An original analytical paper
from ConsultingFootPain

Cartilage erosion in hallux (abducto) valgus. Is there a concern?

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Thomas Roukis (2005) suggests cartilage mapping might offer some prediction in regard to long-term outcomes of first toe pathology. This paper considers the evidence that might support this hypothesis. While there are no reasons why earlier interventions should not avert patient's hallux valgus does produce some pathological effects that can be difficult to override. The earlier intervention the better the outcome.

'The gap between clinical sciences and bedside medicine is quite substantial.' Dayton (2018)

Introduction

Many papers on hallux valgus concentrate on surgery with little evidence on conservative care. While deformity plays less of a role in why patients come to us (Tollafield 2019), Dayton (2018) suggesting that pain arises from secondary features such as the medial eminence (70-75%), plantar keratoma (IPK) and metatarsalgia (40-48%). It is secondary features that drive patients to seek assistance Table 1.

Deformity and arthritis of the first toe joint did not determine joint pain as much as general health, educational attainment and level of physical activity (Hurn el al, 2014).

The statistics covering pain (62%) and deformity (37%) were derived from the database PASCOM-10, a tool used by the College of Podiatry covering 1030 responses with 571 statements. This data was derived from surgical consultations. Pain, discomfort and difficulties with walking and wearing shoes are placed into the 60% group of the complainants for this first toe condition (Tollafield 2019).

Metatarsalgia can be arrested depending upon patient footwear considerations in relation to orthoses and insole prescriptions.

What are the objectives of treatment?

The podiatrist needs to know how to use the information reliably to inform patients of prognosis.

Should a patient have an intervention and what intervention is best?

Protecting soft tissue should be paramount as in footwear, local padding or devices suited to protecting the first toe prominence. Splints and taping all have a part to play but no-one has studied the effect on hallux valgus degeneration emanating from erosions within the conservative arena because erosions are either poorly correlated between plain x-rays, or scanning is not used routinely, leaving the main evidence for the surgeon to report after surgical correction.

Grice et al (2017) identifies timeline by recording limitations from steroid injections in the case of hallux rigidus (HR) alone. The benefit drops off over time, 91% down to 14% at 6 months then 9% at 2 years with surgery being required. No similar study has been conducted for Hallux valgus (HV), but the changes observed are very different, with the internal cartilage pathology in HR having more limited movement than HV which as the deformity increases produced adaptations in its range of motion.

Nonetheless changes do arise in HV, and symptoms are beyond secondary features and these fall into the category of capsular inflammatory changes i.e synovitis.

Evidence from Imaging

X-rays

Bock et al (2004) looked at the reliability of x-rays against two methods of recognised evaluation for 265 feet (195 patients). The Kellgren-Lawrence scale 1-4 showing different levels of deterioration by radiographic interpretation, and secondly, the International Cartilage Repair Society scale (ICRS; 1998). In an ideal world there should be reasonable comparison, but 54% (144) underestimated the presence of degeneration and 11% (29) overestimated the presence of degenerative changes. Around 35% (92) agreed with the intra-operative scale using the ICRS. **Table 2** shows the Kellgren-Lawrence scale for radiographic interpretation of damage in hallux valgus

Magnetic Resonance Imaging

The use of **Magnetic Resonance Imaging** (MRI) is still in its early stages of use for hallux valgus. The MRI however is the 'go to tool' in orthopaedics (Choi et al, 2018). Of the MRI they state;

'Considered the most suitable tool to observe soft tissue structures including tendons, ligaments, menisci, and articular cartilages. However, MRI is not usually performed before correcting hallux valgus deformity.'

While it is more ideal to use recent papers, Choi cites Schweitzer M.E, 1999 and says the study was limited by numbers.

'The most common findings observed in hallux valgus were hypertrophic medial eminence (95%), sesamoid proliferation (90%), and adventitial bursitis (90%). They also found that osteophytes (77%), subchondral cysts, and bone marrow edema were commonly found with hallux rigidus.'

The use of MRI for sesamoid degeneration may be used where there is an increasing lateral shift of the medial sesamoid bone and degenerative change within the medial sesamoid-metatarsal complex, Katsui et al (2016). Choi (South Korea) believes that MRI would provide accurate and valuable information about the arthritic changes before surgery. MRI in fact is not as useful after surgery because any metal work will degrade the accuracy of the joint site depending upon its proximity. Computerised tomography might offer a better choice.

Alternative methods

The use of intra-articular **arthroscopy** is probably still in its infancy compared to knees and ankles. Fibre-optic cameras are now small enough to insert into the mtpj as recorded by Lui (2008) cited by Villas (2012).

