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Early development of the cruciate ligaments in staged human embryos

Wojciech Ratajczak

Department of Anatomy, Karol Marcinkowski University School of Medical Sciences, Poland

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Investigations were carried out on 43 serially sectioned human embryos of developmental stages 18 to 23.

The homogenous interzone of the future knee joint is observed in embryos at stage 18. During stage 19 this interzone is differentiated into dense, intensively stained, peripheral parts, which are the primordia of menisci and the medial portion, in which the cruciate ligaments are formed. All structures of the interior of the knee joint are more clearly delineated during stage 20, and they are well developed during the last embryonic week (stages 21–23).

key words: human embryology, development of joints, knee joint, cruciate ligaments

INTRODUCTION

Increasing interest in the development of the cruciate ligaments is due to their clinical importance for stabilisation of the knee joint and for locomotion [10,15]. Despite many studies on the development of the knee joint [1–3,5,7,8] the development of the cruciate ligaments and menisci is not well elucidated as yet. The cruciate ligaments are thought to be derivatives of the homogenous articular interzone [3,9] or the knee joint capsule [7]. Moreover, the exact time of their appearance differs according to authors [1,3,6,8,9]. The purpose of the present study is to trace the early development of the cruciate ligaments in staged human embryos in order to determine the time of appearance and their position among intraarticular structures.

MATERIAL AND METHODS

Investigations were carried out on 43 embryos at developmental stages 18 to 23 (44–56 postovulatory days). The embryos belong to the collection of the Department of Anatomy, University School of Medical Sciences in Poznań. The age of embryos was estimated according to developmental stages [12]. Crown-rump length (C-R), plane of section, age in postovulatory days, and developmental stage are shown in Table 1. Serial sections of embryos in different planes were stained with routine histological methods as well as according to Mallory staining.

RESULTS

In stage 18 the process of chondrification of the bodies of femur and tibia begins. Clearly visible mesenchymal condyles of the femur are observed. Between the blastemal ends of femur and tibia the homogenous interzone is found.

In stage 19 the condyles of the tibia and femur are more advanced. The homogenous interzone begins to differentiate. Cells of peripheral parts of the interzone, which form primordium of menisci, are densely packed, darkly stained and form a distinctive layer. In the middle part of the interzone which faces the intercondylar fossa of the femur the cells are more loosely arranged in obliquely passing strands, forming primordium of the cruciate ligaments (Fig. 1, 2). In stages 20 and 21 chondrification of condyles of the femur and tibia begins. Moreover, in stage 21 the formation of joint cavity in the

Address for correspondence: Wojciech Ratajczak, MD, Department of Anatomy, Karol Marcinkowski University School of Medical Sciences, ul. Święcickiego 6, 60–781 Poznań, Poland, tel: +48 61 86 99 181, fax: +48 61 86 58 985

Table 1. Features of the specimens used

Embryo	C-R length [mm]	Developmental stage	Age in days	Plane of section
B 122	14.5	18	44	frontal
Bł 4	15.0	18	44	transverse
A 6	15.5	18	44	transverse
Z 11	16.0	18	44	sagittal
B 66	16.5	19	46	transverse
A 1	17.0	19	46	transverse
Bł 5	17.0	19	46	transverse
Z 13	17.0	19	46	frontal
Bł 10	17.5	19	46	transverse
B 123	17.5	19	46	sagittal
Bł 9	17.5	19	46	transverse
X 19	17.5	19	46	sagittal
A 10	18.0	19	46	transverse
KA 2	18.5	19	46	transverse
KA 3	18.5	19	46	sagittal
PJK 1	19.0	19	46	sagittal
B 126	19.0	19	46	transverse
B 173	19.0	19	46	transverse
B 99	19.5	20	49	transverse
Bł 3	20.0	20	49	frontal
Bł 2	20.0	20	49	sagittal
PJK 27	18.0	20	49	transverse
B 124	19.5	20	49	sagittal
Z 19	20.0	20	49	transverse
B 76	20.0	20	49	transverse
B 178	20.0	20	49	sagittal
B 127	23.5	21	51	sagittal
B 170	22.5	21	51	transverse
A 4	23.5	21	51	frontal
PK 61	24.5	21	51	sagittal
A 13	26.0	22	52	frontal
Z 3	26.5	22	52	transverse
Z 2	26.5	22	52	transverse
B 223	26.5	22	52	sagittal
B III	27.0	22	52	sagittal
WR II	27.0	22	52	transverse
WR III	27.5	22	52	transverse
B 114	28.0	23	56	sagittal
B 187	27.0	23	56	sagittal
B 177	28.5	23	56	transverse
B 184	29.0	23	56	sagittal
A 3	29.0	23	56	transverse
A 5	30.0	23	56	sagittal

femoropatellar joint is observed. The cruciate ligaments as well as the menisci are clearly visible and separated by a mass of loose connective tissue cells of the interzone. The different direction of the anterior cruciate ligament and the posterior cruciate ligament is observed.

