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Impact of knee varus and valgus deformity on alignment in lower extremities after total knee arthroplasty (TKA)

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Abstract. – OBJECTIVE: To investigate the impact of knee varus and valgus in varying degrees on the alignment in lower extremities of patients who received the total knee arthroplasty (TKA).

PATIENTS AND METHODS: We retrospectively analyzed the condition of varus and valgus deformity in full-length X-ray films of double lower extremities in weight-bearing position of 120 patients before and after they firstly received the TKA between March 2012 and May 2014 to discover the impact of knee varus and valgus in varying degrees on the alignment in lower extremities of patients who received the total knee arthroplasty (TKA). 120 patients were divided into three groups by the pre-operative hip-knee-ankle angle (HKA), the HKAs of three groups were compared after operation, and linear regression analysis was conducted to identify the correlation between pre- and post-operative HKAs. In addition, comparison between the pre- and post-operative lean of arms and legs (LMAL) was carried out to explore the variations before and after operation as well as the differences in the average variations among three groups.

RESULTS: The differences were statistically significant in comparison of the pre- and post-operative HKAs and medial proximal tibia angles (MPTA) of all affected extremities ($p<0.05$), but no statistically significant difference was shown in comparison between the pre- and post-operative knee physical valgus angles (KPVA) ($p>0.05$). The post-operative lengths of 86.57% of affected extremities (116/134) were longer than those before operation with statistically significant differences ($p<0.05$). However, no statistically significant difference was identified in comparison between the pre- and post-operative lengths of extremities that did not receive any operation ($p>0.05$). The ratios of HKAs between -3° and 3° in normal group, mild-deformity group and severe-deformity group were respectively 90.48%, 81.25%, and 34.69% with a statistically significant difference ($p<0.05$). Besides, the scatter plot revealed that there was a linear regression relation between pre- and post-operative HKAs ($F=51.197$, $p<0.05$). There were statistically significant differences in comparisons of the pre-operative KPVA and MPTAs among three groups ($p<0.05$).

CONCLUSIONS: Severe knee varus and valgus deformity can increase the deviation of alignment in lower extremities after TKA, and most of LMALs after TKA are longer than those before TKA, and the most significant extension is identified in severe varus and valgus deformity.

Key Words

Knee varus and valgus deformity, Alignment in lower extremities, total knee arthroplasty.

Introduction

Total knee arthroplasty (TKA) is the most effective treatment for advanced gonarthrosis for various advantages, such as relieving the pain of patients and restoring the function of knee joint[1]. Even a slight deviation in alignment in lower extremities can cause instability of knee joint, persistent pains and an increase in the risk of wear-out failure of polyethylene components and looseness rate of implant[2]. Thus, effectively restoring the alignment in lower extremity is a key factor in achieving the satisfying efficacy.

Many studies[3,4] have confirmed that the varus and valgus angles after TKA manipulated less than 3° are the idle outcome. A follow-up study showed that the looseness rate of implant was only 3% in the 12th year after TKA when the post-operative varus and valgus angles were manipulated less than 3°. However, for patients with the angles more than 3°, the looseness rate of implant in the

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8th year after TKA could be as high as 24%[5]. Knee varus and valgus deformity, as clinical symptoms manifested in the advanced osteoarthritis, can lead to the abnormal load distribution, further promoting the progressive development of osteoarthritis[6]. We retrospectively analyzed the condition of varus and valgus deformity in full-length X-ray films of double lower extremities in weight-bearing position of 120 patients before and after they firstly received the TKA between March 2012 and May 2014 to discover the impact of knee varus and valgus in varying degrees on the alignment in lower extremities of patients who received the total knee arthroplasty (TKA).

Patients and Methods

General Material

In this study, the patients with the history of fracture of lower extremity or artificial hip joint arthroplasty were excluded. A total of 120 patients (134 affected knees) were enrolled, in which there were 23 males (25 affected knees) and 97 females (109 affected knees), and the age of patient ranged from 42 to 83 years old with an average of (67.46±6.61) years. 114 patients (127 affected knees) were clinically diagnosed with osteoarthritis, 5 (6 affected knees) with rheumatoid arthritis and 1 (1 affected knee) with traumatic arthritis. This study was approved by the Ethics Committee of Weifang People's Hospital. Signed written informed consents were obtained from all participants before the study.

