

Management of Post Traumatic Segmental Defect of Long Bones

Essay

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Aim of the work

The aim of this essay is to review the literature on the different modalities of treating segmental bony defects of long bones after trauma . Bone transport , bone graft , vascularized and nonvascularized bone graft with either internal or external fixation and other possible methods of management will be discussed . The most applicable methods of treatment in these challenging situations will be mentioned and identified .

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Introduction

Segmental defect of bone are usually associated with severe open fractures.⁽¹⁾ These injuries usually occur due to vehicle accidents.

In the treatment of segmental defect of long bone the surgeon confronts one of the most challenging problems in traumatology.⁽²⁾

Because of difficulty in managing post traumatic segmental bone defects and the resultant poor outcome amputation was the preferred treatment in the past.⁽³⁾

Current treatment options for large segmental defects in long bones include bone grafting, and free vascularized bone grafting. Bone transfer and distraction osteogenesis is in common use. ^(4,5,6,7,8,9,10)

Another recent option is the use of titanium mesh cage combined with bone grafts and an intramedullary nail.⁽¹¹⁾

Gustilo and others stress the importance of leaving the wound open and repeated debridement every 24 to 48 hours until closure at 5 to 7 days by delayed primary closure, skin grafting or skin flaps.⁽¹²⁾

Bone graft substitutes continue to be developed , but they have not yet reached clinical efficacy for post traumatic segmental bone defect. Although each of the new techniques has shown some success, complications remain common.⁽³⁾

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ANATOMY OF LONG BONES

Definition of long bone:

Is that bone with greater length than width.

A typical long bone consists of the following parts:

1-Diaphysis:

The shaft or long main portion of the bone.

2-Epiphysis:

The extremities or ends of the bone.

3-Metaphysis:

The region in a mature bone where the diaphysis joins the epiphysis. In growing bone, it is the region that includes the epiphyseal plate where cartilage is replaced by bone. The epiphyseal plate is a layer of hyaline cartilage that allows the diaphysis of the bone to grow in length.

4-Articular Cartilage:

A thin layer of hyaline cartilage covering the epiphysis where the bone forms an articulation (joint) with another bone . The cartilage reduces friction and absorbs shock at freely movable joints.

5-Periosteum:

The periosteum is a membrane around the surface of the bone not covered by articular cartilage. It consists of two layers. The outer fibrous layer is composed of dense, irregular connective tissue that contains blood vessels, lymphatic vessels, and nerves that pass into the bone. The inner osteogenic layer contains elastic fibres, blood vessels, and various types of bone cells. The periosteum is essential for bone growth in diameter, repair, and nutrition. It also serves as a point of attachment for ligaments and tendons.

6-Medullary Or Marrow Cavity:

This is the space within the diaphysis that contains the fatty yellow bone marrow in adults.

7-Endosteum:

Lining the medullary cavity is the endosteum, a membrane that contains osteoprogenitor cells and osteoclasts.⁽¹⁾

