	Talocalcaneal		
			AP mean (95%CI)	Lateral mean (95%CI)	Index mean (95%CI)
All treatments	430	655	16.2 (14.9-17.5)	26.9 (23.9-29.9)	46.0 (41.4-50.7)
Ponseti method	147	224	15.8 (14.5-17.2)	29.9 (19.3-40.5)	45.7 (33.4-58.0)
Ippolito *et al*[1]	32	49	16.1 (14.6-17.6)	38.8 (37.1-40.4)	54.9 (51.7-58.0)
Laaveg *et al*[5]	70	104	14.5 (12.8-16.2)	20.9 (19.8-22.0)	35.5 (33.5-37.5)
Cooper *et al*[6]	45	71	17.0 (15.1-18.9)	30.0 (28.4-31.6)	47.0 (43.5-50.5)
Soft-tissue release	283	431	18.9 (15.0-22.8)	26.6 (23.5-29.8)	46.1 (41.0-51.1)
Ippolito *et al*[1]	32	47	14.1 (12.2-16.0)	33.2 (30.7-35.7)	47.3 (42.9-51.7)
Dobbs *et al*[3]	45	73	12.8 (11.1-14.4)	23.3 (21.8-24.8)	36.1 (32.9-39.3)
Fridman *et al*[10]	50	71	20.8 (19.3-22.3)	22.5 (20.9-24.0)	43.3 (40.9-45.6)
Singh *et al*[12]	18	33	28.4 (27.0-29.8)	30.9 (29.2-32.6)	59.3 (56.2-62.4)
Prasad *et al*[13]	30	50	18.5 (16.2-20.8)	27.4 (24.6-30.1)	45.8 (43.3-48.4)
Herbsthofer *et al*[15]	38	62	16.1 (14.6-17.6)	23.0 (21.3-24.7)	39.1 (36.0-42.2)
Abulsaad *et al*[16]	54	70	16.4 (15.1-17.6)	21.4 (19.9-23.0)	42.2 (39.7-44.7)
Docquier *et al*[17]	16	25	24.3 (21.5-27.1)	32.2 (29.6-34.8)	56.5 (51.1-61.9)
Difference between treatment			Q = 2.09, P = 0.15	Q = 0.33, P = 0.57	Q = 0.002, P = 0.96

Table 3 Comparison of talus-1^{st} metatarsal, 1^{st}-5^{th} metatarsal, and calcaneus-5^{th} metatarsal angles between patients treated with the Ponseti method and surgically managed patients

Studies	Patients	Feet	Talus-1^{st} metatarsal		1^{st}-5^{th} metatarsal	
			AP mean (95%CI)	Lateral mean (95%CI)	Lateral mean (95%CI)	AP mean (95%CI)
All treatments	516	655	1.27 (-0.23-2.77)	6.24 (5.00-7.48)	15.6 (16.7-17.9)	-5.11 (-6.83 - -3.40)
Ponseti method	147	224	0.96 (-0.59-2.51)	5.51 (4.20-6.82)	15.4 (14.7-16.1)	-6.49 (-8.33 - -4.65)
Ippolito *et al*[1]	32	49	0.94 (-1.01-2.89)	6.39 (4.40-8.38)	15.5 (14.2-16.7)	-6.8 (-9.20 - -4.40)
Laaveg *et al*[5]	70	104	-	-	14.7 (13.5-15.9)	-4.9 (-6.92 - -2.88)
Cooper *et al*[6]	45	71	1 (-1.56-3.56)	5 (3.60-6.40)	16 (14.8-17.2)	-8 (-10.33 - -5.67)
Soft-tissue release	283	431	6.04 (-0.06-12.13)	12.08 (8.38-15.79)	25.2 (19.3-31.0)	3.86 (-0.84 - 8.57)
Ippolito *et al*[1]	32	47	8.28 (5.97-10.59)	9.4 (6.69-12.11)	22.1 (20.3-23.9)	-0.62 (-3.04 - 1.80)
Dobbs *et al*[3]	45	73	15.95 (13.24-18.66)	7.68 (4.06-11.30)	18.1 (15.4-20.8)	10.32 (8.55 - 12.09)
Fridman *et al*[10]	50	71	3.97 (1.27-6.67)	-	-	1.32 (-0.70 - 3.34)
Singh *et al*[12]	18	33	11.9 (9.89-13.91)	15.7 (13.14-18.26)	28.2 (25.9-30.5)	-
Prasad *et al*[13]	30	50	6.92 (2.49-11.35)	18.54 (11.90-25.18)	46.2 (38.7-53.7)	5.8 (2.22 - 9.38)
Herbsthofer *et al*[15]	38	62	10.29 (7.68-12.90)	-	-	9.95 (7.90 - 12.00)
Abulsaad *et al*[16]	54	70	-5.43 (-6.85-4.02)	-	-	-
Docquier *et al*[17]	16	25	-3.5 (-6.52-0.48)	10.9 (6.43-15.37)	15.9 (12.7-19.1)	-3.9 (-7.04 - -0.76)
Difference between treatment			Q = 2.50, P = 0.11	Q = 10.74, P = 0.001	Q = 10.48, P = 0.001	Q = 16.12, P < 0.001

adherent to low level of evidence studies analyzed and the relatively loose entry criteria.

