Morphometry of the patellar ligament in human fetuses

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Özet

İnsan fetuslarında ligamentum patellanın morfometrisi

Amaç: İnsan fetuslarında ligamentum patella'nın detaylı morfometrik verilerinin elde edilmesi amaçlandı. Gereç ve yöntem: Çalışma yaşları 18.-32. haftalar arasında değişen, patolojisi ve anomalisi olmayan 32 insan fetusunda (18 erkek, 14 kız) gerçekleşti. Genel eksternal ölçümlerden sonra her bir fetusun diz bölgesi diseksiyonu yapıldı. Ligamentum patellanın komşu yapılarla olan ilişkisi ve lokalizasyonu belirlendi. Uzunluk, genişlik ve kalınlık gibi morfometrik veriler elde edildi. Bulgular: Bütün parametrelerin haftalara göre ortalamaları ve standart sapmaları hesaplandı. Ölçülen parametreler ile gestasyonel yaş arasında anlamlı ilişki vardı ($p<0.001$). Cinsler arasında parametreler yönünden fark bulunamadı ($p>0.05$). Elde edilen tüm sonuçlar daha önce yapılan çalışmalarla karşılaştırılarak tartışıldı. Sonuç: Çalışmamızda elde edilen verilerin fetal dönemde ligamentum patella gelişimi ile ilgili anomali, patoloji ve varyasyonların belirlenmesinde obstetri, perinatoloji, adli tıp ve fetopatoloji gibi bilim dallarındaki çalışmalara, teşhis ve tedavilere katkıda bulunabileceğini düşünmekteyiz.

Anahtar kelimeler: Ligamentum patella, morfometri, insan fetusu, diz, anatomi

Abstract

Objective: To gather detailed morphometric data of the patellar ligament in human fetuses. Method: Present study is carried out on 32 human fetuses (18 males, 14 females) aged 18–32 weeks of gestation with no gross pathology or anomaly. Following the general external measurements of the fetuses each knee region were dissected. The relationships between the patellar ligament and surrounding structures and its localization were determined. Morphometric data on length, width, thickness and diameters were gathered. Results: Means and standard deviations of all parameters were calculated for each gestational week. There were significant relations between measured parameters and gestational age ($p<0.001$). There were no sex differences in parameters ($p>0.05$). All data were compared with previous studies and discussed. Conclusion: Data obtained in this study will contribute to other studies carried out in the areas of obstetrics, perinatology, forensic medicine and fetal pathology, aimed at identifying anomalies, pathologies and variations of the patellar ligament and treatment of such cases.

Key words: Patellar ligament, morphometry, human fetus, knee, anatomy

Introduction

Knee joint is the largest joint in the body with the largest synovial membrane, joint space and synovial fluid volume correspondingly (1). The patellar ligament–which is an extracapsular ligament of the knee joint-is a thick and sturdy ligament with a 8 cm length, 2–3 cm width and 0.5 cm thickness that extends from the quadriceps femoris muscle to the apex patellae and tibial tuberosity traversing the anterolateral surface of the patella (1). Patellar ligament is involved in the extensor mechanism of the knee and is utilized as a graft in anterior cruciate ligament ruptures (2–6).

In previous studies it is implied that patellar ligament is developed in stage 20 [according to the classification of O'Rahilly R (7, 8). The development of the patellar ligament in the fetal period between 9 weeks and term is important as a consequence of the possible

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relationship of its shape and dimensions with various congenital malformations (9–11). Also the pathologies associated with the patellar ligament in the adult may be related to the fetal development. As a result, it is stated that early diagnosis of such pathologies is very important (9–11).

