

Evaluation of patellar tendon morphology in Turkish population: a cross-sectional study

Ali Köksal^{1,2}, Berin Tuğtağ Demir³, Fatih Çankal^{3,4}

¹Department of Radiology, Ankara Bayındır Private Hospital, Ankara, Turkey

²Department of Radiology, Vocational School of Health Services, Atılım University, Ankara, Turkey

³Department of Anatomy, Faculty of Medicine, Ankara Medipol University, Ankara, Turkey

⁴Department of Radiology, Pursaklar State Hospital, Ankara, Turkey

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ABSTRACT

Aim: This study aims to investigate the length, width and thickness of the patellar tendon and the type and length of the patella with MRI and to reveal the normal values of patellar tendon morphology specific to the Turkish population.

Material and Method: The study was conducted with 348 individuals (137 males, 211 females) who applied to our hospital, had no anterior knee pathology, and had knee MRIs. The length, proximal and distal width and thickness of the patellar tendon, patella type, prepatellar and infrapatellar fat pad signal characteristics and Insall-Salvati ratio were evaluated on knee MRI images of these individuals.

Results: Type I patella was detected in 23.9%, type II in 57.2%, type III in 16.1%, and type IV in 2.9% of individuals. The mean length of the patella was 41.26 ± 4.36 mm, the patellar tendon length was 47.36 ± 6.70 mm, the proximal width was 28.86 ± 3.49 mm, the distal width was 23.53 ± 2.69 mm, the proximal thickness was 3.62 ± 1.47 mm, and distal thickness was 5.21 ± 1.1 mm. It was determined that the Insall-Salvati ratio did not cause a statistical difference according to age, but the patella type showed significance with the Insall-Salvati classification.

Conclusion: While evaluating MRI images, the effect of social differences on measurements should not be ignored; normal measurement values of the tendon should be known to evaluate pathological measurements.

Keywords: Patellar tendon, Patella type, Insall-Salvati ratio

INTRODUCTION

Knee stability depends on the mechanical axes of the joint, bony contours, fat pads (infrapatellar and prepatellar), intra-articular stabilizers (meniscus and cruciate ligaments) and extra-articular stabilizers (capsular ligaments, lateral ligaments and musculotendinous units) (1). The patellar tendon is the main component that plays a role in this stabilization. Some of the fibers in the central part of the common tendon of the quadriceps femoris muscle extend to the tibia after its attachment to the patella and form the patellar tendon, and this tendon plays a role in the extension of the knee by transmitting the force created by the quadriceps femoris to the tibia (2). Inflammatory conditions such as patellar tendinopathy, Osgood Schlatter disease, and Sinding Larsen Johansson syndrome can affect the patellar tendon, increasing its thickness.

The patellar tendon is also used as an autograft in anterior cruciate ligament reconstruction operations (3). Due to the fixed length of the patellar tendon, graft-tunnel

length mismatch is a common intraoperative technical problem. Too narrow or too long patellar tendon affects the results of this operation negatively. This condition is usually caused by the excessive length of the tendon (4). Since the patellofemoral joint is a complex joint with high functionality and a complex biomechanical structure, patellofemoral joint anatomy is thought to be determinant in problems in the anterior part of the knee. Therefore, diagnosing and treating diseases that cause patellofemoral pain mainly depends on understanding this joint's anatomy and biomechanics. However, studies investigating patellofemoral morphology have generally focused on pathological conditions, infrapatellar (Hoffa's fat pad) impingement syndrome (5, 6) and patellofemoral chondromalacia (2, 7). In all these studies, symptomatic patients were selected, and patellar tendon morphology in healthy individuals was not emphasized. Especially in patients

Corresponding Author: Berin TUĞTAĞ DEMİR, berrintugtag@hotmail.com



whose infrapatellar and prepatellar fat pads have been removed for pathological reasons, the importance of fat pads has been clearly understood by the changes in the mechanics of the knee and the emergence of the effects of friction (8). Therefore, this study also investigated whether the infrapatellar and prepatellar fat pads in healthy individuals were edematous.