Extensive soft-tissue release was the preferred method of treatment for many decades because it often provides definitive correction of the deformity. Full correction by addressing all components of the deformity was recommended. Surgical approaches most commonly used can be classified into three main categories: the Turco posteromedial incision[34], the Crawford's circumferential Cincinnati incision[35], and the two-incision Carroll approach[36]. Ponseti *et al*[33] pioneered his manipulative and serial casting technique in the late 1940s and first published his method in 1963. He proposed simultaneous correction of all components of clubfoot by abducting the foot under the talus while a counter pressure is applied to the talar head. Based on long-term follow-up studies of patients who underwent extensive soft-tissue releases for the management of idiopathic clubfoot before 1980, it has been shown that aggressive surgical management results in poor long-term foot function due to pain, stiffness, and degenerative arthrosis[1-4]. Until today, there is a lack in the literature of studies evaluating adults with clubfeet treated with selective posteromedial release techniques, as these were described after 1983. The present meta-analysis, by including data of clubfeet treated with both aggressive and comprehensive release techniques, demonstrated that patients managed with the Ponseti method had a higher rate of excellent or good outcomes than patients treated with open surgery.

Noncompliance of the family to follow the brace protocol is associated with unexpected high recurrence rate ranging from 30% to 45%[7,37-49]. According to a recent study, there is no association between the poor bracing compliance and the families educational level, income or cultural origin[50]. Distance from the treatment centers and accessibility to the health care system are important parameters that may also adversely affect compliance, and secondarily the success rate. In addition, concurrent

Table 4 Between and within-study heterogeneity in outcomes of clubfoot treatment

	Overall		Ponseti method		Soft-Tissue release	
	Q	I^2	*Q*	I^2	*Q*	I^2
Laaveg-Ponseti score	468.8[a]	98.7	2.3	57.2	465.8[a]	99.1
Excellent/Good Laaveg-Ponseti ratings	72.5[a]	86.2	0.35	0	55.6[a]	87.4
TCA-AP	346.8[a]	97.1	4.1	50.9	312.5[a]	97.8
TCA-LT	496.3[a]	98.0	320.8[a]	99.4	158.1[a]	95.6
TCI	274.5[a]	96.4	114.3[a]	98.3	265.5[a]	95.4
TMT-AP	376.3[a]	97.6	0.001	0	365.2[a]	98.1
TMT-LT	67.3[a]	91.1	1.3	20.5	21.0[a]	80.9
MTT-LT	203.8[a]	96.6	2.3	12.0	89.0[a]	95.5
CMT-AP	328.7[a]	97.6	4.0	50.6	121.5[a]	95.9

[a]P < 0.05 *vs* patients who underwent open surgery, significant variability. TCA-AP: Anteroposterior talocalcaneal angle; TCA-LT: Lateral talocalcaneal angle; TCI: Talocalcaneal index; TMT-AP: Anteroposterior talus-first metatarsal angle; TMT-LT: Lateral talus-first metatarsal angle; MTT-LT: Lateral first-fifth metatarsal angle; CMT-AP: Anteroposterior calcaneus-fifth metatarsal angle.

Table 5 Correlations between functional and radiographic outcomes after clubfoot treatment

	Length of follow-up *r* (*P* value)	Laaveg-Ponseti excellent/good outcomes *r* (*P* value)
TCA-AP	-0.31 (0.39)	0.80 (0.006)
TCA-LT	0.43 (0.22)	-0.26 (0.46)
TCI	0.13 (0.73)	0.48 (0.16)
TMT-AP	0.27 (0.49)	-0.36 (0.34)
TMT-LT	-0.66 (0.16)	-0.06 (0.91)
CMT-AP	-0.26 (0.53)	-0.64 (0.091)
MTT-LT	0.11 (0.82)	-0.13 (0.79)

TCA-AP: Anteroposterior talocalcaneal angle; TCA-LT: Lateral talocalcaneal angle; TCI: Talocalcaneal index; TMT-AP: Anteroposterior talus-first metatarsal angle; TMT-LT: Lateral talus-first metatarsal angle; MTT-LT: Lateral first-fifth metatarsal angle.

illnesses may affect management of clubfeet with the Ponseti method.