During stage 22 formation of intercondylar eminence is found (Fig. 3). The articular cavity appears in the middle and peripheral parts of the femorotibial joint, both in the femoromeniscal and meniscotibial compartments. In the middle part of the knee joint the interzone is still present and the medial parts of the developing menisci are continuous with cruciate ligaments and interzone (Fig. 4).

At stage 23 ossification of shafts of the tibia and femur begins. All intraarticular structures and the joint cavity of the knee joint are present. The menisci resemble the cellular zone which covers surfaces of condyles. Cruciate ligaments form thick bands of longitudinally directed connective tissue fibers (Fig. 5, 6). The blood vessels are observed in the area of the cruciate ligaments and at the periphery of the menisci.

DISCUSSION

Mc Dermott [8] reported in 9 and 10 week foetus a dense blastemal mass between the femur and tibia. Palacios and Rhode [14] observed the cruciate ligaments in 8 week embryo, and Hines [6] found the ligaments as condensation of mesenchyme that was located in the intercondylar space in embryos 20 mm long. Andersen [1] found condensation of mesenchymal tissue in the site of future cruciate ligaments in embryos 23 mm long. Gray and Gardner [4], Gardner and O'Rahilly [3], O'Rahilly [11] and Merida — Velasco et al. [9] gave detailed descriptions of the developing knee joint. According to Gardner and O'Rahilly [3] and Merida — Velasco [9] the cruciate ligaments appear in stage 20 and more frequently in stage 21. They form the cellular condensation of homogenous interzone. In one case they observed such primordia in stage 19. The present study showed early appearance of the cruciate ligaments as well as the menisci in all investigated embryos. Both structures appeared in stage 19 as condensations of blastemal cells in the homogenous interzone.

In stages 22 and 23 Gardner and O'Rahilly [3] and O'Rahilly [11] observed the cruciate ligaments as distinct cellular condensation, with blood vessels around them. This was confirmed in the present

