ASEPTIC NECROSIS FOLLOWING DISTAL OSTEOTOMIES OF THE FIRST METATARSAL

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INTRODUCTION

Review of the literature reveals a significant variance in the incidence of aseptic necrosis following distal osteotomies of the first metatarsal. Various types of distal osteotomies have been commonly performed for surgical correction of hallux abducto valgus. Previous investigators report an incidence of aseptic necrosis following distal osteotomies of the first metatarsal ranging from 4% to as great as 40%. The author's preliminary review of the literature clearly suggests a significantly higher incidence than is experienced by the surgeons at the Podiatry Institute. A principle objective of this paper is to document our experiences and identify factors which contribute to a much lower incidence of aseptic necrosis at our institution.

PURPOSE

The purpose of this presentation is to discuss the factors that contribute to the development of aseptic necrosis following distal osteotomies and to identify those factors necessary to prevent aseptic necrosis. Emphasis is placed on distal osteotomies involving the first metatarsal head. This presentation is supported by a preliminary 10 year retrospective study performed at the Podiatry Institute reviewing distal osteotomies involving the first metatarsal head. The study tests the validity of the assumption that necrosis following distal osteotomies does not occur if the following conditions are met during surgery: 1) Preservation of blood supply to maintain viability of the capital fragment. 2) Preservation of adherent soft tissues on the lateral aspect of the first metatarsal head. 3) Maintenance of good bony apposition.

Other factors, including anatomic dissection and the use of internal fixation to encourage primary bone healing, will be emphasized as important factors in preventing aseptic necrosis.

The study is divided into two phases and will present the preliminary results. Phase one is a physician's survey to determine the incidence of aseptic necrosis following distal osteotomies performed at HCA-Doctors Hospital over the past ten years. Each physicians' responses and comments were confidential and were used in combination with other responses for statistical purposes only. The results of the survey are included in this paper.

Phase two is a 10 year retrospective study consisting of a random sampling of 120 patients out of over 2,500 patients who underwent distal osteotomies of the first metatarsal. The preliminary results are presented along with case presentations.

DEFINITION

Aseptic necrosis, also known as avascular necrosis, osteonecrosis, and ischemic necrosis, is a condition representing a series of pathologic changes starting with an initial loss of blood supply to bone with resultant bone death followed by gradual replacement of dead bone by living bone.

INCIDENCE

The incidence of aseptic necrosis following distal osteotomies of the first metatarsal varies greatly as reported in the literature. Some investigators report a low incidence while others report an incidence as high as 20% to 40%.

Meisenhelder, Harkless, and Patterson, (1984) in a review of 54 procedures between 1975-1980 reported two cases of aseptic necrosis following distal osteotomies of the first metatarsal with an incidence of 4%. This 4% rate of occurrence is based on the 34% or 30 patients from a total of 87 patients who responded to the study. The average follow-up was 41 months with the longest being 78 months and the shortest 16 months. In all cases radiographs were obtained to determine the presence of aseptic necrosis following distal osteotomies of the first metatarsal.

Meier and Kenzora (1985) reported an incidence of 20% when aseptic necrosis occurred in 12 of 60 patients following Chevron osteotomy of the distal aspect of the first metatarsal. This incidence as reported rose to 40% when an adductor tenotomy was performed in combination with the Chevron osteotomy.

In this study of the 10 patients that underwent Chevron osteotomy with an adductor tenotomy, 4 of the 10 patients developed aseptic necrosis with an incidence of 40%. One of 12 patients who had a Mitchell osteotomy or 8% also developed aseptic necrosis. Overall the results demonstrate aseptic necrosis in 13 of the 72 cases (18%).