With regard to the patellar ligament Koyuncu E et al. (12) studied the fetuses. Studies measured the length and width of the patellar ligament. The studies in the adults embrace the ultrasographic and magnetic resonance images (MRI) studies, the pathological conditions associated with the ligament, its functions and anatomy (5, 13–21). The length, width and the thickness of the patellar ligament is measured in the ultrasonographic and MRI studies (4, 13, 20–22). Ultrasonography is also utilized in the imaging of the knee ligaments and the diagnosis of the pathologies associated with these structures (10, 22). In the studies associated with the pathological conditions of the ligament its rupture and tendonitis and symptoms related to these conditions are mentioned (14, 18, 19, 22, 23). There are also studies that mention the functions of the ligament in the knee joint function (4, 5, 19). The thickness and width of the ligament in its origin and insertion sites and its length is measured in morphologic studies (16, 17, 21). In various studies the potential use of the patellar ligament as a graft in anterior cruciate ligament ruptures is mentioned (2, 3, 24, 25).

Especially during sport activities minor physical traumas might trigger anterior knee sore among the young population. That anterior knee sore might result in discomfort for healthy life. In researches done it is stated that the lateral deviations of patellar tendon cause anterior knee sore. In addition, it is indicated that where tendon adhesion occuring in patellar regio is an important factor to lead to anterior knee sore (5, 26-28).

In this study our aim was to obtain the detailed morphometric data on the ligament and its localization based on gross anatomical dissections in the fetuses between 18–32 weeks of gestational ages.

Materials and Method

32 human fetuses (18 male, 14 female) between 18–32 gestational weeks [Crown Rump Length (CRL)= 119–280 mm] were used in this study. None of the fetuses had any gross anomaly. The fetuses vere medicolegally obtained from Ankara Maternity and Health Academic and Research Hospital. While the gestational ages of the fetuses were obtained from the hospital records when possible they were determined according to a scale incorporating the parameters CRL, head circumference (HC), biparietal diameter (BPD), femur length (FL) and foot length (29). Approval from the Ethical Committee has been established.

Initially, general parameters, namely CRL, HC, BPD, FL and foot length were measured on each fetus. All measurements were performed as described below using measuring tape, digital caliper, plastic and metal rulers, silk suture thread and thin metal rods.

Crown Rump Length (CRL): The vertical distance from the vertex to the bottom of the buttocks.

Head circumference: The distance around the skull passing through the glabella, parietal tuber, and external occipital protuberance (inion) of the occipital bone.

Bi-parietal width: Transverse distance between parietal tubers.

Femur length: Vertical distance between the tip of the greater trochanter and knee joint.

Foot length: Distance between the posterior-most point of the heel and the tip of the longest toe.

Two transverse incisions, one cranial to the patella and the other caudal to the tibial tuberosity, and one vertical incision in the median plane were done in order to expose the patellar ligament. Firstly, in the case of anatomical dissection the neighbourhood relationship of patellar ligament with knee joint capsule, patella, tibia, quadriceps femoris muscle, medial and lateral retinaculum has been examined. Then morphometric measurements of the patellar ligament were done.

Localization of the patellar ligament: The localization of the ligament in the region between the patella and the tibial tuberosity was evaluated (Figure 1).

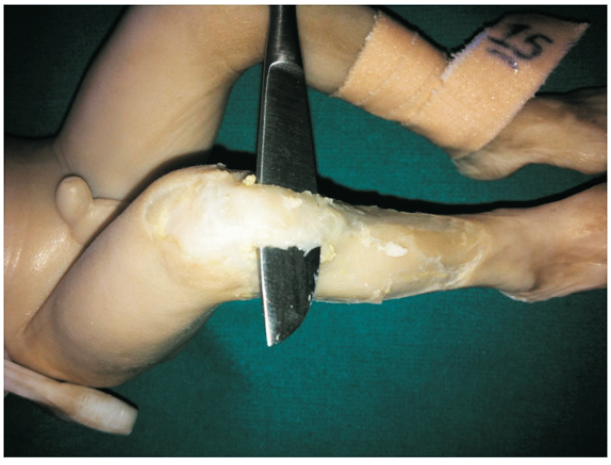

Figure 1: 24-week fetus. İmage of the patellar ligament.

