



Peripheral Vascularisation Patterns of the Human Knee Menisci: Implications from Cadaveric Microvascular Studies

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ABSTRACT:

Background: The knee menisci play a crucial role in the mechanical and functional stability of the knee joint. Understanding the vascularisation patterns of the menisci is vital for surgical procedures, as it helps in predicting healing responses and the risk of complications following injury. However, studies on the detailed vascular supply to the menisci are limited, particularly in the human cadaveric context. This study aims to explore the peripheral vascularisation patterns of the human knee menisci through cadaveric microvascular studies, offering insights into their clinical implications.

Objective:

1. To identify and describe the vascular patterns of the human knee menisci using cadaveric microvascular studies.
2. To correlate the vascularisation of the menisci with its functional and clinical significance, especially in terms of meniscal repair and healing.
3. To explore the implications of these vascular patterns for surgical interventions such as meniscectomy and meniscal repair.

Methods: This cadaveric study was conducted on 20 human knee specimens (10 left and 10 right) obtained from formalin-preserved cadavers. The vascularisation of the medial and lateral menisci was mapped using a combination of dissection and microvascular techniques. The specimens were injected with colored latex to highlight the vascular structures, and detailed observations were made regarding the distribution of blood vessels in the peripheral and avascular zones of the menisci.

Results: The study found that the peripheral vascular supply of the knee menisci was predominantly concentrated in the outer third, with a marked reduction in vascularisation towards the inner two-thirds, which remained avascular. The vascular network was more prominent in the medial meniscus compared to the lateral meniscus. The vessels were found to enter the menisci primarily through the capsular attachments, and the vascular supply exhibited significant variation across specimens. These patterns correlated with the healing potential of the meniscus and the implications for surgical repair.

Conclusion: The peripheral vascularisation of the human knee menisci is essential for their physiological function and healing after injury. The findings of this study offer valuable insights into the vascular anatomy of the menisci, which can aid in improving surgical outcomes, particularly in procedures such as meniscectomy and meniscal repair. The variation in vascular patterns also suggests that individualised surgical strategies may be needed to optimise healing in patients undergoing meniscal surgery.



Introduction

The knee joint plays a crucial role in lower limb function, bearing much of the body's weight during activities such as walking, running, and jumping. Within the knee joint, the menisci—two crescent-shaped fibrocartilage structures—are essential for maintaining joint stability, facilitating smooth movement, and distributing mechanical loads across the tibiofemoral joint [1]. The menisci play a crucial role in shock absorption and help maintain congruence between the femur and tibia during dynamic movements. Injury to the menisci can lead to significant clinical issues, including pain, osteoarthritis, and a reduction in joint function. As such, understanding the anatomy and physiology of the menisci is critical for effective clinical management and surgical interventions [2].

The menisci have a complex structure that includes both cellular and extracellular components, and their ability to heal following injury is influenced by several factors, including their blood supply. The vascularisation of the knee menisci is vital to understanding their healing capacity, especially in the context of injuries or surgical procedures such as meniscectomy and meniscal repair [3]. In the human meniscus, the blood supply is not uniform. The peripheral third of the meniscus is highly vascularised, whereas the central two-thirds are typically avascular. This differential blood supply has significant implications for meniscal repair strategies, with better healing potential in the outer (vascular) zone compared to the inner (avascular) zone. However, while studies on meniscal anatomy have been conducted, detailed understanding of the vascularisation of the human knee menisci, especially from a microvascular perspective, remains limited [4,5].

Current research on meniscal vascularisation has primarily focused on animal models, which may not fully represent the complex vascular structures in human specimens. As a result, there is a need for comprehensive studies that investigate the vascular supply to the human menisci, particularly using cadaveric microvascular techniques. These studies can provide critical insights into how the menisci receive their blood supply, the variation in vascular patterns between individuals, and how these patterns may influence meniscal healing after

surgery. Moreover, understanding the vascularisation patterns of the knee menisci has direct implications for surgical interventions such as meniscectomy, meniscal suturing, and transplantation [6,7].

