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Gait assessment in patients with thrust plate prosthesis and intramedullary stemmed prosthesis implanted to each hip

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Abstract
Introduction There has not been any study regarding comparative gait analysis in patients with intramedullary stemmed prosthesis (ISP) and thrust plate prosthesis (TPP) implanted to each hip.
Patients and methods Four patients (three females and one male) who had undergone operation due to coxarthrosis were selected. The mean age was 60.5 (37–78) years. TPP and ISP had been implanted to the left and right hip, respectively, in three patients, and one patient received TPP to the right and ISP to the left hip. Gait was analyzed with a BTS Elite System consisting six cameras and two Kistler force plates using Helen Hayes marker set to assess the gait parameters. The clinical outcome was also evaluated according to Harris hip score (HHS).
Results The average HHS was 95.0 (82–100) points after a mean follow-up of 45.0 (30–50) months for TPP and 94.5 (80–100) points after a follow-up of 60.0 (14–122) months for ISP. Neither of the HHS scores and follow-up time nor gait parameters obtained from the TPP-implanted side were statistically different when compared to those of the ISP-implanted side.
Conclusion TPP and ISP as the implants with their own biomechanical specifications did not produce any remarkable difference in gait.

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Keywords Gait assessment · Gait symmetry · Thrust plate prosthesis · Intramedullary stemmed prosthesis · Total hip arthroplasty

Abbreviations

TPP	Thrust plate prosthesis
ISP	Intramedullary stemmed prosthesis
THA	Total hip arthroplasty
HHS	Harris hip score
GRF	Ground reaction force

Introduction

Thrust plate prosthesis (TPP) is an implant with metaphyseal fixation to the proximal femur, which leaves the diaphyseal bone intact. It was considered as a true alternative to the conventional intramedullary stemmed prosthesis [5]. It requires the removal of a minimum amount of bone stock, which is important in young patients for further revision arthroplasty that is known to be complicated due to bone loss and decreased stability of the second implant [1, 5, 7]. TPP provides more physiological stress transmission on the proximal femur. However, it shows a slightly higher failure rate than the ISP because of the stress to a limited area of bone or fixation [2, 4, 6].

Recent studies have been aimed to investigate the effects of ISP on gait parameters in different patients compared with healthy age-matched groups [9, 10, 12]. A limited number of studies related to TPP that are available in literature focus on the biomechanical analysis, and radiological and clinical outcome rather than gait analysis [2–5, 15–17]. However, short- and medium-term outcomes of unilateral TPP have been studied by Steens et al. [14] using gait analysis, besides clinical and radiological assessment.

To the best of our knowledge, no study aimed to assess the kinematic, kinetic, temporal and spatial parameters of gait in patients with TPP and ISP implanted bilaterally has been published, and no report on the different types of bilateral prostheses exists in literature. Since gait is considered to be a vital part of daily functioning, the possible effects of TPP on gait parameters may be clarified if both types of prostheses are implanted bilaterally (Fig. 1). This has been guidance for us to evaluate the gait parameters in patients received TPP and ISP on each hip.

Patients and methods

In a retrospective investigation, four patients (three females and one male), who had undergone operation due to coxarthrosis, with an average age of 60.50 (SD = 20.14) were selected. Three of these patients received TPP on their left hip and ISP on the right hip. One patient received TPP on her right hip and ISP on the left hip. None of them had any neurological or musculoskeletal pathology other than hip replacement. All of the patients were able to walk independently and were free from the use of any assistive device. The demographic data and the type of hip replacement are tabulated in Table 1.

Fig. 1 TPP and ISP implanted to hip joints bilaterally

Table 1 Demographic data of the patients

Case no.	Sex	Age (years)	Body weight (kg)	Body length (cm)	Implant
1	F	68	74	153	Left TPP right ISP
2	F	53	69	157	Left TPP right ISP
3	M	77	78	164	Left TPP right ISP
4	F	37	58	148	Right TPP left ISP

After signing of the informed consent by each patient, gait analysis was performed with BTS (Bioengineering Technology System, Milano, Italy) EliClinic System consisting of six cameras, two force platforms and retro reflective markers. A Helen Hayes marker set was selected for analysis. The marker trajectories were recorded with six cameras at a frequency of 100 Hz, and the ground reaction forces (GRF) were measured simultaneously at 500 Hz with two Kistler force plates (Kistler Inc. Sweden) embedded in a 10 m long walkway.