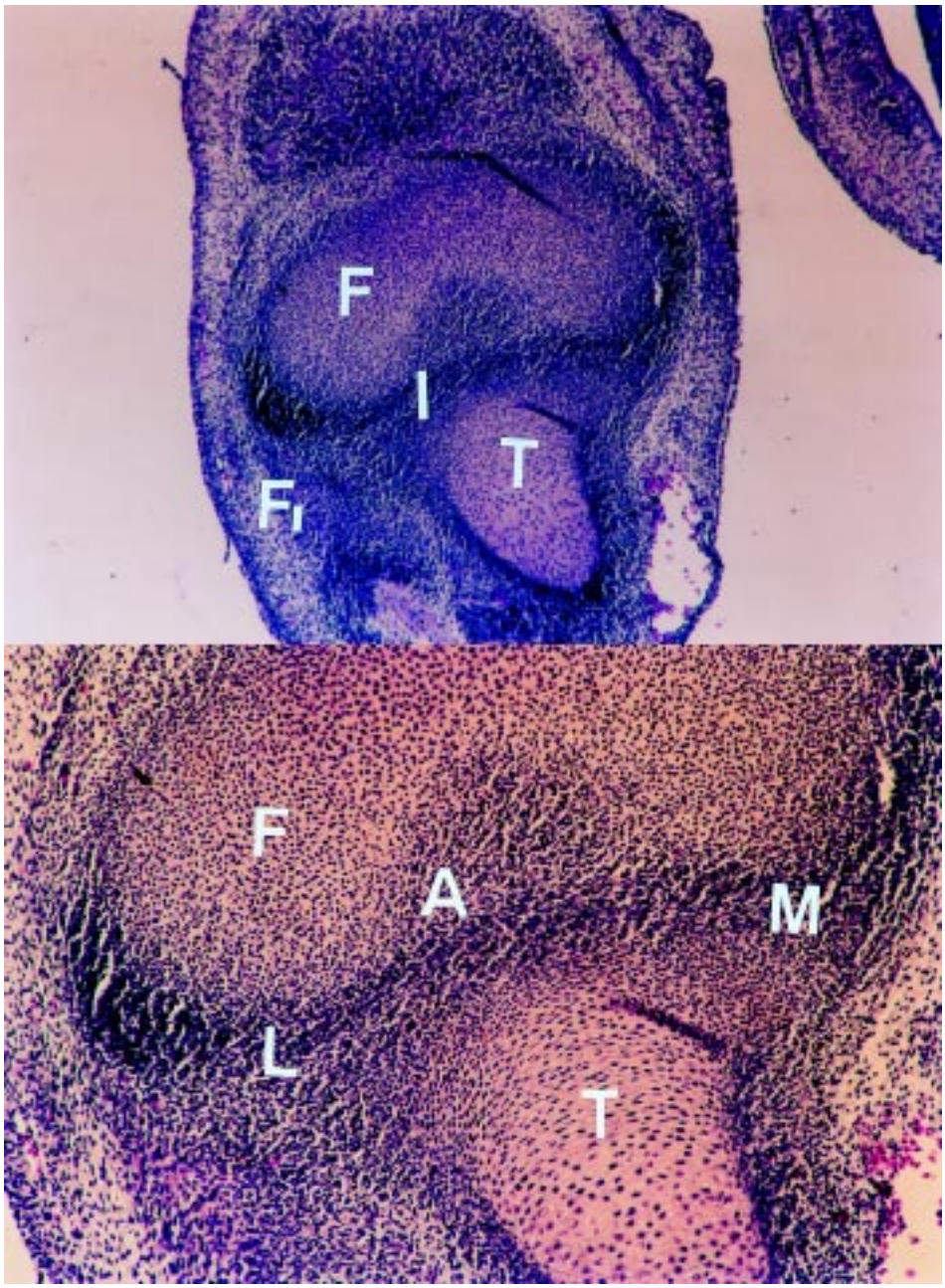

Figure 1. Interzone in the knee joint of embryo at stage 19. Frontal section, H&E. Fig. A x50. Fig. B x100. A — anterior cruciate ligament, F — femur, Fi — fibula, I — interzone, L — lateral meniscus, M — medial meniscus, T — tibia.

study. Andersen [1] observed blood vessels around these ligaments in embryos 23 mm long.

The posterior meniscofemoral ligament was not observed in my investigations. It was described in 10th week by Gray and Gardner [4] and Palacios and Rhode [14], and in 12.5 weeks by McDermott [8]. Only Andersen [1] reported appearance of the Wrisbergs ligament in 23 mm long embryos.

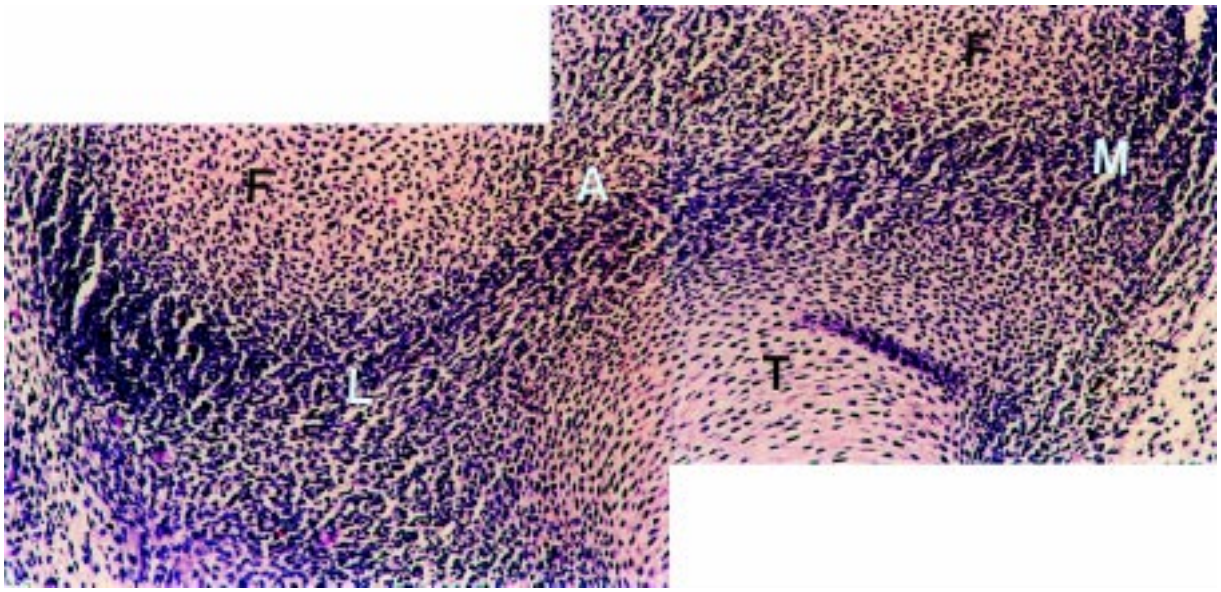

Figure 2. Primordia of cruciate ligaments and menisci in stage 19. Frontal section, H&E, x200. A — anterior cruciate ligament, F — femur, Fi — fibula, I — interzone, L — lateral meniscus, M — medial meniscus, T — tibia.