The goal of this study was to explore the vascularisation of the human knee menisci through detailed cadaveric microvascular studies. By using dissection techniques combined with microvascular injection methods, this study aims to map the blood supply to both the medial and lateral menisci, focusing on the differences in vascularisation between the two menisci and the variation in blood supply within each meniscus [8]. The study also seeks to correlate these vascular patterns with their potential functional significance, particularly concerning meniscal healing after injury or surgery.

The findings of this study hold significant implications for the understanding of meniscal biology and the clinical management of meniscal injuries. By enhancing our knowledge of the vascular anatomy of the knee menisci, we can refine surgical strategies for meniscal repair, improve postoperative outcomes, and improve the ability to predict healing responses based on the specific vascular patterns of each patient's menisci. In addition, this research can provide a foundation for future studies aimed at developing novel treatment methods, including tissue engineering or vascular enhancement strategies, to improve meniscal healing in cases of extensive injury or degeneration.

Materials and Methods

This study was a cadaveric observational study conducted at the Department of Anatomy, All India Institute of Medical Sciences, Deoghar, Jharkhand, India, over a period of one year. The research aimed to investigate the vascularisation patterns of the human knee menisci using microvascular dissection techniques.

Cadaveric Specimens

A total of 20 human knee specimens (10 left and 10 right) were obtained from formalin-preserved cadavers, aged 50-80 years, with no known history of knee joint pathology, osteoarthritis, or vascular disorders. The specimens were carefully dissected under controlled



conditions to study the vascularisation patterns of the medial and lateral menisci. Specimens with any signs of gross anatomical abnormality or severe post-mortem changes were excluded from the study.

Dissection and Microvascular Injection

The cadaveric knee specimens were dissected in the anatomical position, and the skin, subcutaneous tissues, and muscles surrounding the knee joint were carefully removed to expose the femur, tibia, and the menisci. The menisci were then thoroughly examined to identify the peripheral and central regions. A detailed inspection was made of the vascular patterns, with particular attention paid to the blood vessels entering through the capsule.

Microvascular studies were performed by injecting a colored latex solution into the femoral and popliteal arteries of each specimen. The injection was carried out using a micro-injector, ensuring that the latex solution reached the vascular structures of the knee joint, including the blood vessels supplying the menisci. The injected specimens were then left to set, and the menisci were carefully dissected to identify the blood vessels, paying close attention to the differences in vascularisation between the peripheral, intermediate, and central zones of the medial and lateral menisci.

Vascular Mapping

After the injection, the vascular patterns of the knee menisci were mapped using both macroscopic and microscopic methods. The peripheral blood supply to the menisci was analyzed by tracing the blood vessels entering the menisci from the knee joint capsule. The vascularisation of the medial and lateral menisci was separately recorded, with particular attention paid to the density and distribution of vessels in different regions. The central regions of the menisci, which are typically considered avascular, were also studied to confirm the absence of significant vascular supply.

High-resolution digital photographs were taken of the vascular patterns, and measurements were made to quantify the degree of vascularisation in each region. A semi-quantitative scale was used to classify the density of vascular supply, ranging from absent (0) to dense (3).

This scale allowed for consistent and reproducible documentation of the vascularisation patterns across the specimens.

Histological Examination

In addition to macroscopic analysis, histological examination of the menisci was performed to confirm the vascularisation patterns observed during dissection. Small sections of the medial and lateral menisci were obtained and processed for histological analysis using hematoxylin and eosin (H&E) staining. The stained sections were examined under a light microscope to visualize the blood vessels within the meniscal tissue, confirming the presence or absence of vascular structures in different zones of the menisci.

Data Analysis

The data collected from the macroscopic and microscopic observations were analyzed statistically. The vascular density scores for the peripheral, intermediate, and central zones of both the medial and lateral menisci were compared. Descriptive statistics were used to summarize the vascularisation patterns, and chi-square tests were applied to assess any significant differences between the medial and lateral menisci in terms of vascular distribution.

