A SYSTEMATIC REVIEW OF THE FACTORS CONTRIBUTING TO THE DEVELOPMENT OF 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. 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 Northlake Regional Medical Center. A principle objective of this paper is to identify the factors which contribute to a much lower incidence of aseptic necrosis and to document our experiences. A thorough understanding of the factors in the development of aseptic necrosis will help the surgeon avoid potential complications concerning this significant risk management concern. Early diagnosis and treatment of aseptic necrosis is essential in preventing the potentially disastrous complications of avascularity of the first metatarsal head following distal metatarsal osteotomies.

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. Preliminary results support the assumption that necrosis following distal osteotomies are less frequent if the following conditions are met during surgery:

1. Preservation of blood supply to maintain viability of the capital fragment.
2. Preservation of soft tissue attachments over the lateral aspect of the first metatarsal head.
3. Maintenance of good bony apposition.
4. Avoidance of thermal necrosis of bone with power instrumentation.
5. Respect for the vascular anatomy of the first metatarsal in selection of osteotomy site.

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

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 20-40%.

Meisenhelder, Harkles, and Paterson, (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. Also in this study, 10 patients underwent a Chevron osteotomy with an adductor tenotomy. Four of the ten patients (40%) developed aseptic necrosis. One of 12 patients (8%) who had a Mitchell osteotomy also developed aseptic necrosis. Overall the results demonstrate aseptic necrosis in 13 of the 72 cases (18%).

A comparison of these two studies clearly demonstrates a wide difference in the potential incidence of aseptic necrosis following distal osteotomies of the first metatarsal. Further investigation and study is necessary in documenting our experiences concerning this potential postoperative complication.

ETIOLOGY

The etiology of aseptic necrosis is not clearly understood or adequately described in the literature. Most investigators agree that aseptic necrosis is primarily a condition which results from an ischemic episode to that particular portion of bone. Subsequent to ischemia there is actual bone death or necrosis. In time the necrotic bone is replaced with living material. The degree of resultant deformity depends upon the force exerted on the first metatarsal phalangeal joint during this replacement process. Early recognition and appropriate treatment is essential in preventing progression to more advanced sequelae. Potential problems are the development of degenerative arthritis, hallux limitus, and hallux rigidus. In advanced cases of aseptic necrosis, complete loss of the first metatarsal head with an accompanied shortening of the great toe can occur. Once aseptic necrosis is identified, control of abnormal biomechanical forces at the level of the first metatarsal phalangeal joint is essential in preventing progression of the disease and deformity.

Other known causes of aseptic necrosis of subchondral 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.

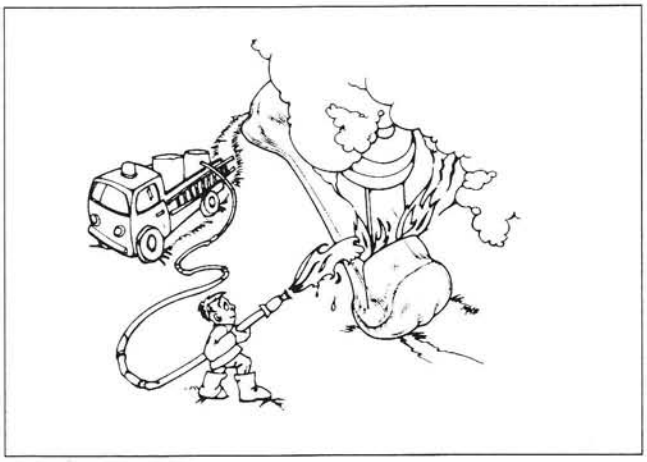

Fig. 1. Avoid burning of bone with power instrumentation.

Hematologic

Hematological 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.

Steroids

Long term use of corticosteroids have been implicated in aseptic necrosis.

VASCULAR ANATOMY OF THE FIRST METATARSAL

Preservation of the vascular anatomy of the first metatarsal is essential in the prevention of aseptic necrosis following distal metatarsal osteotomies. The vascular supply to the first metatarsal is described in Fig. 2. Primary blood supply to the first metatarsal is through the nutrient artery, metaphyseal arteries, periosteum and synovial fluid outlining the articular cartilage. Proper selection and placement of the osteotomy site is essential in preventing avascularity of the first metatarsal head following use of power instrumentation. Common metaphyseal osteotomies include the Reverdin osteotomy, (Fig.3) the Austin Short arm, (Fig. 4), the Austin Long arm, (Fig. 5). The Z osteotomy (Fig. 6) and the Mau Oblique osteotomy (Fig.7).