ETIOLOGY

The etiology of aseptic necrosis is not clearly understood as documented by the number of idiopathic clinical disorders involving epiphyses in growing children (Osteochondroses). A detailed discussion of osteochondroses is beyond the scope of this paper. However, the common denominator of aseptic necrosis and its sequelae is basic to this discussion. The etiology of aseptic necrosis remains poorly understood as is its pathophysiology. Most authors agree that aseptic necrosis is primarily postsurgical or traumatic and follows initial loss of blood supply to bone. Also, idiopathic aseptic necrosis of epiphyses is identified as osteochondrosis. The following is a partial list of common osteochondroses with their associated anatomical location.

Legg - Perthe's Disease —— Femoral Head

Osgood - Schlatter's Disease —— Tibial Tubercle

Sever's Disease —— Calcaneal Apophysis

Kohler's Disease —— Tarsal Navicular

Freiberg's Disease —— Metatarsal Head

Other known causes of aseptic necrosis of sub chondral bone include the following:

Physical: Physical causes include thermal, both heat (burns) and cold (frostbite). For example burning bone with power instrumentation compromises blood supply during the normal stages of bone healing following osteotomy (Fig. 1).

Radiation: Radiation with subsequent necrosis of bone may cause aseptic necrosis. This has been demonstrated following radiation of the pelvis for malignancy.

Metabolic: Metabolic causes include Gaucher's disease involving an uncommon inborn error of metabolism in which a lipid (Kerasins) proliferates cells in the bone marrow causing localized osteoclastic lesions of bone complicated by aseptic necrosis.

Hematologic: Hematologic causes include aplastic anemia, polycythemia, and sickle cell disease.

Embolic: Another uncommon cause of aseptic necrosis is nitrogen emboli or decompression illness seen in deep sea divers.

PATHOPHYSIOLOGY AND RADIOGRAPHIC FINDINGS

The pathology and pathogenesis of aseptic necrosis are well correlated with radiographic changes. Salter (1970)

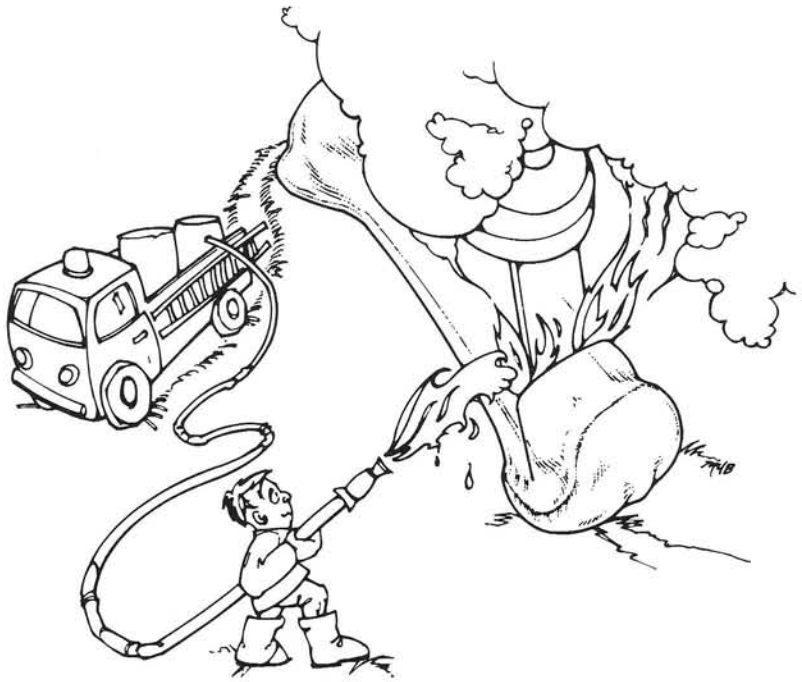

Fig. 1. Avoid burning of bone with power instrumentation.

describes phases of aseptic necrosis based on radiographic changes of the osteochondroses which are applicable to those changes seen in aseptic necrosis of the first metatarsal head following distal osteotomy. The pathological process can be divided into these four phases even though the transition from one phase to another is often gradual and subtle.

