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RESEARCH ARTICLE

Chronological Changes in Gait Oscillation in Patients after Total Knee Arthroplasty

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Abstract:

Background:

Pain and knee function improve immediately following total knee arthroplasty (TKA). However, immediate improvements in gait oscillation are not observed following TKA. This analysis aimed to chronologically assess changes in gait oscillation during walking in post-TKA patients.

Methods:

Twenty patients who were diagnosed with knee osteoarthritis underwent unilateral TKA. A Bi-Surface posterior-stabilized (PS) prosthesis with cementation was used for all patients. Acceleration (anterior, vertical, TKA side -, and -contralateral side directions) was examined during walking. A preoperative analysis was performed followed by postoperative analyses at 3, 6, 9, and 12 months.

Results:

Acceleration in the anterior direction and the sacral region tended to increase until 6 months post-TKA, but remained largely unchanged thereafter. In the dorsal vertebral region, acceleration to the anterior direction trended to decrease over time. Additionally, acceleration in the TKA-side direction in the sacral and dorsal vertebral region also tended to decrease over time. The post-TKA sacral-dorsal vertebral ratio in the TKA-side direction tended to increase over time, and the values on the contralateral side direction tended to increase for up to 6 months; however, there was no significant change thereafter.

Conclusion:

Acceleration in the anterior and lateral directions (TKA side) may improve chronologically after TKA, and gait may be performed mainly on the pelvic girdle during the postoperative course of TKA.

Keywords: Gait analysis, Total knee arthroplasty, Osteoarthritis of the knee, Pain, Patients, HSS.

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1. INTRODUCTION

Patients with knee osteoarthritis (OA) who undergo total knee arthroplasty (TKA) show a significant reduction in pain and an improvement in walking. However, some patients report a feeling of instability during stair stepping after TKA.

There are several studies on performance during daily life after TKA [1 - 5]. Benedetti *et al*. reported that knee kinematic and kinetic abnormalities during load acceptance after TKA were associated with co-contractions in the muscular activation pattern [6]. Beswick *et al*. reported patient dissatisfaction regarding pain, function, and restoration of quality of life improvement in their gait relative to their preoperative state, despite the overall effectiveness of TKA [7].

It has also been suggested that kinematic studies and gait analyses are necessary for proper assessment following TKA.

We previously reported that joint stability during stair-stepping was affected by the design of the femorotibial joint rather than the post/cam engagement or ball and socket joint in

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the Bi-Surface PS (Kyocera Medical Corporation, Japan) arthroplasty [8]. Based on gait analysis, we considered it necessary to assess trunk and gait function. Therefore, we reported on gait oscillations during gait and stair- stepping in patients after TKA with Bi-Surface PS, and in those with two total knee replacement designs [9, 10]. However, the change in gait oscillation appeared chronologically after TKA, rather than immediately. This study aimed to assess the chronological change in gait oscillation during gait, in patients after TKA.

2. MATERIALS AND METHODS

Twenty patients (14 female and 6 male patients) who underwent TKA with the Bi-Surface PS knee prosthesis and who were followed up for 1 year were assessed. All patients had been diagnosed with varus knee OA. Their average age was 73.6 (range: 64-86) years (Table **1**). A single surgeon performed all TKA procedures, using the parapatellar approach. The patella was resurfaced, and all implants were fixed with cement.

Table 1. Patient characteristics.

Mean age	73.6 ± 9
Gender (male/female)	6/14
Mean body mass index	24.5 ± 3.6
Diagnosis (OA)	20
HSS score	94.1 ± 3.3

The mean postoperative Hospital for Special Surgery score was 94.1 for the Bi-Surface KU5 knee prosthesis, respectively.

Gait oscillation analyses in this study were performed by examining gait acceleration (anterior-posterior, vertical, and lateral-contralateral directions). We performed a preoperative analysis and postoperative analyses at 3,6,9, and 12 months.

The root mean square (RMS) of acceleration, which shows the magnitude of acceleration, is frequently used in gait analysis studies [11, 12]. Using a two-point gait oscillometer MVP-WS2-S (Microstone Corp., Japan), we assessed gait oscillation during gait (10 m). Two compact wireless sensors were attached to the dorsal vertebral and sacral regions using a harness and belt [9, 10]. Three successful measurements were recorded, and used for the final analysis. The sacral-dorsal vertebra ratio was defined as the RMS value of the sacral region / the RMS value of the dorsal vertebral region. Statistical analysis was performed using R version 2.8.1software. The Shaffer method was used for the multiple comparison procedure [13].

3. RESULTS

The mean and standard deviation values of the observed variables are shown in Table **2**.

3.1. Acceleration

In the anterior direction

In the sacral region, RMS values tended to increase until 6 months after TKA, then remained largely unchanged. In the dorsal vertebral region, RMS values tended to increase slightly at 6 months after TKA, and then decreased over time. There was no significant difference in RMS values in the anterior direction when assessed chronologically.

In the vertical direction

RMS values remained largely unchanged in both the dorsal vertebral and sacral regions over time. There were no significant differences in RMS values in the vertical direction when assessed chronologically.

In the TKA-side direction

RMS values in the sacral region tended to increase slightly 6 months after TKA, but tended to decrease over time. RMS values in the dorsal vertebral region also tended to increase 6 months after TKA, but tended to decrease over time. There were no significant differences in the RMS values of the TKA-side direction.

Table 2. Mean and standard values.

