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Extra-Osseous Talotarsal Joint Stabilization (EOTTS) in the Treatment of Hyperpronation Syndromes

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<http://dx.doi.org/10.5772/intechopen.76234>

Abstract

The partial dislocation of the talotarsal joint (TTJ) serves as a primary deforming force to many lower extremity pathologies. External measures are limited in their ability to realign and stabilize the TTJ, and osseous reconstruction is associated with many risks, complications, costs, and long-term recovery. EOTTS provides patients an “in-between” solution that can be used with both conservative and other surgical procedures. Hyperpronation syndrome is a generic term used to include many secondary symptoms associated with a prolonged period or an excessive amount of pronation. These include many pathologies within the foot, ankle, knee, hip, and even spine. This chapter discusses the importance of early implementation and importance of EOTTS in the treatment of hyperpronation syndrome.

Keywords: partial talotarsal joint dislocation, overpronation, hyperpronation, extra-osseous talotarsal joint stabilization, arthroereisis, flexible flat foot correction

1. Introduction

The recurrent partial dislocation of the talus on the calcaneus and navicular is a weightbearing pathologic deformity. EOTTS is a minimally invasive, soft tissue procedure where an orthopedic stent is inserted into the sinus tarsi after the realignment of the talus on calcaneus and navicular. The function of the stent is to maintain the alignment of the TTJ while still allowing a normal range of motion. This procedure is performed in both children and adults as a primary, preferred method of treatment to reduce the strain and realign the osseous structures within the foot and ankle. Many times, EOTTS is combined with other forms of treatment.

The TTJ is the foundation joint of the body. Misalignment of the TTJ leads to a faulty foot foundation that will lead to misalignment of proximal structures, i.e., the ankle, knee, hip, pelvis, and spine. The tens of millions of steps taken decade after decade lead to abnormal wear and tear upon these joints contributing to the formation of osteoarthritis. EOTTs can therefore have a positive effect to the proximal joint structures.

Historically EOTTs has been a niche procedure. However, due to improved stent designs and the increasing positive results of many scientific studies, this procedure is becoming more mainstream. The inability of conservative measures, such as arch supports and braces, to realign and stabilize the TTJ has been shown. Furthermore, previously recommended surgical procedures, i.e., osteotomy and arthrodesis, are associated with a longer recovery and greater potential risk of complications. Foot surgeons have longed for “in-between” conservative surgical procedures. EOTTs has proven to fulfill that need.

2. Biomechanics and stability of the talotarsal joint

The TTJ is one of the most important weightbearing joints of the body. It is responsible for handling oblique forces from the proximal body above and the weightbearing surface below. The talus serves as a “transmission” bone between the proximal limb and the foot. The architecture of the talus allows the forces to interact with the lower limb both posteriorly and anteriorly. The stability and alignment of the TTJ are essential for an efficient lower extremity function (**Figure 1**).

The complex range of motions of the TTJ is a very important consideration. Every joint has a normal, ideal range of motion. The TTJ, which has also been called the acetabulum pedis, exhibits triplane motion collectively called supination and pronation (**Figures 2 and 3**).

Supination occurs as the talus moves laterally, dorsally, and posteriorly on the calcaneus. This supinatory motion serves to strengthen the joints of the foot during weightbearing activities. Pronation has the opposite effect: to weaken the joints of the foot as the talus slightly shifts medially, plantarly, and anteriorly.

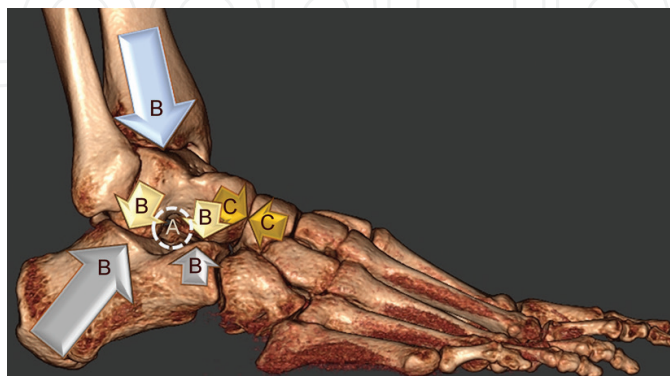


Figure 1. This weightbearing three-dimensional CT illustrates the triplane of forces acting on and between the talus. “A” is the sinus tarsi. “B” is the vertical-plantar-oblique forces, and “C” is the proximal-distal forces.