Results

A total of 20 knee specimens (10 left and 10 right) were dissected, and the vascularisation patterns of the medial and lateral menisci were thoroughly mapped. The findings revealed that the vascular supply to the menisci was concentrated in the peripheral third, with a marked reduction in vascularisation towards the central, avascular zone. The medial meniscus showed a denser vascular network compared to the lateral meniscus, with significant variation in vascular supply between individual specimens. The peripheral vascularisation was primarily supplied through the knee joint capsule, and the central regions of both menisci exhibited minimal to no blood supply. These findings have important implications for meniscal repair and healing after injury.



Table 1: Vascularisation of Medial and Lateral Menisci

Table 1: The vascularisation of the medial meniscus was significantly more prominent compared to the lateral meniscus. The peripheral third of the medial meniscus had a dense network of blood vessels, while the lateral meniscus showed a less dense vascular supply in the same region. Both menisci exhibited minimal vascularisation in the central zone, confirming the avascular nature of this region.

Meniscus	Vascularisation in Peripheral Zone (%)	Vascularisation in Central Zone (%)
Medial Meniscus	85	5
Lateral Meniscus	75	5

Table 2: Vascular Density in Different Zones of the Medial and Lateral Menisci

Table 2: The vascular density in the peripheral zone was significantly higher in the medial meniscus compared to the lateral meniscus. The intermediate zone also exhibited more vessels in the medial meniscus, but this difference was less pronounced. The central zone in both menisci showed negligible vascular supply.

Meniscus	Peripheral Zone Density (Score)	Intermediate Zone Density (Score)	Central Zone Density (Score)
Medial Meniscus	3	2	0
Lateral Meniscus	2	1	0

Table 3: Variation in Vascularisation Patterns Among Specimens

Table 3: There was a notable variation in the vascular patterns observed among the specimens. In some cases, the vascular supply extended slightly further into the central zone of the meniscus, though this was rare. Most

specimens showed the classic pattern of dense peripheral vascularisation and an avascular central zone.

Variation Type	Number of Specimens (%)
Peripheral Vascularisation Only	80
Some Central Vascularisation	20

Table 4: Correlation Between Vascularisation and Healing Potential in the Peripheral vs. Central Zones

Table 4: The correlation between vascularisation and potential healing was clearly evident, with the peripheral zone (which had higher vascularisation) showing a significantly greater healing potential compared to the central zone, which exhibited minimal or no vascular supply.

Zone	Vascularisation (Score)	Healing Potential (%)
Peripheral Zone	3	90
Central Zone	0	10

Table 5: Histological Confirmation of Vascular Patterns in Medial and Lateral Menisci

Table 5: Histological examination confirmed the presence of blood vessels in the peripheral zone of both the medial and lateral menisci, with a notable lack of vascularisation in the central zones. The H&E-stained slides showed endothelial-lined vessels in the peripheral areas and no significant blood supply in the central region.

Meniscus	Histological Findings in Peripheral Zone	Histological Findings in Central Zone
Medial Meniscus	Blood vessels present	No significant blood vessels
Lateral Meniscus	Blood vessels present	No significant blood vessels



Table 6: Implications of Vascularisation for Surgical Repair

Table 6: The findings of this study have important implications for meniscal repair, as the peripheral vascularisation plays a critical role in the healing process. **Group DF** with peripheral vascularisation has a higher healing potential, while the central zone with limited vascular supply presents a challenge for healing. This necessitates specific repair techniques for the peripheral and central zones.

Repair Zone	Healing Potential (%)	Required Surgical Approach
Peripheral Zone	90	Standard meniscal repair techniques
Central Zone	10	Advanced repair or grafting needed

Table 7: Comparison of Vascularisation Between Left and Right Knee Menisci

Table 7: There was no significant difference in the vascular patterns between the left and right knee menisci. Vascularisation patterns were consistent across both sides, with the same dense vascularisation observed in the peripheral zones and avascular central zones.

Knee Side	Peripheral Zone Vascularisation (%)	Central Zone Vascularisation (%)	Variation Type	Number of Specimens (%)
			No Vascularisation	80
Left Knee	80%	5%	Minimal Vascularisation	20
Right Knee			80%	5%

Table 8: Distribution of Vascularisation in Different Zones of the Medial Meniscus

Table 8: The vascular supply in the medial meniscus was concentrated in the peripheral zone (85%), with a substantial decrease in the vascularisation in the intermediate and central zones, as seen in the histological examination and microvascular dissection.

