Skeletal Radiol (2003) 32:13–21
DOI 10.1007/s00256-002-0585-x

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Plantar calcaneal enthesophytes: new observations regarding sites of origin based on radiographic, MR imaging, anatomic, and paleopathologic analysis

Received: 18 June 2002
Accepted: 21 August 2002
Published online: 22 November 2002

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Abstract *Objective:* To determine the relationship between sites of calcaneal plantar enthesophytes and surrounding fascial and soft tissue structures using routine radiography, MR imaging, and data derived from cadaveric and paleopathologic specimens. *Design and patients:* Two observers analyzed the MR imaging studies of 40 ankles in 38 patients (35 males, 3 females; mean age 48.3 years) with plantar calcaneal enthesophytes that were selected from all the ankle MR examinations performed during the past year. Data derived from these MR examinations were the following: the size of the enthesophyte; its location in relation to the plantar fascia (PF) and flexor muscles; and the thickness and signal of the PF. The corresponding radiographs of the ankles were evaluated at a different time by the same observers for the presence or absence of plantar enthesophytes and, when present, their measurements. A third observer reviewed all the discordant observations of MR imaging and radiographic examinations. Two observers analyzed 22 calcaneal specimens with plantar enthesophytes at an anthropology museum to determine the orientation of each plantar enthesophyte. MR imaging of a cadaveric foot with a plantar enthesophyte with subsequent sagittal sectioning was performed to provide further anatomic understanding. *Results:* With regard to MR imaging, the mean size of the plantar enthesophytes was 4.41 mm (SD 2.4). Twenty (50%) enthesophytes were located above the PF, 16 (40%) between the fascia and abductor digiti minimi, flexor digitorum brevis and abductor hallucis muscles, and only one (3%) was located within the PF. In three (8%) cases the location was not determined. The size of enthesophytes seen with MR imaging and radiographs was highly correlated ($P<0.01$). The interobserver agreement for all measurements was good (Pearson >0.8, kappa >0.9). Eleven of the 22 bone specimens had plantar enthesophytes oriented in the direction of the abductor digiti minimi and 11 oriented in the direction of the flexor digitorum brevis and PF. The cadaveric sections revealed different types of enthesophytes. *Conclusions:* Plantar calcaneal enthesophytes arise in five different locations: at the insertion sites of abductor digiti minimi and flexor digitorum brevis muscles; between the PF and these muscles; and, less frequently, within the PF and at the insertion site of the short plantar ligament.

Keywords Plantar calcaneal enthesophyte · Plantar fascia · MR · Radiographs · Cadavers · Paleopathology

Introduction

The plantar calcaneal enthesophyte has classically been described as a bone outgrowth localized just anterior to the medial tuberosity of the calcaneus. This is a common finding and has been reported in 11–27% of asymptomatic persons, as well as 73% of patients presenting with heel pain [1, 2, 3]. The association of subcalcaneal pain and the presence of a plantar calcaneal enthesophyte is so common that it has been designated "heel spur syndrome" and linked to several causes [4].

The reported causative factors of plantar calcaneal enthesophytes have been quite variable. This outgrowth was initially thought to be related to infectious processes such as gonorrhea and tuberculosis [5, 6]. Other considerations have included altered mechanical forces in the hindfoot resulting in a tug lesion [7], rheumatologic disorders such as seronegative spondyloarthropathies [8, 9] and diffuse idiopathic skeletal hyperostosis (DISH) [10], and a phenomenon of natural aging [1, 11, 12]. Although the plantar fascia (PF) has generally been considered the major structure in which the enthesophyte has developed [11], alternative hypotheses have been introduced regarding the site of origin of the enthesophyte, including the calcaneal insertion sites of the intrinsic muscles of the foot alone [12] and in conjunction with the PF [1, 3].

There are many alternatives for the treatment of plantar calcaneal enthesophytes associated with clinical symptoms. Surgical resection of the enthesophyte with or without release of the PF [13], osteotripsy [14], endoscopic removal [15], extracorporeal shock wave treatment [16] and laser therapy [17] are among the potential methods for treatment. A detailed understanding of the anatomy of the structures in the plantar aspect of the hindfoot is of importance for the accurate localization of the enthesophyte formation, which may influence the choice of therapy.

Owing to advances in MR imaging, the identification of plantar enthesophytes and their relationship with the surrounding soft tissue structures can be very well studied. The purpose of our study was to determine the site of origin of plantar calcaneal enthesophytes using routine radiography or MR imaging, or both, in a series of clinical patients, cadaveric specimens, and paleopathologic material.

Materials and methods

Anatomic considerations

The calcaneus is the largest tarsal bone and serves as the junction between the foot and the lower extremity, providing osseous insertion to the muscles of the calf. This irregular cuboid-shaped bone can be divided into six surfaces: dorsal (or superior), anterior, posterior, lateral, medial, and plantar surfaces. The plantar surface of the calcaneus is irregular, particularly its posterior extent, the so-called calcaneal tuberosity. The lateral and medial processes of the tuberosity extend distally for a short distance, separated by a notch. The medial process is the broader of the two [18].

