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The blood supply of the periosteum

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INTRODUCTION

It is now generally agreed that the periosteum is not just a limiting membrane, but that it has an osteogenic role. In the child, this is demonstrated by the circumference of the diaphysis, which has a membranous style of ossification. In the adult, the osteogenic role is demonstrated during fracture repair (Charnley, 1961; Mock, 1928). In addition, periosteum is becoming increasingly attractive for the treatment of certain clinical problems: cleft palate repair (Skoog, 1965), treatment of severely comminuted fractures (Satoh, Tsuchiya & Harii, 1983), pseudarthrosis of the tibia (King, 1976), and for the repair of tracheal defects (Ritsila & Alhopuro, 1973). The last two examples have been performed on animal models and have yet to be transferred to the human.

With the increased use of periosteum as a transplantable tissue a more extensive knowledge of its circulation becomes desirable. Yet despite the increasing surgical importance of the periosteum, details of its blood supply have attracted little attention, a fact that is all the more remarkable since it has been reported that revascularisation of the periosteum is a requirement for successful transplantation (Finley, Acland & Wood, 1978).

The present investigation was conducted in response to this need for more information concerning the blood supply of periosteum and has resulted in the discovery of a new system of vessels reaching the periosteum.

MATERIALS AND METHODS

Twelve limbs (seven hindlimbs and five forelimbs) of adult goats of a crossbred British strain were treated following the modified protocol of Greene & Hopkins (1962). Freshly killed animals were exsanguinated via the internal jugular vein and common carotid artery. The animals were then perfused with a solution of formalin (formalin 10 %, phenol 1 %, glycerine 1 % , arsenious acid 1 %) via the caudal cut end of the internal jugular vein; this was continued until the fluid draining from the animal was clear. After 24 hours, 500 ml of red stained latex (Revultex) was injected via the caudal cut end of the common carotid artery at 8kPa (12 lb/in^2). The blood supply of the periosteum was then displayed by careful dissection using only the naked eye. The surfaces of the femur, tibia, humerus, radius and ulna were examined in all dissections, the scapula and cannon bone in three and the pelvis and metatarsus in four dissections.

No tissue clearing techniques were used prior to photography.

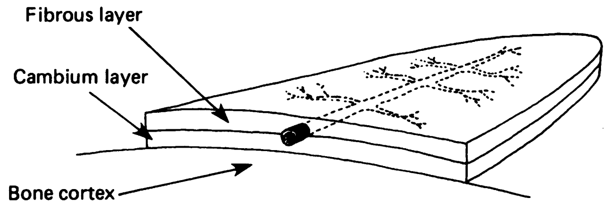


Fig. 1. Intrinsic periosteal vessels lying within the fibrous layer of the periosteum.

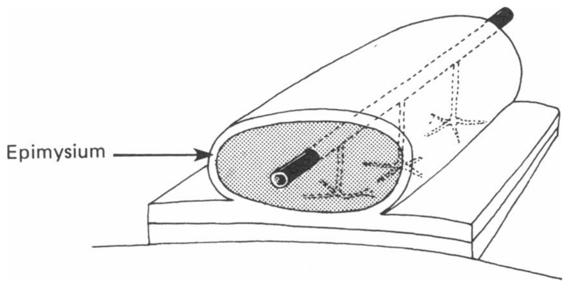


Fig. 2. Musculoperiosteal vessels.

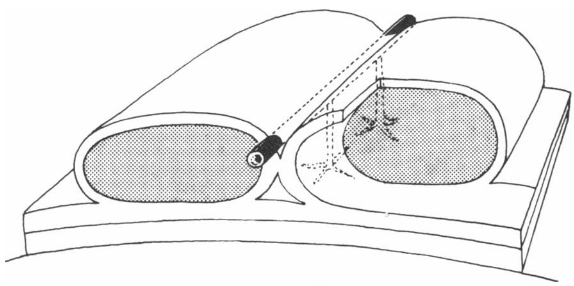


Fig. 3. Fascioperiosteal vessels.

RESULTS

The periosteum consisted of an outer fibrous layer and an inner osteogenic layer. Within the fibrous layer there was a system of vessels (Fig. 1). In some bones this consisted of an arrangement of short vessels, in other bones the vessels followed a predominantly circular pattern (Fig. 4), in others a mainly longitudinal pattern (Fig. 7).