The kinematic data and GRF were computed by BTS GaitEl20 (ver. 2.9.7) software to determine the moment and power on the hip, knee and ankle joints. The trial was selected as successful when each foot contacted one platform, and the gait cycle was time normalized to 100%. Three successful gait cycles were averaged to obtain a mean for each patient. The GRF and moments were also normalized to body weight. The Harris hip score (HHS) was recorded before gait analysis.

The kinematic and kinetic parameters, and spatial and temporal parameters of the gait obtained from both TPP- and ISP-implanted sides were compared with the Mann–Whitney *U* test of SPSS (ver. 10). The level of significance was selected at $P < 0.05$.

Results

The average HHS was 95.0 points ((82–100, SD 8.72) after a mean follow-up of 45 (30–50) months for TPP and 94.5 points (80–100, SD 9.71) after a follow-up of 60 (14–122) months for ISP (Table 2). The difference in the HHS points was not significant when the TPP- and ISP-implanted sides were compared to each other ($P > 0.05$). The temporal and spatial data obtained from gait analysis revealed that there was no significant difference ($P > 0.05$) in all parameters of the TPP versus ISP-implanted side (Table 2). Hip abduction and extension, and knee extension degree in stance were found to be slightly lower in the TPP-implanted side (Table 3). However, none of the hip, knee and ankle joint motions (Table 3) on the sagittal plan was found to be statistically significant ($P > 0.05$).

Average minimum and peak forces data of the vertical GRF on the TPP- and ISP- implanted sides were similar (Table 3) and showed consistency as seen in Fig. 2. Medio-lateral and anterior–posterior components of the GRF in the TPP-implanted side were also consistent with the ISP-implanted side (Table 3, Fig. 3). There was slight, but non-significant increase in the abduction moment on the TPP-implanted hip joint,

Table 2 Follow-up time, Harris hip scores and temporal–spatial parameters of TPP versus ISP-implanted side

	TPP (SD)	ISP (SD)	*P* value
Harris hip score	95.0 (8.72)	94.5 (9.71)	0.32
Follow-up (month)	45.0 (10.10)	60.0 (45.17)	0.72
Velocity (cm/s)	95.75 (6.29)	98.25 (7.54)	0.49
Step length (cm)	54.85 (3.66)	52.42 (2.05)	0.34
Stance duration (% gait cycle)	63.00 (1.91)	60.75 (2.06)	0.11
Swing duration (% gait cycle)	36.50 (1.91)	39.25 (2.06)	0.11
Stride time (s)	1.12 (0.90)	1.12 (0.96)	0.71
Cadence (step/min)	107.25 (8.26)		
Step width (cm)	9.00 (2.94)		

while the first peak of the knee extension moment was found to be non-significantly higher on the TPP side ($P > 0.05$). Difference in knee abduction (valgus) moment on both sides was also not significant (Table 3, Fig. 3). Comparison of the data collected from the TPP- and ISP-implanted sides indicated that the differences in the generated and absorbed power in the hip, knee and ankle joints were statistically not significant ($P > 0.05$).

Discussion

The result of the present study revealed that 45 months following TPP and 60 months following ISP implantation, the average HHS was found to be 95 for the TPP- and 94.5 for the ISP-implanted side. These results were higher than those found for TPP by Steens et al. [14] and for ISP by Aminian et al. [1] at a shorter duration.

Inconsistency in gait velocity and stance duration, and other temporal-spatial parameters of gait exist in the previous studies because of the different follow-up times and average age and number of included subjects. Sliwinski et al. [13] observed slower walking velocity (1.09 m/s) of the operated side of individuals with unilateral total hip arthroplasty (THA) when compared to that of the healthy group (1.26 m/s). The same parameter was found to be 1.14 m/s of both operated and non-operated sides in subjects with unilateral TPP, and 1.23 m/s in healthy subjects [14]. On the other hand, Loizeau et al. [8] found the stance duration and gait velocity to be 0.70 m/s on the operated side of patients with unilateral THA and 0.95 m/s in the healthy group. In the present study, gait velocity and stance duration as well as the other spatial and tempo-