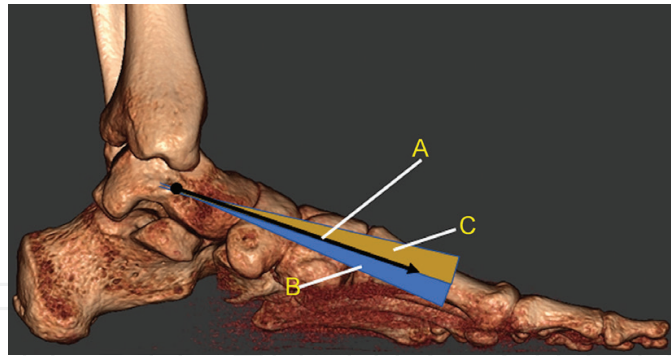


Figure 2. Lateral weightbearing three-dimensional CT. TTJ is in neutral position. "A" is the bisection of the talus. "B" indicates TTJ pronation. "C" indicates TTJ supination.

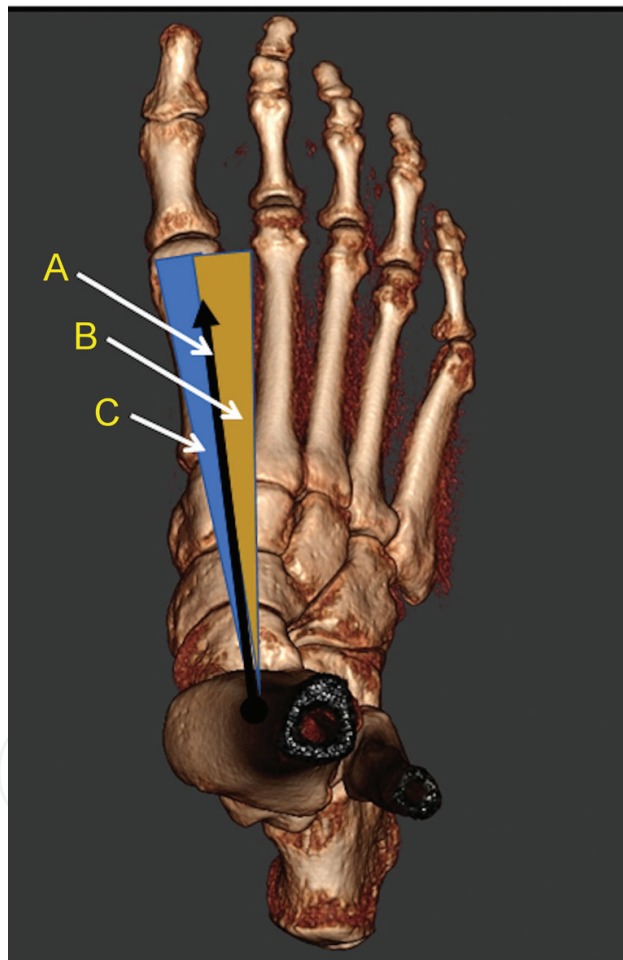


Figure 3. Dorsoplantar weightbearing three-dimensional CT. TTJ is in neutral position. "A" is the bisection of the talus. "B" indicates TTJ supination. "C" indicates TTJ pronation.

The normal, ideal ratio of supination to pronation has been determined to be 2/3 supination and only 1/3 pronation [1]. There should be only a slight amount of pronation of the TTJ. This shows that the locking, supination, of the TTJ mechanism is more important than the

unlocking, pronation, during weightbearing activities. An excessive pronation motion creates an imbalance of the homeostasis of that joint leading to a prolonged weakness of the foot structure.