The phases are as follows:

1. Early Phase (Avascularity)

The early phase, the phase of avascularity, begins when the blood supply to the fragment is compromised or severely violated. After obliteration of the blood vessels, the osteocytes and bone marrow cells die. However, the osseous structures may remain unchanged radiographically for months. The articular cartilage which is nourished by synovial fluid remains viable. Although radiographs are usually normal in the early phase of avascularity, nuclear bone scans frequently reveal little or no uptake within the necrotic metatarsal head indicating necrosis. Frequently only a portion of the metatarsal head is involved and not the entire head.

During the later stages of the early phase of avascularity, radiographs may reveal increased radiodensity within the metatarsal head as disuse atrophy (osteoporosis) of the proximal metatarsal and forefoot give the false appearance of increased density within the metatarsal head (Fig. 2). During the early phase of avascularity the radiographic density of bone remains unchanged since neither bone resorption nor bone formation can occur without vascular supply. The early phase of avascularity is also designated by many authors as the pre-collapsed stage of aseptic necrosis.

2. Phase of Revascularization with Bone Deposition and Resorption

The phase of revascularization is characterized by deposition of new bone and resorption which represents the vascular reaction of the surrounding tissues to necrotic bone. These changes are readily detectable radiographically. Radiographs reveal increased radiodensity of the metatarsal head as new bone is laid down on dead trabeculae. Nuclear bone scans during this stage reveal an increased uptake. This new bone is easily modeled into either a normal or abnormal shape depending on the biomechanical forces applied during this stage. During the revascularization phase a pathologic fracture may occur at the point of maximal stress. This may result in pain, synovial effusion, and limitation of motion. Continued micro trauma and motion promotes fibrous and granulation tissue resulting in osteoclastic resorption. This may involve only a portion of the metatarsal head or in severe cases the entire head may

Fig. 2. Early phase or phase of avascularity (pre-collapsed phase).

be resorbed. The late stage of the phase of revascularization is also referred to by many authors as the collapsed phase of aseptic necrosis.

It is important to note that not all aseptic necrosis of the metatarsal head will collapse as a part of the repair process. A collapsed phase may occur when the ratio of necrotic bone is greater than the reossified bone. Collapse occurs at the junction of necrotic and reossified bone which may produce degenerative arthritis (Fig. 3).

In many instances repair will be complete and radiographs will chronicle the progress and actual increase in the radiodensity as new bone is laid down on the surface of necrotic trabeculae.

3. Phase of Bone Healing

The phase of bone healing refers to the cessation of bone resorption and the continuation of bone deposition in order that the fibrous and granulation tissue are slowly replaced by new bone. Once re-ossification is complete the contour of the bone remains relatively unchanged and any residual deformities present will persist. Early and late degenerative arthritic changes are characteristic of phase 3 or the phase of bone healing (Fig. 4). Fragmentation may be present during this stage with the formation of subchondral cysts and joint narrowing indicating early signs of degenerative arthritis.

In some instances it is impossible for the surgeon to determine that the lytic changes within the metatarsal

Fig. 3. Phase of revascularization with bone deposition and resorption (collapsed phase).

Fig. 5. Phase of deformity characterized by obvious residual deformity.

head associated with joint narrowing involve aseptic necrosis of bone. Serial radiographics pre and postoperatively may help provide an accurate diagnosis in these cases. A low grade septic joint can be difficult to diagnose and can be misdiagnosed as an aseptic necrosis.

Fig. 4. Phase of bone healing characterized by early and late regenerative and arthritic changes.

4. Phase of Deformity

The phase of deformity is characterized by evidence of obvious residual deformity. The residual deformity of the metatarsal head with its associated incongruity and limitation of motion in later life usually leads to the development of degenerative joint disease. Any residual deformity persists (Fig. 5).