-	Preop	3M	6M	9M	12M	-
Acceleration	-	-	-	-	-	-
To the Anterior	-	-	-	-	-	-
Sacral region	2.20±0.89	2.23±0.83	2.76±1.52	2.75±1.91	2.54±2.12	-
Dorsal vertebral region	2.84±1.09	2.08±0.66	2.63±1.34	1.86±0.73	1.77±0.51	-
To the vertical	-	-	-	-	-	-
Sacral region	9.93±0.22	9.90±0.16	10.33±1.84	10.08±0.93	9.93±0.18	-
Dorsal vertebral region	9.57±0.44	9.82±0.22	10.33±2.04	9.62±2.11	9.43±1.68	-
To the TKA Direction	-	-	-	-	-	-
Sacral region	1.62±0.65	1.54±0.64	1.72±0.66	1.24±0.43	1.39±0.48	-
Dorsal vertebral region	1.63±0.75	1.28±0.36	1.39±0.52	1.26±0.40	1.37±0.40	-
To the contralateral direction	-	-	-	-	-	-
Sacral region	1.83±0.94	1.47±0.60	1.21±0.38	1.42±0.52	1.76±0.56	Preop >12M*, 9M<12M*
Dorsal vertebral region	1.43±0.89	1.221±0.37	1.72±0.87	1.24±0.43	1.39±0.48	-
Ratio of sacral region/ dorsal vertebral region	-	-	-	-	-	-
TKA side	1.08±0.43	1.21±0.35	1.21±0.38	1.22±0.31	1.26±0.42	-
The contralateral side	0.31±0.33	1.27±0.56	1.33±0.42	1.31±0.66	1.32±0.42	-

In the contralateral side direction

In the sacral region, the RMS value tended to decrease until 6 months after TKA, and it tended to increase thereafter. Significant differences were observed between preoperative and 12 months values ($p<0.05$), and between values obtained at 9 and 12 months postoperatively ($p<0.05$). RMS values tended to increase slightly in the dorsal vertebral region 6 months after TKA and decrease over time.

Regarding the sacral-dorsal vertebral ratio, the value in the TKA-side direction tended to increase over time after TKA, and the value in the contralateral side tended to increase for up to 6 months; however, there was no significant change thereafter.

4. DISCUSSION

Some patients report restrictions in daily living activities after TKA. Dickstein *et al*. reported that one of the factors that lead to dissatisfaction after TKA is the limitation in the use of stairs [14]. Additionally, Benedetti *et al*. and Hilding *et al*. reported that gait impairment remains after TKA [15, 16]. Banks *et al*. reported that superior performance was associated with devices that provided the greatest intrinsic control of knee motion. Intrinsically stable knees may be significantly beneficial for patient function and reduction of wear [17]. Prieto-Alhambra *et al*. reported that the risk of hip fractures increased significantly in the year after TKA. These rates then declined to correspond with those seen in controls 3 years postoperatively and continued to decrease until the end of the follow-up period [18]. These reports suggest that improvements in knee function and gait oscillation are essential and can influence daily living activities after TKA. We previously assessed the influence of the knee joint on gait oscillation during gait and stair-stepping in patients with knee OA. Knee OA influenced acceleration in the anterior and lateral directions in the dorsal vertebral; it also influenced the ratio of the center of gravity maximum values during gait oscillation [10].

In this study, the gait oscillation change during gait in patients after TKA was assessed chronologically. RMS of acceleration provided a better understanding of gait oscillation than our previously reported values. Acceleration in the anterior direction in the sacral region tended to increase until 6 months after TKA, but remained almost unchanged thereafter. In the dorsal vertebral region, acceleration in the anterior direction tended to decrease over time. These findings suggested that gait oscillation to the anterior direction in the trunk might have improved chronologically during the postoperative course after TKA. Regarding acceleration to the lateral side, the ratio of sacral-dorsal vertebra in the lateral direction (TKA side) tended to have increased over time after TKA, and the values in the contralateral side direction tended to have increased up to 6 months; however, there was no significant change thereafter. These findings suggest chronological improvement in gait oscillation to the lateral direction (TKA side) after TKA, and gait performance mainly on the sacral region or pelvic girdle during the postoperative course of TKA. Therefore, adjustment in gait oscillation may occur chronologically during the postoperative course after TKA.

This study has some limitations. The small number of patients weakens the statistical power of the results. Further investigations with larger sample sizes are required to obtain more clinical data. In addition, no control group was included in the analysis, and the standard error of the measurements may have decreased the generalization power of this study. Despite these limitations, this study contributes significantly to the understanding of the improvement in gait oscillation after TKA.

CONCLUSION

Acceleration to the anterior and lateral direction (TKA side) may improve chronologically after TKA, and gait may be performed mainly on the pelvic girdle during the postoperative course after TKA. Acceleration to the lateral direction (contralateral side) may increase for up to 6 months after TKA; thereafter, an adjustment in gait oscillation may occur, although the changes may not be significant.

AUTHOR'S CONTRIBUTION

TM designed the study, analyzed the data, and wrote the manuscript. YF, MH, HT, KI, HK, MS, RK, and YT collected the data and participated in the design of the study. YF, MH, and HT analyzed the data and helped write. All authors have read and approved the final manuscript.

LIST OF ABBREVIATIONS

TKA	=	Total Knee Arthroplasty
OA	=	Osteoarthritis
PS	=	Posterior-Stabilized
RMS	=	Root Mean Square
HSS	=	Hospital for Special Surgery

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by Ethical Review Board of Kanmon Medical Center (Shimonoseki, Japan).

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human research procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent to participate in our study was obtained from participants. We have obtained consent to publish from the participants.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The authors are unable to share raw data because ethical approval was not obtained for data sharing. In addition, informed consent for data sharing was not obtained from the individuals. Please find all summarized datasets reported in the results section and the tables.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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Declared none.

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