An understanding of the stabilizing factors of the TTJ must be understood. The talus is the only foot bone not to have the insertion of a tendon. Therefore, talar stability relies first on the articular surfaces on the calcaneus and then the navicular. There is a vast ligament network that serves to keep talar motion in check. These ligaments are attached anteriorly, medially, posteriorly, laterally, and plantarly in a very strategic pattern to limit excessive talar motion. Furthermore, there are Golgi sensors within the ligament that will signal a neuro-response to trigger muscle activity to also limit excessive talar motion.

3. Recurrent talotarsal joint dislocation

The loss of constant congruent articulation within the TTJ serves as a primary pathologic deformity that can lead to many secondary pathologies and hyperpronation syndrome(s). The partial dislocation initially occurs as recurrent deformity, i.e., it occurs again and again or repeatedly. It is possible that due to osseous changes over time or the formation of a coalition, the partial dislocation can become a fixed deformity. Early intervention prior to the formation of a fixed deformity is preferred as it affords more conservative treatment.

The mechanism for the recurrent TTJ dislocation occurs during weightbearing following a period of non-weightbearing. The articular surfaces of talus abnormally displace medially, anteriorly, and plantarly during the early stance phase of the gait cycle. The axis point of the TTJ shifts to an excessive pronatory direction. As the limb/foot becomes non-weightbearing, i.e., during the noncontact, swing phase of the gait cycle, there will be a realignment of the articular surfaces. Immediately following initial heel contact during the weightbearing stance phase, there again will be a loss of alignment and stability of the TTJ.

This orthopedic deformity, recurrent talotarsal joint dislocation (RTTJD), can be observed clinically and documented radiographically by comparing non-weightbearing to weightbearing images. Clinically, the TTJ range of motion can be checked. The preferred method to evaluate TTJ pronation is to grasp the back of the heel with the same hand of the foot being evaluated, i.e., the right hand would cup the right heel. The opposite thumb would be placed under the necks of the fourth and fifth metatarsal, lateral column of foot bones, and maximum pronatory force would be applied (dorsal, lateral, proximal) (**Figure 4**).

There should only exist a few degrees of motion, 3–6. Unfortunately, due to the variation between examiner and examiner, this observation is only a clue to a possible RTTJD deformity. There are no validated tools to adequately and clinically measure this amount of TTJ pronation.

The patient is then told to stand for static, non-weightbearing observation. Common signs of RTTJD include the appearance of a “second” medial malleolus. There could be a lowering of the medial arch, but this is dependent on the presence of a navicular drop, a finding that is

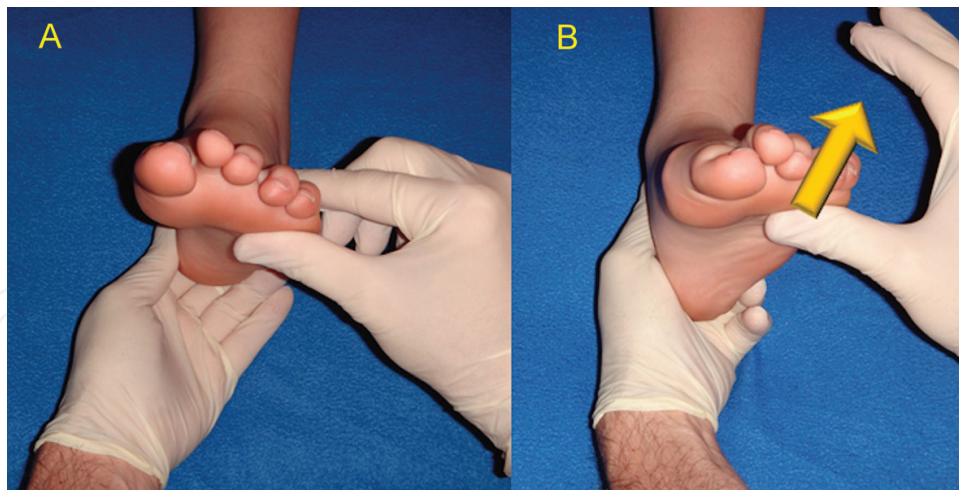


Figure 4. (A) The amount of TTJ pronation within a patient's left foot is being examined. (B) The right hand cups the heel, and a pronatory force is exerted to the lateral column of the foot.