There are many soft tissue structures beneath the plantar surface of the calcaneus, some of which serve to support the plantar arch. The most superficial of these structures is the skin, which is repeatedly subjected to forcible shearing and impact stress in locomotion, particularly in the area of the posterior calcaneal tubercles. A pad of adipose tissue is interposed between the skin and the PF which is crossed by a network of fine but collectively strong connective tissue strands [18].

Deep to the skin, a strong fibrous investing layer extends along the sole of the foot, the PF. It plays both a static and a dynamic role in supporting the longitudinal arch of the foot. Arising from the plantar aspect of the posteromedial calcaneal tuberosity in the hindfoot, the PF progressively subdivides into central, medial, and lateral components as it gradually widens and courses distally [18, 19]. The central, or major, component of the PF is the largest, thickest, and strongest. It is comprised of collagen fibers oriented primarily along the long axis of the foot with a small transverse component.

Deeper to the PF, the muscles of the plantar aspect of the foot are customarily divided into four layers. The first layer includes the abductor hallucis (AH) and digiti minimi (ADM) muscles and the flexor digitorum brevis (FDB) muscle. These three muscles arise from the medial and lateral calcaneal tuberosities and extend to the toes. The AH has a medial location in the foot, arising primarily from the flexor retinaculum. It also takes part of its origin from the medial process of the calcaneal tuberosity, the PF, and the intermuscular septum between it and the FDB muscle. Its course parallels the long axis of the calcaneus, and the muscle inserts in the medial side of the base of the proximal phalanx of the great toe. The FDB muscle arises from the medial process of the calcaneal tuberosity and the central part of the plantar aponeurosis. It is immediately above the central part of the plantar fascia and also demonstrates a course parallel to the long axis of the calcaneus. This muscle divides into four tendons distally, which insert into the middle phalanges of the four digits. The ADM muscle is found in the lateral border of the foot. It arises from the medial and lateral processes of the calcaneal tuberosity, the plantar surface of the bone between them, the plantar aponeurosis, and the intermuscular septum between it and the FDB muscle. The ADM muscle has a course approximately 18° lateral to the long axis of the calcaneus. Distally its tendon along with that of the FDB muscle inserts in the lateral side of the proximal phalanx of the fifth toe, acting more as a flexor than an abductor (Fig. 1).

The second layer of muscles in the plantar aspect of the foot is composed of the flexor digitorum accessorius and the lumbricals. The flexor digitorum accessorius muscle arises from two heads: the medial head is attached to the medial concave surface of the calcaneus and the lateral head arises in the calcaneus in front of the lateral process of the tuberosity and from the long plantar ligament. This muscle inserts in the tendon of the flexor digitorum longus muscle. The muscles in the third and fourth layers as well as the lumbricals (second layer) arise distal to the calcaneus.

Deep to the muscular planes of the plantar aspect of the foot, two important ligaments are found that comprise a part of the calcaneocuboid articulation: the long and the short plantar ligaments. The long plantar ligament is attached posterior to the plantar surface of the calcaneus in front of the medial and lateral processes of the tuberosity, to the anterior tubercle, and anterior to the ridge and tuberosity of the plantar aspect of the cuboid bone. Some fibers continue to insert into the metatarsal bones. The short plantar ligament is a short but wide ligamentous band of great strength; it attaches to the anterior tubercle of the calcaneus and inserts in the plantar aspect of the cuboid [18] (Fig. 2).

A subcalcaneal bursa can be found between the most prominent point of the tuberosity and the plantar fat pad. The frequency of this bursa in the general population is not well defined [3, 19].