The potential for avascularity following osteotomy increases with the amount of vascular anatomy compromised by the selection of osteotomy types as depicted in the above figures. Preliminary results indicate that the distal osteotomies in the area of the metaphyseal arteries have a lower incidence of aseptic necrosis in comparison to the other osteotomy techniques with extended osteotomies.

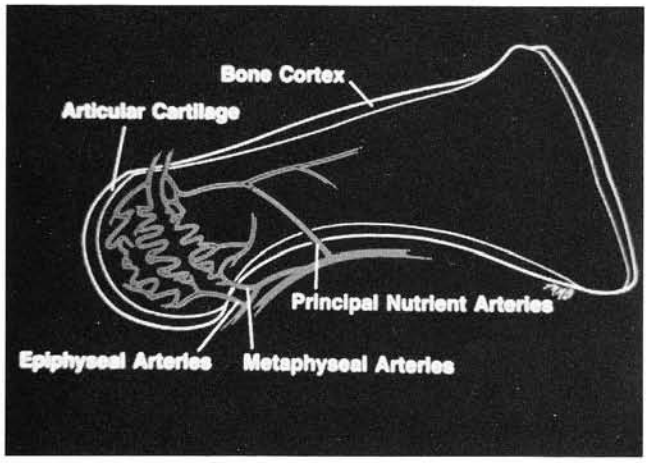

Fig. 2. Anatomical Design of Vascular Supply of the First Metatarsal.

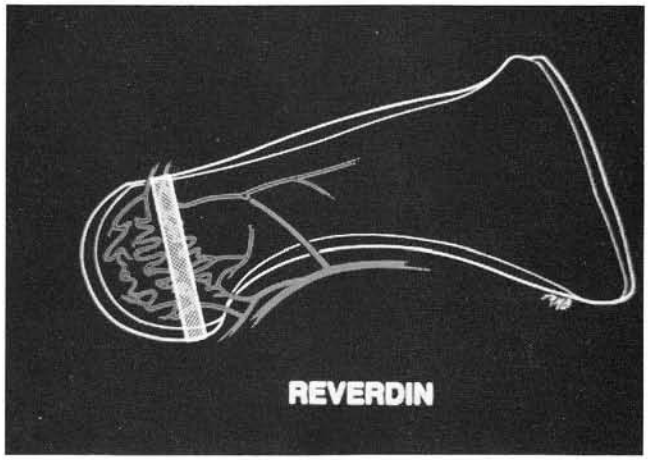

Fig. 3. Reverdin Osteotomy.

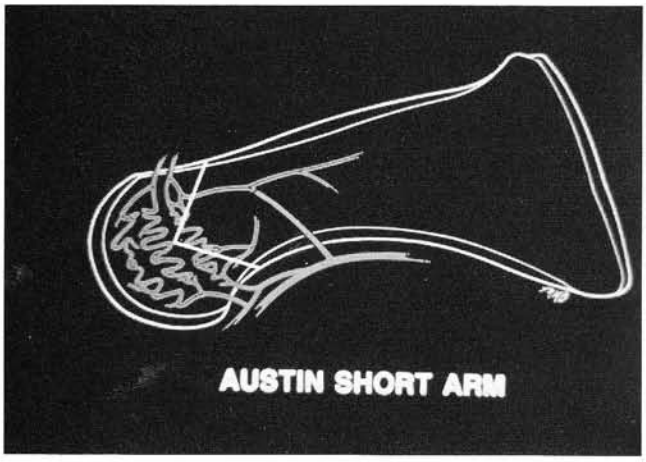

Fig. 4. Austin Short Arm Osteotomy.