In an effort to objectively evaluate idiopathic clubfoot, assess treatment, and classify residual deformities, a large number of angular measurements have been proposed on the anteroposterior and lateral radiographic projections[51-53]. The TCA-AP and the TCA-LT, as well as the TCI (sum of TCA-AP and TCA-LT angles) are the most widely used parameters and reflect the anatomic relationship between the talus and the calcaneus. Among the other radiographic angles usually used in clinical practice, TMT-LT and MTT-LT angles measure midfoot cavus deformity, whereas TMT-AP and CMT-AP angles are expressions of forefoot adduction that characterize clubfoot. Our study did not reveal statistically significant difference in TCA-AP and TCA-LT angles between clubfeet treated with open surgery or the Ponseti method. The average TCI was measured above 40 in clubfeet managed with Ponseti method as well as in surgically treated clubfeet. A statistically significant difference was recorded in TMT-LT, MTT-LT, and CMT-AP angles.

Although radiographic evaluation has been extensively used as a measure of success of idiopathic clubfoot treatment, several authors have questioned the correlation between functional and radiographic outcomes as well as the prognostic value of radiographs[6,14,54,55]. Evaluation of radiographs is difficult to reproduce due to complexity of the deformity in various planes with multiple bone involvement, the small size or complete absence of ossific nuclei, particularly that of the navicular, the considerable overlap between radiographic values of normal feet and clubfeet, and difficulty in positioning the stiff and deformed foot[56]. Furthermore, the use of different functional systems does not allow direct comparison between studies in order to identify any association between these radiographic parameters and the functional outcome. In the present meta-analysis, the Laaveg-Ponseti score was used to study the correlation between the clinical scoring and angular measurements since it does not rely on any radiographic parameters. A higher TCA-AP angle was associated with a better functional outcome. This is in agreement with several previous studies[57,58], although many authors have found strong correlation between the functional rating and TCA-LT[5,18,34,59,60] or TCI[52,57,61]. Herbsthofer *et al*[15] demonstrated no correlation between angular measurements and functional outcome. It is our opinion, however, that several radiographic parameters representing each of the clubfoot deformities should be used to provide a comprehensive radiological assessment of the three dimensional clubfoot deformities. By measuring TCA-AP, MTT-LT, and TMT-AP angles, the heel varus, midfoot cavus, and forefoot adduction, can be radiologically assessed and correlated with the functional outcome. In contrast, using a severity evaluation system that is based exclusively on radiographic criteria may overestimate the value of radiographs.

Long-term follow-up studies of treated clubfeet evaluating function beyond skeletal maturity are rare[1-3,6,62]. The studies with the longer follow-up were those of Cooper *et al*[6] with an average of follow-up of 34 years, Ippolito *et al*[1] with an average duration of follow-up of 25 years, and Dobbs *et al*[3] with a mean of follow-up of 30 years. Cooper *et al*[6], evaluated 71 clubfeet in 45 patients treated with the Ponseti method. Seventy-eight percent of the patients had an excellent or good outcome. Mild arthrosis in the foot and ankle was found in 35% of the patients. Twenty-seven percent of the patients had an excellent or good outcome. Ippolito *et al*[1] compared the results of adult patients with idiopathic clubfoot treated during infancy either with the Ponseti method or extensive soft-tissue release. They recorded better long-term functional outcomes when the former technique was used. The mean Laaveg-Ponseti score was 85.4 and 74.7 for the Ponseti method and surgically treated group, respectively. Seventy-eight percent of the patients treated with the Ponseti method had an excellent or good outcome. In contrast, only 43% of the patients treated with extensive soft-tissue release had an excellent or good outcome. Thirty percent of the surgically treated patients and 38% of the patients treated with the Ponseti method were found to have recurrences requiring additional intervention. Among these recurrences, 86% in the surgical group and 27% in the Ponseti group were major. Dobbs *et al*[3] followed 73 clubfeet who had undergone either an extensive combined posterior, medial, and lateral release or a posterior release and plantar fasciotomy. They reported a correlation between the extent of soft-tissue release and the degree of functional impairment. Moderate to severe evidence of arthrosis in the foot and ankle was found in 56% of surgically treated patients. The mean Laaveg-Ponseti score was 65.3. Our study was in agreement with these findings, suggesting that foot function deteriorates over time in patients treated with open surgery. However, it should be noted that surgically treated patients in the last two long-term studies, as well as 20.87% of surgically treated clubfeet included in our study, were operated with extensive soft-tissue releases which does not represent the current surgical practice.

