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Original Article

The effect of preoperative lateral flexibility of the lumbar spine on perceived leg length discrepancy after total hip arthroplasty.

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Background: Leg length discrepancy (LLD) after total hip arthroplasty (THA) is a significant factor of patient dissatisfaction. Patients with dissociation between preoperative radiographic LLD and perceived LLD sometimes feel LLD postoperatively even if bilateral leg lengths are equal. There is no publication describing how to decide the amount of leg lengthening in such cases.

Purpose: By examining the influence of preoperative lumbar lateral flexibility on postoperative perceived LLD, this study aims at creating a guideline for the optimal planning of leg lengthening in THA.

Methods: In 59 cases undergoing primary unilateral THA, radiographic LLD, perceived LLD, pelvic tilting and lumbar lateral flexibility were measured preoperatively. The amount of leg lengthening and the sequential change of the perceived LLD were measured postoperatively.

Results: Twelve cases (20%) felt the perceived LLD at two years after surgery. All these cases felt the operative side longer than the non-operative side. In 32 cases with preoperative pelvic inclination to the affected side, postoperative perceived LLD was significantly greater if lumbar spine was rigid. In eight cases with pelvic tilting and rigid lumber spine, the amount of leg lengthening that exceeded preoperative perceived LLD affected the postoperative perceived LLD.

Conclusions: In cases with preoperative pelvic inclination downward to the affected side and with rigid lumbar spine, amount of leg lengthening should not be excessively greater than preoperative perceived LLD. In other cases, lengthening the leg to the same length as the contralateral side rarely results in postoperative perceived LLD.

Key word: Total hip arthroplasty,Perceived leg length discrepancy,Lateral flexibility of lumbar spine

Introduction

Leg length discrepancy (LLD) after total hip arthroplasty (THA) is a significant factor of patient dissatisfaction. In fact, perceived LLD after THA is one of the largest causes of litigation [1]. In most of cases, LLD is presented as the feeling that the affected side is too long [2]. Avoiding perceived postoperative LLD requires both appropriate preoperative planning and the accurate surgical technique for lengthening the leg during surgery. While there have been several publications describing intraoperative techniques [2-7], there are none, to our knowledge, that address the adequate amount of leg lengthening in planning of THA in order to avoid patient-perceived LLD postoperatively.

In patients with hip diseases where the morbidity period is short, such as rapidly destructive coxarthrosis, lengthening the leg to the same length as the contralateral side rarely results in patient-perceived LLD problems. However, in cases with chronic hip disease (e.g. unilateral secondary osteoarthritis due

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to developmental dysplasia of the hip), the patient-perceived LLD may be more or less compared to the true LLD, which can be clinically confirmed by the radiograph, due to the pelvic inclination. In such cases, it is not easy to determine the optimal amount of lengthening. If the amount of leg lengthening is as the same length as the preoperative patient-perceived LLD, it is unlikely that the patient feel LLD postoperatively. However, the true LLD and the inclination of the pelvis remain postoperatively. Such a situation is not ideal since the inclination of the pelvis has been suggested to be the cause of the lumbar disease [8]. On the other hand, if we lengthen the affected leg to the extent of the true LLD, patients may perceive the LLD when the pelvic inclination remains postoperatively. While the optimal leg lengthening amount may lie between the perceived and actual leg-length discrepancy values, the determination procedure remains unclear.

We hypothesized that the degree of preoperative lumbar spine mobility plays a role in determining perceived postoperative LLD: If the patient who has a flexible lumbar spine receives leg lengthening equal to the true LLD, it is less likely that they will perceive a discrepancy postoperatively. On the other hand, if the patient who has a rigid lumbar spine receives leg lengthening equal to the true LLD, the chances for perceived LLD are increased. By examining the influence of preoperative lumbar lateral flexibility on postoperative perceived LLD, this study aims at creating a guideline for the optimal lengthening of the leg during the operation in order to avoid patient-perceived LLD problems.

Materials and Methods

Sixty two consecutive cases (53 female, nine male) undergoing primary unilateral THA due to hip disease between January 2004 and March 2005 were investigated prospectively. Three patients whose postoperative radiographic LLD were 10 mm or more (the operative side was longer than the contralateral side radiographically) were excluded from this study. The average age at the time of the operation was 63.9 years old (47 to 86). Of the 59 cases, 53 were diagnosed as osteoarthritis (secondary osteoarthritis due to developmental dysplasia of the hip: 50, traumatic osteoarthritis: one, primary osteoarthritis: two), three as rapidly destructive coxarthrosis, and three as idiopathic osteonecrosis of the femoral head. All the operations were carried out in the lateral decubitus position using the posterolateral approach. Care was taken not to lengthen the leg over the preoperative radiographic LLD. Verification of the leg length via radiography or navigation system was not employed intraoperatively.