Table 3 Kinetic and Kinematic parameters of TPP versus ISP-implanted side

	TPP (SD)	ISP (SD)	*P* value
Ground reaction forces			
Vertical 1 peak (%BW)	95.16 (6.44)	98.11 (7.07)	0.56
Vertical minimum (%BW)	84.47 (3.31)	83.96 (1.79)	0.56
Vertical 2 peak (%BW)	101.62 (7.03)	104.12 (3.40)	0.39
Medial (%BW)	6.37 (1.44)	5.79 (1.17)	0.39
Lateral (%BW)	−2.65 (1.85)	−4.14 (2.23)	0.56
Anterior (%BW)	10.16 (4.16)	14.45 (4.03)	0.15
Posterior (%BW)	−8.52 (3.51)	−10.45 83.65)	0.39
Hip			
Flexion (°)	35.16 (8.29)	35.76 (7.91)	0.77
Extension (°)	−0.84 (8.29)	−2.76 (9.77)	0.39
Abduction (°)	−1.66 (4.11)	3.67 (4.01)	0.08
Adduction (°)	−8.55 (3.22)	−6.29 (5.87)	0.39
Extension moment (Nm/kg)	0.58 (0.19)	0.66(0.26)	0.56
Abduction moment (Nm/kg)	0.50 (0.19)	0.60 (0.11)	0.39
Generated power (W/kg)	0.53 (0.21)	0.76 (0.32)	0.39
Absorbed power (W/kg)	−0.45 (0.23)	−0.45 (0.19)	0.56
Knee			
Flexion in stance (°)	10.18 (9.47)	5.73 (5.81)	0.77
Flexion in swing (°)	58.19 (7.17)	59.31 (6.49)	0.77
Extension moment (Nm/kg)	0.33 (0.08)	0.31 (0.12)	0.56
Abd. (valgus) moment (Nm/kg)	0.41 (0.16)	0.44 (0.21)	0.77
Generated power (W/kg)	0.43 (0.04)	0.43 (0.12)	0.99
Absorbed power (W/kg)	−0.63 (0.26)	−0.80 (0.34)	0.25
Ankle			
Dorsiflexion (°)	17.52 (3.96)	10.75 (7.18)	0.39
Plantar flexion (°)	−4.30 (4.63)	−11.75 (4.63)	0.15
Dorsiflexion moment (Nm/kg)	1.39 (0.12)	1.14 (0.41)	0.25
Plantar flex. moment (Nm/kg)	−0.02 (0.01)	−0.02 (0.02)	0.25
Generated power (W/kg)	2.40 (0.59)	1.62 (0.68)	0.20
Absorbed power (W/kg)	−0.64 (0.13)	−0.44 (0.32)	0.56