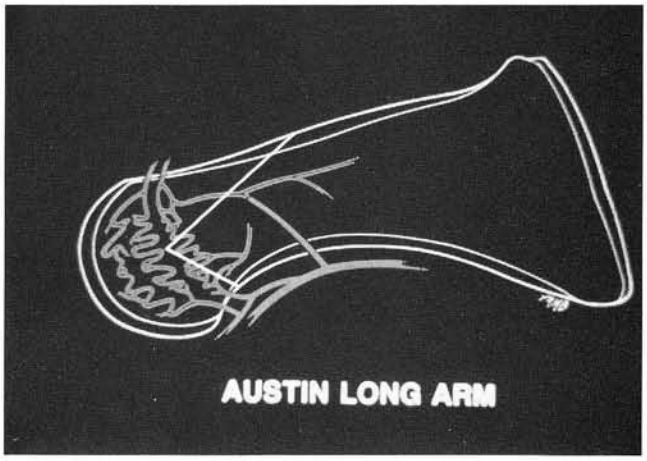

Fig. 5. Austin Long Arm Osteotomy.

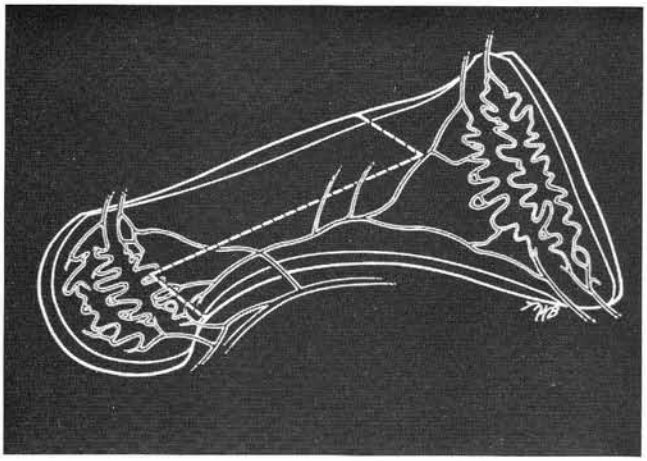

Fig. 6. Z Type Osteotomy.

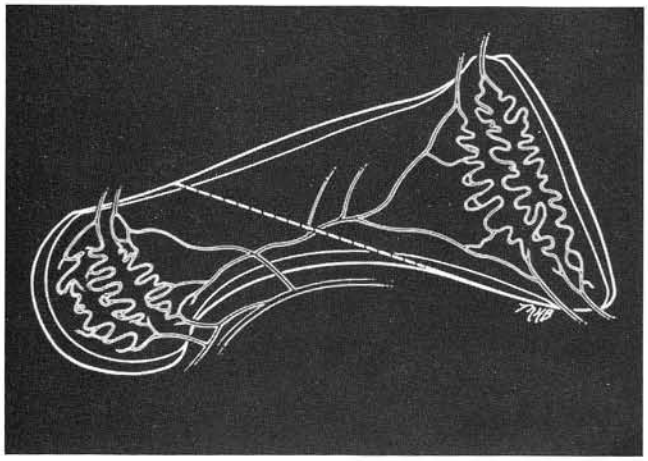

Fig. 7. Mau - Oblique Metatarsal Osteotomy.

Fig. 8. Early Phase of Avascularity Phase (Pre-collapse Phase).

PATHOPHYSIOLOGY

The pathophysiology of aseptic necrosis is not well defined. However, the pathology and pathogenics are well correlated with readily identifiable radiographic changes. Salter (1970) described the four phases of aseptic necrosis. Although discussed in regard to other osteochondroses, these findings are applicable to those changes seen in the first metatarsal head affected by postoperative aseptic necrosis. The four phases of development in aseptic necrosis are often gradual and subtle and may be reversed depending on the biomechanical stresses placed upon the joint.

PHASES OF ASEPTIC NECROSIS

Early Phase (Avascularity)

The early or the avascular phase begins when the blood supply to the distal fragment of the first metatarsal is compromised. Following loss of blood supply, the osteocytes and bone marrow cells die. Many authors also refer to this phase as the pre-collapsed stage of aseptic necrosis. (Fig. 8)

Revascularization Phase With Bone Deposition and Resorption.

The phase of revascularization is characterized by resorption of necrotic bone and the deposition of new bone as the vascular supply of the surrounding tissues respond to the necrotic tissue (Fig. 9). During this stage, a pathological fracture may occur at the point of maximum stress. This may be referred to as the collapse phase of aseptic necrosis. It is important to note that the metatarsal head may not collapse as part of the repair process in all cases. Collapse of the metatarsal head depends not only on the stress applied to the joint, but also on the ratio of necrotic to reossified bone. Collapse of the bone may occur when the ratio of necrotic bone predominates. In many instances repair of necrotic bone will be complete without collapse of the first metatarsal head. Depending on the amount of stress applied to the first metatarsal head there may be complete collapse or loss of the metatarsal head or possibly only loss of a small portion of the metatarsal head.