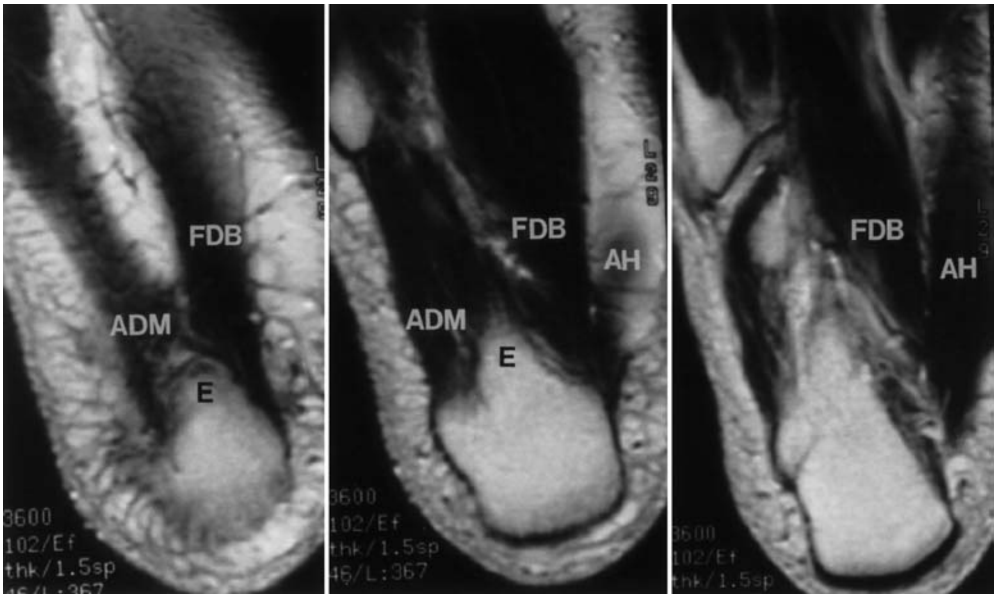


Fig. 1 Inferior view of the muscles of the first layer of the foot. Axial T2-weighted SE MR images (3600/102) demonstrate abductor hallucis (*AH*), flexor digitorum brevis (*FDB*), and abductor digiti minimi (*ADM*) muscles inserting i nto the calcaneus. Note the calcaneal enthesophyte (*E*)

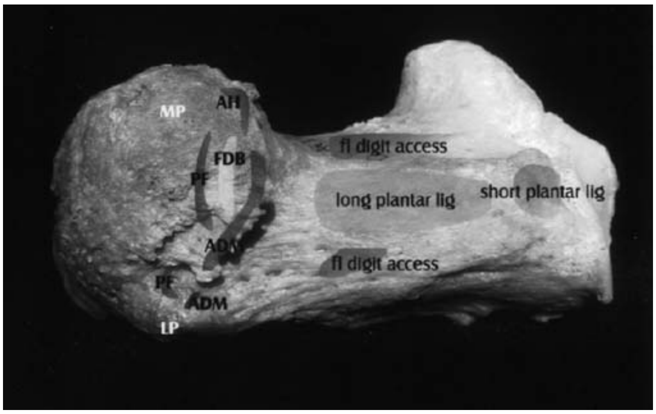


Fig. 2 Schematic drawing superimposed on a paleopathologic specimen showing the insertion sites of the muscles, ligaments, and fascia in the calcaneal bone. *HA* abductor hallucis muscle, *FDB* flexor digitorum brevis, *ADM* abductor digiti minimi, *PF* plantar fascia, *MP* medial process and *LP* lateral process of the calcaneal tuberosity, *fl dig access* flexor digitorum accessories

Clinical study

Images were acquired with a 1.5 T MR imager (Signa; GE Medical Systems, Milwaukee, Wis.). In all cases, imaging was performed in three standard planes with the following sequences: coronal and sagittal, spin echo (SE) T1-weighted (360–850/12–25), fat-suppressed T2-weighted fast SE (3267–4394/67–75, echo train length of 4–6), fat-suppressed fast SE intermediate-weighted (2000–2200/20–30), and short inversion time inversion recovery (STIR) (3000/34–60/150 [inversion time, ms]). In three cases, T1-weighted SE MR images with and without fat suppression were acquired before and after intravenous administration of a gadolinium-containing contrast material (Magnevist; Schering, Berlin, Germany).

All MR imaging studies of the ankle (n=90) performed over a 1 year period at a single institution were reviewed for the presence of plantar calcaneal enthesophytes. The imaging criterion to establish enthesophyte formation was the presence of an osseous excrescence greater than 1 mm projecting from the plantar calcaneal tuberosity in sagittal T1-weighted images [20]. Two musculoskeletal radiologists analyzed the images in consensus. Imaging studies in 40 feet in 38 patients (35 males, 3 females; mean age 48.3 years) demonstrated the presence of plantar calcaneal enthesophytes.

Two independent observers retrospectively analyzed the MR imaging studies showing plantar enthesophytes and were asked to analyze several parameters. Readers determined the anteroposterior size of the osseous excrescence in sagittal T1-weighted images. The location of the enthesophyte was noted as: (1) within the PF, (2) between the PF and muscles, or (3) intramuscular. If the excrescence was within muscles, the exact location (HA, FDB and ADM muscles) was noted. Sequential sagittal images were examined to determine whether enthesophytes were located in the medial, central, or lateral third of the calcaneus. The integrity, signal intensity, and superior to inferior measurement of the PF at a point 1 cm from its calcaneal insertion were recorded. Any bone marrow changes in the calcaneus were noted. Measurement of the angle between the FDB and ADM muscles in the axial plane was also performed to establish a constant relationship in the orientation of these two muscles that could subsequently be used to analyze cadaveric and paleopathologic specimens.

Radiographs of those cases in which MR imaging showed plantar enthesophytes were evaluated at a different time for the presence or absence of plantar enthesophytes by two independent observers.

Interobserver correlation was determined by the Pearson and kappa test. A third observer reviewed all the discordant observations of MR images and radiographs.