Parameters such as a patient's actual patellar tendon length, patella type and diameter constitute anthropometric measurements that are clinically important and can guide racial studies (9, 10). Even the absence of one of these stabilizing factors will impair the normal function of the knee (11, 12). In the researches, it has been determined that the patellar tendon morphology specific to Turkish society has not been determined in detail. Therefore, this study aimed to determine the normal morphology of the patellofemoral junctions and the reference values specific to the Turkish population by MRI. The normal mechanics and stability of the knee occur with the synchronized function of these components. Therefore, knowing the community-specific values of patellar tendon morphology will provide great convenience to Turkish surgeons in today's knee surgery. This study aims to measure the width, thickness, type and length of the patellar tendon with MRI and to reveal the patella type, length and normal values of tendon dimensions.

MATERIAL AND METHOD

Study Design

This study was a retrospective, observational, and single center study conducted between 01.2021 and 01.2023. The study was carried out with the permission of Bayındır Hospital Ethics Committee (Date: 16.02.2023, Decision No: BTEDK-06/23). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Excluding criteria: Among the 524 individuals who underwent knee MRI in our center between 01.2021 and 01.2023, 479 individuals over the age of 18 were selected and who had a previous knee operation, fracture, dislocation, osteomyelitis, necrosis, anterior knee pain, apophysitis, mass, patellar tendinopathy were excluded from the study, and 348 patients were included.

Including criteria: Individuals without any symptoms were included in the study. Unilaterally, 348 anterior knee pathologic were evaluated.

Research Parameters

All measurements of patellar tendon dimensions were measured from the localizations specified by Chang et al. (13) and noted.

Patellar type: In this study, patella classification was performed as described by Wiberg (14) and Baumgartl (15). Three different types of the patella were defined by Wiberg (1941), and then Baumgartl (1964) defined type IV as "Jaegerhut" patella, which has no medial face and, therefore, no median protrusion.

Insall-Salvati ratio: Insall-Salvati ratio is the ratio of the patellar tendon to the patellar length in the sagittal plane from the section where the largest width of the patella was measured. Its normal value is between 0.8-1.2. If it is less than 0.8, it is called patella baja; if it is larger than 1.2, it is called patella alta (16).

MRI Protocol

MRI examinations were performed using a 1.5 T scanner (Gyrosan Intera, Philips Medical Systems, Nederland B. V.) with a standard dedicated knee coil. During scanning, the patients were given a supine position with their knees at 0-30 degrees of flexion. The imaging protocol constituted the following five routine sequences: Coronal fast spin-echo T1-weighted, sagittal fat-suppressed proton density-weighted, coronal fat-suppressed proton density-weighted, axial fat-suppressed proton density-weighted and sagittal fast spin-echo T2-weighted. All measurements were made by two radiologists at different times and independently of each other. The study examined intra-observer and inter-observer agreement by calculating Cohen's kappa coefficient and intra-class correlation coefficient. Inter-observer agreement was analyzed as 91%.

Statistical Analysis

The quantitative parameters were measured manually using the Extreme Picture Archiving and Communications System (PACS) system (Ankara, Türkiye) for the study groups. All the measurements were performed on the osseous surfaces. Length measurements are in millimeters (mm). Statistical analyses were carried out using SPSS for Windows statistical package (version 21.0; SPSS, Chicago, Illinois), and a p-value <0.05 was considered statistically significant.

RESULTS

It was determined that 39.7% of the individuals included in the study were male, 60.3% were female, 37.4% were between 18-39, and 42.5% were between 40 and 59. Type I patella was detected in 23.9%, type II in 57.2%, type III in 16.1%, and type IV in 2.9% (Table 1). The Insall-Salvati ratio was found to be patella baja in 1.7% (n=6), normal in 79% (n=275), and patella alta in 19.3% (n=67). Edema in the prepatellar fat pad was diagnosed in 46.3% of the patients, and edema in the infrapatellar fat pad in 15.2% (Figure 1 and 2).

Length of the patella, patellar tendon length and proximal diameter were higher in males than females (p<0.05). The

mean patellar length was 41.26 ± 4.36 mm, the patellar tendon length was 47.36 ± 6.70 mm, the proximal width was 28.86 ± 3.49 mm, and the distal width was 23.53 ± 2.69 mm. It was determined that distal width, proximal and distal thickness, and Insall-Salvati ratio did not differ according to gender ($p > 0.05$). The mean Insall-Salvati ratio was $1.18 \pm .59$ (Table 2).