Patellar ligament length: The vertical distance between the origin and the insertion of the ligament (Figure 1).
Patellar ligament width: The transverse distance interconnecting the vertical lines on the lateral sides of the ligament at its midpoint (Figure 1).
Patellar ligament thickness: The sagittal distance interconnecting the vertical lines on the anterior and posterior sides of the ligament at its midpoint (Figure 1).
The mean values and their standard deviation for the parameters according to sex and gestational age were calculated with SPSS. The relationship between the parameters and the gestational age were analyzed with Pearson correlation test. Linear regression analysis were done between the patellar ligament parameters and the gestational age. Student's t test was used to compare the parametric data according to sex and the side of the ligament. $p<0.05$ was accepted as statistically significant.

Results

The mean values of the general parameters for each gestational week group involved (CRL, HC, BPD, FL, foot length) were calculated (Table 1). There were no differences due to sex between the female and male group ($p>0.05$).

Table 1: Means of fetal parameters by weeks (mm).

Age (week)	N	CRL	Head circumference	Bi-parietal diameter	Femur length	Foot length
18	3	119	115	46	34	26
19	1	129	130	49	36	29
20	2	138	145	51	38	30
21	2	146	162	55	40	34
22	4	159	178	57	45	36
23	2	165	193	59	48	40
24	2	178	205	60	50	43
25	1	190	220	61	52	44
26	2	210	231	63	56	46
27	1	219	250	65	60	51
28	2	229	274	69	65	54
29	3	240	290	71	67	55
30	2	252	310	74	72	56
31	2	263	323	77	74	59
32	3	280	340	79	78	62

Patellar ligament and the surrounding structures were exposed with careful dissections in all of the fetuses.

Table 2: Means (mm) and standard deviations of patellar ligament parameters by weeks.

Age (week)	N	Right patellar ligament length	Left patellar ligament length	Right patellar ligament width	Left patellar ligament width	Right patellar ligament thickness	Left patellar ligament thickness
18	3	6,33±0,57	6,00±0,00	4,00±0,00	4,00±0,00	0,36±0,05	0,33±0,05
19	1	6,50±0,00	6,33±0,57	4,10±0,00	4,15±0,00	0,50±0,00	0,50±0,00
20	2	7,90±0,14	8,00±0,00	5,00±0,00	5,10±0,14	0,55±0,07	0,55±0,07
21	2	10,00±1,41	9,65±1,20	5,15±0,21	5,50±0,70	0,70±0,00	0,68±0,00
22	4	11,62±0,47	11,25±0,64	5,87±0,25	5,60±0,56	0,72±0,09	0,75±0,07
23	2	12,15±0,21	12,50±0,00	6,00±0,00	5,80±0,62	0,85±0,07	0,82±0,09
24	2	12,70±0,28	12,65±0,21	6,30±0,00	6,00±0,00	0,90±0,09	0,88±0,07
25	1	12,90±0,00	13,00±0,00	6,55±0,70	6,30±0,00	1,00±0,00	0,95±0,07
26	2	13,15±0,07	13,10±0,14	6,60±0,00	6,45±0,07	1,05±0,07	1,00±0,00
27	1	13,50±0,00	13,30±0,00	6,90±0,00	6,70±0,00	1,10±0,00	1,10±0,00
28	2	14,15±0,21	14,10±0,14	7,00±0,00	7,00±0,14	1,25±0,07	1,21±0,03
29	3	14,83±0,20	15,00±0,20	7,70±0,30	7,80±0,30	1,30±0,10	1,26±0,15
30	2	15,55±0,21	15,70±0,14	8,45±0,07	8,40±0,14	1,50±0,00	1,37±0,00
31	2	16,00±0,00	15,90±0,14	9,10±0,14	9,05±0,21	1,60±0,14	1,60±0,06
32	3	16,50±0,50	16,43±0,51	9,63±0,15	9,56±0,11	1,76±0,05	1,73±0,05