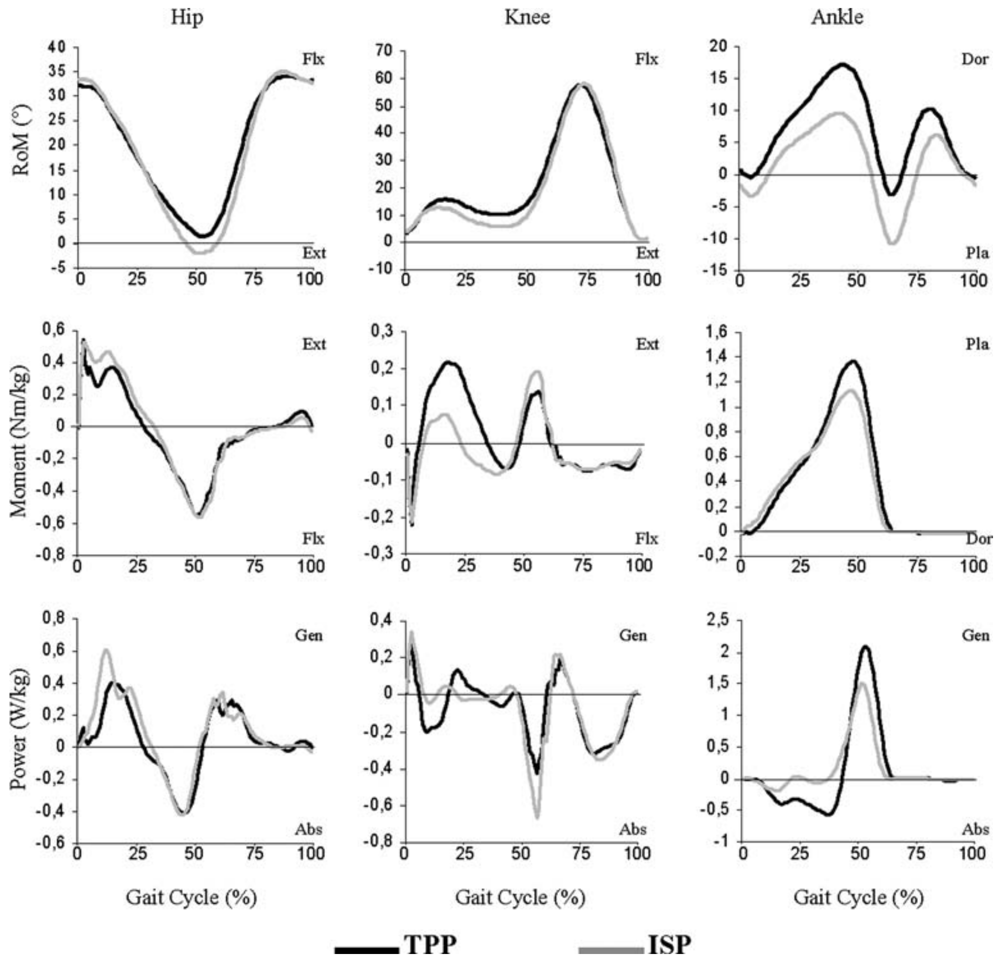

Fig. 2 Graphical representation of the kinetic and kinematic parameters on the sagittal plan (*Flx* flexion, *Ext* extension, *Abd* abduction, *Add* adduction, *Dor* dorsi flexion, *Pla* plantar flexion, *Gen* generated, *Abs* absorbed)

ral parameters (Table 2) revealed that there was no significant asymmetry in gait when the TPP- and ISP-implanted sides were compared with each other. However, our data were not similar to those of other authors. This inconsistency was thought to arise because of a smaller number and higher mean age (Table 1) of our patients.

Decreased stance and stride times are often seen in populations where balance impairments are commonplace and more evident on the operated side of subjects with unilateral THA, when compared to the unaffected side, because shorter stance time decreases the GRFs [9]. The TPP-implanted side showed stance, swing and stride times very similar to those recorded in the ISP-implanted side (Table 2).

As a common finding, asymmetrical gait pattern in THA was reported [10, 11, 12, 14] because of decreased hip extension that leads to an increase in the knee flexion and ankle dorsiflexion on the stance, and decrease in gait velocity. The results of this study revealed a nNSon-significant decrease in hip abduction (Fig. 3) and extension, knee extension, and increased dorsiflexion of ankle (Fig. 3) at stance on the TPP side when compared to that of the ISP side. This relative adduction position of the TPP-implanted hip probably led to lateral prominence of TPP (Fig. 1), which should be taken into consideration during the marker placement.

Ground reaction forces provide indirect information about limb loading during gait, and any difference of GRFs generated on both sides indicates an asymmetrical gait pattern. First and second peaks and minimum value of the vertical component of the GRF (Table 3) indicated that both TPP and ISP provide symmetrical limb loading (Fig. 3). Data were also consistent with literature [9, 14]. There was no published study found to compare the medio-lateral and anterior posterior components of the GRF measured with TPP. Nevertheless, comparison of the TPP- and ISP-implanted sides in these parameters also revealed symmetrical limb loading.

Significantly, decreased hip extension and abduction moments were found in the early postoperative stage on the operated hip of patients who had undergone

