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Acquired changes in thickness and length of patellar tendon after primary total knee arthroplasty: a prospective ultrasonographic study with over 4 years of follow-up

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Previous literature has reported changes in the length or thickness of the patellar tendon (PT) following primary total knee arthroplasty (TKA). This study aims to determine the structural changes in both the length and thickness of the PT after primary TKA using ultrasound (US) and to investigate the association between these changes and clinical outcomes after a minimum follow-up of 48 months. This prospective study used the US on 60 knees of 32 patients (aged 54-80, mean 64.8±7 years) before and after primary TKA to evaluate changes in both the length and thickness of the patellar tendon. Clinical outcomes were assessed with HSS and Kujala scores. At the latest follow-up evaluation, there was a significant overall shortening of PT by 9.1% (p<0.001), in addition to significant global thickening by 20% (p<0.001). Besides, there was significant thickening by 30% in the proximal 1/3 (p<0.01) and 27% in the middle 1/3 (p<0.01) segments of PT. There was a significant negative correlation between the thickening identified in all three parts of the tendon and both clinical outcome measures (p<0.05). The results show the presence significant changes in PT in terms of length and thickness after primary TKA; in addition, increased thickness in PT was more strongly and significantly associated with inferior clinical outcomes, including functionality and anterior knee pain, than shortness in PT. This study also suggests that the US is a viable, non-invasive method for documenting PT changes in both length and thickness after TKA with serial scans.

Keywords: patellar tendon; USG; knee; arthroplasty; thickness; length; HSS; Kujala.

INTRODUCTION

Previous studies reported structural changes in the patellar tendon (PT) following primary total knee arthroplasty (TKA)[1,2]. Shortening is the most renowned and documented change in the structure of the PT after TKA. Some authors argue that exposure to ischemic or traumatic injury during surgery provokes shortening of the PT[3,4]. Previous reports suggest significant shortening of the PT after TKA leads to patella baja (infera), which can cause patellofemoral pain and impair functional outcomes; nevertheless, the exact etiology and prevalence of structural changes in the PT after primary TKA are still controversial[2,5-7].

Various methods relying on plain radiographs were described for assessing PT length; however, these techniques have several disadvantages, such as differential magnification errors or the need for precise positioning in addition to the required radiation exposure[8-11]. Magnetic resonance imaging (MRI) was also suggested to determine PT length; yet, this is definitely an expensive approach in more extensive patient series[12]. Direct ultrasonography (US) is a convenient and accurate method for investigating soft tissues such as tendons. Previous reports suggest using the US to evaluate structural changes in the PT after TKA[13,14]. This study used direct ultrasonographic (US) examination to determine PT changes in both length and thickness and compared US results with the widely accepted ISR technique to check for consistency between methods[15].

A comprehensive review of the literature revealed that no prospective US study investigating structural changes in both thickness and length of the PT after primary TKA matched the four years or longer follow-up period in this study. Besides, most previous reports focused particularly on changes in “length” rather than the thickness of the PT. The authors of this study think that postoperative structural changes in the PT, not only in length but also in thickness, indicate the pathological condition of the tendon. Therefore, more precise identification of postoperative acquired changes in PT structure will provide evidence-based information about their impact on clinical outcomes after TKA. This study hypothesizes that the PT may not only shorten after primary TKA but also get thicker, and the increase in thickness may also affect clinical outcomes.

PATIENTS AND METHODS

This prospective study initially enrolled 86 knees of 46 patients who were admitted to the Orthopaedics and Traumatology Department. All patients were diagnosed with advanced-stage gonarthrosis and scheduled for TKA surgery. Sixty knees of 32 patients were eligible for analyses after applying inclusion and exclusion criteria and eliminating patients who did not attend follow-up visits or died during the follow-up period (Figure 1). Approval for the study was obtained from the ethics committee of Afyonkarahisar Health Sciences University, numbered 2013/01-022, and all the participants provided written informed consent.