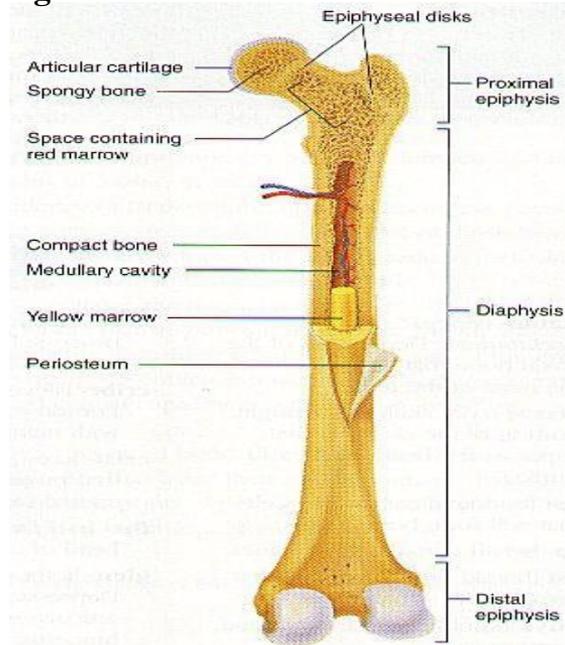


Fig . (1) diagram of long bone

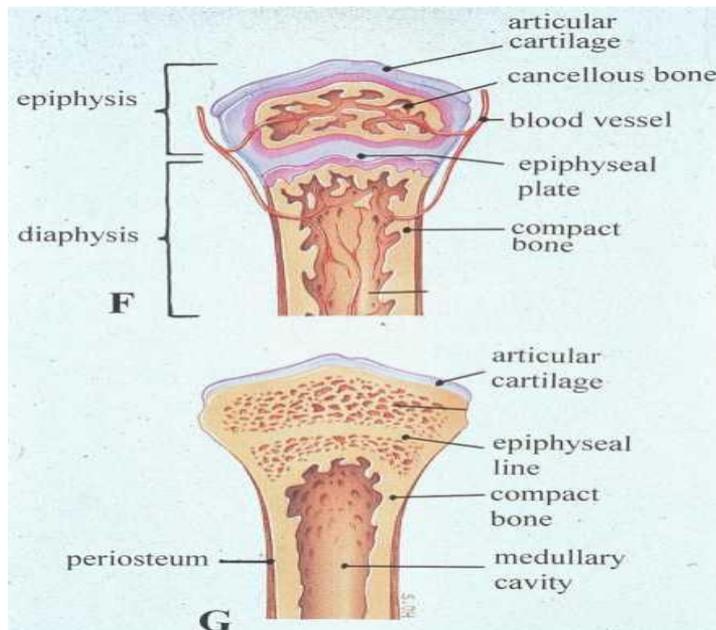


Fig. (2) epiphysis and diaphysis of cortical bone

HISTOLOGY OF LONG BONE

Like other connective tissues , bone or osseous tissue contains an abundant matrix surrounding widely separated cells. The matrix is about 25% water 25% protein fibres , and 50% mineral salts .There are four types of cells in bone tissue .

1-Osteoprogenator cells:

Unspecialized cells derived from mesenchyme , the tissue from which all connective tissues are derived.They can undergo mitosis and develop into osteoblast . Osteoprogenator cells are found in the inner portion of the periosteum , in the endosteum , and in canals (perforating and central) in bone that contain blood vessels .

2-Osteoblasts:

Are the cells that form bone , but they have lost the ability to divide by mitosis .They secrete collagen and other organic components needed to build bone tissue .

3-Osteocytes:

Are mature bone cells that are derived from osteoblast , they are the principal cells of bone tissue. Like osteoblasts, osteocytes have no mitotic potential. Osteoblasts are found on the surface of bone , but as they surround themselves with matrix materials they become trapped in their secretions and become osteocytes . Osteocytes no longer secrete matrix materials. Whereas osteoblasts initially form bone tissue , osteocytes maintain daily cellular activities of bone tissue , such as the exchange of nutrients and wastes with the blood.⁽²⁾

4-Osteoclasts :

Are believed to develop from circulating monocytes (one type of white blood cells) . They settle on the surfaces of bone and function in bone resorption (destruction of matrix) , which is important in the development , growth , maintainance , and repair of bone .

Unlike other connective tissues , the matrix of bone contains abundant mineral salts , primarily a crystallized form of tricalcium phosphate called hydroxyapatite and some calcium carbonate .

In addition , there are small amounts of magnesium hydroxide , fluoride , and sulfate . As these salts are deposited in the framework formed by the collagen fibres of the matrix , crystallization occurs and the tissue hardens . This process is called calcification or mineralization . In general , mature bone contains more matrix than immature bone .

Although the hardness of bone depends on the crystallized inorganic mineral salts , without the organic collagen fibres it would be very brittle . Like reinforcing metal rods in concrete , the collagen fibres and other organic molecules provide bone with the tensile strength , which is rsistance to being stretched or torn apart .

Bone is not completely solid but has many small spaces (sometimes microscopic only) between its hard components . The spaces provide channels for blood vessels that supply bone cells with nutrients . The spaces also make bone lighter . Depending on the size and distribution of the spaces , the regions of a bone may be categorized as compact or spongy .⁽³⁾

TYPES OF BONE

(A) Compact Bone Tissue :

compact (dense) bone tissue contains few spaces . It forms the external layer of all bones of the body and the bulk of the diaphysis of long bones . Compact bone tissue provides protection and support and helps the long bones resist the stress of weight placed on them .

Blood vessels , lymphatic vessels , and nerves from the periosteum penetrate the compact bone through perforating (Volkmann) canals .The blood vessels and nerves of these canals connect with those of the medullary cavity , periosteum , and central (Haversian) canals . The central canals run longitudinally through the bone .