	Frequency	Percent
Sex		
Male	138	39.7
Female	210	60.3
Age		
18-39	130	37.4
40-59	148	42.5
60 and over	70	20.1
Side		
Right	144	41.4
Left	204	58.6
Patellar Type		
Type I	83	23.9
Type II	199	57.2
Type III	56	16.1
Type IV	10	2.9
Prepatellar Fat		
Normal	187	53.7
Edematous	161	46.3
Infrapatellar Fat		
Normal	295	84.8
Edematous	53	15.2
Insall-Salvati Ratio		
Less than 0.8 (Patella baja)	6	1.7
0,8-1,2 (Normal)	275	79.0
Larger than 1.2 (Patella alta)	67	19.3

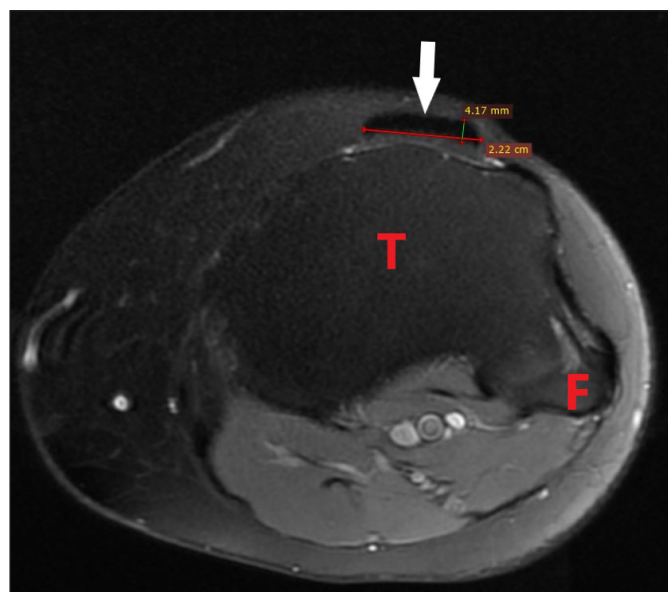


Figure 1: Thickness and diameter measurements of the patellar tendon on transverse MR image (fat-suppressed PD T2A). T: Tibia, F: Fibula, White arrow: patellar tendon (section taken 1 cm from the distal attachment level).

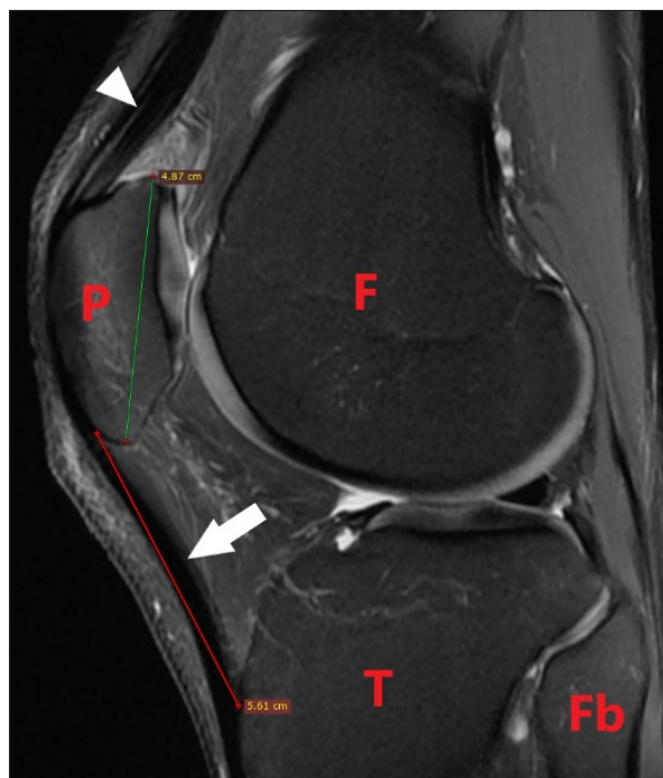


Figure 2: Patella and patellar tendon length measurements on sagittal MR image (fat-suppressed PD T2A). P: Patella, F: Femur, T: Tibia, Fb: Fibula, White arrowhead: quadriceps tendon, White arrow: patellar tendon