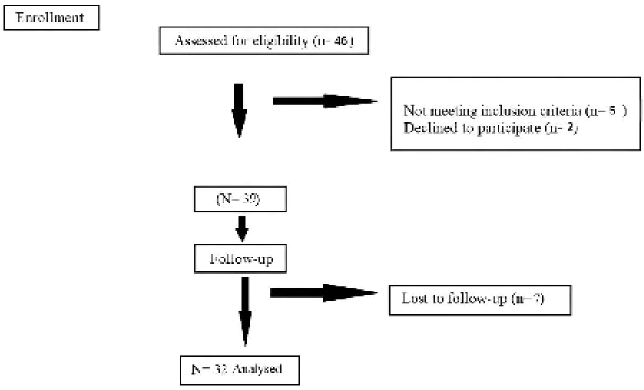

Figure 1. — Flowchart of the study.

All patients underwent US examinations for baseline PT length and thickness measurements before TKA surgery. In accordance with the inclusion criteria, all patients in this study had a minimum follow-up of 48 months. The exclusion criteria for this study included: (1) history of primary or revision knee arthroplasty; (2) valgus deformity of the knee (3) primary or revision hip arthroplasty; (4) fracture involving the lower extremity; (5) intraoperative lateral release; (6) amputation of the lower extremities at any level; (7) evidence of anterior overstuffing on X-rays; or (8) lack of follow-up visit compliance.

This study excluded patients with ≥3mm anterior femoral overstuffing (AFO). AFO is described as the offset error of the femoral component via selecting a femoral component that is too large or an overly

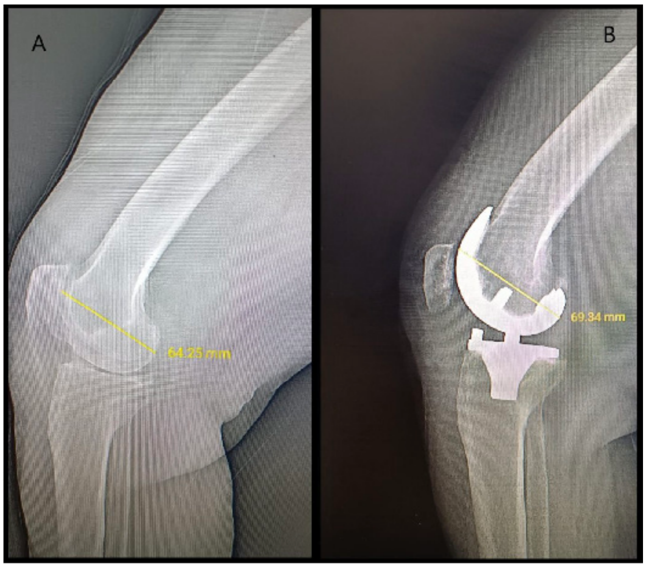

Figure 2. — The anterior offset of the femoral component is an important factor on the biomechanics of the patellofemoral joint. Anterior femoral overstuffing (AFO) can lead to increased pressure of the patella and its surrounding structures.

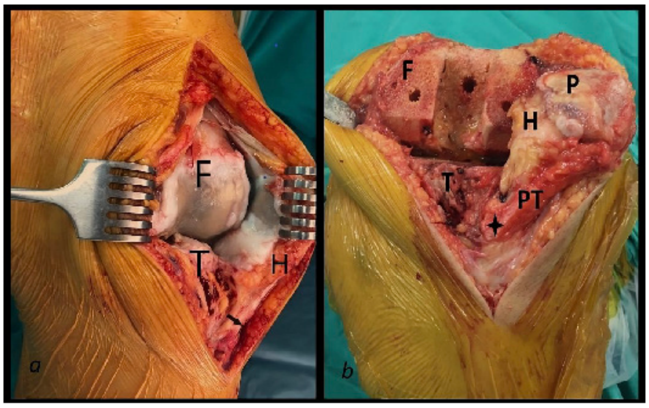

Figure 3. — Intraoperative photo during primary TKA. a. Arrow demonstrates the sagittal thickness of patellar tendon prior to femoral (F) and tibial (T) cuts and excision of Hoffa's fat pad (H) b. Please note the change in posture of the tendon after patellar eversion, which may cause injury during surgery, especially at the attachment site marked with an asterisk.

minimal anterior resection of the anterior femur. It was measured on non-weight-bearing lateral X-rays with the knee in 30° flexion (Figure 2). Since none of the patients had patellar resurfacing, no measurements were taken in the skyline view with the knee in 45° flexion.