Fig. 9. Phase of Revascularization with Bone Deposition and Resorption (Collapse Phase).

Fig. 10. Phase of Bone Healing Characterized by Early and Late Degenerative Arthritic Changes.

Bone Healing Phase

This phase is characterized by further bone resorption and the replacement of more primitive bone tissue by a more mature counterpart. Following the re-ossification phase of bone healing, the contour of the bone will remain relatively unchanged and any residual deformities present will persist. Early signs of degenerative arthritis may be present during this stage as fragmentation may occur with the formation of subchondral cysts or the development of joint narrowing. The appearance of those characteristics normally found in late degenerative arthritis are characteristic of phase three. It is often difficult for the surgeon to differentiate the lytic changes within the first metatarsal head and the joint narrowing as the formation of hallux limitus condition or an aseptic necrosis condition. In addition a low grade septic joint must be included in the differential diagnosis. (Fig. 10).

Fig. 11. Phase of Deformity Characterized by Obvious Residual Deformity.

Phase Of Deformity

The fourth phase or deformity phase, is characterized by the evidence of obvious residual deformity of the affected joint. The residual deformity may be mild or severe in nature. In later life, the patient may develop degenerative joint disease resulting in hallux limitus or hallux rigidus. (Fig. 11). In severe cases there may be complete collapse and loss of the first metatarsal head.

RADIOGRAPHIC FINDINGS

Iatrogenic aseptic necrosis is well correlated with radiographic changes and divided into four phases:

Early Phase (Avascularity)

During the first phase the radiographs are usually normal. The radiographic density of the bone remains unchanged since neither bone resorption nor bone formation can occur without a vascular supply. Nuclear bone scans during phase one frequently reveal little or no uptake within the first metatarsal head indicating necrosis. Rather than the entire head being involved, frequently only a portion of the metatarsal head is involved in the development of aseptic necrosis.

Revascularization Phase With Bone Deposition And Resporption

Radiographs during phase two are characterized by bone deposition and resorption revealing increased radiodensity of the metatarsal head as new bone is laid down on dead bone. The new bone formation will be modeled into either a normal or abnormal shape depending on the biomechanical forces applied to the first metatarsal phalangeal during this stage. Nuclear bone scans during stage two reveal an increased uptake. This may involve only a portion of the metatarsal head or in a more severe case the entire metatarsal head may be absorbed during the aseptic necrosis process. Many authors refer to this phase as the collapse phase of aseptic necrosis.

Bone Healing Phase

Late degenerative arthritic changes are characteristic of phase three. Radiographs may reveal fragmentation and formation of subchondral cysts with joint narrowing indicating early signs of degenerative arthritis at the level of the first metatarsal phalangeal joint. Serial radiographs pre and postoperatively are important in providing an accurate diagnosis in these cases and determining the phase of aseptic necrosis.

Phase Of Deformity

Radiographs during the phase of deformity are characterized by an obvious presence of a residual deformity. The deformity may demonstrate severe degenerative joint disease which will persist and may require additional surgical intervention.

PREVENTION

Table 1 presents the factors which help prevent the development of iatrogenic aseptic necrosis following distal osteotomy of the first metatarsal for correction of hallux valgus. The potential risk management concerns and complications associated with aseptic necrosis can be prevented by following these guidelines. Aseptic necrosis varies in its clinical presentation and can often be confused with hallux limitus. The postoperative onset of aseptic necrosis may vary from six months to five years. Serial x rays are essential in any case where aseptic necrosis may be suspected. Since aseptic necrosis is commonly misdiagnosed as a hallux limitus, early recognition and appropriate treatment is essential. It is a distinct contraindication to provide aggressive physical therapy or range of motion exercises in the early stages of