Subsequently, anatomical dissection, lig. patella and knee joint capsule, patella, tibia, quadriceps femoris muscle, medial and lateral retinaculum at the nearby region have been made to be visible. It has been determined that the relation between patellar ligament and the other neighbour organs is normal in all the researches and there is not any kind of abnormality. Patellar ligament was between the patella and the tibial tuberosity in all of the fetuses. The mean values of the patellar ligament length, width and thickness for each gestational week group are presented in Table 2. Moreover, means and standard deviations of patellar ligament parameters according to their genus are shown in Table 3. The mean values and their standard deviations for the length, width and thickness of the right patellar ligament are 12.36±3.24 mm, 6.59±1.71 mm and 1.01±0.43 mm, respectively (Table 4). The mean values and their standard deviations for the length, width and thickness of the left patellar ligament are 12.30±3.30 mm, 6.57±1.71 mm and 0.99±0.43 mm, respectively (Table 4). The increment in the given parameters were in accordance with the advancement of the gestational week and the general parametric values ($p<0.001$, Figure 2). There was no significant difference for the sex and the side of the ligament for any parameter ($p>0.05$, Table 4). Also there was a positive correlation between the parameters of the patellar ligament ($p<0.001$).

Table 3: Means (mm) and standard deviations of patellar ligament parameters by sexes.

Age (week)	N	Right patellar ligament length	Left patellar ligament length	Right patellar ligament width	Left patellar ligament width	Right patellar ligament thickness	Left patellar ligament thickness
Male	18	12,22±3,35	12,10±3,37	6,60±1,76	6,57±1,77	1,00±0,44	0,99±0,44
Female	14	12,54±3,21	12,56±3,31	6,57±1,72	6,58±1,69	1,03V0,43	0,99±0,43
Total	32	12,36±3,24	12.30±3.30	6.59±1.71	6.57±1.71	1.01±0.43	0.99±0.43

Table 4: Means (mm) and standard deviations of general highest and lowest values of patellar ligament parameters. Comparison of patellar ligament parameters between sexes and right-left.

Patellar ligament parameters	General means	Highest mean value	Lowest mean value	Comparison between sexes	Comparison between right-left
Right patellar ligament length	12.36±3.24	16,50±0,50	6,33±0,57	P=0,669	P=0,245
Left patellar ligament length	12.30±3.30	16,43±0,51	6,00±0,00	P=0,679	
Right patellar ligament width	6.59±1.71	9,63±0,15	4,00±0,00	P=0,894	P= 0,835
Left patellar ligament width	6.57±1.71	9,56±0,11	4,00±0,00	P=0,990	
Right patellar ligament thickness	1.01±0.43	1,76±0,05	0,36±0,05	P=0,832	P=0,073
Left patellar ligament thickness	0.99±0.43	1,73±0,05	1,73±0,05	P=0,969	

P>0.05: There was no difference between the sexes and between right and left of the groups.

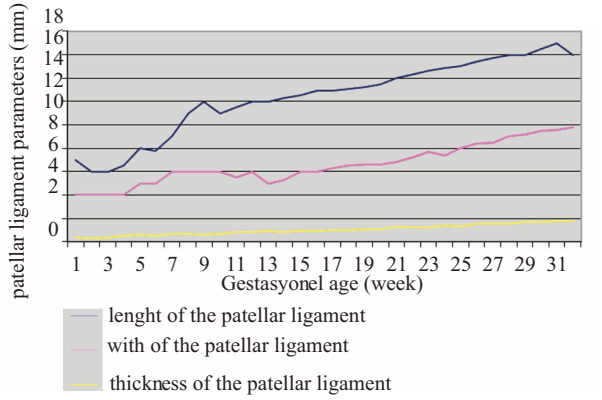

Figure 2: Relation between gestational age and patellar ligament parameters.