	Mean±SD	Male (138)	Female (210)	t/p
Length of patella	41.26 ± 4.36	43.89 ± 4.78	39.49 ± 2.86	10.72/.00
Patellar tendon length	47.36 ± 6.70	49.93 ± 6.72	45.63 ± 6.12	6.14/.04
Proximal width	28.86 ± 3.49	30.72 ± 3.2	27.64 ± 3.09	8.88/.00
Distal width	23.53 ± 2.69	24.96 ± 2.42	22.59 ± 2.44	.01/.90
Proximal thickness	3.62 ± 1.47	$3.65 \pm .89$	3.59 ± 1.73	1.91/.95
Distal thickness	5.21 ± 1.10	5.48 ± 1.6	5.03 ± 1.02	1.65/.20
Insall-Salvati ratio	$1.18 \pm .59$	$1.21 \pm .91$	$1.16 \pm .17$.79/.43

Test: Independent t-test, $p < 0,05$

According to age and Insall-Salvati classification, 74.6% normal, 24.6% patella baja were detected in patients between 18-39 years old, 79.7% normal, 2.7% patella alta in patients between 40-59 years old, and 85.7% normal, 12.9% patella baja in patients older than 60 years (Figure 3).

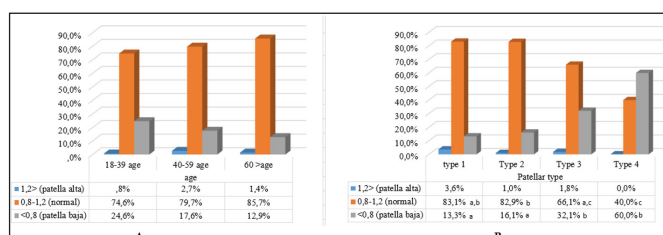


Figure 3. The relation of patella height/position with A-age ($p > 0.05$) and B-patella type ($p < 0.05$) according to the Insall-Salvati index

It was determined that the Insall-Salvati index did not cause a statistical difference according to age. The patella type showed significance with the Insall-Salvati classification (Figure 1). According to the Insall-Salvati index, normal was observed in type I patella with a rate of 83.1%, patella baja was observed in type III patella with the highest rate (60.0%), and patella alta was observed in the highest rate (%3,6) in type I patella (Figure 3).

It was determined that there was a decrease in the Insall-Salvati index with age, but this decrease was not statistically significant between age groups. In addition, it was determined that the Insall-Salvati ratio-infrapatellar fat pad relationship did not differ significantly between normal (1.18±0.63) and edematous (1.17±0.28) individuals. Likewise, the Insall Salvati ratio-prepatellar fat pad relationship was not statistically significant between normal (1.21±0.79) and edematous (1.18±0.16) subjects (p>0.05) (Figure 4).

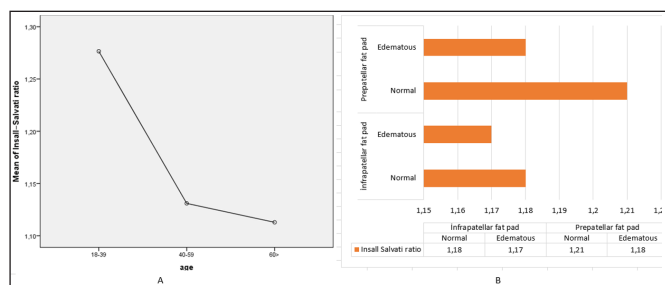


Figure 4. A. Variation of Insall-Salvati ratio by age B. Relationship between the infrapatellar and prepatellar fat pad and Insall-Salvati ratio

DISCUSSION

Lateral knee radiographs, which usually require a specific knee position, have also been used to evaluate patellar height (9). However, measuring patellar tendon length on lateral knee radiography is problematic because it is sometimes difficult to identify the distal attachment point of the tendon in the tibial tubercle due to differences in bone morphology in this region. However, magnetic resonance imaging (MRI) is recognized as a valuable, accurate and reproducible tool for structural joint measurements. In addition, MRI is much more reliable than other invasive methods, as it clearly shows the proximal part of the patellar tendon and allows the entire patellofemoral joint to be shown fully and clearly (10, 11). Various publications in the literature measure the dimensions of the patellar tendon by ultrasonography or MRI images, intraoperatively or in cadaver studies. However, it has been reported in many studies that cadaver and ultrasonographic measurements do not yield real results (17, 18). MRI method has been used with increasing frequency in recent years in imaging of the knee joint due to its possibility of high soft tissue contrast, multiplanar imaging opportunity and no known side effects. Although the structures of the knee joint can

be evaluated with ultrasound and computed tomography, the morphology (length, thickness, width, Insall-Salvati ratio, etc.) of the patellar tendon was analyzed with MRI in this study, as it is the gold standard in the evaluation of soft tissues in the knee and provides excellent resolution in soft tissues.