Posterior-stabilized cemented TKA implants (T08 Total Knee System /Tıpsan® A.Ş., Izmir, Turkey) were used without patellar resurfacing since the implant design was patellar friendly. A single surgeon performed all procedures. All knees had varus deformity; therefore, a standard anterior midline approach with medial parapatellar arthrotomy was employed, along with partial Hoffa excision. The surgeon performed patellar eversion routinely in all cases for better visualization (Figure 3).

Conventional gray-scale US imaging was used to measure the PT's thickness and length before surgery and at the last follow-up visit. All cases were evaluated by a single radiologist with more than 20 years of experience in musculoskeletal imaging and analysis using a Hitachi Preirus (Hitachi Ltd., Tokyo, Japan) device with a 13 MHz linear probe. With the knee at 30° flexion, the radiologist placed a support under the knee to maintain the appropriate flexion angle. The flexion angle helped to stretch the extensor mechanism and prevent anisotropy (concavity) of the PT. The viscous scanning gel at room temperature ensured proper contact between skin and transducer[16]. The transducer was placed along the long axis of the tendon (Figure 4).

PT length was measured between the tibial tuberosity and patellar insertion points as described by Gellhorn et al.[17] (Figure 5). This technique uses: (1) the apex of the patella as the landmark of the beginning of the patellar tendon since it is a well-defined hyperechoic structure with posterior acoustic shadowing. (2) The bony ridge at the proximal tibia at the level of the epiphysis is the distal landmark since it is a well-defined and easily distinguishable bony landmark. The total length was divided into three parts to measure the sagittal thickness at the PT's proximal, median, and distal thirds. The average of these three measurements was used to evaluate global tendon thickness (Figure 6). The same radiologist measured the length and thickness of the tendon before surgery and at the final follow-up at least four years after surgery. The absolute change in millimeters and relative change (percentage change) in the length and thickness of the tendon was noted and calculated.

The authors of this study aimed to check consistency of the PT measurements with the US method using the results of the widely-accepted ISR technique. Therefore, preoperative and postoperative ISR (maximum PT diagonal length/patella length) values were calculated for each patient on plain knee radiographs obtained at 30° flexion[9].

Figure 4. — (a) Transducer placement in the sagittal plane (black box) over the anterior knee (b) knee positioning for USG evaluation in 30° of flexion.

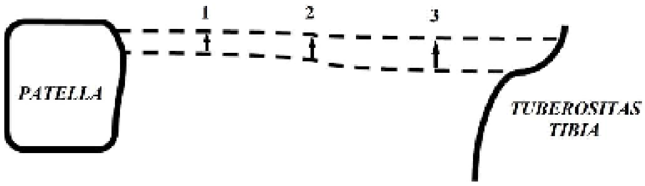

Figure 5. — A basic schematic demonstration about USG measurement of patellar tendon. Total length was measured between patella and tuberositas tibia. Thickness of patellar tendon is evaluated at three segments: (1) proximal, (2) middle and (3) distal.

Demographic data of the participants, as well as baseline Hospital for Special Surgery (HSS) knee scores[18] and Kujala patellofemoral scores[19] were recorded before TKA. Validated Turkish versions of the HSS and Kujala scoring systems were used[20,21]. HSS knee and Kujala scores were recorded before and after the procedure.

In the HSS scoring system, which consists of a total of 100 points, increased score indicates better results. A knee score greater than 85 points was considered excellent (minimal symptoms), 84-70 was good, 69-60 was mediocre, and lower than 60 was graded as poor (very poor clinical outcome and severe symptoms).

There are several scoring systems for knee symptoms, but we preferred to use the scoring system published by Kujala et al in 1993, since it is a patient-reported assessment of patellofemoral disorders and assesses subjective symptoms or functional limitations through a scale focused specifically on patellofemoral pain[19]. The Kujala questionnaire has a total of 100 points, and higher score indicates better results.