Discussion and Conclusion

The development of the patellar ligament in the fetal period is important as a consequence of the possible relationship of its shape and dimensions with the congenital malformations (9-11). The pathologic conditions of the patellar ligament in the adulthood may be associated with the fetal development. Therefore early diagnosis of these pathologies is very important (9-11).

Koyuncu E. et al (12) morphometry study on the patellar ligament and his colleagues have made fetuses. Study looked at length and width of the patellar ligament. As a result, as in our study increased during the fetal period, and age-related parameters correlated with the patellar ligament say. The studies in the adults include the imaging studies utilizing MRI and ultrasonography, the pathologic conditions of the ligament, its functions and its anatomy (5, 13-21). The length, width and the thickness of the patellar ligament was measured in the ultrasonographic and MRI studies (4, 13, 20-22). There are also studies on the ultrasonographic imaging of the ligaments in the knee and the diagnosis of the pathologic conditions associated with these ligaments (10, 22).

We intended to obtain the detailed morphometric data on the ligament and its localization in the fetuses between 18 and 32 weeks of gestational age. No anomaly of the relationships of the patellar ligament was found during the dissections.

Table 5: Comparison of the length parameter results of patellar ligament in our study with the length parameter results of patellar ligament.

	Patellar ligament length (mm)					
Author	Mean	Male		Female		P value
Mahadevan V (1)	80	-		-		-
Andrikoula S (4)	43,0	-		-		-
Yoo JH (21)	40,2	40,7		38,0		0,001
Basso O (17)	73,1	-		-		-
Present study	12,3	right	left	right	left	right left
		12,2	12,1	12,5	12,5	0,669 0,679

Then we determined the localization of the patellar ligament in the knee region. In the previous studies on the patellar ligament and the textbooks it is stated that the patellar ligament extends between the patella and the tibial tuberosity (1, 4, 10). We also observed that the patellar ligament extends between the patella and the tibial tuberosity in all of the cases. We think that the data we obtained on the localization of this ligament would be useful for the evaluation of the development of the ligament, its pathologies and its relationships. Moreover, it is emphasized in the researches that where tendon adhesion occuring in patellar regio is an important factor to lead to anterior knee sore (5, 26-28, 30). That's why; we are firmly of the opinion that knowing the ligamentum localization would be helpful in order to diagnose the patologies such as anterior knee sore early. Fetal period, lasting from the ninth week of pregnancy to birth, is a term body grows rapidly and organs develop (29). In this period, patellar ligament, as other fetal organs, gets bigger. In our study, about the sizes of patellar ligament between the 18th – 32nd weeks of the fetal period, length, width and thickness parameters of patellar ligament have been determined. In the research we have made, we have not come across any study about the sizes of patellar ligament during fetal period as stated above. We have found a study about the length of patellar ligament and its width and thickness at the point it starts and ends in adults (1, 4, 10). In the studies made and in reference books, it is stated that the size of patellar ligament in adults is much bigger in comparison with fetal period (1, 4, 10). In our study, it has been determined that size parameters of patellar ligament increase gradually between the 18th – 32nd weeks during the fetal period (Table 2). Accordingly, it can be said that the size of patellar ligament continues growing during the period after birth and this growing lasts to the adulthood. The length parameter results of patellar ligament in our study were compared with the length parameter results of patellar ligament performed among the adults in Table 5. Also, in our study, it has been determined that there is no difference between the sexes about the size of patellar ligament between the 18th - 32nd weeks in fetal period ($p>0.05$, Table 4). However, Yoo Jh. et. al. (21) have stated in their study among the adults that except for the proximal thickness of patellar ligament there is a difference between the genus in the other measurements, which was interpreted that patellar ligament has continued to grow after the birth and that the difference between the genus has come into beingÊ after the birth. In addition, it has been found out that the size of patellar ligament is not different in terms of right and left ($p>0.05$, Table 4). We hope the data about the size of patellar ligament, acquired in our study, will be helpful for identification, diagnosis and treatment of patellar ligament pathologies during prenatal and postnatal period. Patellar ligament functions in extensor mechanism of knees (4, 5, 19). Ligamentum function loss can be seen in pathologies like patellar tendinitis and partial or complete ligamentum tears (19). It is stated that complete ligamentum tears are mostly seen in the young, in volleyball and basketball players and athletes (19, 23, 31, 32). It is indicated that this case is called "jumper's knee" and it causes mucoid degeneration in ligament (19, 23, 31, 32). It is told in such cases patella slips to proximal and extension loss occurs in leg due to the interruption of extensor mechanism of knee (19, 23, 31, 32). On such an occasion, man's activity level will be restricted and his quality of life will decrease. And this shows us patellar ligament is important for vital activity.