Around the canals concentric lamellae , rings of hard calcified matrix . Between the lamellae are small spaces called lacunae , which contain osteocytes . Osteocytes , as noted earlier , are mature bone cells that no longer secrete matrix materials .⁽²⁾

Radiating in all directions from the lacunae are minute canals called canaliculi , which are filled with extra cellular fluid . Inside the canaliculi are slender finger-like processes of osteocytes . The canaliculi connect lacunae with one another and , eventually , with the central canals . Thus there is an intricate , miniature canal system throughout the bone . This branching network of canaliculi provides many routes for nutrients and oxygen to reach the osteocytes and wastes to diffuse away . Osteocytes from neighboring lacunae from communicating (gap) junctions with each other , facilitating easy movement of materials from cell to cell .

Each central canal , with its surrounding lamellae , lacunae , osteocytes , and canaliculi , forms an osteon (Haversian system) . The areas between osteons contain interstitial lamellae . These also have lacunae with osteocytes and canaliculi . Interstitial lamellae are fragments of older osteons that have been partially destroyed during bone replacement . (3)

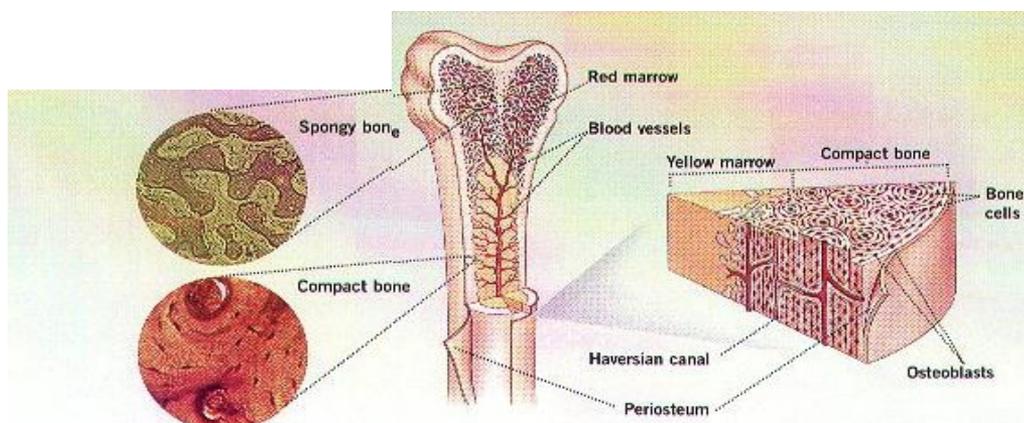


Fig.(3) compact and spongy bone

(B) Spongy Bone Tissue :

In contrast to compact bone , spongy (cancellous) bone does not contain true osteons . It consists of lamellae arranged in an irregular lattice work of thin plates of bone called trabeculae . The macroscopic spaces between the trabeculae of some bones are filled with red bone marrow , which produces blood cells . Within the trabeculae are osteocytes that lie in lacunae . Radiating from the lacunae are canaliculi . Blood vessels from the periosteum penetrate through to the spongy bone . Osteocytes in the trabeculae receive

nourishment directly from the blood circulating through the marrow cavities . Osteons are not necessary in spongy bone because osteocytes are not deeply buried (as in compact bone) and have access to nutrients directly from the blood .⁽²⁾

CIRCULATION OF LONG BONE

Vascular Anatomy Of The Diaphysis

Periosteum

The periosteum has a complex vascular network that is anastomosed with the overlying vessels of the skeletal muscle and the bone⁽⁴⁾. The superficial vascular plexus directly overlies the fibrous layer of the periosteum . It is anastomosed at the gross and microscopic level with the vessels of the skeletal muscle and with the vascular plexus of the cambium layer of the periosteum . The finer vascular plexus of the cambium layer in turn blends with the anatomically similar plexus of the underlying cortical bone . At skeletal maturity the cambium layer disappears and the superficial layer becomes thin and almost acellular ; but its vascular plexus remains intact and interconnected with the vessels of the diaphysial bone . Although the periosteal vessels diminish and the periosteal contribution to the circulation of bone may decrease as the bone ages , the periosteal vascular plexus remains an important collateral pathway for diaphysial cortical bone in adulthood .⁽⁵⁾