Cadaveric study

Eleven cadaveric feet, harvested from unembalmed cadavers, were examined with radiography to ensure the presence of a calcaneal plantar enthesophyte and to rule out bone or soft tissue pathologic conditions. Five fresh human feet derived from two men and two women (age range 70–88 years at the time of death, mean age 78 years) were subsequently selected for the MR imaging and anatomic study. The cadaveric specimens were immediately deep-frozen at –60 ºC (Bio-Freezer; Forma Scientific, Marietta, Ohio). None of the specimens had evidence of surgical intervention or previous injuries in or about the foot. The cadaveric specimens were allowed to thaw for 18 h at room temperature prior to MR imaging. Subsequently, the cadaveric specimens were prepared according to methods described in the literature [21].

MR images were acquired with a 1.5 T superconducting MR imager (Signa; GE Medical Systems, Milwaukee, Wis.) with a 5 inch standard flexible surface coil (Flex Coil; Medical Advances, Milwaukee, Wis.). All cadaveric feet were placed in a neutral position and immobilized with foam pads. Imaging was performed in coronal, transverse, and sagittal planes. The MR imaging protocol consisted of T1-weighted SE sequences (repetition time ms/echo time ms: 600/20–23). To acquire a higher signal-to-noise ratio, a section thickness of 2.5 cm by 0.5 cm was used. The field of view was 10×10 cm in the sagittal, coronal, and axial planes. The data acquisition matrix was 512×256. MR images were evaluated by the consensus of two musculoskeletal radiologists with emphasis on the location of the calcaneal plantar enthesophytes with respect to adjacent structures.

After MR imaging had been performed, the cadaveric specimens were frozen again at –60 ºC for more than 96 h and were subsequently sectioned with a band saw into slices 3 mm thick, so that anatomic slices corresponded closely to each of the four MR imaging planes. Each slice was photographed and imaged (Faxitron; Hewlett Packard, McMinnville, Ore.). To determine the anatomic relationships of the calcaneal plantar enthesophyte with the PF and adjacent muscles, the findings at MR imaging were correlated with those derived from inspection of cadaveric slices.

From these five cadaveric feet, three were selected for histologic analysis. In each case a l cm^2 en bloc resection of the region of the plantar enthesophyte and adjacent structures was obtained and sent for evaluation by histologic analysis using hematoxylin and eosin preparation. An experienced bone pathologist analyzed the tissues with attention to the location and appearance of the plantar enthesophyte, subchondral bone, cartilaginous areas, PF, and superficial muscles of the foot. The presence of inflammatory or fibrotic tissue was noted.

Paleopathologic review

Two observers in consensus analyzed 22 calcaneal specimens with plantar enthesophytes at the San Diego Museum of Man in an attempt to determine the site of origin and orientation of the plantar excrescence. The specimens had been collected between 1930 and 1940 and were believed to have been derived from persons who were 70–90 years of age. The orientation of the plantar enthesophyte with respect to the long axis of the calcaneus was recorded. Osseous excrescences paralleling the long axis of the calcaneus were recorded as arising from the FDB muscle or PF. Those with 15° or more of lateral angulation were recorded as arising from the ADM muscle.

Results

Clinical study

With regard to MR imaging, the mean size of the plantar enthesophyte was 4.41 mm (SD 2.4, 1–11 mm) with good interobserver correlation (Pearson 0.84). Twenty (50%) enthesophytes were located in the muscles (FDB, ADM), 16 (40%) between the PF and the muscles, and only one (3%) within the fascia (Fig. 3). The agreement between the two observers was 85% (kappa 0.74). A third observer decided the final location in discordant cases. In three cases (8%), the exact location of the plantar enthesophyte with respect to the PF could not be determined due to tissue of abnormal signal intensity in the hindfoot. Seventeen (43%) plantar enthesophytes were located in the medial border of the calcaneus, 17 (43%) were located in the middle of the calcaneus, and six (15%) were located in the lateral border of the calcaneus. In two cases the presence of two enthesophytes in the calcaneus was seen (for statistical purposes, only the larger were analyzed). In one of these cases, the second enthesophyte was located between the fascia and the muscles and in the other in the muscles.

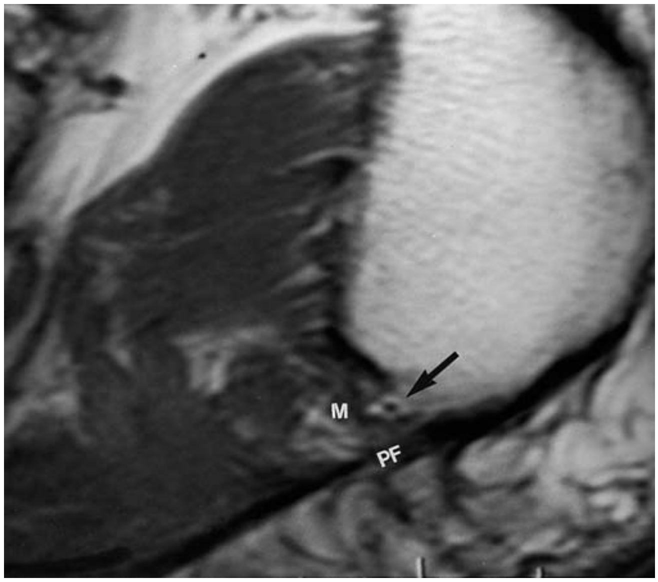


Fig. 3 Sagittal T1-weighted SE MR image (500/14) in a patient with foot pain reveals a plantar enthesophyte (*arrow*) arising at the site of origin of the muscles (*M*) of the first layer of the foot. *PF* plantar fascia

The PF measured 4.95 mm (SD 2.35, 2–12 mm) 1 cm from its insertion in the calcaneus (Pearson 0.87). The thickness of the PF correlated with advancing age ($P<0.001$). In six (15%) cases there was a high signal within the PF in T2-weighted images. In three of these cases, the high signal was present at the insertion of the fascia into the bone, and thickening of the PF and adjacent calcaneal edema were also seen.