In addition, another clinical importance of patellar ligament is that it is used as graft for anterior cruciate ligament tears (2, 3, 24, 25). As it is known, anterior cruciate ligament is one of the ligaments responsible for stabilization of knee-joint (1, 33). In ligament tears, the stability of knee-joint will be destroyed and it will not function properly. And this will cause restriction in man's life. For normal functioning of knee-joint, anterior cruciate ligament tear should be mended. To mend this ruptured ligament, patellar ligament is used as graft. And this, once more, reveals the importance of patellar ligament in knee joint. The localization of ligament and morphometric parameters about ligament should be known developmentally starting from fetal period. It is important for early diagnosis and treatment of anomaly and pathologies of patellar ligament, both functioning in extensor mechanism of knee and used as graft for anterior cruciate ligament tears.

As a result, we can conclude that the data acquired in our study will contribute to determination of anomaly, pathology and variations about patellar ligament development during fetal period and to the studies, diagnoses and treatments in the fields such as obstetrics, perinatology, forensics and fetopathology.

References

1. Mahadevan V. Pelvic girdle and lower limb. In: Standring S. Gray's Anatomy-The Anatomical Basis of Clinical Practite. Fortieth Edition. Churchill Livingstone, 2008; pp 1396–1397.
2. Pang J, Shen S, Pan WR, Jones IR, Rozen WM, Taylor GI. The arterial supply of the patellar tendon: anatomical study with clinical implications for knee surgery. Clin Anat, 2009; 22(3):371–6.
3. Luk KM, Wong NM, Cheng JC. Anthropometry of the patellar tendon in Chinese. Journal of Orthopaedic Surgery, 2008; 16(1):39–42.
4. Andrikoula S, Tokis A, Vasiliadis HS, Georegoulis A. The extensor mechanism of the knee joint: an anatomical study. Knee Surg Sports Traumatol Arthrosc, 2006; 14(3):214–20.
5. Ahmad CS, Kwak SD, Ateshian GA, Warden WH, Steadman JR, Mow VC. Effects of patellar tendon adhesion to the anteiror tibia on knee mechanics, 1998; 26(5):715–24.
6. Krevolin JL, Pandy MG, Pearce JC. Moment arm of the patellar tendon in the human knee. J Biomech, 2004; 37(5):785–8.
7. Merida-Velasco JA, Sanchez-Montesinos I, Espin-Ferra J, Merida-Velasco JR, Rodriguez-Vazquez JF, Jimenez-Collado J. Development of the human knee joint ligaments. Anat Rec, 1997; 248(2):259–68.
8. Merida-Velasco JA, Sanchez-Montesinos I, Espin-Ferra J, Rodriguez-Vazquez JF, Merida-Velasco JR, Jimenez-Collado J. Development of the human knee joint. Anat Rec, 1997; 248(2):269–78.
9. Chung CB, Skaf A, Roger B, Campos J, Stump X, Resnick D. Patellar tendon lateral femoral condyle friction syndrome: MR imaging in 42 patients, 2001; 30(12):694–7
10. Lee D, Bouffard JA. Ultrasound of the knee. Eur J Ultrasound, 2001; 14(1):57–71.
11. Messina D, Meister K, Montgomery WJ. Bilateral congenital absence of patellar tendon. AM J Knee Surg, 1997; 10(1):23–5.