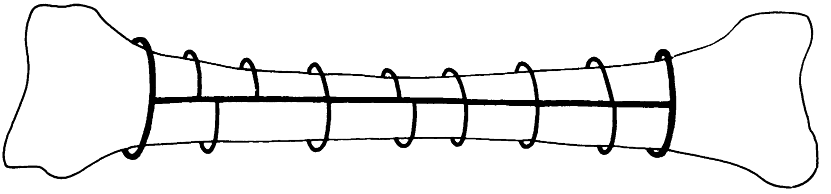
On the upper part of the shaft of the femur (Fig. 6), as a result of complete covering of this part of the surface of the bone by muscle attachments, many musculoperiosteal vessels reached the periosteum. From each of them a group of short vessels arose. A similar but less distinct pattern was seen on the scapula and the hip bone.

On the metatarsal bone, ring vessels arose from the dorsal metatarsal artery and encircled the bone. Finer irregular vessels then linked these rings (Fig. 5).

Vessels running longitudinally in the fibrous layer of the periosteum were found following the anterior margin of the tibia (Fig. 8) and on the medial aspect of the radius descending from the nutrient artery of the radius (Fig. 9).

At each end of the bone, outside the fibrous capsules of the joints there was a network of anastomosing vessels. The longitudinal vessels linked with this system.

There were also some bones where no system predominated but which incorpo-



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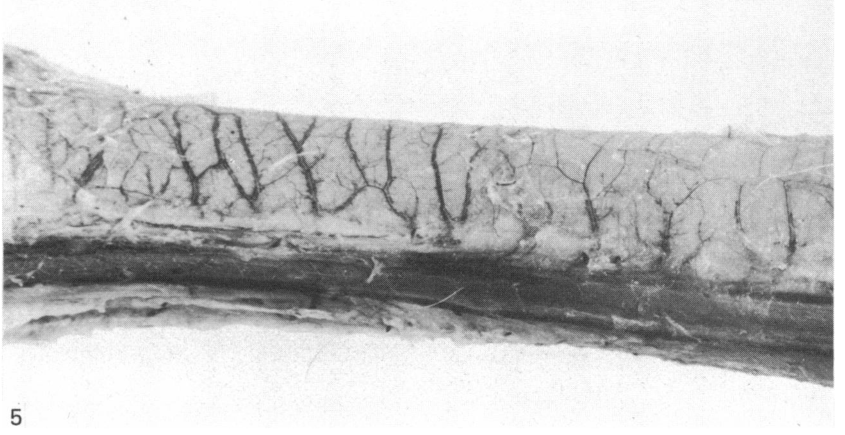

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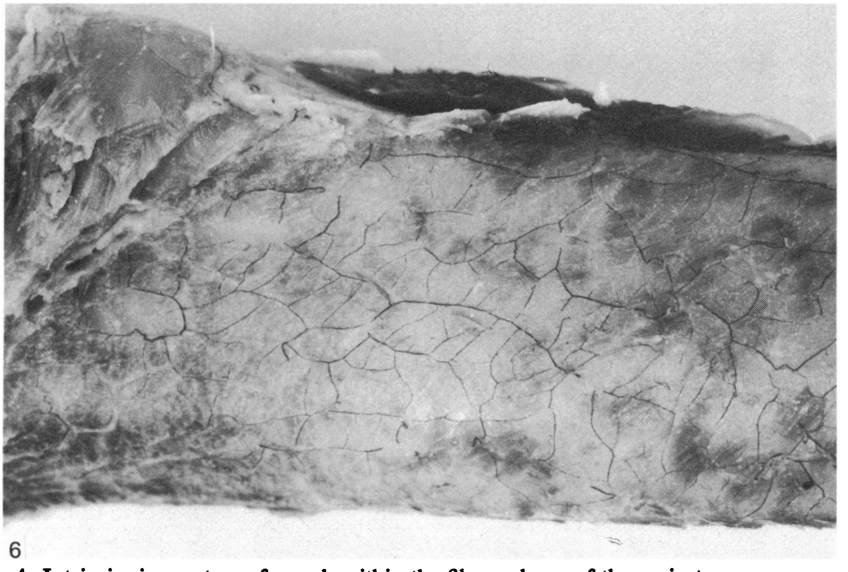