Of the 40 ankles that had undergone MR examinations, 25 (63%) had radiographs, all demonstrating plantar calcaneal enthesophytes. The size of plantar enthesophytes seen on radiographs was highly correlated with that noted on MR imaging ($P<0.01$). Calcification not detected by MR imaging was present radiographically adjacent to the plantar enthesophyte in two cases.

In 23 patients both the ADM and FDB could be identified on a single axial image, allowing evaluation of an intervening angle whose average measurement was 18.7°.

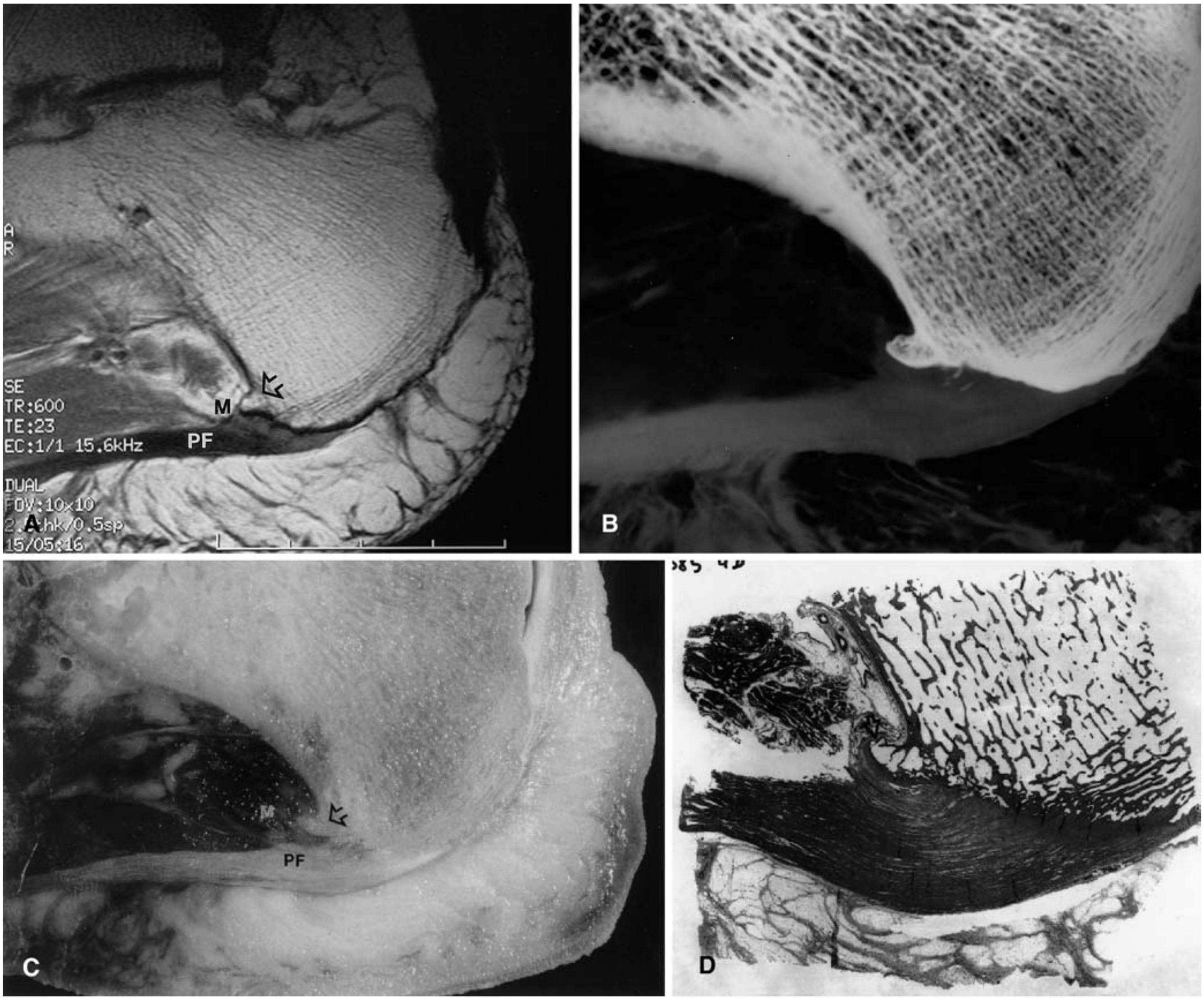


Fig. 4A–D Correlation of MR imaging with gross anatomic findings in a cadaveric specimen with a plantar enthesophyte arising just above the plantar fascia. **A** Sagittal T1-weighted MR image (600/20, 512×256 matrix, 10 cm FOV), **B** corresponding faxitron, **C** anatomic slice, and **D** histologic specimen (sagittal slice, H&E). *Arrow* enthesophyte, *PF* plantar fascia, *M* muscle