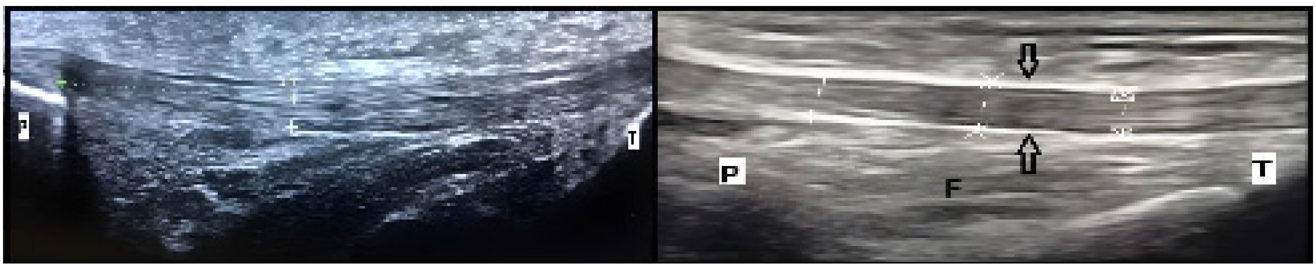

Figure 6. — US image of the patellar tendon (Arrowheads). P, patella; T, tibia; F, Hoffa's fat pad.

Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA) and MedCalc (MedCalc Software bv, Ostend, Belgium) software. Numeric variables are summarized as means and standard deviations, and categorical variables are presented as numbers and percentages. The Shapiro-Wilk test was used for numeric variables with normal distribution. When parametric test conditions were met, the differences between the mean values of numeric variables in the 2 groups were analyzed using t-tests, and the Mann-Whitney U test was used for non-parametric variables. The relationships between numeric variables are presented as Pearson or Spearman correlations. In addition, the percentage change (relative change), which is defined as the change in value divided by the absolute of the original value multiplied by 100, was calculated for the difference in the total length and thickness of the 3 parts of the tendon and for the clinical scores in order to perform correlation analyses. The significance level was set at $p<0.05$ for all statistical analyses.

A post hoc power analysis was performed using the "G. Power-3.1.9.2" software[22] based on determining the significance of the change in pre- and postoperative length as the primary outcome measure. As a result of the analysis applied to 60 subjects at α= 0.05 level, the effect size was found to be 0.8053 and the power of the study was calculated as 0.99. The minimum power value required for post hoc analysis is 0.67. In this respect, the power of the study was found to be at an acceptable level.

RESULTS

A total of 60 operated varus knees (29 right, 31 left) of 32 patients who underwent primary knee arthroplasty were included in this study. Twenty-three patients (71.9%) were female, and 9 (28.1%) were male. The mean age of the patients was 64.8±7 years (range: 54-80 years), and the mean follow-up period was 52.32 (range: 48-72) months (Table I).

US measurements indicated that mean baseline PT length of the patients was 40.11±5.99 mm, whereas mean postoperative length was 35.8±4.31 mm, suggesting significant shortening of the tendon (p<0.001) (Table II). The mean PT length of patients after TKA was 4.31±6.9 mm shorter than the baseline measurement (Figure 7). Additionally, percentage change values (PCV) showed an average of 9.1% reduction in PT length after primary TKA.

Table I. — Demographic and clinical characteristics of the patients

	N	%	Mean±SD
Number	32		
Gender			
Female	23	70,8	
Male	9	29,2	
Age (year)	32		64,78 ± 7
Female	23	70,8	62,78 ±6
Male	9	29,2	69,88± 7,2
Side	60		
Right	29	48,3	
Left	31	51,7	
Follow-up period (month)			52,32

Table II. — Pre-operative and post-operative patellar tendon measurements by ultrasound method

	Pre-operative	Post-operative	p
Total Length (mm)	40,11±5,99	35,8±4,31	**<0,001**
Sagittal thickness (mm)			
Proximal 1/3	4.29±0.94	5.39±1.12	**<0,001**
Middle 1/3	3.57±0.77	4.46±1	**<0,001**
Distal 1/3	4.78±1.24	4.92±0.98	**=0,796**
Global	4.21±0.82	4.92±0.93	**<0,001**

