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Editorial

# Femoral and tibial blood supply: A trigger for non-union?

The blood supply of bone is of vital importance in both physiological and pathological conditions. During the fracture healing process in particular, it plays an essential role by facilitating bone resorption and callus formation and subsequently through the process of neoangiogenesis and revascularisation at the fracture site; it contributes to the development of endochondral ossification. The formation of vascular osseous tissue from the avascular cartilaginous tissue constitutes the hallmark of a successful fracture healing response [1–4].

The blood supply of long bones is provided by three main systems of vessels including the nutrient system, the metaphyseal–epiphyseal system and the periosteal system [5–12].

The Nutrient system is the principal one supplying the bone marrow and the inner two thirds of the diaphyseal cortex and anastomoses both with the metaphyseal system at the end of the diaphysis and with the periosteal system [5,6]. The metaphyseal–epiphyseal system provides blood supply to the distal part of the bone and it anastomoses with the Nutrient system [5,6,8].

The periosteal system is composed by many small branches that pierce the cortex with a transversal type of orientation and supplies the outer third of the bone, anastomosing with the nutrient vessels [5–8]. These small branches were found to be capillaries with thin walls without any muscular or elastic tissue [5], especially numerous under muscular and ligamentous attachments [6].

While most long bones possess the vascularisation pattern previously described, anatomical characteristics exist and certain bones in the human skeleton, (i.e. the carpal scaphoid, the fifth metatarsal and the proximal femur) have been shown to have a distinct blood supply distribution, which under certain injury related conditions may be damaged leading to the phenomenon of idiopathic local bone necrosis and an impaired fracture healing response [13–16]. Over the years, a lot of scientific attention has been given to the phenomenon of avascular necrosis of the above mentioned bones but interestingly, less attention has been given on the blood supply distribution of other bones and particularly the femur and the tibia which are known to be associated with a high non-union rate [17].

Are there any areas of compromised blood supply in the femur and tibia where following a fracture an impaired healing response could be attributed amongst others to the poor local vascular tree distribution?

A review of the literature was undertaken to investigate the existing evidence of the vascular distribution of the shaft area of both the femur and the tibia in order to assess whether there are any distinct zones of a compromised blood supply predisposing these areas to an increased risk of non-union following a fracture.

The review was conducted in a systematic manner following the PRISMA guidelines [18].

Studies were identified by searching the literature from 1946 to the present day using the following databases: Ovid Medline, PubMed Medline, Embase and the Cochrane Library.

The search consisted of titles and abstracts containing the following keywords: 'femur' OR 'tibia' OR 'long bones' AND 'blood supply' OR 'vascularization' OR 'nutrient artery' OR 'nutrient foramina'. The bibliographies of each identified article were reviewed in order to retrieve any further eligible articles. Original articles were selected that satisfied the following inclusion criteria: (1) containing description of the anatomical femoral and tibial blood supply of the diaphysis of these bones; (2) the full text of the article was available; (3) studies could be of anatomical, surgical or imaging nature. Clinical studies reporting on less than 10 patients, animal and foetal studies and studies other than the English language were excluded.

The articles were reviewed by an unblinded, standardised method. Most citations were excluded based on their titles or abstracts. Of the citations that met the inclusion criteria, the full manuscript was obtained and carefully reviewed. Relevant information about journal name, publication year, author's name, type of study, patients' demographics, origin, number and distribution of femoral and tibial nutrient arteries and their branches, number, location and level of femoral and tibial nutrient foramina, and direction of nutrient artery within the canal, origin and distribution of femoral and tibial periosteal arteries were carefully extracted.

## Results

The electronic search initially retrieved 2509 manuscripts, but only 21 [5,10–12,19–35] fulfilled the inclusion criteria. The search through the bibliographies of the original 2509 results, aided in the collection of a further 43 studies, of which five [36–40] met the inclusion criteria. In total 26 articles [5,10–12,19–40] formed the basis of this review (Fig. 1).

The overall sample size of the studies which specified the number of specimens was 3577 bones, of which 2243 were femurs and 1382 were tibias. The specimens were aged between 21 and 98 years (three articles [28,38,39] included a minority of children but their age was not specified). Some of the selected papers contained more than one study of interest: three articles [25,36,37] contained more than one study (three in total) whereas another