This study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. Although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

COMMENTS

Background

During the second half of the twentieth century, the primary treatment of idiopathic clubfoot has ranged from gentle manipulations to aggressive surgical treatment. Although there are a plethora of studies that have assessed the functional and radiographic outcomes following different treatment protocols, there are only a few studies that directly compare open surgery and Ponseti method for the management of idiopathic clubfoot. This can be mainly attributed to variable and simplistic grading systems for scoring the severity of the deformity as well as the differing evaluation systems for assessing outcomes.

Research frontiers

The present study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. The findings suggest that foot function deteriorates over time in patients treated with open surgery.

Innovations and breakthroughs

In the present long-term study, although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

Applications

The study results suggest that serial manipulation and casting is the accepted initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected.

Terminology

Ponseti method is the conservative treatment of idiopathic clubfoot consisting of manipulations and serial casting, and frequently minimal invasive surgery.

Peer review

This is an excellent meta-analysis in which authors analyze a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. The results are interesting and suggest that Ponseti method has a higher rate of excellent or good outcomes.

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CASE REPORT

Profunda femoris artery pseudoaneurysm following revision for femoral shaft fracture nonunion

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Abstract

Femoral artery pseudoaneurysms (FAPs) have been described following internal fixation of intertrocantheric, subtrocantheric and intracapsular femoral neck fractures as well as core decompression of the femoral head. The diagnosis of FAP is usually delayed because of non-specific clinical features like pain, haematoma, swelling, occasional fever and unexplained anaemia. Because of the insidious onset and of the possible delayed presentation of pseudoaneurysms, orthopaedic and trauma surgeons should be aware of this complication. We report a case of Profunda Femoris arterial branch pseudoaneurysm, diagnosed in a 40-year-old male 4 wk after revision with Kuntscher intramedullary nail of a femoral shaft nonunion. The diagnosis was achieved by computed tomography angiography and the lesion was effectively managed by endovascular repair. The specific literature and suggestions for treatment are discussed in the paper.

Key words: Arterial injury; Pseudoaneurysm; Nonunion; Femoral shaft; Endovascular repair

Core tip: Femoral artery pseudoaneurysms (FAPs) are a reported possible complication of intramedullary nailing for acute femoral shaft fractures. In this report we describe the delayed occurrence of a FAP after revision surgery for femoral shaft nonunion, its diagnosis and management by endovascular repair and discuss the pertinent findings in the medical literature.

Valli F, Teli MGA, Innocenti M, Vercelli R, Prestamburgo D. Profunda femoris artery pseudoaneurysm following revision for femoral shaft fracture nonunion. *World J Orthop* 2013; 4(3): 154-156 Available from: URL: http://www.wjgnet.com/2218-5836/full/v4/i3/154.htm DOI: http://dx.doi.org/10.5312/wjo.v4.i3.154

INTRODUCTION

A pseudoaneursym is a collection of blood leaking from a damaged arterial wall. The damage can be caused by traumatic or iatrogenic perforations. Femoral artery pseudoaneurysms (FAPs) have been described to arise after different surgical procedures, including internal fixation of intertrocantheric, subtrocantheric and intracapsular femoral neck fractures, intramedullary nailing of femur, core decompression of femoral head for osteonecrosis and revision total hip arthroplasty[1-4].

Because of the insidious onset and possible delayed presentation of FAPs, orthopaedic and trauma surgeons should be aware of this complication. FAPs may close spontaneously if the tear is small enough to allow for clotting and sealing. On the other hand, rupture of the aneurysm can trigger thrombosis, distal embolization and compression of adjacent structures. Compartment syndrome of the tigh has also been observed after formation of a pseudoaneurysm of the femoral artery or of its branches[1].

As far as treatment is concerned, small-sized FAPs can be managed by coil or balloon embolisation, stent

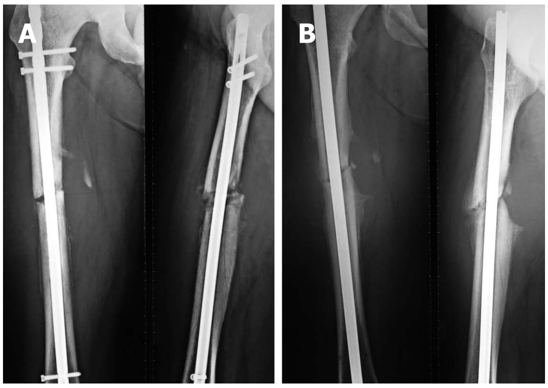

Figure 1 X-ray appearance of pseudoaneurysm. A: Anteroposterior and lateral radiograph of femoral shaft nonunion 8 mo after interlocking IM nailing; B: An ovoid, soft tissue mass behind the fracture site is visible 1 mo after exchange nailing.