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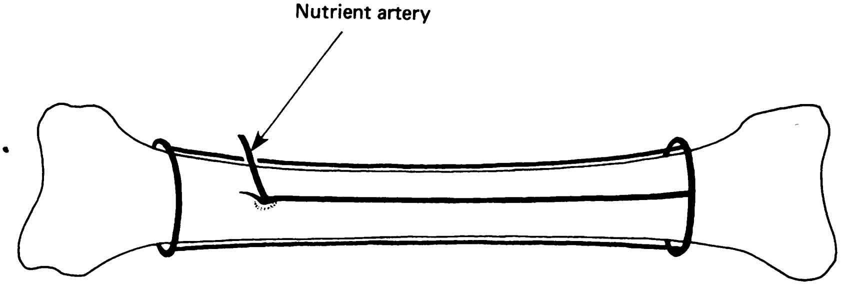
Fig. 4. Intrinsic ring system of vessels within the fibrous layer of the periosteum.

Fig. 5. Ring vessels on metatarsal bone.

Fig. 6. Intrinsic short vessel system within the fibrous layer of the periosteum on the upper shaft and trochanteric area of the femur. × 3.



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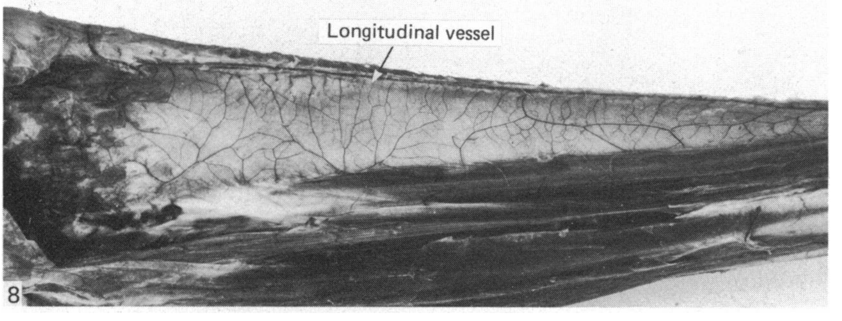

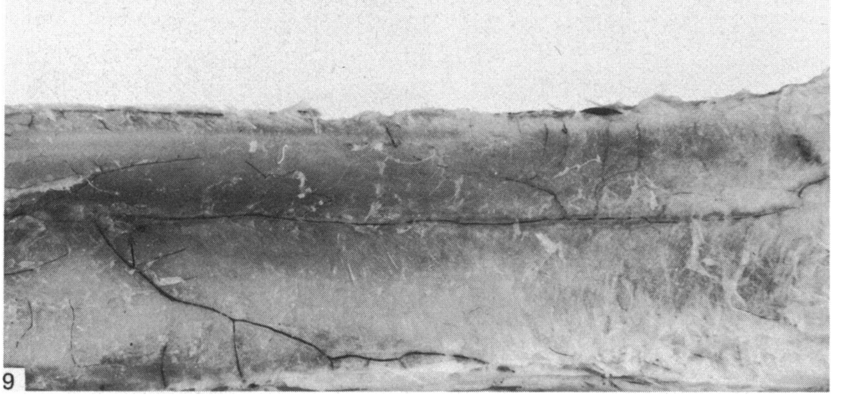

Fig. 7. Intrinsic longitudinal system of vessels within the fibrous layer of the periosteum.

Fig. 8. Longitudinal periosteal vessel following the anterior margin of the tibia. × 0·8.

Fig. 9. Longitudinal periosteal vessel arising from the nutrient artery of the radius. Arrow shows nutrient artery entering the nutrient foramen of the radius. × 3.

Fig. 10. Musculoperiosteal vessels lying within the infraspinatus muscle. Periosteum is seen covering the bone cortex at the bottom left of the Figure. × 10.

Fig. 11. Fascioperiosteal vessels descending from the posterior tibial artery to the periosteum of the tibia. × 3.

Fig. 12. Vessels of the deep fascia communicating with vessels of the periosteum. *T*, muscle tendon; *P*, periosteum covering subcutaneous surface of tibia; *D*, deep fascia pulled away from tibia; *V*, vessel showing a communication between the vessels within the deep fascia and those within the periosteum. × 5.