Cadaveric study

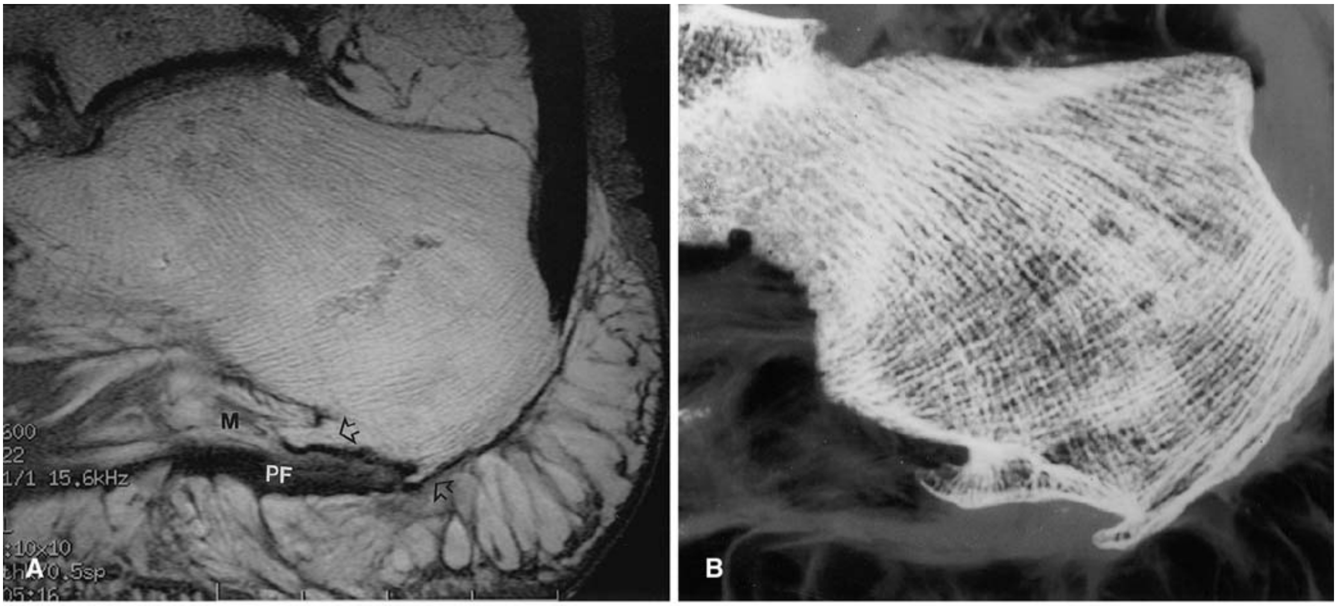
Seven plantar enthesophytes were present in the five cadaveric feet studied with high-resolution MR imaging, anatomic sectioning, and faxitron radiography. The results are shown in Table 1.

The coronal and axial MR imaging planes were of little value in the determination of the site of origin of the plantar enthesophyte. In one case, the enthesophyte followed the course of the FDB and in the other, that of the ADM.

The axial plane was of great value in the study of the muscular anatomy. In all cases the ADM muscle had its insertion more superficially than the FDB muscle and had a broader insertion site, extending from the middle of the medial process to the lateral process of the calcaneal tuberosity. The AH muscle had a very small insertion site in the bone, and its location was much more medial than the location of the enthesophytes. The muscles of all cadavers revealed mild to severe atrophy.

Histologic study

Four plantar enthesophytes contained in three specimens were studied histologically. Three enthesophytes were located between the muscles (ADM and FDB) and the PF. Two of the four enthesophytes involved the superior surface of the PF and the inferior surface of the ADM muscle (Fig. 4). One enthesophyte involved the superior surface of the PF and was surrounded by fat superiorly. One enthesophyte was located centrally within the PF