Surgical Method

When the patient was under the general anesthesia, an anterior midline incision was made and intramedullary positioning was realized by fixing the navigation trackers was fixed on femur. Suitable type of steel plate was chosen to perform the osteotomy from four directions. For osteotomy of tibia, we fixed the navigation trackers on tibia for extramedullary positioning. The orientation of osteotomy should be perpendicular to the mechanical axis of tibia. After the osteotomy, we placed the test implant and adjusted the position of surrounding soft tissues in a balanced state. Then the stable types of implants of femur and tibia (Smith, Nephew and Stryker, London, UK) were selected based on the type of test implant. Subsequently, implant that was filled by bone cement and the intubation tubes were together placed on the surface, which had been rinsed through pulse irrigation followed by the close of incision.

Measurement of Alignment in Lower Extremities

Before operation and between the 3rd day and 6th day after operation, we took the full-length X-ray images of double lower extremities in weight-bearing position of patients using the Philips BACKY DIAGNOST 500 mA X ray shoot apparatus, and perform the measurements of alignment in low extremities on the full-length X-ray images of double lower extremities in weight-bearing position using the Digimizer V3.7.1.0 (MedCalc Software, Ostend, Belgium), an analysis software of medical image. During the measurements, centers of femur, knee joint and ankle joint were firstly identified, in which the concentric circle method was applied for identifying the femur center, and the midpoint between the medial and lateral malleolus was taken as the center of knee joint, and the center of ankle joint was determined by the midpoint ligature passing through the medial and lateral malleolus on the surface of distal joint of tibia. In addition, the midpoint of horizontal width of femoral shaft that was 10 cm above the space between knee joints was taken as the second center of femoral shaft[7].

Under physiological state, the mechanical axis of lower extremities, i.e. the ligation between the centers of femur and ankle joint, passed through the center of knee ankle. The length of mechanical axis of lower extremity (LMAL) referred to the distance between the centers of femur and ankle joint. Mechanical axis of femur referred to the ligation between the centers of femur and knee joint. Anatomical axis of femur referred to the ligation between the center of knee joint and the second center of femoral shaft. The mechanical axis and anatomical axis of tibia were the same, i.e., the ligation between the centers of knee joint and ankle joint. Hip knee ankle angle referred to an angle between the mechanical axes of femur and tibia, and the ideal angle was 0°. If the angle was larger than 0°, patient could be diagnosed with knee varus deformity, and if the angle was smaller than 0°, patients with knee valgus deformity. KPVA was an angle between the mechanical axes of femur and tibia, and the Medial proximal tibia angle (MPTA) was an inside angle between the mechanical axis and surface of tibia joint (Figure 1). According to the pre-operative measurements of HKA, we found in this study there were 119 varus knees and 15 valgus knees. Besides, patients were divided into groups by following criteria: The HKA that was in the range from -3° to 3° was taken as normal, and the HKA