not always present. Looking at the back of the heel, the patient may have a calcaneal valgus. However, calcaneal valgus may not always be present. Finally, observation of a forefoot valgus is confirmed with the "too many toes" sign. Normally, only the fifth and a portion of the fourth toe should be observed. If the entire fourth, at minimum, or a portion of the third toe is visually present, then this would indicate a positive "too many toes" sign.

The last portion of the clinical examination is observation of the gait cycle. Many times, RTTJD is suspected during the non-weightbearing portion but is not seen during static weightbearing, only to return during dynamic weightbearing. Common observations are an abductory twist, "too many toes" sign, and a prolonged period of pronation.

Truly, the best confirmation of RTTJD is via weightbearing radiographic imaging. This is the "gold standard" for establishing a diagnosis for osseous pathology. Standardized weightbearing radiographs have the least degree of interobserver error, unlike range of motion testing. They are validated radiographic measurements and observations to establish the diagnosis of RTTJD.

The two most important views are the lateral and dorsoplantar (DP) images. Specific observations on the lateral radiograph include the geometry of the sinus tarsi. Partial to full obliteration of the sinus tarsi is an unnatural finding. The sinus tarsi should remain "open." The abnormal closure of the sinus tarsi is the first indication of RTTJD; however, there are no validated measurements to indicate normalcy. There are several radiographic angles that can be used to determine normal or abnormal talar alignment. The talar declination angle is commonly used to determine sagittal plane alignment of the talus on the lateral radiograph. Historically, the normal accepted value is <21 degrees; however, this has been recently questioned [2] (Figure 5).

Other considerations on the lateral radiograph include the anterior deviation of the anterior border of the talus to the anterior border of the calcaneus. There are no validated measurements, but a "significant" anterior deviation of the talus over the calcaneus is considered to

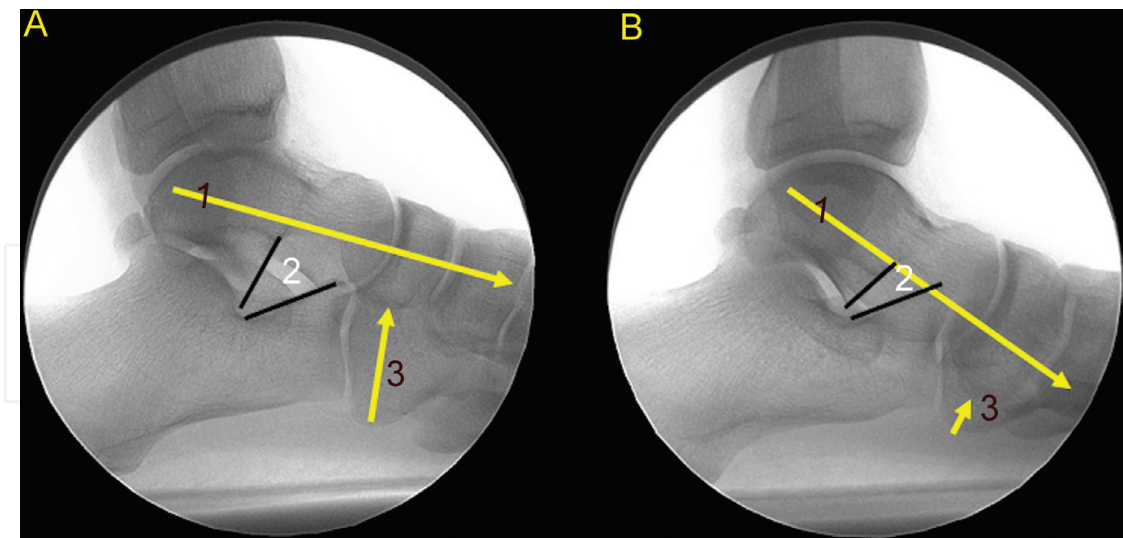


Figure 5. Weightbearing lateral radiograph of the same patient’s foot. A. Patient’s TTJ is in neutral position. (A1) Talar bisection is within normal limits. (A2) The open sinus tarsi space. (A3) Normal navicular height. (B1) Abnormal plantar flexions of the talus. (B2) Abnormal partial obliteration of the sinus tarsi. (B3) Shows a pathologic lowering of the navicular.