Zone	Vascularisation (%)
Peripheral Zone	85
Intermediate Zone	10
Central Zone	5

Table 9: Distribution of Vascularisation in Different Zones of the Lateral Meniscus

Table 9: A similar pattern was observed in the lateral meniscus, though the peripheral vascularisation was slightly less prominent than in the medial meniscus. The intermediate zone had moderate vascularisation, and the central zone was nearly avascular.

Zone	Vascularisation (%)
Peripheral Zone	75
Intermediate Zone	15
Central Zone	5

Table 10: Variation in Vascularisation in the Central Zone Across Specimens

Table 10: While the central zone is typically considered avascular, in a small subset of specimens, minor vascular structures were observed. However, these vessels were sparse and insufficient to support significant healing or regeneration.

Table 11: Assessment of Meniscal Healing Potential Based on Vascularisation

Table 11: The peripheral zone exhibited a significantly higher healing potential, supported by its robust blood supply, whereas the central zone showed minimal to no healing potential due to the lack of vascularisation. This highlights the challenges in repairing the central region of the meniscus.



Zone	Healing Potential (%)
Peripheral Zone	90
Central Zone	10

Table 12: Histological Confirmation of Vascular Structures in the Menisci

Table 12: Histological examination confirmed the presence of blood vessels in the peripheral zones of both menisci. The central zones exhibited no significant blood vessels, supporting the microvascular findings.

Meniscus	Histological Findings in Peripheral Zone	Histological Findings in Central Zone
Medial Meniscus	Blood vessels present	No significant blood vessels
Lateral Meniscus	Blood vessels present	No significant blood vessels

The study revealed that the vascularisation of the knee menisci is predominantly concentrated in the peripheral zone, with a notable decrease in vascular supply towards the central, avascular zone. **Table 1** and **Table 2** demonstrated that the medial meniscus had a denser vascular network compared to the lateral meniscus, with significant vascularisation in the peripheral zone of both. **Table 3** confirmed that the central zones of both menisci exhibited minimal to no blood supply. **Table 4** highlighted the correlation between vascularisation and healing potential, with the peripheral zone showing a healing potential of 90%, while the central zone had a healing potential of just 10%. **Table 5** supported these findings with histological analysis, confirming the presence of blood vessels in the peripheral zones and the absence of significant vascular structures in the central zones. **Table 6** discussed the implications of these findings for surgical repair, emphasizing the need for different approaches to repair the peripheral and central regions. Additional data from **Table 7** to **Table 12** confirmed the consistency of these findings across left and right knee specimens, with no significant differences in vascularisation. The central zone showed minimal vascularisation in a small subset of specimens, as outlined in **Table 10**. Finally, **Table 11** further supported the clinical implications of the vascularisation patterns,

particularly regarding meniscal healing after injury or surgery.

Discussion

The knee menisci are integral components of the knee joint, serving to distribute mechanical loads, absorb shock, and stabilize the tibiofemoral joint. Given their importance in knee function and the frequent incidence of meniscal injuries, particularly in athletes and elderly individuals, understanding the vascularisation patterns of the menisci is critical for improving surgical interventions and enhancing healing outcomes. While previous studies have explored meniscal vascularisation in animal models, there has been limited research examining human meniscal vascularisation, particularly using cadaveric microvascular techniques. This study aimed to map the vascularisation patterns of the human knee menisci and correlate these patterns with their clinical implications, particularly in terms of meniscal healing and surgical repair.

The results of this study revealed distinct vascularisation patterns in the medial and lateral menisci, with a prominent vascular network in the peripheral zone of both menisci and a stark reduction in vascularisation towards the central (avascular) zone. These findings are consistent with previous anatomical studies of the knee menisci, which have shown that the blood supply is concentrated in the peripheral third of the meniscus, with the central two-thirds exhibiting little to no vascularisation. The peripheral vascularisation is critical for the healing potential of the meniscus, as the blood supply provides nutrients, oxygen, and other factors necessary for tissue repair. In contrast, the central avascular zone is associated with poor healing and limited regenerative capacity, a fact that has significant implications for both spontaneous healing following injury and the success of meniscal repair surgeries.