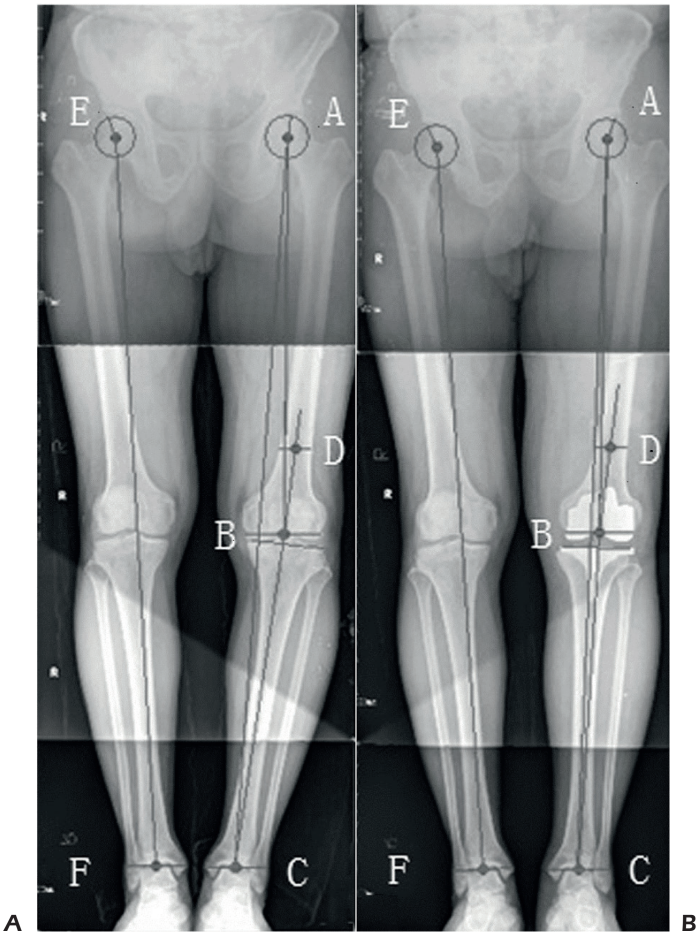

Figure 1. Pre- and post-operative weight bearing full-length X-rays of lower extremities. **A**, Pre-operative X-ray of lower extremities. **B**, Post-operative X-ray of lower extremities. A (E): center of femur head. B: center of knee. C (F): center of ankle. D: Second center of femoral shaft. AC (EF): Mechanical axis of lower extremities. AB: Mechanical axis of femur. BC: Mechanical axis of tibia. BD: Femoral shaft anatomical axis. Hip knee ankle angle (HKA): the angle between AB and BC. Knee physical valgus angle (KPVA): the angle between AB and BD. Medial proximal tibia angle (MPTA): the angle between BC and tibia facet. Lean of arms and legs (LMAL): the length of AC or EF.

that was -10°≤HKA <-3°or 3°<HKA≤10° as mild knee varus and valgus deformity, and the HKA that was >10° or HKA <-10° as severe knee varus and valgus deformity. They were divided into 3 groups: Normal group (n = 21 knees), in which there were 15 knees that were placed by implants of Smith & Nephew and 6 that were placed by Stryker and the average of age was (67.38±8.21) years and the BMI average was (27.31±4.00) kg/m^2; mild deformity group (n = 64 knees), in which there were 42 knees that were placed by implants of Smith and Nephew and 22 that were placed by Stryker and the average of age was (67.05±7.17) years and the BMI average was (26.82±4.32) kg/m^2; severe deformity group (n = 49 knees), in which there were 30 knees that were placed by implants of Smith and Nephew and 19 that were placed by Stryker and the average of age was (68.10±5.77) years and the BMI average was (25.97±3.31) kg/m^2. No statistically significant differences were identified in comparison of ages and BMIs among the three groups (p>0.05).

Statistical Analysis

Statistical analysis was performed for data using Statistical Product and Service Solutions 17.0 statistical analysis software (SPSS Inc., Chicago, IL, USA). Measurement data were presented as mean ± standard deviation ($\bar{x}$±s). Comparison between groups was done using One-way ANOVA test followed by Least Significant Difference (LSD) Post Hoc Test. The x^2-test was adopted in the intergroup comparison of count data, and simple linear regression analysis was conducted in identifying the correlations between the pre- and post-operative HKAs and between the pre-operative HKA and KPVA. $p<0.05$ suggested that the difference was statistically significant.

Results

The differences were statistically significant in comparison of the pre- and post-operative HKAs and MPTA of all affected extremities ($p<0.05$), but no statistically significant difference was shown in comparison between the pre- and post-operative KPVA ($p>0.05$). The post-operative lengths of 86.57% of affected extremities (116/134) were longer than those before operation with statistically significant differences ($p<0.05$). However, no statistically significant difference was identified in comparison between the pre- and post-operative lengths of extremities that did not receive any operation ($p>0.05$) (Table I). Furthermore, the differences were statistically significant in comparisons between the lengths of mechanical axis in double lower extremities before and after TKA ($p<0.05$), but the average of variations in the mechanical axis of double lower extremities before TKA was less than that after TKA with a statistically significant difference ($p<0.05$) (Table II). Comparisons of HKAs after TKA among three groups showed that the HKAs in severe deformity group were different from those in normal group and mild deformity group with a statistical significance ($p<0.001$), while no statistically significant difference was found in comparison of HKAs between the normal group and mild deformity group ($p>0.05$, Figure 3b). Moreover, the ratios of HKAs between -3° and 3° in normal group, mild-deformity group and severe-deformity group were respectively 90.48% (19/21), 81.25% (52/64), and 34.69% (17/49). There was no statistically significant difference in comparison between the normal group and mild deformity group ($p>0.05$), but the differences were statistically significant in both of the comparison between the normal group and severe deformity group ($p<0.001$) as well as between the mild deformity group and the severe deformity group ($p<0.001$, Figure 2a). Besides, the scatter plot analysis revealed that there was a linear regression relation between pre- and post-operative HKAs ($p<0.001$, Figure 2a). In normal group, mild deformity group and severe deformity group, the ratios of post-operatively extended LMAL on the side of operation were respectively 80.95% (17/21), 87.50% (56/64), and 87.76% (43/49) and the extended length were respectively 5.53 mm, 9.55 mm and 12.44 mm. There were statistically significant differences in comparisons of average of extended length among the three groups ($p<0.05$), in which the average of extended length in severe deformity group was longer than that in normal group with a statistically significant difference ($p<0.01$), but there were no statistically significant differences in comparisons between the normal group and the mild deformity group ($p>0.05$), as well as between the mild deformity group and the severe deformity group ($p>0.05$, Figure 3a). Besides, the analysis using scatter plots of pre-operative HKA and KPVA indicated that there was a linear regression relation between these two parameters ($p<0.001$, Figure 2b). There were statistically significant differences in comparisons of the pre-operative KPVAs and MPTAs among three groups ($p<0.05$). Howev-