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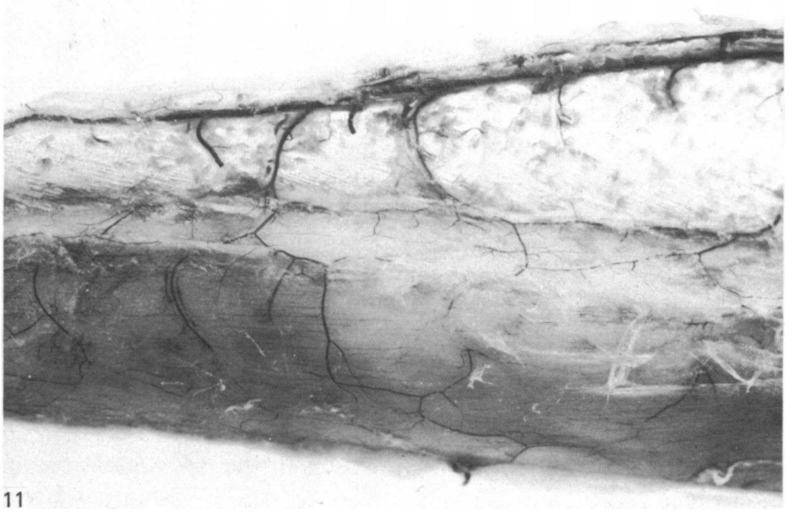

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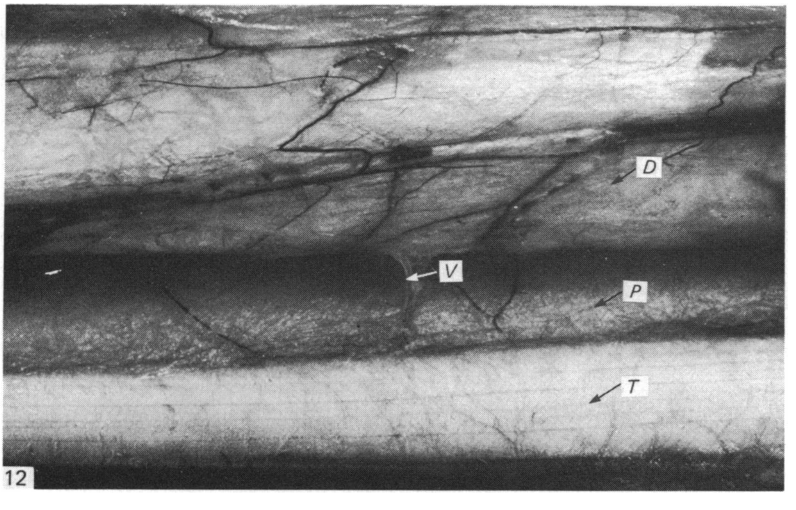

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rated features of more than one of the patterns. The cannon bone of the forelimb was such a bone. This exhibited a mixture of longitudinal and circular patterns.

This network of vessels in the fibous layer of the periosteum derived a blood supply from connections with vessels in muscle, fascia and bone. This last group consisted of capillaries in the bone cortex linking the intramedullary and periosteal circulations and was not displayed in this study.

Where a muscle actually arose from a bone and was attached to it by Sharpey's fibres, the periosteum was fused with the epimysium, in such a way that pulling the muscle from the bone resulted in stripping of the periosteum. It was found that in such a region there was a free anastomosis between the vessels of the muscle and those of the periosteum (Fig. 2). This was most easily shown on the scapula where the vessels of the subscapularis and infraspinatus muscles (Fig. 10) communicated with scapular periosteal vessels; similar anastomoses were also found in other regions where muscle origins were dissected.

Where a muscle belly was lying just adjacent to the bone, and not actually taking origin from it, the epimysium was distinct from the periosteum. Here the muscle could be pulled from the bone without removing the periosteum. In these regions there was movement of the muscle belly relative to the bone. The resultant shearing force might be expected to preclude musculoperiosteal vessels in this region and this was indeed the case, although exceptionally there were a few vessels present.