VASCULAR SUPPLY TO FIRST METATARSAL HEAD

An understanding and appreciation of the blood supply to the first metatarsal is important in preventing vascular compromise of bone which may develop aseptic necrosis. The vascular supply to the first metatarsal is complex. Jaworek (1973) performed a thorough and exhaustive study with the purpose of familiarizing the surgeon with the complex vascular design of the first metatarsal and the residual effects of first metatarsal osteotomies. The importance of the principle nutrient artery (P.N.A.) is demonstrated with its role in osseous circulation. Jaworek reports the principle nutrient artery (P.N.A.) is located 2.7 cm. proximal to the articular cartilage and 0-4 cm. from the dorsal aspect of the lateral border of the first metatarsal. One should be aware of the relationship of the following sources in the vascular source of a normal first metatarsal (Fig. 6).

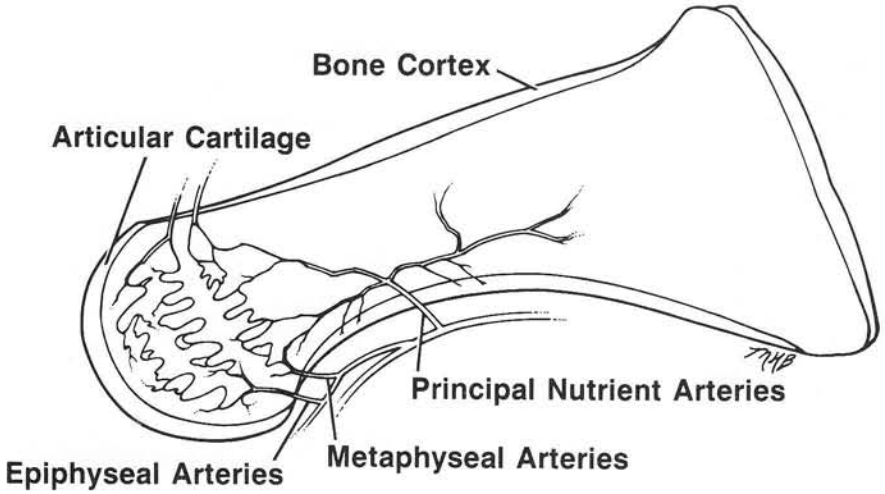

Fig. 6. Anatomical design of vascular supply of normal first metatarsal. PNA = Principle nutrient artery. EPA = Epiphyseal artery. MA = Metaphyseal artery. AC = Articular cartilage.

The stump demonstrates the importance of the vascular supply of the metatarsal in determining the site and extent of an osteotomy which might compromise the blood supply leading to bone death and aseptic necrosis.

RESULTS, PHASE I OF STUDY

The following responses to questions concerning aseptic necrosis following first metatarsal osteotomies demonstrate the experience of surgeons at the Podiatry Institute.

Each surgeon was given an opportunity to comment on factors considered important in the decreased incidence of aseptic necrosis at our institution compared to the much higher incidence in previous studies performed elsewhere. The responses are summarized in this paper. The purpose of the survey and statistical study is to correlate the factors which are essential in preventing avascular necrosis as a postoperative complication.

The following questions concern aseptic necrosis following distal osteotomies of the first metatarsal. Each physician rated their responses to each question below and the results are as follows. Percentages of each response are indicated for comparison. (Table 1)

In addition to the responses above, each physician surveyed was given an opportunity to make comments or recommendations. The following questions were presented and the more common responses are included as results.

> What factors do you consider important in the prevention of aseptic necrosis?

A significant number of physicians surveyed recommend strict avoidance of burning of bone with power instrumentation when performing distal metatarsal osteotomies. The importance of frequent lavage of the operative area with sterile water was discussed as an important factor. Twenty percent of the physicians surveyed recommended non weightbearing or semi weightbearing following distal osteotomies.

> How would you treat aseptic necrosis postoperatively?

The physicians who responded to this question recommended non weightbearing or the avoidance of stress and biomechanical forces to the area. Surgical considerations in the symptomatic patient included consideration of arthroplasty or implant arthroplasty.

> What percentage of your patients develop aseptic necrosis following osteotomies of the first metatarsal head?