12. Koyuncu E, Cankara N, Sulak O, Özgüner G, Albay S. The morphometry of patella and patellar ligament during the fetal period. 2011; 24(2):225-31
13. Fredberg U, Bolvig L, Andersen NT, Stengaard-Pedersen K. Ultrasonography in evaluation of Achilles and patella tendon thickness. Ultraschall Med, 2008; 29(1):60–5.
14. Amlang MH, . Damage to large tendons: Achilles, patellar and quadriceps tendons. Chirurg, 2006; 77(7):637–49.
15. Muratli HH, , Hapa O, Biçimoğlu A. Bilateral patellar tendon rupture in a child: a case report. Knee Surg Sports Traumatol Arthrosc, 2005; 13(8):677–82.
16. Nevret P, Robinson AH, Le Coultre B, Lapra C, Chambat P. Patellar tendon length-the factor in patellar instability? Knee, 2002; 9(1):3–6.
17. Basso O, Johnson DP, Amis AA. The anatomy of the patellar tendon. Knee Surg Sports Traumatol Arthrosc, 2001; 9(1):2–5.
18. Duri ZA, Aichroth PM, Wilkins R, Jones J. Patellar tendonitis and anterior knee pain. M J Knee surg, 1999; 12(2):99–108.
19. Yu JS, Petersilge C, Sartoris DJ, Pathria MN, Resnick D. MR imaging of injuries of the extensor mechanism of the knee. Radiographics, 1994; 14(3):541–51.
20. Sell S, Esenwein S, Gaissmaier C, Moosmaier J, KüsswetterW. Ultrasound imaging of the patellar tendon--an experimental study. Z Orthop Ihre Grenzgeb, 1997; 135(3):261–5.
21. Yoo JH, Yi SR, Kim JH. The geometry of patella and patellar tendon measured on knee MRI. Surg Radiol Anat, 2007; 29(8):623–8.
22. El-Khoury GY, Wira RL, Berbaum KS, Pope TL Jr, Monu JUV. MR imaging of patellar tendinitis. Musculoskeletalradiology, 1992; 184(3):849–54.
23. Garau G, Rittweger J, Mallarias P, Longo UG, Maffulli N. Traumatic patellar tendinopathy. Disabil Rehabil, 2008; 30(20–22):1616–20.
24. Moholkar K, Taylor D, O'Reagan M, Fenelon G. A biomechanical analysis of four different methods of harvesting bone-patellar tendon-bone graft in porcine knees. J Bone Joint Surg Am, 2002; 84-A(10):1782–7.
25. Atkinson PJ, Oyen-Tiesma M, Zukosky DK, DeCamp CE, Mackenzie CD, Haut RC. Patellar tendon augmentation after removal of its central third limits joints tissue changes. J Orthop Res, 1999; 17(1):28–36.
26. Fulkerson JP. Diagnosis and treatment of patients with patellofemoral pain. Am J Sports Med, 2002; 30(3):447–56.
27. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. Am J Sports Med, 2003; 31(1):2–11.
28. Basso O, Amis AA, Race A, Johnson DP. Patellar tendon fiber strains: their differential responses to quadriceps tension. Clin Orthop Relat Res, 2002; (400):246–53.
29. Moore KL, Persaud TVN. The Developing Human (Clinically Oriented Embryology), 7th edn. WB Saunders Company, Philadeıphia, 2003; pp 255–286.
30. Paulos LE, Wnorowski DC, Greenwald AE. Infrapatellar contracture syndrome. Diagnosis, treatment, and long-term followup. Am J Sports Med, 1994; 22(4):440–9.
31. Zwerver J. Patellar tendinopathy ('jumper's knee'); a common and difficult-to-treat sports injury. Ned Tijdschr Geneeskd, 2008; 152(33):1831–7.
32. Hoksrud A, Ohberg L, Alfredson H, Bahr R. Color doppler ultrasound findings patellar tendinopathy