be an anteriorly deviated cyma line. The position of the navicular bone to the cuboid also can provide valuable information. Normally, the plantar aspect of the navicular should be located dorsal to the horizontal-vertical bisection of the cuboid.

The DP radiographic image provides transverse plane data. There are several radiographic angles that can be evaluated; however, the ideal is the talar second metatarsal angle. Many

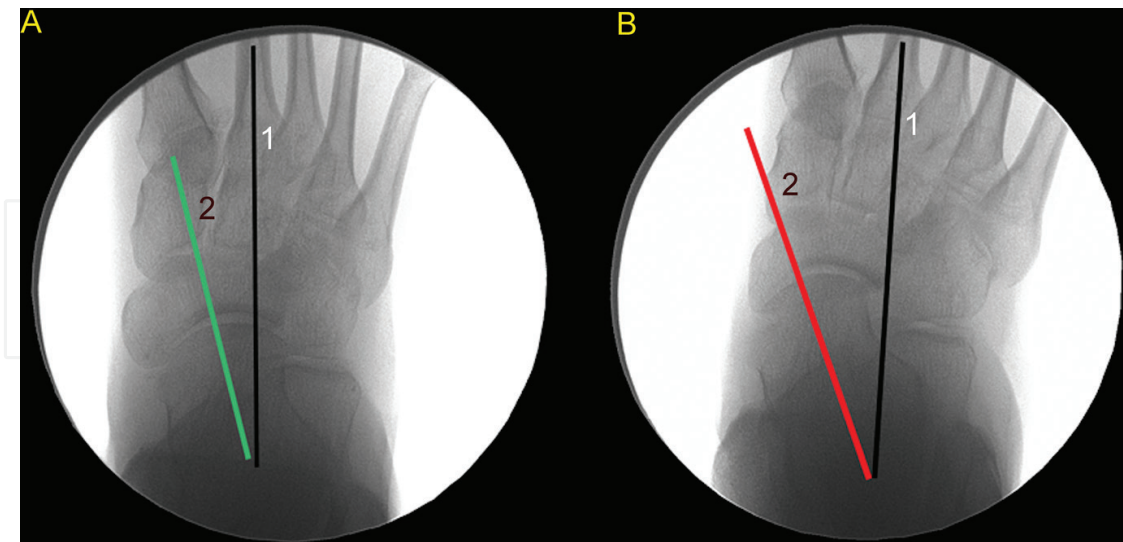


Figure 6. This DP weightbearing fluoroscopic image illustrates the talar second metatarsal angle. (A) The patient can realign the TTJ into neutral position. (A1) This is the bisection of the second metatarsal. (A2) This is the bisection of the talus. This angle is within normal limits, greater than 3 and less than 16. (B) The patient now is standing in relaxed stance position. Notice the increased angle between the (1) talar bisection and (2) the second metatarsal. This angle is greater than 16 and is considered abnormal.

authors have historically advocated the talar first metatarsal angle, but many times, patients can have an increased first intermetatarsal angle that compromises a medial transverse plane talar rotation measurement. This would result in a false-negative finding, when in fact the talus was pathologically rotated medially. The ideal talar second metatarsal angle is 3–6 degrees, but up to 16 has been considered within normal [3] (**Figure 6**).

When a patient has abnormal radiographic findings indicating TTJ dislocation, a second set of radiographs should be taken with the TTJ in neutral position. This will help to diagnose a fixed or flexible deformity and assist with ruling out a tarsal coalition. A “reopening” of the sinus tarsi and normalization of other radiographic findings should be visualized in a flexible deformity. Ruling out a flexible versus rigid TTJ dislocation is important when considering treatment options.