The majority of the physicians surveyed indicated 0%. The highest percentage indicated was 1%.

CASE HISTORY #1

M.M. is a 51 year old female who underwent modified McBride-Austin osteotomy on the first metatarsal left, Akin osteotomy great toe left, and metaphaseal

TABLE 1

1 = Strongly agree 2 = Agree 3 = Neutral 4 = Disagree
5 = Strongly disagree NA = Not applicable/don't know

	1	2	3	4	5	NA
A. Aseptic necrosis is a common postoperative complication with your patients (Greater than 207)	0	0	0	15%	75%	10%
B. Aseptic necrosis is a rare postoperative complication (Less than 1%)	75%	15%	0	0	0	10%
C. The incidence of aseptic necrosis at HCA-Doctors Hospital is significantly less than the national incidence	40%	20%	0	0	0	40%
D. Aseptic necrosis is a postoperative complication which can easily be prevented	35%	50%	10%	57	0	0
E. Aseptic necrosis is difficult to diagnose and can commonly be confused with delayed bone healing	15%	50%	15%	10%	10%	0
F. Aseptic necrosis is irreversible and causes complete destruction of the first metatarsal head	0	35%	25%	30%	10%	0
G. Aseptic necrosis is more common when NO internal fixation is utilized	15%	60%	10%	5%	0	10%
H. Aseptic necrosis is more common in the ambulatory, weight-bearing patient	5%	25%	40%	15%	0	20%
I. Preservation of blood supply maintains viability of the capital fragment and prevents aseptic necrosis	40%	60%	0	0	0	0
J. Preservation of adherent soft tissues on the lateral aspect of the first metatarsal prevents aseptic necrosis	20%	45%	10%	10%	15%	0
K. Maintenance of good bony apposition is essential in preventing aseptic necrosis	30%	60%	5%	5%	0	0
L. Anatomic dissection and proper tissue handling help to prevent aseptic necrosis	75%	25%	0	0	0	0
M. Internal screw fixation is superior to internal K-wire fixation in preventing aseptic necrosis	15%	20%	40%	25%	0	0
N. Screw fixation and K-wire fixation are superior to wire or absorbable suture fixation in preventing aseptic necrosis	25%	40%	25%	10%	0	0
O. Osteotomies without any fixation are more prone to aseptic necrosis	20%	55%	0	5%	5%	0
P. The incidence of aseptic necrosis increases with the age of the patient	20%	45%	20%	5%	0	10%
Q. Aseptic necrosis is more common in female patients than in male patients	0	5%	55%	5%	0	35%
R. Aseptic necrosis is more common when bilateral foot surgery is performed at the same interval	5%	20%	50%	5%	5%	15%
S. Aseptic necrosis is more common in the patient with osteoporosis	15%	40%	20%	10%	0	15%
T. The podiatric and orthopedic literature report a higher incidence of aseptic necrosis than that experienced at HCA-Doctors Hospital over the last 10 years	45%	15%	5%	5%	0	30%
U. Aseptic necrosis is more common when osteotomies are performed at the distal and proximal aspects of the first metatarsal	5%	15%	25%	35%	5%	15%
V. The patient's foot type may be a factor in the development of aseptic necrosis	5%	40%	25%	5%	10%	15%
W. The incidence of aseptic necrosis varies according to the surgeon and his experience and training.	25%	60%	0	0	0	15%
X. Aseptic necrosis is more common following the Reverdin bunionectomy in contrast to the Austin-McBride bunionectomy	5%	30%	30%	0	5%	30%

osteotomy third metatarsal,bilaterally. Physical examination revealed a well-developed and well-nourished patient in good health with a chief complaint of painful bunion left foot and painful callus under the third metatarsals of both feet. The above procedures were performed in April of 1985 without complications and the hospital course was unremarkable.