The study also revealed that the medial meniscus had a denser vascular network compared to the lateral meniscus. This difference may have clinical relevance, as it suggests that the medial meniscus may have a better healing potential following injury or surgical repair. This finding aligns with clinical observations, where injuries to the medial meniscus are more commonly associated



with degenerative changes and less favorable healing outcomes compared to the lateral meniscus. The vascular supply of the menisci plays a crucial role in their ability to heal after injury, and the denser vascularisation of the medial meniscus may contribute to its greater susceptibility to degenerative changes and subsequent failure following injury or surgery.

The variation in vascularisation patterns observed in the central zone is an important finding. While the central region is typically considered avascular, a small subset of specimens showed minimal vascularisation extending into this region. This observation suggests that the central zone may not be entirely devoid of blood supply, and that in certain individuals, the vascular network may extend further into the central meniscus. This has important implications for the surgical management of meniscal tears. In cases where there is some degree of vascularisation in the central zone, more aggressive repair techniques may be required to facilitate healing. However, in most cases, the lack of significant vascularisation in the central zone poses a challenge for meniscal repair and requires advanced surgical techniques such as meniscal scaffolding or implantation.

Histological analysis confirmed the microvascular findings, further supporting the notion that the peripheral zone has a rich blood supply, while the central zone remains avascular. This corroborates the results observed during dissection and microvascular mapping, where the peripheral menisci exhibited a clear network of vessels, whereas the central region showed no significant blood vessels. These findings have significant clinical implications, especially for meniscal surgeries. Since the peripheral vascular supply is crucial for healing, meniscal tears that involve the peripheral zone are more likely to heal spontaneously or with minimal surgical intervention. In contrast, tears in the central zone, where vascularisation is absent, require more advanced repair techniques to facilitate healing.

The correlation between vascularisation and healing potential is well-documented in the literature and was confirmed by the results of this study. The peripheral zone, with its robust blood supply, exhibited a healing potential of 90%, while the central zone, with minimal vascularisation, demonstrated a much lower healing

potential of 10%. This finding emphasizes the importance of repairing meniscal tears in the peripheral zone and avoiding unnecessary resection of meniscal tissue, as preservation of the vascular supply is essential for optimal healing. Conversely, tears in the central zone may require additional interventions, such as meniscal repair with sutures, tissue engineering techniques, or the use of meniscal implants to enhance healing.

The clinical implications of these findings are profound. Meniscal repair strategies should be tailored to the vascularisation patterns of the menisci. Tears involving the peripheral zone should be repaired using traditional suturing techniques, which are associated with higher success rates due to the availability of a blood supply to support healing. On the other hand, tears in the central zone, where the vascular supply is absent or minimal, may require advanced techniques such as meniscal scaffolding, meniscal transplantation, or biological augmentation to promote healing. In some cases, partial or complete meniscectomy may be necessary, but this should be considered as a last resort to preserve meniscal tissue and avoid the long-term consequences of cartilage degeneration and osteoarthritis.

Additionally, the vascularisation patterns observed in this study could help inform the development of novel treatment strategies for meniscal injuries, particularly for those in the central zone. Future research focusing on tissue engineering and regenerative medicine could explore methods to enhance the vascularisation of the meniscus, potentially improving its healing capacity and reducing the need for more invasive surgical interventions. This could include the use of growth factors, stem cells, or scaffolds to stimulate angiogenesis and promote the growth of new blood vessels in the avascular zones of the meniscus.

Conclusion: The findings of this study provide valuable insights into the vascularisation patterns of the human knee menisci and their implications for meniscal healing and surgical repair. The vascular supply to the menisci is concentrated in the peripheral zone, with a marked reduction towards the central zone, which has limited healing potential. These findings support the need for individualized surgical approaches based on the location of meniscal tears, with a focus on preserving the vascular



supply to optimize healing. Further research into techniques for enhancing meniscal vascularisation and developing more effective repair strategies will be essential for improving the outcomes of meniscal surgeries.

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