Table I. Compare ofvarous degrees between pre-operation and post-operation of total knee arthroplasty (TKA).

	Pre-operation	Post-operation	Mean changes	*t*-value	*p*-value
HKA°	7.21±7.43	2.29±2.73	4.92±6.21	8.729	<0.01
KPVA°	7.03±2.87	6.71±2.81	0.22±2.18	1.253	0.167
MPAL°	85.23±3.41	89.29±2.37	-4.06±3.79	-11.978	<0.01
LMAL 1 (mm)	746.89±46.28	756.92±45.70	-9.03±8.91	-11.952	<0.01
LMAL 2 (mm)	750.07±45.89	750.31±45.78	-0.24±2.19	-0.789	0.417

Table II. Compare of lean of arms and legs (LMAL) in both side of legs (n=106, $\bar{x}$±s, mm).

LMAL	Operative side	Non-operative side	Different length of both sides	*t*-value	*p*-value
Per-operation	731.56±41.25	740.13±40.15	-8.57±9.23*	-8.505	<0.001
Post-operation	742.01±1.07	740.19±40.09	1.82±8.16*	1.811	0.012

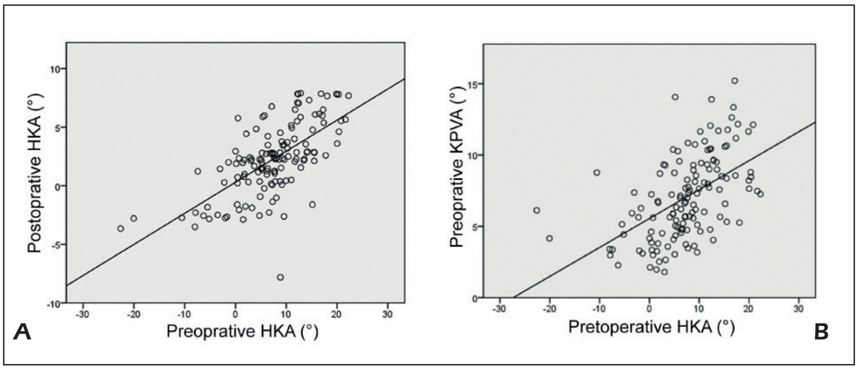

Figure 2. Scatter plots of hip knee ankle angle (HKA) and knee physical valgus angle (KPVA). **A**, Linear regression relation between the pre-operative and post-operative HKA. **B**, Linear regression relation between the pre-operative HKA and KPVA.

er, in comparisons of post-operative KPVAs and MPTAs among 3 groups, there was no statistically significant difference between the normal group and the mild deformity group, but statistically significant differences were lying between the severe deformity group and the normal group, as well as the severe deformity group and mild deformity group (Figure 3c and 3d). In addition, there was no statistically significant difference in comparison of the number of patients using either type of implant among three groups after operation (p>0.05), and the data, thus, were comparable.