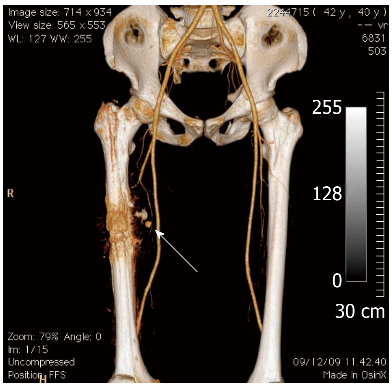

Figure 2 Computed tomography appearance of pseudoaneurysm. Computed tomographic angiogram showing pseudoaneurysm of profunda femoris artery (arrow).

graft repair, transducer-directed compression and other percutaneous or endoluminal treatments[2].

We report a case of a profunda femoris arterial branch pseudoaneurysm, diagnosed in a 40-year-old male 4 wk after revision with Kuntscher intramedullary nail for a femoral shaft nonunion.

To the best of our knowledge this is the first report of femoral pseudoaneurysm occurring after intramedullary nailing for nonunion of the femoral shaft.

CASE REPORT

A 40-year-old male cyclist in good health was involved in a collision with a car that was travelling at 45 miles (65 km) per hour. He sustained an isolated, closed femoral shaft fracture. There were no concomitant abdominal or thoracic injuries. His Injury Severity Score was 9. On X-rays he showed a type 32-A2 fracture according to the AO-ASIF classification[5].

The patient consented to have surgical treatment in the form of unreamed intramedullary nailing (T2 Femur Nail, Stryker Trauma). This was done on the day of injury. There were no reported intraoperative complications. Postoperative radiographs revealed a minimum gap between the proximal and distal fragments. The patient was discharged 4 d after surgery with progressive weight bearing on a assisted rehabilitation protocol. He obtained a complete range of motion after 1 wk and full weight bering after 1 mo, but he complained of a degree of pain during ambulation.

X-rays at 8 mo follow-up revealed nonunion (Figure 1A). After consulting the patient, a revision with intramedullary exchange nailing was planned with reamed insertion. This involved the removal of a previously placed implant and reaming the medullary canal to a larger diameter. The diameter of the new nail (Kuntscher Nail, Stryker Trauma) was 2 mm larger than that of the previous nail and the intramedullary canal was over-reamed by 1 mm more than the diameter of the new nail. Postoperatively, the hemoglobin level never fell down under 9.0 g/dL, without any signs and symptoms of hypovolemia.

Four weeks after surgery, a tender swelling over the medial thigh was noted, and radiographs revealed an ovoid soft tissue mass behind the fracture site (Figure 1B). A residual hematoma (confirmed by duplex ultrasound) was diagnosed, and observation was recommended based on intact distal pulses and neurological function.

However, 3 wk later the enlargement of the mass had continued and associated pulsatile swelling was noticed. A pseudoaneurysm instead of a simple hematoma was suspected. Further investigation, including computer tomographic angiography, confirmed a lesion originating from a profunda femoris arterial branch adjacent to the fracture site (Figure 2).

The patient was therefore referred to an Interventional Radiology department. An angiogram confirmed a rapidly enhancing pseudoaneurysm sac arising from a branch of the right profunda femoris artery. Using a microcatheter, the segmental branch feeding the pseudoaneurysm was selectively cannulated (Figure 3A) and a total of five microcoils (3 mm × 3 cm) were deployed in the vessel distally and proximally to the pseudoaneurysm neck. After embolisation, a control angiogram showed satisfactory hemostasis with occlusion of the feeding vessel, no further filling of the pseudoaneurysm, and no extravasation of contrast (Figure 3B). The compressive discomforts were quickly relieved.

Over the next 6 mo, intact neurovascular status without recurrent painful swelling or reported complications were observed. No additional complications arose during follow-up. The femoral shaft nonunion healed at 6 mo follow-up (Figure 4).

DISCUSSION

There are different causes of FAP caused by orthopaedic procedures reported in the literature. Arterial damage can occur because of bone spikes, screws, drills, displaced implants and retraction of surrounding tissues[6]. Others reports stress the point that locking screws are potential causes of FAPs in case of penetration of inner cortex[7]. The most likely cause of the pseudoaneurysm seen in this case report was over penetration of the drill bit during the intramedullary exchange nailing with reamed inser-

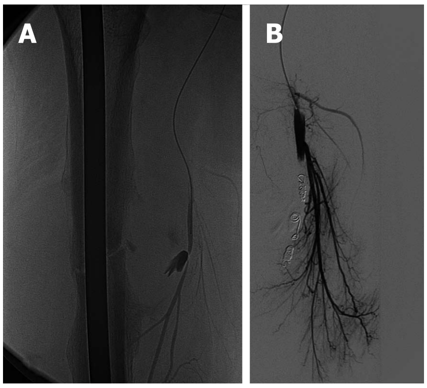

Figure 3 Embolisation. Elective (microcatheter) right deep femoral angiography pictures showing the pseudoaneurysm adjacent to the fracture site. A: Before coil embolization; B: After coil embolization (digital subtraction angiography).