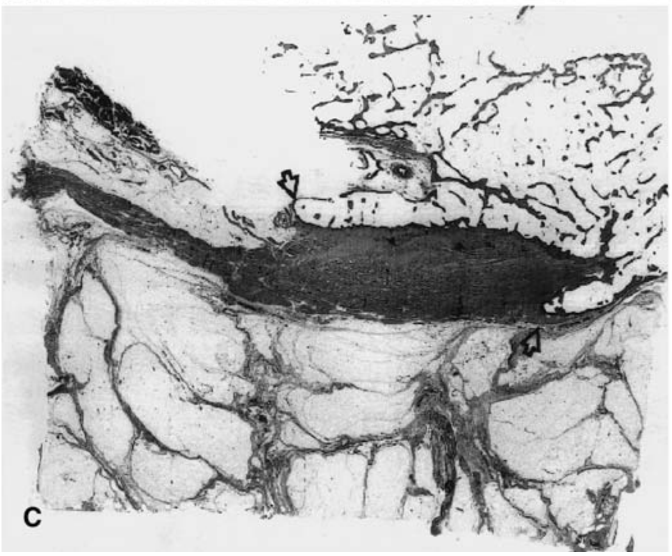


Fig. 5A–C Correlation of MR imaging with gross anatomic findings in a cadaveric specimen with two plantar calcaneal enthesophytes, one in the plantar fascia and the other above it. **A** Sagittal T1-weighted MR image (600/20, 512×256 matrix, 10 cm FOV), **B** corresponding faxitron, and **C** histologic specimen (sagittal slice, H&E). *Arrow* enthesophyte, *PF* plantar fascia, *M* muscle

(Fig. 5). In all cases the PF contained areas of degeneration. Inflammatory tissue was not found around the enthesophytes. In two specimens a thick zone of cartilaginous proliferation was found in the PF insertion into the calcaneus in the inferior portion of the enthesophyte. In the other specimen, the attachment of the PF to the calcaneus did not demonstrate chondral tissue.

Paleopathologic study

Eleven of the 22 museum specimens had plantar enthesophytes oriented in the direction of the longitudinal axis of the calcaneus (parallel to the FDB muscle and thickest portion of planar fascia) and 11 were angulated laterally greater than 15°, the direction of the ADM muscle (Fig. 6). No plantar enthesophyte revealed a medial angulation, the angulation of the AH muscle, or was located at the AH muscle insertion site. One enthesophyte was found in the insertion site of the short plantar ligament (Figs. 7, 8).

Discussion

Inferior calcaneal enthesophytes, frequently found in lateral radiographs, can also be identified with MR imaging, a method that also elucidates the relation of the plantar enthesophyte and the surrounding structures. Such enthesophytes usually arise in the superficial layer of muscles of the hindfoot (ADM, FDB and AH muscles), in a region between the PF and these muscles and,

Table 1 MR imaging, anatomic section, and faxitron of cadaveric specimens (*ADM* abductor digiti minimi, *FDB* flexor digitorum brevis, *PF* plantar fascia)

Cadaveric specimens/ side	Location on MR imaging	Location on anatomic section	Size on MR imaging	Size on anatomic section	Calcification adjacent to the enthesophyte on MRI	Calcification adjacent to the enthesophyte on faxitron
1/left	Between PF and muscles	Between PF and muscles	4 mm	5 mm	None	Three calcified dots inside the PF
2/left	In the muscles (ADM or FDB)	In the muscles (ADM or FDB)	4 mm	3 mm	None	None
3/right	Between PF and muscles	Between PF and muscles	6 mm	7 mm	In the PF	Ossification in the PF
4/right	Between PF and muscles	Between PF and muscles	10 mm	11 mm	None	Calcification in the PF
	Within the PF and fat pad	Within the PF and fat pad	6 mm	5 mm		
	Short plantar ligament	Short plantar ligament	3 mm	3 mm		
5/right	Between PF and muscles	Between PF and muscles	3 mm	3 mm	None	None

Fig. 6 Paleopathologic specimen with a plantar enthesophyte (*E*) oriented in the direction (*arrow*) of the fibers of the abductor digiti minimi

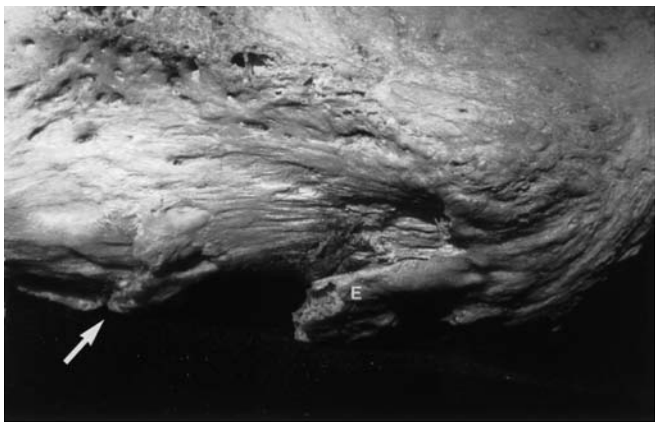


Fig. 7 Paleopathologic specimen with two plantar enthesophytes, one located at site of attachment of the short plantar ligament (*arrow*). *E* enthesophyte at the calcaneal tuberosity

less frequently in the PF itself. In three clinical cases in our study, the plantar enthesophyte was engulfed by abnormal inflammatory tissue compatible with the diagnosis of plantar fasciitis. In these cases the anatomic layer between the soft tissue structures was lost, and the site of origin of the enthesophyte could not be determined. In one case the enthesophyte was located above the muscles of the first layer, in the substance of the short plantar ligament.