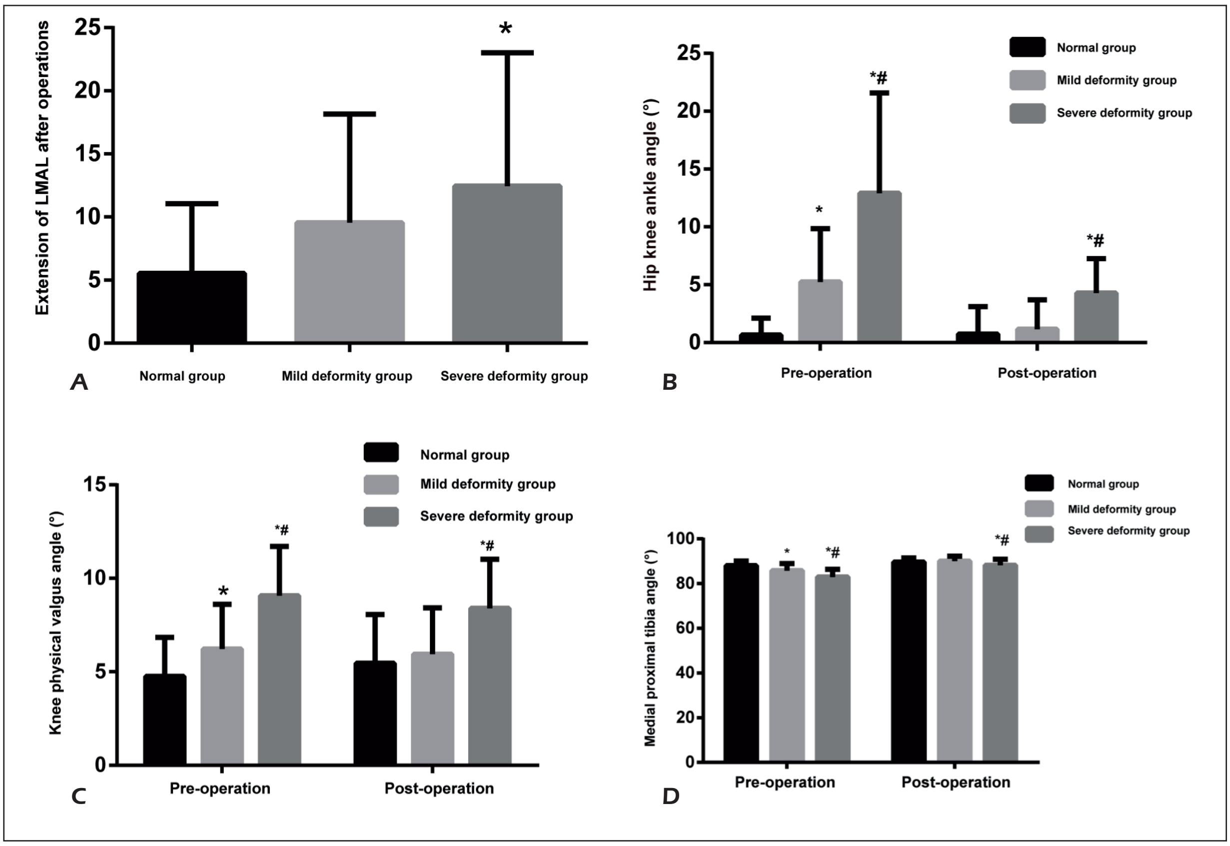

Figure 3. Compare of lean of arms and legs (LMAL) and various degrees in the normal group, mild deformity group and severe deformity group. **A**, Extension of lean of arms and legs (LMAL) after operation. *p<0.05, compared with Normal group. **B**, Compare of hip knee ankle angle (HKA) between pre-operation and post-operation. *p<0.05 compared with Normal group, #p<0.05 compared with mild deformity group. **C**, Compare of knee physical valgus angle (KPVA) between pre-operation and post-operation. *p<0.05 compared with Normal group, #p<0.05 compared with mild deformity group. **D**, Compare of medial proximal tibia angle (MPTA) between pre- and post-operation. *p<0.05 compared with Normal group, #p<0.05 compared with mild deformity group.

Discussion

TKA can alleviate the pains suffered by patients with advanced gonarthrosis and improve the functions of knee joint. However, recovery of normal alignment in lower extremities plays a crucial role[1]. In this investigation, the average of HKAs after TKA was 2.29°, indicating that the alignments in lower extremities were recovered to the normal status. Moreover, our results suggested that severe knee varus and valgus deformity can also affect the recovery of alignments in lower extremities after TAK. Besides, the linear regression relation between the pre- and post-operative HKAs also showed that severe knee varus and valgus deformity can increase the deviation of alignment in lower extremities. In relevant studies, Hsu et al[8] reported that the varying degrees of knee varus and valgus deformity can impact on the alignment in lower extremities after conventional TKA. Additionally, the ratios of HKAs larger than 12° and smaller than 12° were 69% and 32%, respectively. In a study carried out by Bae et al[9], they confirmed that in comparison of the post-operative HKAs in knee varus and valgus deformity larger than 10° and smaller than 10°, the former was significantly larger than the latter.