Figure 4 Fracture healing. Anteroposterior and lateral radiograph of the femoral shaft 6 mo from revision surgery, showing fracture union.

tion. The drilling probably injuried the arterial wall with subsequent external hemorrhage.

Early diagnosis of a pseudoaneurysm of the femoral artery or one of its banches can be done if non-specific clinical signs are evaluated and any swelling over the medial aspect of the proximal thigh is investigated properly. However, these findings may be normal when the injury only involves a minor vessel.

The time frame necessary to detect traumatic pseudoaneurysms varies from hours to years depending on the involved region and clinical signs. Clinical manifestations include an enlarging pulsatile swelling, audible bruit, palpable thrill, pain, edema and compressive neuropathy. Without a clear history of trauma, the lesion may mimic some soft tissue conditions like abscesses or neoplasms. Because of the presence of heat and tenderness in the surrounding area, the inflammation during the organisation of the hematoma may appear as a postoperative infection[8]. Therefore, a high index of suspicion and radiological imaging [particularly computed tomography (CT) angiography and duplex ultrasonography] plays a major role in obtaining a diagnosis. Multidetector CT angiography enables 3-dimensional reformatting of the lower limb vasculature. Although the image quality can be impaired by metallic implants, it is a quick and non-invasive method, with high sensitivity (90%-95%) and specificity (98%-100%) for detecting arterial injury after trauma[9].

The management of pseudoaneurysms depends mostly on their location and size. Small asymptomatic lesions or those involving non-critical vessels may be observed for 4-6 wk to detect possible spontaneous recovery. However, active intervention is indicated in larger (> 3 cm) symptomatic lesions. Current therapeutic approaches include open surgical repair, ultrasound-guided compression, ultrasound-guided thrombin injection and endovascular repair using coil embolization or stent-graft insertion as seen in this case.

In conclusion, to the best of our knowledge this is the first report of a delayed pseudoaneurysm caused by drilling during a revision intramedullay nailing for femoral shaft nonunion. Therefore, a pseudoaneurysm should be suspected not only in fracture cases, but also in revisions of nonunions. Due to the rarity of the condition, in case of suspicion the early use of CT angiography is highly recommended. Endovascular repair is an effective minimally invasive treatment for delayed pseudoaneurysms of the femoral artery.

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CASE REPORT

Solid fusion after lumbosacral arthroplasty

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Abstract

A 55-year-old female was diagnosed with L5-S1 degenerative disc disease (DDD). Initial scores by the visual analogue scale (VAS) were 5 (back) and 9 (leg) and the Oswestry disability index (ODI) was 32. Arthroplasty was performed. Clinical and radiographic monitoring took place thereafter at one month, three months, six months and annually. At one month, VAS scores were 2 (back) and 3 (leg), ODI was 12 and ROM was 2.1° by radiographs. At two years, VAS scores were 1 (back) and 2 (leg), ODI was 6 and ROM was approaching 0. Five years after surgery, the entire operated segment (L5-S1) was solidly fused. A malpositioned disc implant may impair normal spinal movement, culminating in heterotopic ossification or complete fusion of the operated segment.

Key words: Total disc replacement; Lumbar spine; Heterotopic ossification; Fusion, Arthroplasty; Solid fusion

Core tip: A 55-year-old female was diagnosed with L5-S1 degenerative disc disease. Initial scores by the visual analogue scale were 5 (back) and 9 (leg) and the Oswestry disability index was 32. Arthroplasty was performed. Clinical and radiographic monitoring took place thereafter at one month, three months, six months and annually. A malpositioned disc implant may impair normal spinal movement, culminating in heterotopic ossification or complete fusion of the operated segment.

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INTRODUCTION

Total disc replacement (TDR) is currently advocated for degenerative disc disease (DDD) as a substitute for fusion surgery in certain cases. In theory, TDR may preserve normal range of motion (ROM) in diseased segments and prevent adjacent segment degeneration (ASD)[1-3]. However, a number of complications undermining these benefits have been observed following lumbar TDR, such as heterotopic ossification, facet arthrosis, subsidence, ASD and device migration[1-5]. This report details an unusual occurrence of solid spinal fusion subsequent to lumbosacral TDR and the factors likely contributing to device failure.