Our study suggests that plantar enthesophytes develop as a result of tensile forces placed in a variety of structures that attach to the calcaneus. As normal fibers in various muscles in the first layer of the foot interdigitate with each other and with the PF, tensile forces probably result from traction placed on many different structures at the same time. This repetitive pull results in a histologic response characterized by connective tissue hyperplasia and the formation of fibrocartilage and bone [7]. Such findings were observed histologically in two of our specimens. The pathologic changes secondary to the chronic plantar soft tissue tension also include low-grade periostitis with edema, fibroblastic proliferation, and inflammatory cell infiltration [3], alterations that were probably seen in MR images in three cases characterized by abnormal signal and distorted anatomy in the insertion site of the plantar structures.

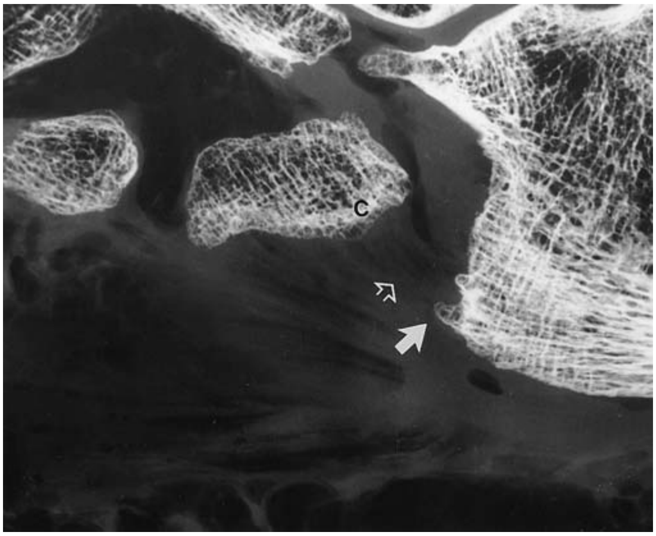


Fig. 8 Faxitron of one cadaveric specimen showing a plantar enthesophyte (*arrow*) arising at the short plantar ligament (*open arrow*) insertion site. *C* cuboid bone

There is still controversy as to whether plantar heel pain can be attributed to the presence of a calcaneal enthesophyte. Although such outgrowths are frequent in persons with heel pain, the plantar enthesophyte is now believed to be unrelated to such pain [22, 23]. Other authors have attributed inferior calcaneal pain to irritation of either the medial or the lateral plantar nerve or a branch of the medial calcaneal nerve [24], or entrapment neuropathy of a muscular branch of the lateral plantar nerve to the ADM muscle [25]. Loss of specialized architecture of the plantar calcaneal fat pad resulting from acute or chronic trauma has also been considered to be a cause of inferior calcaneal pain. In our cases, alterations in the nerves or the fat pad were not observed.

Despite the uncertainty regarding the clinical significance of the plantar calcaneal enthesophytes, many different forms of surgical treatment have been advocated, ranging from simple excision to more recently developed techniques such as endoscopic excision [15], as well as nonoperative treatment strategies including extracorporeal shock wave treatment [16] and laser therapy [17]. The chosen therapeutic technique is often combined with release of the PF.

The high signal in T2-weighted images in the PF adjacent to an enthesophyte found in six patients may indicate tissue inflammation or repair that may or not play a role in the development of an enthesophyte. The presence of the high signal in fluid-sensitive sequences in the PF may be indicative of a partial fascial tear or plantar fasciitis [26]. In many patients increased signal intensity was evident within the PF only in T1-weighted images, and this change was particularly frequent at the fascial insertion into the calcaneus. In the cadaveric specimens, this same abnormality, present in all specimens, occurred exactly at the point of angulation of the insertional fibers of the PF. As the histologic analysis of the fibers was normal in three specimens, a magic angle artifact is likely the cause of this change in signal intensity.

The cadaveric portion of this study documented the multiple sites of origin of plantar enthesophytes. Additional analysis of the paleopathologic specimens further confirmed two different types of calcaneal enthesophytes: one that extends along the longitudinal axis of the calcaneus; and another that extends in an oblique lateral direction. Based on previous analysis of the muscle anatomy as demonstrated with MR imaging (particularly in the axial plane), with the documented angulation between the FDB and ADM muscles, we conclude that the lateral-inclined enthesophytes were related to the fibers of the latter muscle and perhaps form as a response to tensile forces related to its action. Alternatively, our results suggest that the AH muscle does not have an important role in the formation of the enthesophyte.

We recognize that our study has some limitations. The clinical study is somewhat limited due to the small patient population and incomplete clinical information. In addition, no verification of imaging findings exists in this population. With regard to the cadaveric study, the atrophy of the muscles of the foot present in many specimens made the analysis of the location of the enthesophyte difficult. Also, histologic analysis was not performed in all cadaveric specimens.

In conclusion, our analysis based on imaging, anatomic, and paleopathologic investigation confirms five different locations at which enthesophytes arise: at the insertion sites of abductor digiti minimi and flexor digitorum brevis muscles; between the PF and these muscles; and, less frequently, within the PF and in the insertion site of the short plantar ligament.

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