According to our research results, type I patella was detected in 23.9%, type II in 57.2%, type III in 16.1%, and type IV in 2.9% of individuals. The mean length of the patella was 41.26±4.36 mm, the patellar tendon length was 47.36±6.70 mm, the proximal width was 28.86±3.49 mm, the distal width was 23.53±2.69 mm, the proximal thickness was 3,62±1.47 mm, and distal thickness was 5.21±1.1 mm. It was determined that the Insall-Salvati ratio did not cause a statistical difference according to age, but the patella type showed significance with the Insall-Salvati classification. Also, the Insall Salvati ratio-prepatellar fat pad relationship was not statistically significant between normal (1.21±0.79) and edematous (1.18±0.16) subjects.

In evaluating patellar tendon morphology with age, Uçucu (19) stated that men's patellar tendon width, thickness and length were higher than women in all age groups, but there was no difference between ages. Similarly, the literature has reported that men's patellar tendon sizes are generally larger than women's (13, 20). Our study found that the patella and patellar tendon lengths of men were longer than women but did not differ according to age.

Fredberg et al. (20) reported that patellar tendon sizes were higher in males, the mean patellar tendon length was 40.0 mm, and its width was 36.0-35.0 mm at the proximal and distal. Andriakoula et al. (21), in their study on cadavers in the Greek population, reported that the patellar tendon was, on average, 31.9 mm in width at the proximal and 27.4 mm at the distal. Svensson et al. (22) measured the midpoint of the tendon in their MRI study on Swedes and reported the mean width as 28.6 mm. Basso et al. (17) reported that the mean proximal width of the patellar tendon is 31.2 mm, and its width decreases towards the distal. In addition, the finding that the patellar tendon is thinnest in the middle part suggests that the width in the middle part is an adequate reference for defining the very narrow tendon. Chang et al. (13) stated in their intraoperative research that a tendon width of <27 mm is insufficient for load bearing and renders it inadequate for graft. The findings of Chang et al. (13) on length (40.2 mm) suggest that Korean patients have a shorter patellar tendon. Shaffer et al. (9) reported the mean patellar tendon length as 48.4 mm (range, 40-63 mm). Andriakoula et al. (21) and Peace et al. (18) reported patellar tendon thickness and length as 3.7 mm-43.0 mm and 3.7 mm-42.6 mm, respectively. Uçucu (19) reported the mean patellar tendon length as 42.09±4.88

mm, proximal and distal width as 27.06-28.80 mm, and thickness as 3.88-4.50 mm. In parallel with Uçucu's (19) research results, in our study, the mean length of the patellar was 41.26 ± 4.36 mm, the patellar tendon length was 47.36 ± 6.70 mm, the proximal width was 28.86 ± 3.49 mm, and distal width was 23.53 ± 2.69 mm. Proximal and distal thicknesses were measured as 3.62 ± 1.47 mm and 5.21 ± 1.10 mm, respectively. Pathologically long/short or thicker than normal patellar tendon will directly affect knee joint surgery. In addition, edema and thickening of the anterior suprapatellar fat pad from any cause may affect the patellar tendon. It has even been stated that the thickening of the patellar tendon may increase inflammation in the anterior suprapatellar fat pad with the effect of friction and cause the problem to become chronic (5). In summary, it is thought that patellar tendon sizes for patellofemoral region surgery may differ between populations, and racial differences should be considered before surgical approaches.