All 59 cases were followed up for two years. With all the cases, the following items were measured at one or two weeks preoperatively: The teardrop tilting angle, radiographic LLD, bending range of the lumbar spine, and perceived LLD. All the items except perceived LLD were measured using plain radiographs. We defined the terms and methods of measurement of these values as below.

- Perceived LLD: In order to measure the patient's perceived LLD, we placed blocks beneath the leg perceived to be shorter. We defined "perceived LLD" as the thickness of the block at the point at which the patient did not perceive LLD. It was measured repeatedly until the value was confirmed. It was recorded in 2.5 mm unit intervals (Figure 1). A positive value indicates that the patient feels the affected side longer than the contralateral side.
- Radiographic LLD: Radiographic LLD was measured on standard anteroposterior views of the pelvis with the hips extended and internally rotated. Radiographic LLD was defined as the difference between the distances from teardrop line (a line that connects bilateral inferior margin of the acetabular teardrop) to the center of the lesser trochanter for each femur as in previous studies [4, 9]. The value was corrected with magnifying power of the radiograph which was calculated using the known diameter of the metal head of the femoral component in each case. A positive value indicates that an affected side is longer than the contralateral side.
- Teardrop tilting angle: An angle between the teardrop line and the horizontal line in the standing position. A positive value indicates that the pelvis tilts toward the affected side. Cases were classified into three groups according to tear drop tilting angle: tilt-affected-side group (tear drop tilting angle$\geq$2 degrees), horizontal group (-2 degrees < tear drop tilting angle<2 degrees), and tilt-unoperated-side group (tear drop tilting angle $\leq$ -2 degrees) (Figure 2).
- Lumbar bending range: An angle between the upper surface of the first lumbar vertebra and the Jacoby line was measured using the anteroposterior radiographs of the lumbar spine taken in standing position. A positive value indicates that the lumbar spine bends to the operative side. We defined "lumbar bending range" of the lumbar spine as the difference of the angles between the natural standing position and the maximum lateroflexion to the affected side (Figure 3).

Figure 1. Measurement of "perceived LLD".
Perceived LLD was defined as the thickness of the block at the point at which the patient did not perceive LLD.

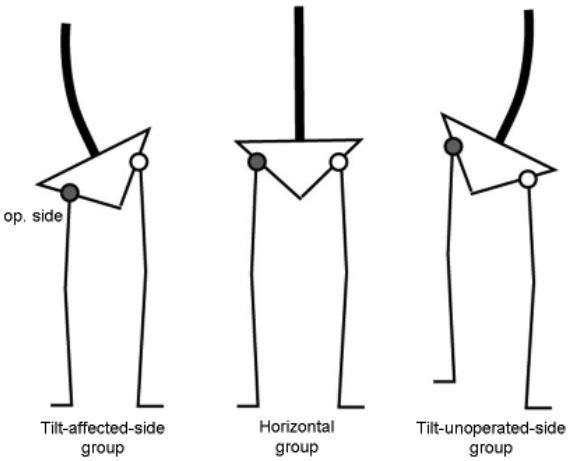

Figure 2. Classification according to the preoperative pelvic tilting.
Tilt-affected-side group: tear drop tilting angle ≥ 2 degrees
Horizontal group: -2 degrees < tear drop tilting angle < 2 degrees
Tilt-unoperated-side group: tear drop tilting angle ≤ -2 degrees

Cases were classified into three groups according to lumbar lateral flexibility: flexible group (lumbar bending range > 15 degrees), mid group (5 degrees < lumbar bending range ≤15 degrees), and rigid group (lumbar bending range ≤ 5 degrees).

Additionally, radiographic leg lengthening and lengthening beyond perceived LLD were measured postoperatively. We defined the terms as below.

- Radiographic leg lengthening: Radiographic LLD measured at three months postoperatively minus preoperative radiographic LLD. A positive value indicates that the operated side was lengthened. Radiographic LLD was also measured at six months, one year, and two years postoperatively.
- Lengthening beyond perceived LLD: Preoperative perceived (not radiographic) LLD plus amount of leg lengthening. This value means the amount of leg lengthening beyond the preoperative perceived LLD.