Bone scans, such as radioactive labelled scans with Technician^{99} have some value in showing active changes but are non-specific to cartilage.

Current studies of value

Roukis et al (2005) set out to consider the predictive aspect of analysis between clinical, radiographic and intra-operative findings. Roukis' paper was published a year later than Bock (2004). Bock cited the presence of lesions and did not mention mapping but identified three zone; lateral, medial and inferior sesamoid.

In terms of validity or observer validation the ICRS was reviewed by Van den Borne et al (2007) for 7 observers, while Smith (2011) considered the ICRS for 2 observers reporting on first toe joint erosive mapping. **Table 3** - International Cartilage repair society grading for erosive changes based on depth.

Fig. 1 Mapping cartilage lesions
international cartilage repair society score 1-4 as in first toe joint. Tollafield

Roukis et al (2005) suggested mapping exercise on live patients rather than falling back on cadaveric studies. Such studies may have predominated previous work on cartilage defects (Scranton & Rutowski,1980, Doty, 2013) where sesamoids were blamed for erosive changes. Roukis cites Dereymaeker (1996), where erosive changes existed under the first toe joint in cadaveric studies. Such studies tend to use subjects that fall into an older age bracket. Cadaver studies are limited and often driven at the older age spectrum.

Pathophysiology

The pearly white material (lamina splendens) is the superficial layer of cartilage, gradually yellowing with age and loss of substance. The thickness of cartilage in the first metatarsal is <1mm thick and the *l.*splendens is around 4-8 microns thick. However, the chondrocyte content is low (0.4-2%) relying on the specialised effect of collagen fibres, proteoglycans and water. The deeper two zones do not play an immediate part in dealing with stress. Any replacement that does arise will repair with fibro-cartilage, Walsh et al (2007).

Adaption to cartilage and bone is seen in hallux rigidus around the dorsal elements of the first mtpj anatomy and this is called **mechano-transduction**. This is where the mechanical stress is converted to biochemical changes.

Roukis et al (2005) suggested erosive cases existed in a 100% over the age of 50 in a study of 166 feet

affecting one or other part of the mtpj. Jastifer et al (2014) found 91% in his patient cohort had osteochondral lesions in 56 consecutive feet. The numbers may appear low when compared to a study by Bock et al (2004), Austria, who reported 73% of their 265 joints (196 patients) had erosions.

Jastifer et al (2014) also used the ICRS scale for observation damaged and followed 79% patients for two years.

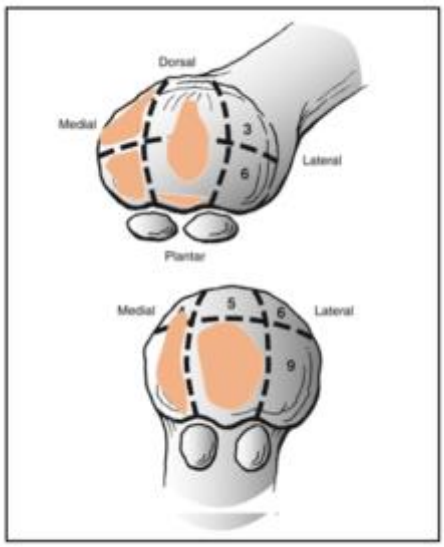

Fig. 2
Common areas of erosions across all papers. Adapted by author from Jastifer et al (2014)

Are we better informed?

Bock (2004) looked at the comparison between radiology and cartilage damage with the backdrop of x-rays. Roukis considered the principle 13 zone map and concluded the common zones affected and also considered measurable angles. This included the proximal articular set angle (PASA), hallux angle (HA), intermetatarsal angle (IMA 1-2) and tibial-sesamoid position/joint (TSP)/TSJ).

Roukis felt that such angles could help predict the incidence of likely lesions, but this turned out to be speculative. Jastifer (2014) disagreed with Roukis on the angles of deformity and relationship with erosions which failed to correlate to degeneration. The involvement of the TSJ relationship remain less clear and no studies involved capsular pathology. The chief outcome measure used was the Visual Analogue Scale or American Orthopaedic Foot & Ankle Scale 0-100

Although now 8 years old, Jastifer's paper (2014) is the latest in a small series on first MTP joint erosions. Their conclusion however suggests that the grade of the cartilage lesion and extent of lesions do not have a strong correlation with the severity of the deformity.

We know that as the deformity increases, the number of lesions found increase. Jastifer found similar findings for the most frequent locations. The medial inferior and superior zones held the greatest frequency, but this was not universally found between all authors. Medial wear was considered due to compression forces, rotation of the metatarsal head as the deformity increases and the effects of medial ligament strain.