CASE REPORT

A 55-year-old female was hospitalized for low back pain radiating to the left thigh and calf. Her past medical history was otherwise unremarkable. Initial scores by the visual analogue scale (VAS) were 5 (back) and 9 (leg) and the Oswestry disability index (ODI) was 32. Radiographic findings were indicative of DDD at the L5-S1 level. After six weeks of unproductive nonsurgical therapy (NSAID, physical therapy), she underwent lumbosacral TDR. Preoperative ROM was 8.6° by radiographs and preoperative computed tomography and magnetic resonance image shows no stenosis or facet arthroplasty at the L5-S1

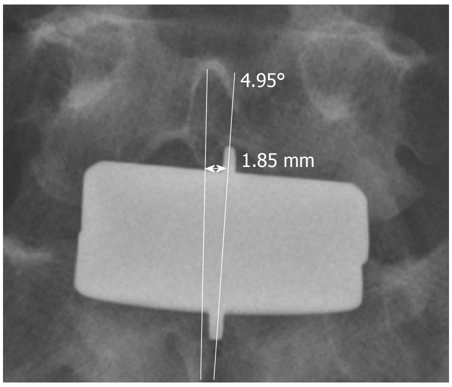

Figure 1 In the anteroposterior view, the superior endplate of the implant deviated 1.85 mm to the left of midline with 4.95° angular displacement.

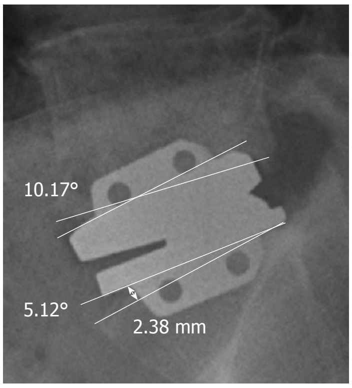

Figure 2 In the lateral view, angular gaps of 10.17° and 5.12° existed between the upper and lower implant endplates, respectively, and 2.38 mm of the lower anterior vertical keel did not insert completely into the S1 upper endplate.

level. The procedure entailed standard left-sided anterior retroperitoneal[4] insertion of a Maverick® (Medtronic Sofamor Danek, Inc., Memphis, TN, United states) implant, requiring 120 min to complete. Estimated blood loss was 200 cc.

In the immediate postoperative period, the patient's condition was satisfactory. There were no significant early complications. Nevertheless, radiographs showed that the superior endplate of the implant deviated 1.85 mm to the left of midline in anterior-posterior (AP) view, with 4.95° angular displacement (Figure 1). In the lateral view, angular gaps of 10.17° and 5.12° existed between the upper and lower implant endplates, respectively, and 2.38 mm of the lower anterior vertical keel did not insert completely into the S1 upper endplate (Figure 2). The patient's clinical course was uneventful. Four days postoperatively, VAS scores were 3 (back) and 4 (leg) and she was discharged seven days after surgery in a stable condition. Clinical status and standing lateral radiographs were evaluated at each follow-up visit. At one month, VAS scores were 2 (back) and 3 (leg), ODI was 12 and ROM was 2.1° by radiographs (Figure 3). At two years, VAS scores were 1 (back) and 2 (leg), ODI was 6 and ROM was approaching 0° (Figure 4). VAS scores and ODI

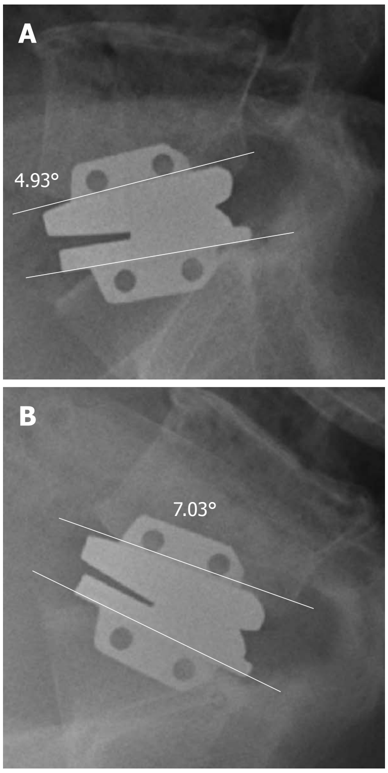

Figure 3 One month after the operation, range of motion of the implant was checked 2.1° (Left: Extension; Right: Flexion).

were unchanged at three years, but calcific bony spurs (heterotopic calcification) were noted on radiographs at the anterior and posterior implant margins (Figure 5). At the final follow-up (five years), VAS scores of 1 (back) and 1 (leg) and ODI of 3 were recorded. By radiographs, the L5-S1 segment was completely fused (Figure 6).