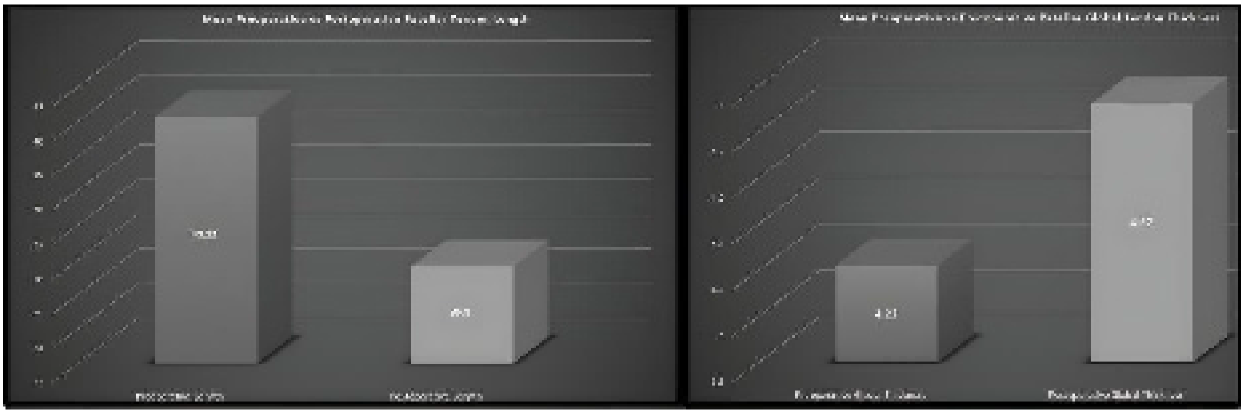

Figure 7. — Change in mean PT length and global thickness with USG evaluation after primary TKA

Table III. — Pre-operative and Post-operative Scores

Variable	Female (n=23)	Male (n=9)	Total (n=32)
HSS (mean±SD)			
Preoperative	58 ± 6,04	58,42 ± 9,4	58,1 ± 6,8
Postoperative	66,71± 7,68	68,5 ± 9,7	67,1 ± 8,1
*Δ HSS**	0,17 ± 0,09	0,17 ± 0,09	0,17± 0,09
Kujala (mean±SD)			
Preoperative	42,6 ± 11,2	45,8 ± 13,4	45,01 ± 11,19
Postoperative	63,5 ± 7,3	67,2 ± 10,4	65,81 ± 11,28
*Δ Kujala***	0,6 ± 0,2	0,5 ± 0,2	0,53 ± 0,23

SD: Standard Deviation. * (Postoperative HSS – Preoperative HSS)\ (Preoperative HSS). **(Postoperative Kujala – Preoperative Kujala)\ (Preoperative Kujala).

In addition, the ISR value was calculated on the plain radiograph of each patient included in the study. The mean baseline ISR value was 1.03±0.13, while the mean ISR value after primary TKA was 1.00±0.13. Consistent with the US measurements, the difference between baseline and postoperative ISR values suggested significant shortening of PT after primary TKA ($p \leq 0.001$).

Tendon thickness was measured separately in 3 segments using US as previously mentioned in the methods section. The mean thicknesses in the proximal, middle, and distal third of the PT were 4.29±0.94 mm, 3.57±0.77mm, and 4.78±1.24 mm, respectively, for baseline measurements. Mean thickness of all segments reached 5.39±1.12 mm, 4.46±1 mm and 4.92±0.98 mm after primary TKA (Table II). The mean amounts of increase in the thickness of the proximal, middle and distal portions of the PT were 1.09±1.24 mm, 0.89±0.96 mm and 0.13±1.5 mm, respectively. Analysis of these values showed a significant increase in thickness in the proximal and middle third of the PT ($p<0.01$), while the increase in thickness in the distal third of the tendon was not significant ($p>0.05$). PCV analysis showed an average thickness increase of approximately 30%, 27%, and 11% in the proximal, middle, and distal portions of the tendon, respectively. (Table II).

Global tendon thickness, which was derived from the mean thickness of three segments, increased from a baseline value of 4.21±0.82 mm to 4.92±0.93 mm at last US evaluation at least four years after surgery (Figure 7). These results showed that there was a significant increase in the global thickness of the PT after primary TKA ($p<0.01$). PCV analysis showed 20% increase in global thickness of PT (Table II).

The mean baseline Kujala scores for all patients were calculated as 45.01±11.19 (females: 44.23±11.28, males: 47.57±10.90), and scores were 65.81±11.28 (females: 65.63±10.48, males: 66.85±14.03) after TKA. This study illustrated that the mean Kujala scores of the patients showed a significant increase after primary TKA ($p \leq 0.001$) (Table III). PCV analysis also showed that mean Kujala score of the patients increased by an average of 53% after TKA.