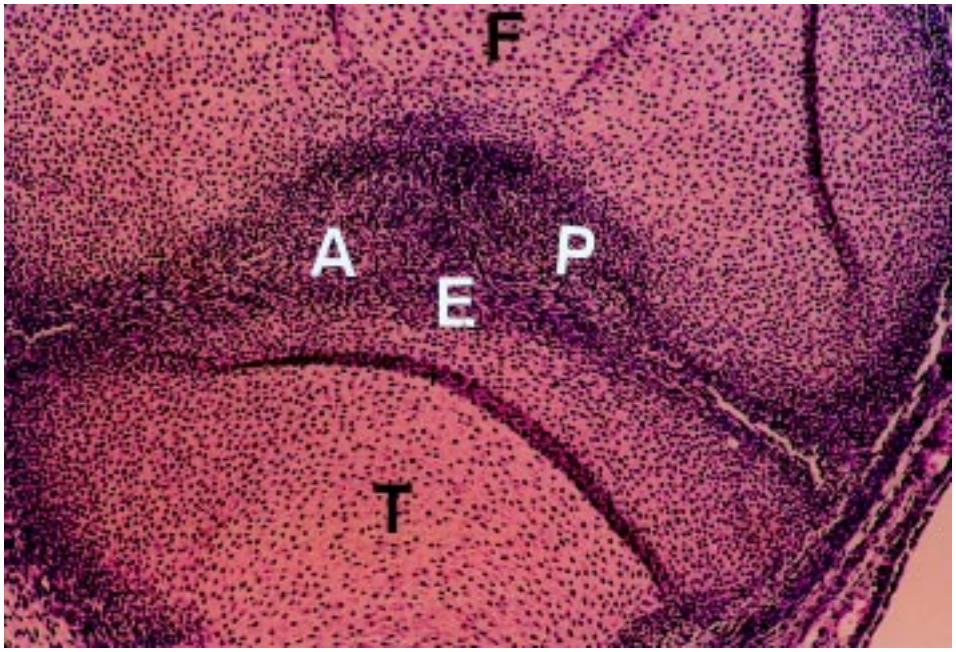

Figure 3. The intercondylar eminence in embryo at stage 22. Sagittal section, H&E, x100. A — anterior cruciate ligament, E — intercondylar eminence, F — femur, P — posterior cruciate ligament, T — tibia.