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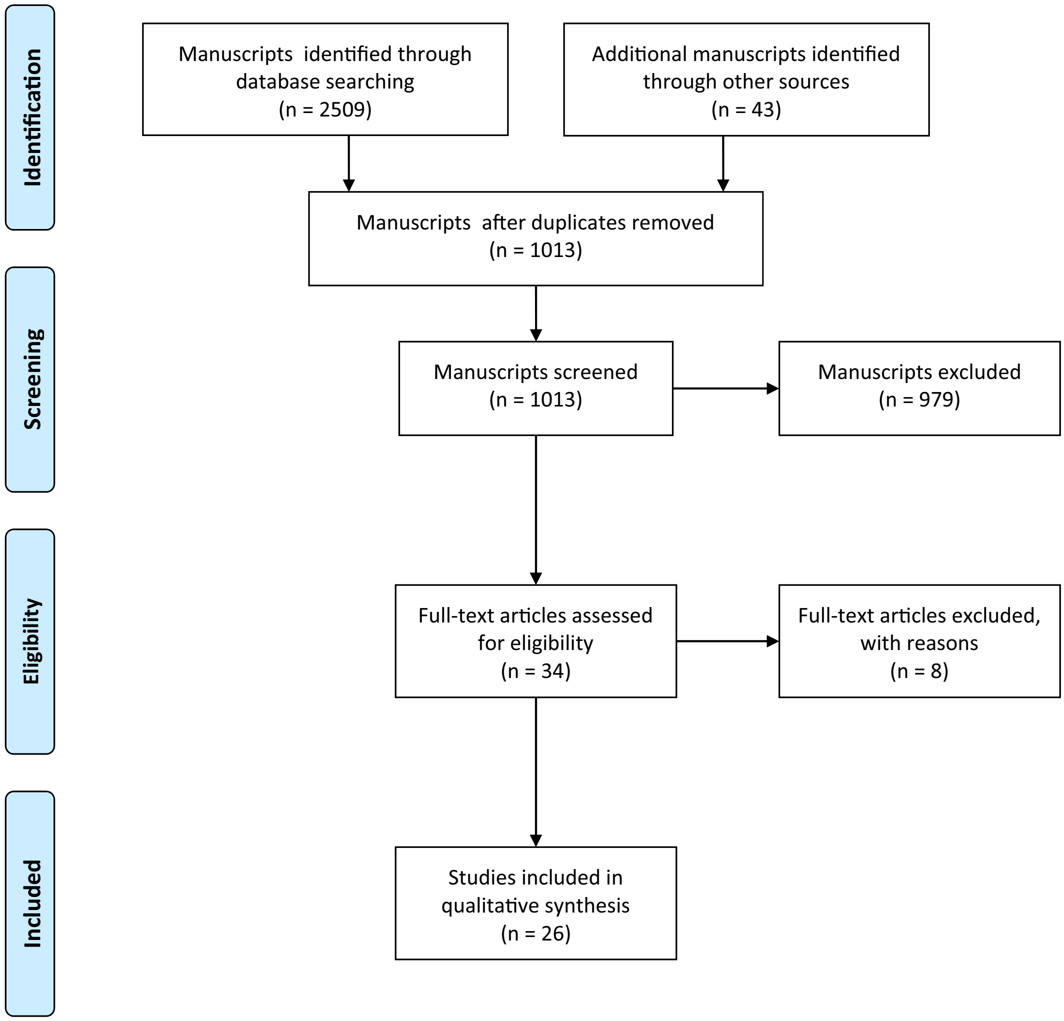


**Fig. 1.** Summary of search strategy.

five articles [5,24,35,38,39] contained two different studies. Thus, out of 26 articles we were able to analyse 37 studies: 28 anatomical and 9 imaging studies. Frequently, studies of both the femur and the tibia were reported in the same manuscript (31 [5,10–12, 19–40] were about the femur and 19 [5,11,20,22–27,29–32,34,40] about the tibia). An anatomical description of the nutrient vascular system was outlined in 12 articles [5,10,19–21,24,25,35–39], the periosteal vascular system in eight articles [5,11,19,20,25,29, 36,39] and information of nutrient foramina characteristics was given by 18 articles (Tables 1–4) [12,20–23,25–28,30–34, 36–38,40].

For the purpose of this study, focus was given to the nutrient and periosteal vascular systems of the femur and tibia.

*Femur*

*Nutrient vascular system*

The number of nutrient arteries supplying the femur have been found to be variable with studies reporting some femurs having two arteries and others having just one [20,35–39].

Most commonly the nutrient arteries derive from the perforating branches of the deep femoral artery [25,36,38,39], whereas in some cases it was found to arise directly from the deep femoral artery itself [20]. In case of a single artery, it has been described as originating from the second perforating artery [10,19,21]. Where two arteries were described, some authors found the superior one arising from the first perforating artery and the inferior one arising from one of the other perforating arteries with a varying manner [21,38].

The nutrient artery was found by a number of authors to enter the bone through the nutrient foramen, usually going upwards towards the femoral head and away from the knee [30–32]. However, recent research found a small sample of femurs exhibiting a transverse and downward direction of the canals [12].

Several studies have been conducted on the nutrient foramina, considering their number, location and level [12,20–23,25–28,30–32,34,35,37,40] (Table 5).

There was no conclusive evidence with respect to the number of foramina. Half of the studies found the majority of the femurs to have one foramen [23,26–28,32,35,37,40], while the other half exhibited a majority of their femurs containing two foramina [12,22,30,31,34]. Almost every study found a small sample of femurs with three foramina [22,23,25,27,28,30–32,34,40] and just few of them found femurs with more than three foramina [23,27,30,34]. Finally, some studies reported few cases without foramina [23,30,32,37].

Some studies have reported differences relating to gender and the number of foramina.

Men were found to have 2:1 chances of having two foramina on the left leg and 2:1 probabilities of having a single one on the right leg. Women showed a 2:1 chance of having two foramina in the right leg [36,37].

With regards to the location of the nutrient foramina most of the studies described them as mainly being located on the