Effectively restore of the alignment in lower extremities mainly depends on the rational adjustment in the balance between the precise osteotomy performed in the distal end of femur and the proximal end of tibia and the soft tissues in TKA. Clinically, intramedullary positioning has been frequently applied to the osteotomy in distal end of femur and the valgus angle is identified through KPVA, usually 5° or 6°[10]. However, Bardakos et al[11] believed that osteotomy at the distal end of femur is applicable to at least 30% of patients with the valgus angle smaller than 5° or larger than 6° and that for patients with hip valgus or varus deformity. The valgus angle that is suitable for osteotomy in distal end of femur in TKA should be smaller than 5° or larger than 6°. The reason could be the impact of ipsilateral cervicofemoral angle and eccentric distance (the distance from the center of femur to the axis of femur) on the valgus angle in performing the osteotomy at distal end of femur in TKA. In the research of Mullaji et al[12], they found that a larger variation is observed in the KPVA in patients with knee osteoarthritis. In this study, the pre-operative KPVA was (7.03±2.87)°, in which the pre-operative KPVA with the knee varus and valgus deformity larger than 10° was higher than that smaller than 10°. Furthermore, the linear regression relation between the pre-operative HKAs and KPVAs revealed that the KPVA in knee varus deformity was larger than that in knee valgus deformity. Thus, for the knee varus deformity smaller than 10°, it is safe to set the valgus angle between 5° and 7° for osteotomy at the distal end of femur. The KPVA is usually larger in patients with severe knee varus deformity, and KPVA is relatively smaller in patients with severe knee valgus deformity. Thus, an appropriate increase or decrease of valgus angle either in the patients with severe knee varus deformity or with severe knee valgus deformity in osteotomy at the distal end of femur may increase the precision of alignment in the lower extremities after operation. Generally, extramedullary positioning is applied to the osteotomy in the proximal end of tibia with the horizontal line in osteotomy perpendicular to the mechanical axis of tibia (MPTA = 90°). A research[8] has shown that deviation in positions where the implant of tibia is to be placed can affect the precision of alignment in lower extremities after surgery. In this study, the MPTAs of all patients were (89.29±2.37)°, which were increased by (4.06±3.797)°, suggesting a relatively smaller deviation in the position of tibia implant in general. Nevertheless, the comparison of post-operative MPTAs of patients with knee varus and valgus deformity in varying degrees, we found a significant deviation of 90° in post-operative MPTA of patients with the knee varus and valgus deformity larger than 10°. Due to the difficulties in complete correction for patients with severe knee varus and valgus deformity, a relatively large varus angle can frequently be observed in the position of tibia implant after TKA, which may cause the deviation in alignment in lower extremities. Besides, correct release of ligament and suitable adjustment in the balance of soft tissues, in addition to the precise osteotomy, are also the key links in effectively restoring the alignment in lower extremities for patients with severe knee varus and valgus deformity[13,14].

In this study, we also found that the LMALs in 86.57% of affected extremities after TKA were longer than those before TKA. The extremities with severe deformity accounted for 87.76% with the most significant extension extent and their average extended length was 6.54 mm more than that in the normal group. Even though the length of affected extremity that was extended after operation was 1.82 mm in average longer than that in normal extremity, the difference in lengths of double extremities after operation was significantly smaller than that before operation. In the study of Lang et al[15], they found that the lengths of 83.3% of affected extremities after TKA were longer than those before operation. Those with severe valgus deformity (valgus angle larger than 10°) showed a more significant extending degree. Hence, the extension in affected extremities can always be observed after TKA, especially those with severe knee varus and valgus deformity. Also, the difference in post-operative lengths of double lower extremities led by the extension in double lower extremities is frequently seen in total hip replacement, which may result in various complication such as low back pains, sciatic pains and gait disorder, lowering the satisfying degree of patients. Currently, few studies have focused on the extension in lengths of lower extremities after TKA and the relevant complications, and, thus, further studies should be carried out.

Conclusions

Severe knee varus and valgus deformity can increase the deviation of alignment in lower extremities after TKA, and most of LMALs after TKA are longer than those before TKA, and the most significant extension is identified in severe varus and valgus deformity

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Conflict of Interests:

The authors declared no conflict of interest.

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