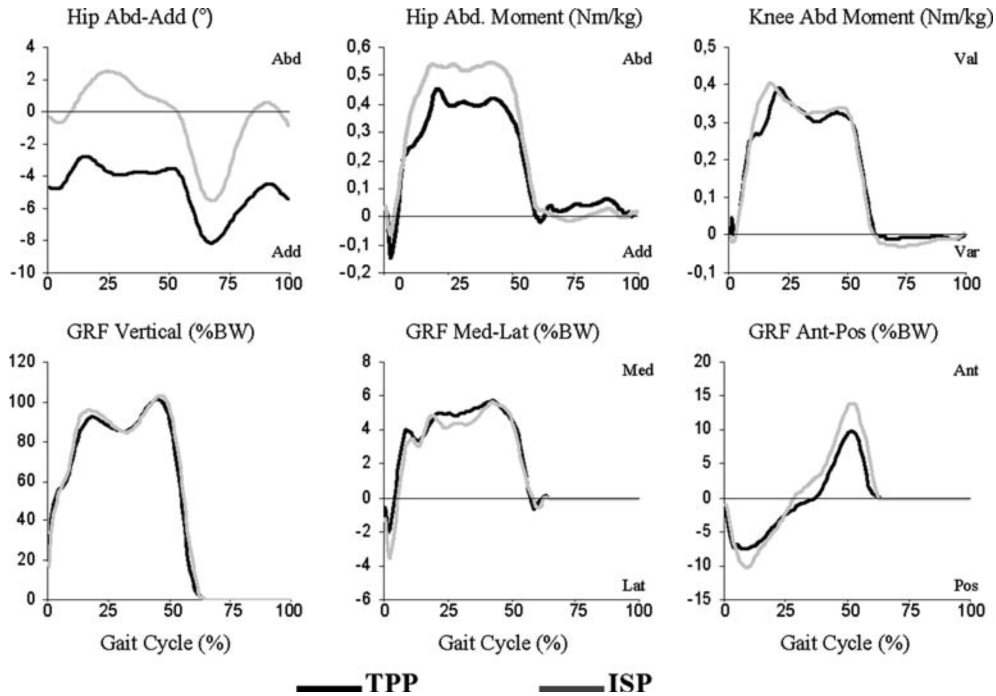

Fig. 3 Graphical representation of the kinetic and kinematic parameters on the frontal plan (*Abd* abduction, *Add* adduction, *Val* valgus, *Var* varus, *GRF* ground reaction force, *Med* medial, *Lat* lateral, *Ant* anterior, *Pos* posterior)

unilateral THA [11]. It has also been reported in the same study that the hip extension and abduction moments as well as the other gait parameters on the operated side reached that of the non-operated side by 6–12 months after surgery. Contrary to these results, it was revealed that gait disability and residual impairments in the hip and neighboring joints might still exist after a similar follow-up period [12]. In view of the fact that the follow-up period in the present study was longer, however, hip extension (Fig. 2) and abduction moments (Fig. 3) on the ISP-implanted side showed similarity with the data obtained from the THA side by Miki et al. [11] and Perron et al. [12]. Furthermore, the average data on the hip extension moment on the TPP-implanted side in our patients were also consistent with those of ISP. On the other hand, decreased, but non-significant, hip abduction moment and generated joint power were observed on the TPP side when compared to the ISP-implanted side (Table 3). It might be thought that even if there was no significant difference between the two sides, the hip joint with TPP had problems in generating lateral forces during single limb loading, as suggested in the literature [8, 11, 14]. Hence, these results suggested that a detailed investigation and comparison of the mechanical behavior of the hip abductor muscle and limb loading in a sufficient number of patients, who received these different designs of implants, might be worthy.

Knee extension moment, and generated and absorbed joint power data were not comparable because of lack of published data. However, non-significant increase in the knee extension moment was observed at weight acceptance, while it was lower at push-off on the TPP side. This was most likely a compensation for the decreased hip extensor moment and control of the collapsing knee joint as revealed by Louzeau et al. [8].

Generated ankle joint power on the ISP side was consistent with the results of Loizeau et al. [8]. As it was observed from the graphical analysis (Fig. 2), plantar flexion moment, and generated and absorbed ankle joint powers on the TPP side were higher than the ISP-implanted side, although differences were not significant (Table 3). There was no published study found to compare the data obtained from the ankle joint on the TPP-implanted side. Therefore, it has been thought that higher values of these parameters may compensate for the lower peak of moment and power generated at the hip and knee joints on the same side, especially during the push-off period, which is critical for forward progression as well as body weight transfer.

Since patients with TPP and ISP implanted in each hip were included in the present study, such specification did not allow us to increase the number of patients for parametric statistical analysis, because implantation of the both types of prostheses in the same individual was not a common application. To the best of our knowledge, investigation of literature showed that there was no published study aimed to compare the effects on gait of TPP and ISP when implanted in the same patients. Therefore, the present study suggests that the analysis of possible gait alterations due to the different biomechanical designs of these implants may still be worthy. On the other hand, the major weakness of the present study is the small number of patients investigated. However, in our opinion, it is difficult to create a larger series, because prosthesis selection depends on the surgeon's preference and almost all patients with bilateral hip replacement have the same type of prosthesis on each side.

Conclusion

The kinematic and kinetic, and spatial and temporal data of gait obtained from patients who had TPP and ISP implanted bilaterally were compared. Results indicated that the TPP as an alternative hip replacement implant produced a similar gait pattern to those of ISP, even if some slight and non-significant alterations were observed. However, further studies with a large number of patients, necessary for observation of the possible gait alteration due to different biomechanical features of these implants, may be relevant for further surgical and rehabilitative approach.

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