All osteotomies were fixated with .045 Kirschner wires (K-wire). The patient walked semi weightbearing for six weeks with a walker and surgical shoes. The postoperative course was essentially unremarkable except for pin tract irritation three weeks postoperatively, left foot, necessitating early K-wire removal. The patient remained afebrile with no evidence of pus, drainage, or lymphangitis. Four months postoperatively occasional swelling of the left foot was noted. However, the painful callus sub third metatarsal head resolved.

In May of 1988 the patient presented with a new chief complaint of pain and callus under the second, third, and fourth metatarsal heads of the left foot of approximately one year duration. Clinical evaluation revealed a shortening of the great toe with decreased range of motion. Gait analysis demonstrated a slight limp with an apropulsive gait. Radiographs displayed complete absence of the first metatarsal head with associated contractures of the lesser digits (Fig. 7). Conservative care with an orthotic device failed to relieve the symptoms.

Fig. 7. Complete collapse of first metatarsal head.

In July of 1988 the patient successfully underwent fusion of the proximal interphalangeal joints of the second, third, and fourth digits and pan metatarsal head resection 1-5 to correct the digital deformities and relieve painful metatarsalgia under the metatarsal heads. Postoperative radiographs reveal excellent correction with K-wire fixation for eight to ten weeks to assure alignment and healing in a corrected position (Fig. 8).

Pathology report of first metatarsal revealed seven non viable fragments of necrotic bone and cartilage. Intraoperative gram stain revealed no organisms seen. Intraoperative culture and sensitivity for aerobes and anaerobes produced no growth. The patient has progressed well postoperatively with complete relief of symptoms and return to her normal duties three months following surgery. Radiographs 2 1/2 months postoperatively display correction of the deformities with good alignment (Fig. 9).

This case presentation clearly demonstrates a severe case of aseptic necrosis resulting in resorption of the entire metatarsal head with obvious residual deformities which necessitated surgical intervention.

CASE PRESENTATION #2

DB is a 41 year old female who underwent modified McBride bunionectomy with Green-Reverdin osteotomy, first metatarsal base wedge osteotomy with screw fixation, and dorsiflexory wedge osteotomy second metatarsal with screw fixation left foot in April 1983. The chief complaint at the time of original surgery was painful bunion joint and callus under the second metatarsal left foot. Radiographs approximately six weeks postoperative reveal early bone healing and correction of deformity (Fig. 10).

Radiographs approximately four months postoperative reveal adequate bone healing. However, the hallux valgus deformitiy is returning as the patient resumes normal activities (Fig. 11).

Painful internal fixation screw of second metatarsal head was removed seven months postoperatively. A radioluscent area is seen in the second metatarsal head following removal of internal fixation screw (Fig. 12).

Approximately one year following surgery the painful internal fixation screw at the base of the first metatarsal was removed. The patient's chief complaint at this time was a recurrent hallux valgus deformity and a painful transfer lesion beneath the head of the third metatarsal (Fig. 13).

Fig. 8. Postoperative radiograph reveals excellent correction with Kirschner wire (K-wire) fixation.

Fig. 9. Two and a half months postoperative radiographs reveal excellent correction with good alignment.

Fig. 10. Six week postoperative radiographs reveal early bone healing and correction of deformity.

Fig. 11. Four month postoperative radiographs reveal adequate bone healing with recurrent hallux valgus deformity.

The symptoms progressed and were non responsive to conservative care. Additional surgery was required in February of 1985. An Austin-McBride hallux valgus repair was performed and K-wire fixation utilized. An osteotomy of the third metatarsal was also performed (Fig. 14). The patient was immobilized with a below-knee cast and walker and allowed to ambulate semi weightbearing. Radiographs taken July 1985 reveal what appears to be excellent alignment and correction of the recurrent hallux valgus. A mild hallux varus is seen (Fig. 15).

Fig. 12. Seven months postoperative radiographs reveal radiolucent area in second metatarsal head following removal of internal fixation screw.

Fig. 13. Nineteen month postoperative radiographs reveal transfer lesion to the head of the adjacent third metatarsal as indicated by x-ray marker.