The mean preoperative HSS knee score for both groups was 58.1±6.88 (females: 58±6.04, males: 58.42±9.4). The mean postoperative HSS knee score was 67.13±8.14 (females: 66.71±7.68, males 68.5±9.7). Analysis of the mean HSS scores showed a significant increase after TKA ($p \leq 0.001$) (Table III). Mean HSS score of patients increased 17% after TKA (0.17±0.09).

The PCVs of both patellar tendon measurements and clinical scores were calculated in order to per-

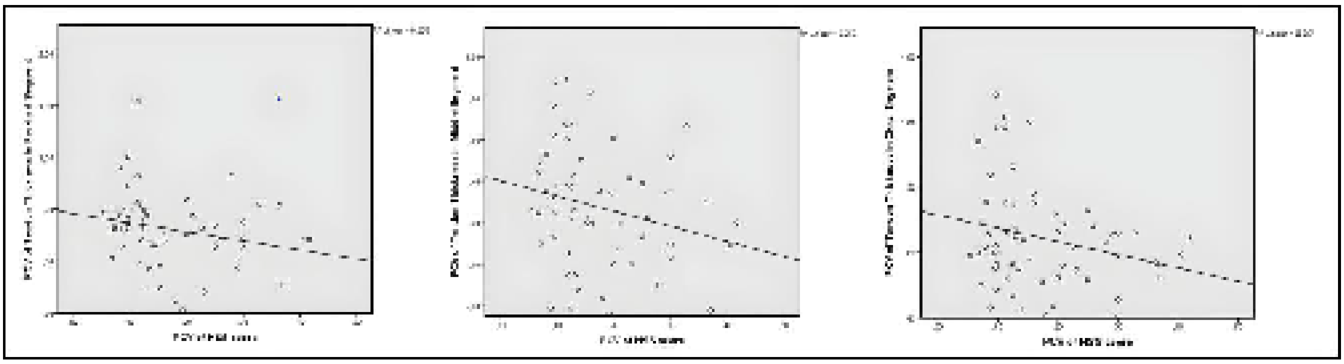

Figure 8. — Correlation between PCV of HSS scores and thickness of PT in each segment. Please note an increased slope of fit line indicating significance.

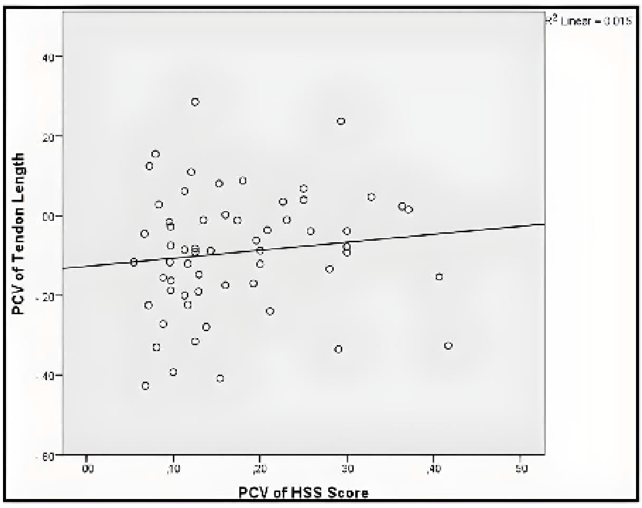

Figure 9. — Correlation between HSS scores and PT length.

form correlation analysis between changes in these parameters.

The PCV in the thickness in any segment of the patellar tendon showed a significant positive correlation with the others (p<0.001). The PCV for thickness in any of the PT segments was negatively correlated with the PCV of PT length; furthermore, the negative correlation was statistically significant regarding the distal segment thickness and length of PT (p=0.011).

Correlation analysis showed that the PCV of HSS score had significant negative correlation with the PCV of PT thickness in the proximal (p=0.003), middle (p=0.015) and distal (p=0.014) parts (Figure 8). The PCV of Kujala score was also found to have significant negative correlation with the PCV of sagittal thickness in the proximal (p=0.036), middle (p=0.027) and distal (p=0.040) segments of the tendon. These results showed that thicker PT was associated with significantly lower clinical outcome scores and increased anterior knee pain.

Correlation analysis between the PCV of PT length and the PCV of the HSS (p=0.576) and Kujala scores (p=0.444) did not demonstrate significance (Figure 9), though the results suggest PT length is positively correlated with HSS and Kujala scores. In other words, shorter PT was associated with poor clinical outcomes and increased anterior knee pain.