It is stated that the patella type can explain the etiology of joint diseases such as knee pain, chondromalacia patella and lateral compression syndrome (16, 19). Wiberg et al. (14), in their prospective study on lateral radiographs, reported that type II and III patella types might be included in the differential diagnosis of patellar pain. Arslan et al. (23) found the incidence of patella types in their anatomical study to be 57% for type II patella, 24% for type I, and 19% for type III. A study performed on Merchant radiographs in Turkish society reported that type I patella was 24%, type II patella 70% and type III patella 6%, and type IV patella was not found in any patient (24). In our study, type I patella was detected in 23.9%, type II in 57.2%, type III in 16.1%, and type IV in 2.9% of individuals. Consistent with the literature, type II patella was primarily detected. Considering that the stress on the patella determines the shape of the patella, type III and type IV patella occur due to the lateral shift of the patella in the sulcus, and there is a symmetrical load on the type I patella.

The position of the patella in the vertical plane is determined by the Insall-Salvati index. The normal value for this ratio is 1 ± 0.2 . Below 0.8 is called the inferior patella (patella baja), and above 1.2 is called the patella alta. Patella alta is a good indicator of patellar instability. In this case, the time for the higher-placed patella to reach the femur in flexion increases, and accordingly, excessive lateral movement of the patella may develop (25). In mechanical model experiments, it has been shown that the patella alta causes a decrease in patellofemoral joint contact and an abnormal increase in the surface force between the patella and trochlea (26). Subhawong et al. (27) reported in a recent study that there is a close relationship between edema in the superolateral corner of Hoffa's fat pad and increased patellar tendon-patella length ratio. Kalichman

et al. (28) found in their MRI study that an increased Insall-Salvati ratio may cause a tendency to chondromalacia in the patellofemoral joint. While Ergun (29) reported that the Insall-Salvati ratio was higher in women than in men and older people compared to young people, there was no significant difference between gender and age in our study. Our study determined that distal width, proximal and distal thickness and Insall-Salvati ratio did not differ according to gender ($p > 0.05$). The mean Insall-Salvati ratio was found to be 1.18 ± 0.59 . Ergun (29) reported that the Insall-Salvati index was measured as 0.99 ± 0.09 and 0.94 ± 0.1 mm on average in women and men, respectively, and that there was a statistically significant difference between them, and that the Insall-Salvati index increased with increasing age. We found that the Insall-Salvati index decreased with increasing age, but this decrease did not create a statistical difference. We determined that the Insall-Salvati ratio was normal in 79.0% of the individuals in our research group and high in 19.3%. In patients with a high Insall-Salvati ratio, the patellar tendon is stretched during knee flexion and the underlying structures are compressed.

Widjajahakim et al. (4) reported that there is a significant correlation between infrapatellar (Hoffa) fat pad edema and Insall-Salvati ratio in patellar tendon/femur lateral condyle friction syndrome, and an increase in fat pad edema may occur as the ratio increases. Subhawong et al. (27) stated that a high patella causes more tension in the patellar tendon during knee movements, which can easily cause pressure on the bursa between the lateral femoral condyle. In this case, inflammation may develop in Hoffa, leading to edema and pain. The 2004 National Joint Registry report for England and Wales showed that surgeons differ in managing the infrapatellar fat pad during primary knee arthroplasty, with 27% complete removal, 59% partial removal, and 14% non-removal (31). It has been shown that complete infrapatellar fat pad excision can devascularize the patella by interrupting the infrapatellar anastomosis. This anastomosis is important as it also feeds the patellar tendon. In our study, edema in the prepatellar fat pad was diagnosed in 46.3% of the patients and the infrapatellar fat pad in 15.2%, but there was no statistical relationship between the Insall-Salvati ratio and the edema in the fat pads.

Limitations

The Insall-Salvati ratio is the most commonly used patellar height measurement method. However, this method has some disadvantages. One of these is an incorrect ratio measurement due to variations in patellar morphology. We used only the Insall-Salvati ratio in our research, but the patella height can be measured with the modified Insall-Salvati ratio, Caton-Deschamps and Blackburne-Peel ratios.

CONCLUSION

This study reveals the patellar tendon dimensions, both descriptively and surgically, and the clinical and social value of MRI evaluations in healthy individuals in Turkish society. However, it does not contain direct evidence that this potential value was realized in a clinical series. In order to test the clinical value, correlation studies can be done by comparing different patient groups in the future.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Bayındır Hospital Ethics Committee (Date: 16.02.2023, Decision No: BTEDK-06/23).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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