Fig. 14. Additional Austin-McBride with K-wire fixation and osteotomy of third metatarsal is performed 22 months following original surgery.

Fig. 15. Excellent postoperative correction of recurrent hallux valgus with mild hallux varus.

As indicated earlier, radiographs are usually normal in the early phase or phases of avascularity of aseptic necrosis. During the phase of avascularity the radiodensity of bone remains unchanged since neither bone resorption nor bone formation can occur without vascular supply. This early phase of avascularity is also referred to as the pre-collapse stage of aseptic necrosis (Fig. 16).

The patient coninued to complain of pain under the third metatarsal with recurrent intractable keratosis and also decreased range of motion of the great toe. Radiographs in October 1987 revealed increased radiodensity and collapse of the first metatarsal head (Fig. 17).

The phase of revascularity as described earlier is characterised by deposition of new bone and resorption

Fig. 16. Early phase of avascularity or the pre-collapsed phase of aseptic necrosis six months following second hallux valgus surgery.

Fig. 17. Thirty-two months postoperative second hallux valgus surgery reveal increased radiodensity and collapse of the first metatarsal head.

Fig. 18. Thirty-eight months postoperative second hallux valgus surgery reveal residual deformity of the first metatarsal head with incongruity, limitation of motion, and the development of severe degenerative joint disease.

Fig. 19. Final x-rays three and a half months postoperatively second hallux valgus surgery reveal persistant residual deformity of the first metatarsophalangeal joint.

representing the vascular reaction of the surrounding tissues to necrotic bone. In this case the new bone is readily molded into an abnormal shape as biomechanical forces are applied to the first metatarsophalangeal joint. This late stage of revascularization is also referred to as the collapsed phase of aseptic necrosis.

Follow-up radiographs in February 1988 demonstrate continued deformity and aseptic necrosis in the final phases of deformity characterized by obvious residual deformities of the metatarsal head with associated incongruity of the joint, limitation of motion, and development of severe degenerative joint disease (Fig. 18).

Final radiographs in April 1988 reveal continued adaption of the first metatarsophalangeal joint (Fig. 19).

This case demonstrates the often gradual and subtle pathologic changes in the development of aseptic necrosis. If symptoms persist surgical correction could entail arthroplasty or implant arthroplasty.

SUMMARY — CONCLUSION

The preliminary results of this ongoing study confirms that if the following conditions are preserved during surgery the incidence of aseptic necrosis is neglegible or may not occur at all.

1. Preservation of blood supply to maintain viability of the capital fragment

2. Preservation of adherent soft tissues on the lateral aspects of the first metatarsal head.

3. Maintenance of good bone apposition.

The study confirms a significantly higher incidence of aseptic necrosis as reported in the literature as compared to the findings at the Podiatry Institute. The overall incidence of aseptic necrosis at this institution is less than 1%.

In addition to the above conditions the majority of surgeons surveyed voiced the following.

1. Aseptic necrosis is a rare postoperative complication with an incidence of less than 1%.

2. The incidence of aseptic necrosis at this Institution is significantly less than the national incidence.

3. Aseptic necrosis is a postoperative complication which can usually be prevented.

4. Aseptic necrosis is more common when no internal fixation is used.

5. Anatomic dissection and proper tissue handling help to prevent aseptic necrosis.

6. Screw fixation and K-wire fixation are superior to wire loop or absorbable suture fixation in preventing aseptic necrosis.

7. Osteotomies without any fixation are more prone to aseptic necrosis.

8. The incidence of aseptic necrosis increases with the age of the patient.

9. Aseptic necrosis is more common in the patient with osteoporosis.

10. The podiatric and orthopedic literature report a higher incidence of aseptic necrosis than the incidence at our Institution over the last 10 years.

11. The incidence of aseptic necrosis varies according to the surgeon and his experience and training.

The preliminary study helps to document our experiences and correlate specific factors which contribute to a much lower incidence of aseptic necrosis following osteotomies of the first metatarsal.

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