In some situations where a longitudinal vessel ran down the limb in an intermuscular fascial septum at some distance from the bone, branches arose from the vessel and ran in the fascia between adjacent muscles to reach the periosteum (Fig. 3).

The best example of this in the goat was the branches from the posterior tibial artery running to the periosteum of the tibia between the flexor digitorum longus and flexor digiti I longus muscles (Fig. 11).

On the subcutaneous surface of the tibia the periosteum fused with the deeper strata of the deep fascia and some of the vessels in the deep fascia communicated with the periosteal vessels and formed a second type of 'fascioperiosteal' system (Fig. 12).

DISCUSSION

Previous studies of the feasibility of transplanting periosteum with subsequent bone formation therefrom have indicated that revascularisation of the tissue is essential for success (Finley *et al.* 1978). However, successful experiments with free periosteal grafts (Uddstromer & Ritsila, 1978) challenge this view. The current view is that revascularisation reinforces the bone forming capacities of a graft (van den Wildenberg, 1982) and allows bone formation to start immediately (van den Wildenberg, Goris & Tutein Nolthenius-Puylaert, 1984).

The vessels within the periosteum were examined by Crock (1967) who showed that on the surface of the human femur there existed a system of ring vessels which arose from the perforating branches of the arteria profunda femoris. Unfortunately his dissections only show one aspect of the femur and it is not possible to tell whether it is the medial or lateral aspect. The evidence from the present dissection studies in the goat suggests that a neat ring system of vessels would be most likely on the medial surface of the human femur since most of this aspect is bare and has no fleshy muscle attachment.

Crock also suggested that the vessels in the periosteum of the human tibia conform to a ring pattern, although a modified one. King (1976) has commented on the longitudinal pattern of vessels of the tibia of the dog. The current report shows that the two systems can exist in the same animal and on the same bone. In addition there are some bones which also have a system of short vessels which are only connected by small vessels to the circular and longitudinal systems. These short vessels exist where there is a fleshy muscle attachment and are supplied by the musculoperiosteal vessels.

The link between the vessels of muscle and periosteum was clearly shown by Zucman (1960) who demonstrated that the intrinsic periosteal vessels can limit the extent of ischaemia in a muscle that has had its other vascular supply removed. This effect is enhanced if the periosteum has been stripped from the bone, as this results in a reactive hyperaemia. In a careful study of the blood supply of bone, Brookes (1971) has shown that capillaries within the cortex link the medullary and periosteal vessels and concludes that flow in the healthy adult bone is from the medulla outwards, although with peripheral vascular disease the flow may be reversed. Thus, via this capillary anastomosis, the bone blood supply is another source of blood for the periosteum. However, Zucman's experiments suggest that these connections are only minor, so the bone medullary circulation is probably not a major source of supply for the periosteum.

The blood supply of periosteum has a number of analogous features to the blood supply of skin. Following the observation of Ponten (1981) that inclusion of the deep fascia improves the survival of pedicled skin flaps on the lower leg, Cormack & Lamberty (1984) have recently shown that there is a fasciocutaneous system of vessels. Where an artery runs at a distance from the bone separated from it by an intermuscular septum (which may just represent two fused layers of epimysium) there is the potential for a fascioperiosteal system of vessels.

This fascial system of vessels has hitherto been unreported for periosteum.

SUMMARY

Twelve goat limbs were injected with red latex and then carefully dissected to display the vessels of the periosteum. The blood supply of periosteum was found to be derived from four sets of vessels: (1) Intrinsic periosteal system. (2) Musculoperiosteal system. (3) Fascioperiosteal system. (4) Cortical capillary anastomoses.

The intrinsic system of vessels lay within the fibrous layer of the periosteum. Acccording to the pattern of these vessels they could be divided into: (*a*) a short vessel pattern, where there were many small vessels with no predominant direction; (*b*) a circular pattern, where the vessels encircled the bone; (*c*) a longitudinal pattern, where the vessels ran parallel to the long axis of the bone.

The musculoperiosteal system consisted of connections between the muscle circulation and the periosteal vessels at the sites of muscle origin.

The fascioperiosteal system consisted of branches from a limb artery that ran in a fascial plane between muscles to supply the periosteum.

The cortical capillary anastomosis consisted of capillaries that ran in the bone cortex between the intramedullary circulation and the periosteal vessels.

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