The periosteum and its vascular plexus form the extraosseous callus in fracture healing .⁽⁶⁾ Therefore , the source of this intrinsic periosteal blood supply is a matter of major importance . The periosteal vessels are more readily filled by connections with the vascular plexus of the skeletal muscle than by connections with vessels in the bone .⁽⁴⁾ This suggests that the blood supply of the superficial and cambium layers of the periosteum are dependent upon vascular connections with skeletal muscles .The periosteum survives and even forms bone after subperiosteal elevation if the intrinsic vessels and attachments to muscle are preserved.⁽⁷⁾

Although it has not been clearly demonstrated that separation of muscle from periosteum causes periosteal necrosis , it is known that extraperiosteal dissection can have deleterious effects on periosteal

bone formation .⁽⁸⁾ It seems reasonable to speculate that this decreased periosteal bone formation is caused by ischaemic effects on the periosteum . The available evidence strongly points toward the extraosseous route as the single most important source of blood supply to the periosteum .

Diaphysial Cortical Bone

The diaphysial cortical bone is considerably less vascular than metaphysis and epiphysis but , nevertheless , has a rich , extensively anastomosed circulation . The vascular anatomy is complex and difficult to study so it is not surprising that is a controversial area . Classically , the blood supply to the inner two-thirds of the cortex has been considered to be supplied by medullary vessels , and that of the outer one-third by periosteal vessels .⁽⁹⁾ however , a group of studies in the 1950s raised some doubt concerning this concept . Relatively high pressures were reported in the medullary canal , high enough to prevent cortical venous blood from returning to the medullary veins .⁽¹⁰⁾ These findings led directly to the hypothesis that blood flows one way (from inside to out) with the periosteal vascular plexus serving as venous drainage for the diaphysis and metaphysis .⁽¹¹⁾ However , Wilke's improved the technique for measuring intramedullary pressure and found marrow interstitial pressures no higher than extraosseous venous pressure .^(quoted from 12) Furthermore , Branemark's vital microscopy techniques clearly demonstrated arterial vessels entering the endosteal surface and venous channels from the diaphysial cortical bone emptying into the medullary canal .^(quoted from 13) Evidence from most of the micro angiographic anatomical studies suggests that arterial and venous channels parallel one another and that venous channels return to the medullary canal from the bone .⁽¹⁴⁾ This is in agreement with the micro angiographic study by Tria's that presents anatomical evidence for arterial blood supply to the diaphysis both from the periosteum and nutrient , and venous drainage from the cortical bone both into the medullary canal and into the periosteum.^(quoted from 5) In this study Tria's demonstrated two separate vascular system of the diaphysial cortical bone with parallel arterial supply and venous drainage . A radial system originates in the medullary canal and branches toward the surface , and venous drainage returns to the

medullary canal and its nutrient vein . This radial system is characteristic of woven bone . As the diaphysis matures and develops Haversian systems , a longitudinal system of vessels develops and increases in importance . After skeletal maturity , both radial and longitudinal systems are found in the diaphysis . The anatomical details described by Tria's are consistent with other reports of direct anastomoses between the arterial circulation of the periosteum and medullary canal .⁽¹⁵⁾ This concept of dual arterial and venous blood supply of the diaphysial bone agrees closely with a study of the effects of surgical procedures on bone circulation . Stripping the diaphysis of all periosteum in the canine and rabbit tibia did not impair venous or arterial blood flow (as measured by the hydrogen washout technique) in the middle layers of the diaphysial cortical bone regardless of wether the animal was mature or immature . This is possible only if arterial as well as venous channels cross the endosteal surface of the diaphysis . Similarly , blood flow in the middle layers of the diaphyseal cortical bone was not significantly slowed by reaming the medullary canal , even in adult rabbits and dogs . This suggests that the diaphysis can receive a major portion of its blood supply from either the periosteum or the medullary canal or the periosteal circulation can provide channels for venous drainage .⁽⁵⁾