4. Hyperpronation syndromes

Medial, anterior, and/or plantar misalignment of the TTJ leads to a prolonged period of pronation during the gait cycle. This, in turn, leads to excessive strain to joints and soft tissues within the foot, ankle, knee, hip, pelvis, and spine [4–6]. Eventually, the excessive strain leads to an imbalance of the ability of the cartilage and supporting tissues to handle the pathologic forces. If the critical tissue strain threshold is reached, that tissue will exhibit a symptom.

The negative effect of TTJ hyperpronation will eventually lead to symptoms in one or more parts of the body. Every symptom has an underlying etiologic factor. Rarely does the etiologic factor become symptomatic. Take, for instance, an ingrown toenail. The portion of the offending nail border that is embedded into the tissue does not hurt; rather, it is the reaction of the tissue that causes the pain, swelling, and infection. Hyperpronation syndrome is a collection of symptoms that can present because of the RTTJD deformity during weightbearing.

Every individual will experience a slightly unique set of symptoms due to the complexity of the TTJ misalignment and the form of compensation of the body. Common foot pathologies that name TTJ excessive pronation as a leading etiologic factor include calcaneal apophysitis, plantar fasciitis/fasciosis, posterior tibial tendon dysfunction, plantar neuropathy/tarsal tunnel, hallux valgus, hallux limitus/rigidus, flexor stabilization hammertoes, intermetatarsal neuroma formation, abductory twist, and metatarsalgia. Proximal symptoms can include osteochondral lesions of the talar dome, growing pains, shin splints, patellofemoral pain, ACL strain, knee OA, sciatica, hip OA, functional leg length discrepancy, pelvic tilt, and spine malalignment.

People with hyperpronation syndrome find that it is difficult to perform weightbearing activity and many times simply give up this important form of exercise. As a result, there is a lowering of their metabolism that can lead to weight gain, obesity, hypertension, diabetes, and heart disease. The leading recommendation for patients with the so-called metabolic syndrome is to simply walk to increase their metabolic rate.

5. EOTTS device classification and mechanism of action

Once the articular facets of the TTJ are realigned, it will require an internal method to maintain the alignment and stability. There have been many materials to achieve this outcome including the insertion of bone graft, Silastic, or an orthopedic screw into the lateral floor of the sinus portion of the sinus tarsi. The partial insertion of a material into the bone is referred to as intraosseous. The mechanism to maintain TTJ stability is via arthroereisis or joint blocking. This method acts as a doorstep to abruptly block joint motion. Also, intraosseous TTJ stabilization has been studied [7–9]. It is effective in the short term, but the long-term results remain under debate. This is primarily due to the fact that the majority of these devices are removed after 1½–2 years. There is little to no data to support the long-term TTJ alignment following removal of the implant.

Due to the limitation of intraosseous devices, surgeons began using extra-osseous stents. There are two types of EOTTS stents, arthroereisis and non-arthroereisis [10]. The arthroereisis device, “first-generation” EOTTS, acts in a similar method to the intraosseous devices, that is, to block the forward motion of the lateral process of the talus. The stent is “sandwiched” between the anterior end of the lateral process and posterior portion of the calcaneal floor. During TTJ supination, the talus externally rotates increasing the diameter of the sinus tarsi. Then, as the TTJ pronates, the sinus tarsi diameter decreases until the motion is blocked with the EOTTS arthroereisis device.