The PCV of the PT length had a significant negative correlation with the PCV of sagittal thickness in the distal part of the tendon suggesting strong association between increased distal thickness and shortening of PT (p=0.002).

DISCUSSION

The results of this prospective study, investigating the changes in the PT after primary TKA with the US, showed significant shortening of PT at a mean rate of 9.1% and a mean global thickening of 20% after a follow-up of 4 years or more (Figure 6). Moreover, the results suggested a significant thickening of 30% in the proximal and 27% in the middle 1/3 segments of the PT. Thickening in any part of the PT had a considerable tendency to provoke thickening in other regions, suggesting that the factors causing the increase in thickness were effective throughout the entire tendon after primary TKA. The results also revealed a significant correlation between thickening in the distal thirds and tendon shortening; this can be interpreted as both thickening and shortening of the PT being interrelated processes in the long term. Patients with shorter PT tended to have lower clinical outcome scores; nevertheless, thicker PT was more strongly and significantly associated with inferior clinical outcomes, including functionality and anterior knee pain (Figure 7, 8).

Previous studies reported that TKA is associated with a significant shortening of the PT[6,23]. Current practice generally relies on indices calculated on x-rays to determine the shortening of the PT. These include the Blumensaat line method, the ISR, the Blackburne–Peel ratio, and the Caton-Deschamps index[8-11]. These techniques require radiation exposure to a certain extent, whereas they are widely used in clinical practice, most commonly the ISR. On the other hand, the US can simultaneously measure the PT's thickness and length as a non-invasive method. Previous studies noted that the most common problem in using these techniques is the potential difference in magnification as the distance between the patient, the radiation source, and the radiation plate is subject to minor variations[24]. In their study of 1055 primary TKA cases, Meneghini et al. reported that half of the patients had actual PT shortening. Still, patella baja was documented in only 9.8% of patients using ISR criteria (ISR < 0.8)[6]. This result shows that some patients may not meet the accepted patella baja margins of "ISR<0.8" despite significant PT shortening. It is most likely because cutting and removing osteophytes in the patellar bone changes the patellar length used in the calculation of ISR. As a result, the ISR technique may be insufficient to determine actual patella baja, especially in patellar replacement cases[24]. Some authors also agree with Meneghini et al., and several different methods were defined to more accurately detect the shortening of the PT (25,26). Other methods, such as Blackburn-Peel[10] or Caton-Deschamps[11], which were suggested to overcome this problem, refer to the joint line. Still, these methods may not distinguish actual PT shortening from pseudo-patella baja due to joint line changes that may develop after TKA[7]. This study used the US technique to "directly" measure the length and thickness of PT without the need for radiation.

Despite all the problems described above, since ISR is generally the most preferred and widely accepted method, the authors calculated the ISR values to check the consistency of the results with the US measurement. The results obtained by the ISR method likewise confirmed that the PT shortened significantly after primary TKA. A recent study using the same US technique to evaluate the PT, but with a short follow-up period, reported significant shortening of the PT at a rate of 7.71% at six weeks and 7.58% at three months after TKA[13]. Consistently, this study also determined a significant PT shortening of 9.1% following primary TKA after more than 4 years of follow-up. In this context, these results suggest that the US method can also be used to successfully detect PT shortening after primary TKA. Thus, a PT release procedure may be employed instead of total revision arthroplasty to reduce infrapatellar adherences in cases with limited ROM.

The use of the US method in this study allowed simultaneous measurement of PT's length and thickness. In a recently published study, Creteur et al.[13] reported a significant 113.5% increase in global PT thickness at three months. However, the results of this present study suggest significant thickening of 30% in the proximal third and 27% in the middle third after a follow-up of 4 years or longer. The authors attribute this discrepancy between results to the fact that the morphological changes seen in the PT may change over time. For instance, Weale et al. reported that significant changes could be observed in the eighth month after TKA and tend to persist up to 5 years after the procedure[2].

Creteur et al. also reported a significant increase in thickness in the middle part of the tendon compared to the proximal and distal portions at the 6th-week follow-up[13]. According to the results of this study, although there was an increase in thickness in the whole tendon, an increase was evident especially in both the proximal and middle 1/3 parts. At this point, another finding that authors should emphasize is the statistically significant shortening of the PT length in patients with increased thickness in the distal third segment of the tendon. In other words, not many patients had increased sagittal thickness in the distal third of the PT; however, when it occurred, it was a good sign of shortening of the tendon.