Subchondral cysts

As the deformity leads to subluxation, could the loss of the integral lubrication system lead to desiccation and easier tangential wear? Disuse atrophy is widely recognised alongside the medial sagittal groove. Subchondral lesions are associated with atrophy and necrosis of chondrocytes. Synovial fluid is forced into the Haversian canal system and forms pockets or cysts. The overlying cartilage is usually thin at this point and affords disruption of the usual matrix fluid transport mechanism. The cysts left are mucoid in nature and also know in radiology as Geode bodies. Filled with gel they comprise mainly hyaluronic acid, part of the proteoglycan mixture found in cartilage.

Hypotheses and paradigms

Symptoms from MTPJs

The nerve supply to the first toe joint is principally the medial branch of the plantar tibial nerve and supplies the abductor hallucis. Stewart et al (2016) found the abductor hallucis atrophied in gout and was associated with limited movement. As the deformity progresses the muscles loss their efficiency. **Hilton's law** suggests that muscles that cross joints share the same nerve innervation with skin and joints. This implies the deformity can become involved with joint irritation and the capsular structure in the presence of inflammation and sensitive to nociceptors.

The cartilage in hyaline joints has no blood supply but the capsule and the inner synovial membrane is innervated. Synovitis is a finding in hallux valgus but can be absent even in the presence of subchondral and chondral erosions. The fluid content changes colour and yellow-dirty brown suggests haemarthrosis.

Where medial erosions are seen few cause problems but the overlying pressure from exuberant bone growth and cartilage degeneration is symptomatic.

The tibial sesamoid joint (TSJ) is far more prone to erosive damage than the base of the proximal phalanx

which may have been the reason why Jastifer did not include the base in his erosion mapping tool.

High pressure over the crista against the smaller surface of the sesamoid seems to invoke a deeper grade 4 lesion which in effect potentially can auto weld the surfaces with scar formation. Fibrin and fibroblastic attachments seen at surgery form a lace network that can tear at health cartilage.

Dayton et al (2013) considers the medial eminence rarely requires resection because it is part of frontal plane rotation and yet we know this is routinely performed by foot surgeons. If this is corrected the medial prominence is minimised.

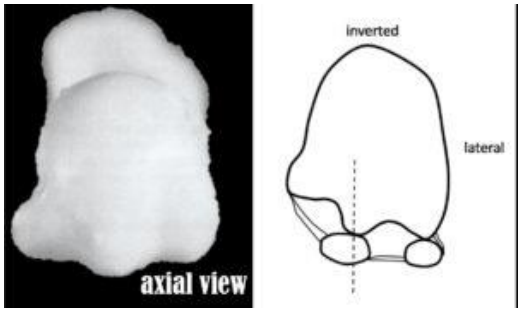

Fig.3 Metatarso-sesamoid articulation relationship of sesamoids and metatarsal

Sesamoid displacement is easy enough to assess from an axial x-ray, but the correlation with actual erosive changes is difficult. Erosive changes in the first MTP joint are compounded by the fact that two sesamoids articulate with the remaining first MTP joint. Males showed more erosive zones when a demarcating map drew 13 different locations, Roukis. As the age of the participants increased, the number of zones involved increased as well as the incidence of a lesion but not the severity of the grade.

A long toe (66%) was considered more likely to be involved when compared to a second, shorter toe, but this only related to one of the zones, at the inferior medial surface. Conversely fewer erosions were seen when the toe in relation to the second digit was shorter, Roukis et al (2005).

Breslauer et al (2001) used cadaveric studies and applied these to patients to show that the metatarsal rotated to increase sesamoid impingement against the crista. They believed that capital osteotomies to correct the PASA angle increased the risk of metatarsal-sesamoid joint damage creating stiffness. Rounded joints fared better than ridged and square joints although the relevance of joint shape still remains unproven by a number of previous authors. There is a suggestion that an increase PASA (norm =0-8) above 8 degrees is likely to lead to more erosive changes.

Dayton et al (2013/2015) provided evidence to support a hypothesis that lack of frontal plane correction reduced the ability for the tibial sesamoid relationship with the crista to recover from a higher displaced position in the transverse plane (TP). Correction of the TP and sagittal plane (SP) deformities alone were reasons for failed surgery.

Getting closer to the answer?

Do erosive changes make a difference to treatment outcome?

The problem with this question is that unless you open up a joint, or place an arthroscope into the joint, you have to rely on MRI or CT scanning. The latter has the disadvantage of producing larger radiation doses. The means might not justify the ends if the risks are seen to outweigh the benefits.