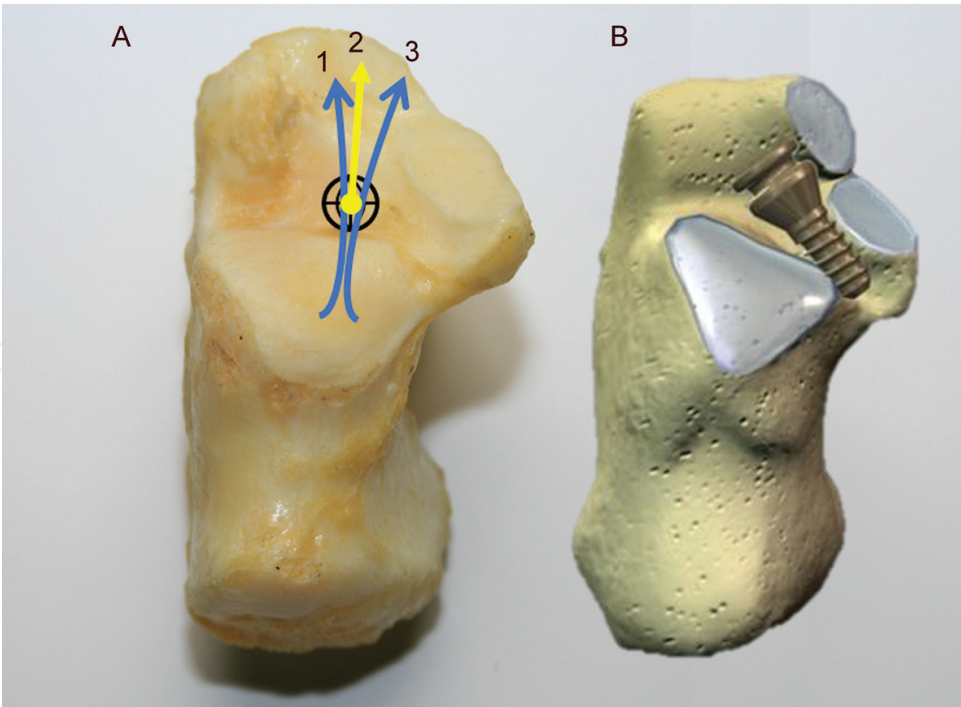


Figure 7. This shows the dorsal surface of the calcaneus. (A1) Indicates the amount of normal TTJ pronation. (A2) Indicates TTJ neutral position. (A3) Shows TTJ supination. (B) Shows the dorsal surface of the calcaneus with the HyProCure sinus tarsi stent (GraMedica, Macomb, Michigan).

The non-joint blocking EOTTS, “second-generation,” devices function with the normal biomechanics of the TTJ. Rather than abruptly blocking talar motion, the second-generation devices reestablish the ideal axis point of the TTJ. The non-arthroereisis EOTTS stents act like the pin within the hinge of a door. There will be minimal contact on the stent without a forced pressure during pronation. Due to the improved biomechanic function of the non-joint blocking EOTTS stent, its success has been measured at a much greater long-term success rate over the arthroereisis devices [11–13] (**Figure 7**).

6. Patient selection for the EOTTS procedure

The need to internally realign and stabilize the TTJ with an EOTTS stent is very important. While RTTJD does not pose an immediate threat to someone’s life, it can severely affect the quality of life and overall health, both physical and mental, even worse are the many associated musculoskeletal deformities that have long been associated with RTTJD. Pain should not be a consideration in the recommendation of EOTTS, when indicated. There are many diseases that are “pain-free” but are still treated. The cumulative effect of walking on feet with RTTJD can reach a point where irreversible damage occurs to other parts of the body. Prevention and early treatment of disease are highly recommended over watch and wait.

EOTTS stents have been used in tens of thousands of pediatric and adult patients for many decades. The ossification of the sinus tarsi occurs by 3 years of age. Therefore, the insertion of the sinus tarsi stent could be considered an option at that point. Most foot surgeons would suggest waiting until the child is a few years older than 3, but it is a case by case determination. There is no upper end age restriction. Upon reaching osseous maturity, the primary deciding factor is the reducibility of the RTTJD deformity. The sinus tarsi space must be restored to its “open” position for the stent to be inserted. Ideally, the reducibility of the RTTJD deformity should be confirmed with radiographic imaging.

There are a few factors that should be ruled out or taken into consideration when recommending the EOTTS procedure. The realignment of the talus on the calcaneus to make sure a tarsal coalition is not present is a very important consideration. This could be an issue when performing EOTTS in younger children because the coalition may not occur until years later. A coalition is not a contraindication, if the coalition can be resected. The posterior heel must be checked for a calcaneal varus deformity. Although rare, a varus deformity of the calcaneus could be exacerbated by performing EOTTS.