TABLE 1

PREVENTION OF IATROGENIC ASEPTIC NECROSIS

1. Anatomical dissection.
2. Proper tissue handling.
3. Preservation of blood supply to maintain viability of capital fragment.
4. Preservation of adherent soft tissues of the lateral aspect of the first metatarsal.
5. Maintenance of good bone apposition.
6. Appropriate internal fixation of osteotomy.
7. Anatomical alignment and osteotomy.
8. Appropriate patient selection and execution of surgical procedure.
9. Avoidance of burning bone with power instrumentation.
10. Importance of serial post operative x rays.
11. Early diagnosis and appropriate treatment.

aseptic necrosis. A hallux limitus condition may respond to range of motion exercises and activity whereas an aseptic necrosis condition will only worsen increasing the abnormal biomechanical stresses on the first MPJ causing further destruction of the metatarsal head with possible collapse or even loss of the entire metatarsal head. From a risk management concern early recognition and appropriate treatment is essential in preventing the potential complications associated with this potentially devastating sequelae to distal metaphyseal osteotomies. Patients should be informed prior to surgery of the potential complications of aseptic necrosis particularly if previous surgery or osteotomy has been performed at the first metatarsal.

TREATMENT

A thorough understanding of the definition, incidence, etiology, pathophysiology, radiographic findings, and factors necessary to prevent iatrogenic aseptic necrosis is essential in assuring the most optimal postoperative result following osteotomies of the first metatarsal. Appropriate early diagnosis and recognition of these disorders is imperative in order to provide appropriate treatment. The treatment, whether conservative or surgical is aimed at controlling abnormal biomechanical forces at the level of the first metatarsal phalangeal joint with the goal of preventing propagation of the deformity. In most cases when the surgeon suspects aseptic necrosis, providing a non-weightbearing attitude for the patient or utilizing a below the knee cast with a walker will prevent any further abnormal stresses on the first metatarsal head. The effectiveness of biomechanical control utilizing semi-rigid orthotic devices helps to control abnormal stresses to the first metatarsal phalangeal joint following hallux valgus surgery. Early diagnosis and control of the mechanical forces are essential in effectively treating this condition. Aseptic necrosis has an insidious onset and the effects of the complications may not be seen for months or several years as a residual deformity.

Table 2 outlines the conservative and surgical principles as they relate to the treatment of iatrogenic aseptic necrosis. In most cases with early diagnosis and appropriate treatment, the potential adverse effects of avascularity of the first metatarsal head can be reversed. In the presence of a residual deformity, considerations for surgical correction may include such techniques as bone grafting-lengthening, step down osteotomy of adjacent metatarsals, implant arthroplasty, arthrodesis of the first metatarsal phalangeal joint, and pan metatarsal head resection metatarsals 1-5. The above surgical procedures for correction of iatrogenic hallux limitus have been previously described in detail in the Podiatry Institute publications. The reader is referred to previous annual updates on Reconstructive Surgery of the Foot and Leg as presented at the surgical seminar of the Podiatry Institute.

SUMMARY

In conclusion, it is extremely difficult in most cases to clinically differentiate between hallux limitus and aseptic necrosis particularly during the early phases of development. Early diagnosis and appropriate treatment is essential in preventing the potentially severe postoperative complications associated with this disorder. The late stages of aseptic necrosis with degenerative joint disease may actually develop into a hallux limitus or hallux rigidus. Serial radiographs preoperatively and postoperatively may help in providing an accurate diagnosis in these cases. Without serial x-rays, the development of aseptic necrosis may go

TABLE 2

TREATMENT OF IATROGENIC ASEPTIC NECROSIS

CONSERVATIVE

1. Shoe modifications.
2. Orthotic devices.
3. Molded or orthopedic shoes.
4. Non-weightbearing crutches.
5. Below the knee cast with walker.

SURGICAL

1. Bonegrafting - lengthening.
2. Step down osteotomy of adjacent metatarsals.
3. Implant arthroplasty.
4. Pan metatarsal head resection 1-5.
5. Arthrodesis first MPJ.

unnoticed until symptoms present in the late phases of deformity. It is hoped that this paper might stimulate further research and investigation in the factors that contribute to the development of aseptic necrosis following distal osteotomies of the first metatarsal.

RISK MANAGEMENT CONCERNS

A thorough understanding of the factors in the development of aseptic necrosis will help the surgeon avoid potential complications concerning this significant risk management concern. Early diagnosis and treatment of aseptic necrosis is essential in preventing the potentially disastrous complications of avascularity of the first metatarsal head following distal metatarsal osteotomies.

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