The results of this study, consistent with previous literature[13], indicate that sagittal plane changes in the tendon involve all segments; however, thickening is prominent mainly in the proximal and middle parts of the PT. From this perspective, the authors think this heterogeneous structure change may affect the tendon's integrity in the long term. Therefore, future biomechanical studies are needed to determine whether an imbalance in thickness can cause relative structural weakness and why increased thickness in the distal third of the tendon strongly correlates with PT shortening.

It has long been known that patella baja can significantly impair clinical outcomes after TKA, and PT shortening is a known cause of patella baja[6,23]. There is consensus that shortening of the PT will result in postoperative pain and impaired function[24]. Weale et al.[2] demonstrated that more than 10% PT shortening would produce pain, and every 1 mm shortening in length would reduce the range of motion by 1°. The authors of this study also concur with these reports. Although not statistically significant, this study illustrated a positive correlation between PT length and clinical outcomes. The authors determined that patients with PT shortening had lower HSS and Kujala scores and worse clinical results.

This study's most essential and interesting finding, not found in the existing literature, was that PT thickness negatively correlated with clinical outcomes in significance. Patients with increased sagittal thickness in all three segments of the PT had significantly impaired clinical outcomes. This study found that thickening in the distal 1/3 part was significantly associated with the shortening of the entire tendon. These results suggest that the shortening and thickening in the tendon may be interrelated processes and adversely affect clinical outcomes. Therefore, the authors recommend orthopedic surgeons screen PT shortening and thickening with the US in a non-invasive fashion in cases with patellofemoral complaints or any doubt after or before TKA. This approach may help reduce patellofemoral complications and improve clinical outcomes after TKA by giving information to the surgeon about the "fibrotic" status and infrapatellar adherences of the patellar tendon before a decision to revise. Then, the surgeon may consider a patellar tendon release instead.

The strengths of this study can be listed as the prospective design, the use of a novel technique to determine morphologic changes in the PT, and the relatively long follow-up time of over four years compared to similar studies in the literature using the same USG technique. There is no prospective study matching the follow-up period of 4 years or over and attempting to monitor changes in the PT's length and thickness with the direct US technique. By virtue of the previous reports suggesting structural changes can persist in the medium-term after surgery[2] this study set a minimum follow-up of 4 years.

On the other hand, this study has some limitations, such as having a relatively small patient population, comprising patients with only posterior-stabilized (PS) implants, and not evaluating US measurements as double-blind. Another weakness of this study is that the intraclass correlation coefficient (ICC) values could not be calculated because the same radiologist made the measurements. However, a previous study by Skou et al. about the intra- and interobserver reliability of ultrasonographic measurements for PT thickness reported that ultrasonographic measurement of PT thickness is a reliable method and changes greater than 0.7 mm can be considered as true changes[27]. In this study, the amount of thickness increase we detected in both the proximal and middle parts of the PT was above this specified figure.

The results of this present study suggest significant changes in both the length and thickness of the PT in patients who underwent primary TKA and were followed for 4 years or longer, and these changes may adversely affect clinical outcomes. This study also showed that these changes can be detected successfully with US, which is a non-invasive method, so that changes in the PT can be followed more effectively during patient follow-up by performing serial US scans. Determining the changes in PT thickness and length after primary knee arthroplasty will be useful for the treatment with a possible "patellar tendon release" instead of revision arthroplasty and follow-up of the patients having persistent anterior knee pain or poor clinical results due to patellofemoral problems in the postoperative period. In addition, it is very important to observe any severe changes in the PT before performing revision knee arthroplasty, as structural deterioration in the tendon can lead to perioperative tears that can truly compromise clinical success.

CONCLUSION

The results of this study suggest that acquired changes in PT structure have the potential to impact clinical outcomes and result in persistent anterior knee pain. Serial US scans of PT in the follow-up period may help orthopedic surgeons to consider a possible PT release procedure instead of revision in cases with limited ROM or patellofemoral complaints. Besides, more accurate documentation of changes in the PT after TKA with serial US scans will help orthopedic surgeons develop new techniques to protect the PT during surgery or avoid existing routines that may damage the tendon.

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