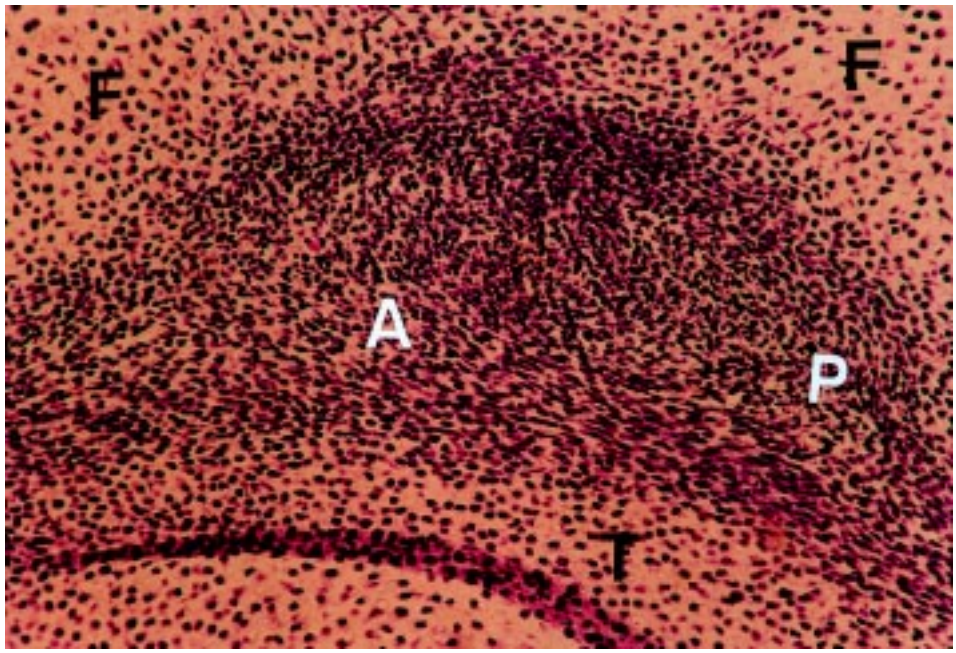

Figure 4. Cruciate ligaments in embryo at stage 22. Sagittal section, H&E, x200. A — anterior cruciate ligament, E — intercondylar eminence, F — femur, P — posterior cruciate ligament, T — tibia.

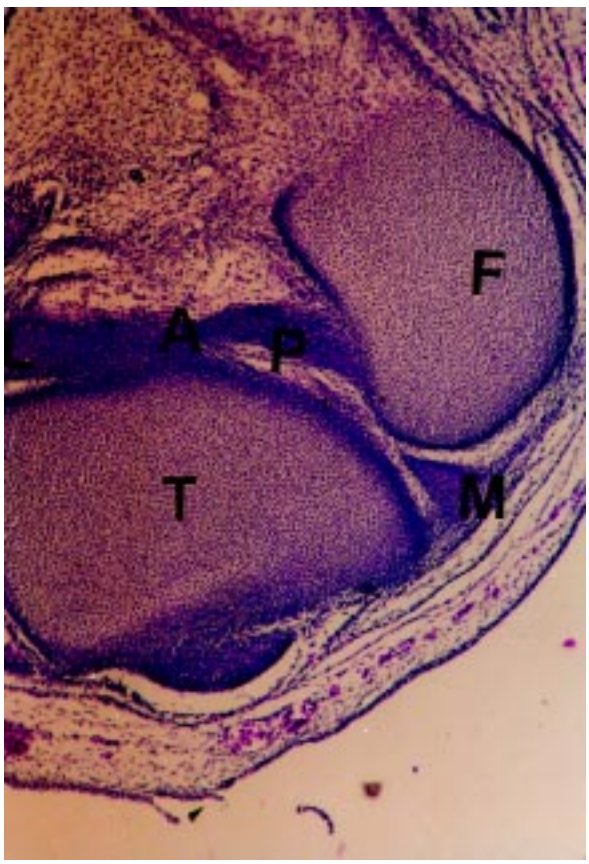

Figure 5. The knee joint in embryo at stage 23. Sagittal section, H&E, x100. M — medial meniscus. P — posterior cruciate ligament, T — tibia, A — anterior cruciate ligament.

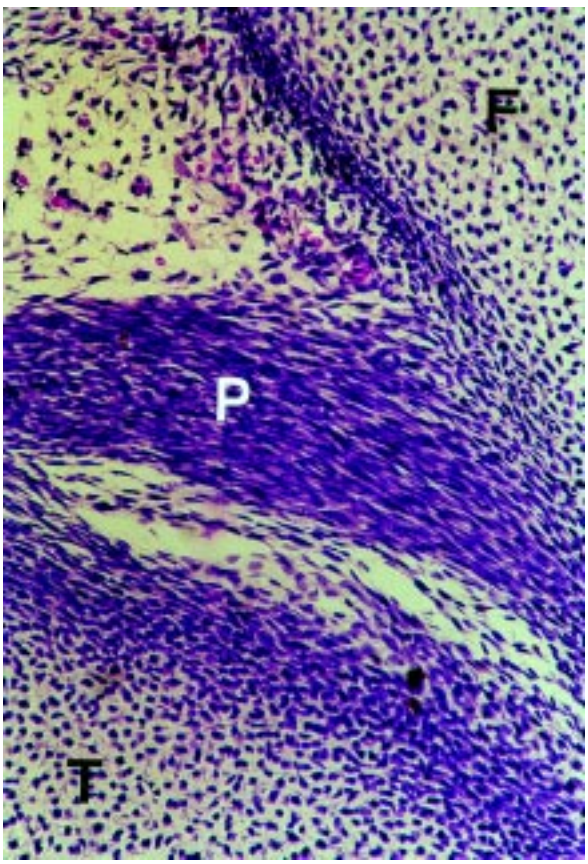

Figure 6. Posterior cruciate ligament in embryo at stage 23. Sagittal section, H&E, x200. P — posterior cruciate ligament, F — medial condyle of femur, T — tibia.

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