The stability and alignment of the first metatarsal must be taken into consideration. Hypermobility or a fixed elevatus could compromise the long-term success of the EOTTS procedure. The altered position of the first metatarsal will lead to a forefoot valgus with heel lift during the gait cycle. This will increase the forces acting on the subtalar joint. The use of an insole or first ray stabilization surgery may be required in addition to the EOTTS procedure.

Metatarsus adductus is another possible coexisting pathology. If the patient is osseously immature, still growing, it is possible the EOTTS procedure could theoretically improve a

mild metatarsal adductus. However, if a significant metatarsus adductus is present in an osseous mature person, EOTTS could exacerbate the appearance. Therefore, metatarsal corrective surgery would be necessary along with the EOTTS procedure.

The inclination of the calcaneus is yet another factor that should be taken into consideration. The increase in anterior-distal forces acting on the calcaneus could cause an abnormal lowering of the normal calcaneal inclination angle (CIA). It is possible that the insertion of an EOTTS device and normalization of forces will also normalize the CIA. On the other hand, it is possible that the lower than normal CIA becomes a fixed deformity and requires surgical intervention. A lower than normal CIA could compromise the overall effectiveness of the EOTTS procedure. A lower than normal CIA is not considered a contraindication of the EOTTS procedure.

Due to the complexity of the foot mechanism, a variety of treatment options could be required from conservative measures to osseous reconstruction. EOTTS can be performed as a stand-alone procedure, when indicated and after coexisting deformities are ruled out, identified, and properly addressed.

7. Evidence basis for the EOTTS procedure

There have been numerous scientific, peer-reviewed articles and textbook chapters published on EOTTS. The medical necessity for EOTTS is well established. There has been much research published on the importance of a balanced and aligned TTJ and the negative impact RTTJD will have to the lower extremity. Scientific studies have approached the use of sinus tarsi implants from many different points. There have been theoretic, cadaveric, radiographic, gait analysis, outcome-based, prospective, and retrospective studies.

The basic evidence that is required to prove the usefulness of EOTTS is simply that it is as effective as or even more effective than other treatment solutions. Foot specialists regularly recommend shoe inserts/arch supports to realign the TTJ. However, their limitations have been long known. A recent article studied their effectiveness against EOTTS. It was found that arch supports are unable to improve TTJ alignment [14]. There have been several manuscripts published on many different EOTTS stents showing radiographic normalization and stabilization of the TTJ [12, 13, 15–95]. The alternative internal surgical options of osteotomy and arthrodesis have been shown to be too aggressive of a treatment. That is, until the RTTJD has reached end-stage when that is the only remaining option.

The overall “staying power” of EOTTS stents must be taken into consideration. Some foot surgeons advocate the short-term use of the sinus tarsi implant, while others would prefer a more permanent solution. Regardless, the insertion of an internal fixation device is used on a regular basis by foot surgeons. Additionally, the removal of orthopedic screws, pins, and plates occurs on a regular basis. The benefit of the EOTTS solution is that the sinus tarsi stent can be removed, if necessary, with little to no ill-effect to the local anatomy.

8. Conclusion/summary

EOTTS serves as a very important treatment option, when indicated. RTTJD should be addressed and internally corrected, the sooner, the better. It is a time-tested, medical necessity and is backed by extensive evidence. This treatment option has historically been considered a niche procedure. Surgeon advocates have found that EOTTS offers their pediatric and adult patients an internal option that makes sense and is more effective than other forms of “similar” treatment. The far-reaching positive effects of EOTTS will be discovered on the knee, hip, pelvis, and spine. Furthermore, because patients can become more active following the correction of RTTJD, they will increase their metabolic rate. This will have a positive effect to their physical and mental health in general. EOTTS is a cost-effective solution with a shorter return to function over more aggressive surgical procedures. It is for these reasons that the advocacy of EOTTS continues to increase year over year, globally.

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