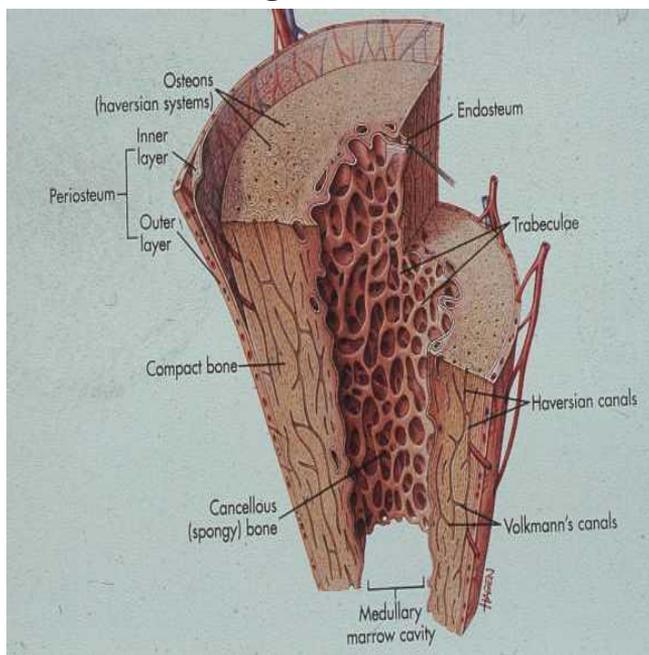


Fig. (4) blood supply. volkmann's canals.

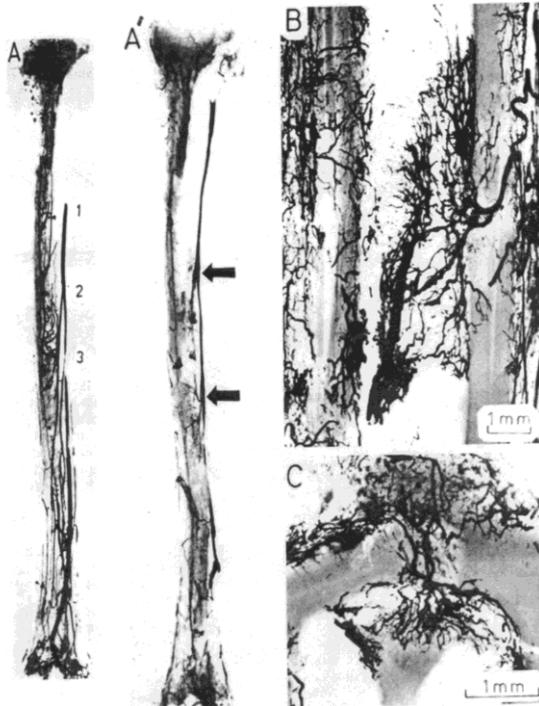


Fig.(5)(A)Arteriogram showing endosteal and periosteal(1, 2, 3) blood supply to rabbit tibia. (A') After intramedullary nailing, the endosteal blood supply is damaged, but blood supply continues from periosteal vessels (arrows j. (B and C) Three weeks later, after damage to the endosteal blood supply, the periosteal vessels penetrate the tibial cortex to ramify and provide vessels to the endosteum. (Q is a sagittal section; C is a cross section.) (From Gothman L. The arterial pattern of the rabbit's tibia. A microangiographic study. Ada Chir Scand 1960; 120:201.)

Medullary Cavity

Many of the misconceptions concerning Medullary blood flow and its relationship to the cortical bone blood flow stem from the previously mentioned studies that reported high pressure in the medullary cavity of long bones .

In all likelihood , the high pressure reported by early investigators was caused by arterial haemorrhage into the closed medullary cavity .⁽¹²⁾ It is now apparent that there are high-pressure arteries as well as low-pressure veins and sinusoids in the medullary cavity .

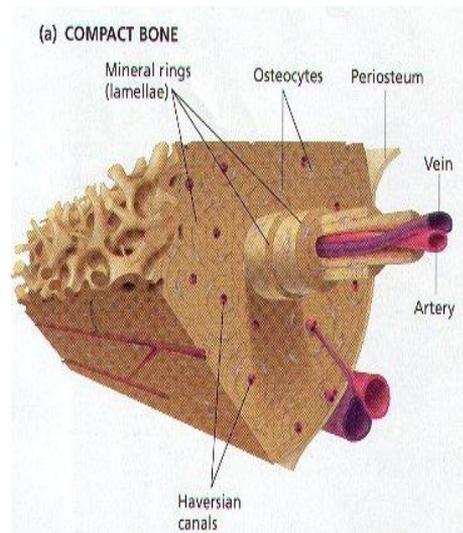


Fig.(6) medullary blood supply

The marrow tissue is fed by a group of arteries separate from the vessels supplying the diaphyseal cortical bone .