We can say that it is more likely that patients with hallux valgus will have erosions as they age and as the deformity increases. We know that Jastifer has provided compelling evidence that correction of HV below 21 degrees does better than >21 degrees over a follow up period of 2 years. As the deformity increases it reaches a point above 30 degrees less area is involved with erosions. Cartilage surface area is increasingly damaged with angular changes. The sesamoids take most of the damage as their surface is smaller.

Assuming systemic forms of arthropathy can be excluded and the patient has not had an injury, it is reasonable that symptoms can be assisted with conservative methods.

Studies to splint toes in a correct position are beneficial but have only been followed for short periods, Karabicak et al (2015), Plaass, C et al (2020).

Both steroid and hyaluronic acid injections can be beneficial. While orthoses have no place in correcting HV, they may well assist settle the joint together with management of secondary conditions.

With insufficient data available on the subject of pain alone, our joint-related research must continue to look for more evidence. We need numbers and we need controls, but we also need reliable diagnostics. Current research tends to use smaller numbers than older research for therapeutic activity. Ethical consideration and tighter criteria will limit active cohort participation.

Lui (2008) found 90% improvement in 121 patients with synovectomy using arthroscopic methods. Attending to those with synovitis appears one avenue that is overlooked by foot surgeons in lieu of performing many of the procedures currently selected.

Surgery

Surgery should be used to offset problems with lower limb pain at the hip and knee and back. Better shoe fit is an advantage and secondary pain problems, and hammer toes can benefit greatly from surgery. The skin and tissue are better without pressure and medial ulcers and recalcitrant ganglia respond well. Jastifer suggests

'Patients should be counselled about the prevalence of these lesions when discussing expectations from surgery but no less the role of the sesamoid articulations.'

The rational for selecting surgical procedures remains imprecise although the frontal plane contribution to the subject of TSJ degeneration is reasonable when it comes to rotation of the hallux deformity. Patients need to be advised of risks they might encounter from surgery including sesamoid realignment.

Stiffness following surgery is common and this is almost certainly down to poor quality of cartilage retention and lack of joint recovery to full range of motion. In the latter respect it is the younger patient who may do best and the argument for leaving deformity must be judged on patient need, symptoms, long term risk as much as home support and of course medical fitness.

As far as mapping is concerned at best it is an observation rather than a reliable prediction of which procedure and who fairs best. Of course, this article covers hallux valgus not hallux rigidus and the difference seems to come down to the position of damage. Hallux rigidus has more damage in the dorsal-superior aspect while hallux valgus relates more to the plantar-inferior position.

What we can learn is that educating our patients and concentrating more on conservative care in the earlier stages could benefit our patients more than perhaps we do.

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Table 1. Secondary features of hallux valgus

Foot

- Subluxed or dislocated 2nd toe with 3rd and 4th toes involved in significant lateral deviation
- Medial eminence soft tissue callus, corn, extravasated tissue damage
- Medial nerve branch compression with or without formation of neuroma
- Sesamoid pain and intra-articular degeneration
- Ganglion formation over medial eminence
- Plantar bursa formation
- Morton's neuroma ¾ or neuroma 2/3
- Hammer toes
- Plantar callus with variable location
- Widening foot with lateral pressure with or without tailor's bunionnette
- Nail dystrophies and medial sulcal pain, onychophosis
- Joplin's neuroma (distal phalanx)
- Chilblains and tissue change due increased pressure over prominences

Proximal limb

- Altered gait, trips or falls in unstable patients
- Internal hip rotation
- Knee pain
- Hip pain
- Lumbar-sacral pain

Non specific

- Depression
- Effect on occupation
- Footwear difficulties
- At risk limbs from peripheral vascular disease or blood dyscrasias slow healing
- Influence of immune suppressant drugs on soft tissues where deformity exists.

Table 1 Parallel conditions associated with hallux valgus

Grade	Description: Kellgren-Lawrence (X-rays)
1	Mild osteophytic lipping, no sclerosis
2	Moderate osteophytic lipping
3	Multiple osteophytic lipping, some sclerosis and possible deformity of bone contour
4	Severe sclerosis and deformity of bone contour

Table 2 Kellgren-Lawrence radiological grading system (Bock et al 2004)

Grade	International Cartilage Repair Society scale (1998) from Bock et al 2004
1	Nearly normal: superficial lesions, soft indentation and/or fissures/cracks
2	Abnormal: lesions extend down to <50% depth of cartilage
3	Severely abnormal: cartilage defect extends >50% from surface
4	Severely abnormal: cartilage defect extends through the subchondral bone

Table 3 International Cartilage repair society grading for erosive changes based on depth