DISCUSSION

The increasing surgical use of artificial discs has raised concern due to related heterotopic ossification (HO). While the etiology of HO remains unclear, perioperative bleeding, implant milieu and ancillary patient conditions (*i.e.*, diffuse idiopathic skeletal hyperostosis) have been implicated[5].

The incidence of HO has been cited as 4.3% in two years of follow-up by Tortolani *et al*[6] who found no effect on ROM or clinical outcomes attributable to HO. They also remarked that the onset of HO was unlikely past the sixth postoperative month. On the other hand, Lemaire *et al*[7] reported a 3% rate of HO after a minimum follow-up of 10 years, all manifested later than five years postoperatively. Finally, Park *et al*[5] detected HO at a rate of 30.5% within 17 mo (on average) after TDR. Four cases actually emerged beyond the third postoperative year. They further cautioned that HO may progress during follow-up, making long-term monitoring imperative. Of note, Fransen *et al*[8] believe nonsteroidal anti-inflammatory drugs (NSAIDs) to be protective in this regard.

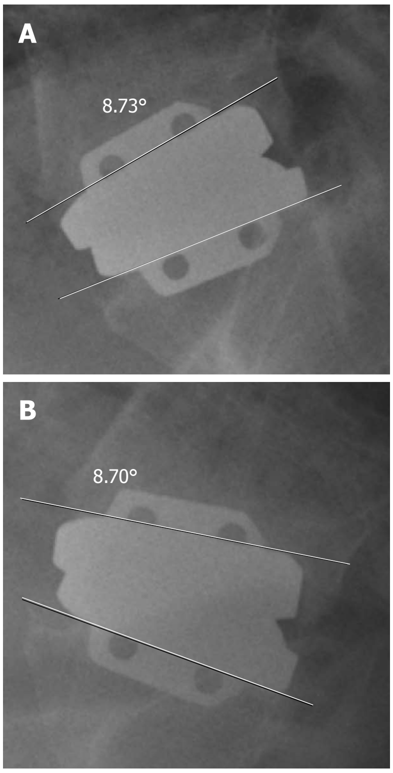

Figure 4 Two years after the operation, radiograph (Above: Extension; Beow: Flexion) shows range of motion of the implant was almost 0°.

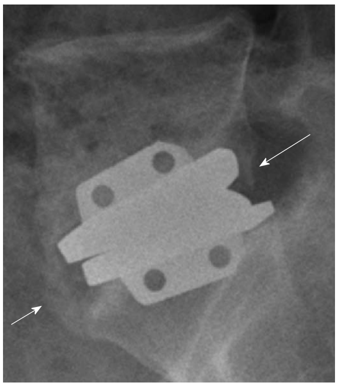

Figure 5 Three years after the operation, calcified spurs (heterotopic ossification) were identified (arrow) at the anterior and posterior margin of the implant.

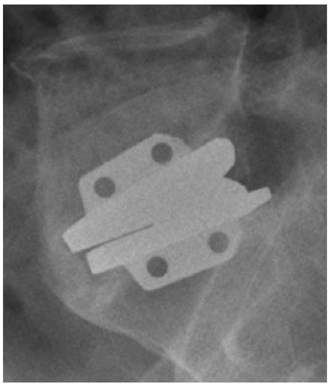

Figure 6 At the last follow-up (5 years), more prominent bony masses were identified and the L5-S1 segment was fused completely.

Implant placement was unsatisfactory in our patient, deviating to the left of midline with angular gaps between the implant endplates and adjacent vertebrae. The implant was also misaligned in the AP plane, improperly inserting into the body of S1 (Figures 1 and 2). In retrospect, we believe that decompression at the L5-S1 posterior lip was excessive, creating a sunken base posteriorly for the implant and impairing its placement as described above. Normal movement clearly appeared compromised as a consequence. ROM was only 2.1° one month after surgery (Figure 3), HO had developed after two years and at the final 5-year follow-up, the operated segment was solidly fused (Figures 5 and 6). According to Huang *et al*[9], the risk of ASD after TDR (followed 8.7 years) is higher when ROM is low (less than 5°). A malpositioned implant may thus produce an outcome over time that is tantamount to fusion surgery, with heightened potential for ASD.

There are obvious limitations to the observations drawn from this single patient. Results here are based on the Maverick® implant specifically and may not apply to all TDR devices. Furthermore, we could not closely pinpoint the onset of HO or spinal fusion once follow-up visits were extended to annual intervals. Nevertheless, we feel that implant positioning may be critical in development of HO by impacting ROM.

In conclusion, a malpositioned implant may impair normal spinal movement, leading to HO or complete fusion of the operated segment. As a preventative measure, careful preparation of the bony endplate and precise alignment of the implant in the coronal and sagittal planes is warranted.

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