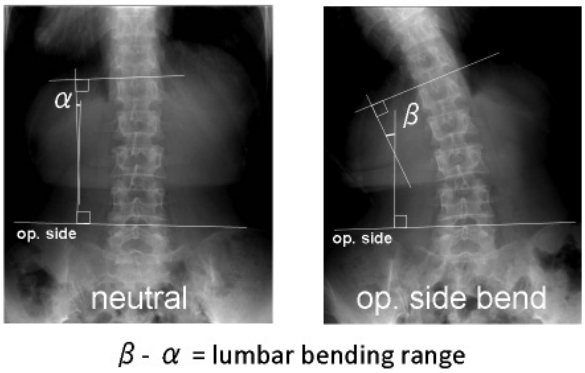

Figure 3. Definition of the "lumbar bending range".
Lumbar bending range was measured using the anteroposterior radiographs of the lumbar spine taken in the natural standing position and the maximum lateroflexion to the affected side. A positive value of both α and β indicates that the lumbar spine bends to the operative side.

We investigated the following: 1) the relation between the preoperative radiographic LLD and the perceived LLD; the preoperative perceived LLD was compared with the preoperative radiographic LLD in each group classified according to the pelvic tilting, and in each group classified according to the lumbar bending range. 2) The sequential change of the perceived LLD and the radiographic LLD; measurement of the perceived LLD was carried out the day before the surgery, at the hospital discharge (one to two weeks postoperatively), and at three months, six months, one year, and two years postoperatively, and the postoperative sequential change of the perceived LLD was investigated. The postoperative sequential change of the radiographic LLD was also investigated. 3) The relation between the postoperative perceived LLD and the preoperative lumbar bending range; in each group classified according to the pelvic tilting, the average perceived LLD at two years postoperatively were compared among the groups classified according to the lumbar bending range. 4) Factors affecting the postoperative perceived LLD; each subgroup classified according to the pelvic tilting and the lumbar bending range was divided into two groups: cases with the perceived LLD and the cases without the perceived LLD. The postoperative radiographic LLD, the radiographic leg lengthening, and the lengthening beyond perceived LLD were compared between the two groups to investigate the significant factor affecting the postoperative perceived LLD.

Table 1. Relation between preoperative radiographic LLD and preoperative perceived LLD in each group according to pelvic tilting.

	n	preop. radiographic LLD (mm)	preop. perceived LLD (mm)	
tilt-affected-side group	32	-14.4 ± 9.3	-7.0 ± 6.0	$p < 0.0001$
horizontal group	24	-6.0 ± 6.5	-4.3 ± 6.4	$p = 0.03$
tilt-unoperated -side group	3	-9.2 ± 10.7	-16.7 ± 15.3	$p = 0.52$
		(average ± SD)		(paired t-test)

We obtained informed consent about this study from all the patients.

Statistical analysis: The preoperative radiographic LLD and the perceived LLD were compared by a paired t-test. The sequential change of the perceived LLD was analyzed by a repeated measure one way ANOVA. The average of postoperative perceived LLD in each group classified according to the lumbar bending range was compared by a one way ANOVA followed by a Scheffe test. The postoperative radiographic LLD, the radiographic leg lengthening and the lengthening beyond perceived LLD were compared between the cases with the perceived LLD and the cases without the perceived LLD by a Mann-Whitney test. All the analyses were performed using StatView for Windows Version 5.0 data analysis software (SAS Institute Inc, Cary, NC, USA). The level of significance applied was $p < 0.05$.

Results

1) Relation between the preoperative radiographic LLD and the perceived LLD

The pelvis in natural standing position inclined to the affected side in excess of two degrees in 54.2% (tilt-affected-side group), horizontal in 40.7% (horizontal group), and inclined to the unoperated side in 5.1% (tilt-unoperated-side group) preoperatively. Causes of inclination to the unoperated side were severe adduction contracture of the affected side hip joint, or lumbar scoliosis. The relation between the radiographic LLD and the perceived LLD in each group is shown in Table Ⅰ. In tilt-affected-side group, the absolute value of the perceived LLD was significantly smaller than that of the radiographic LLD ($p < 0.0001$). In horizontal group, there was significant difference between the radiographic LLD and the perceived LLD ($p = 0.03$), although the difference was smaller than that of Tilt-affected-side group. In tilt-unoperated-side group, the perceived LLD was greater than the radiographic LLD in one of three cases, and the difference between the perceived LLD and the radiographic LLD was not significant ($p = 0.52$).

The relation between the radiographic LLD and the perceived LLD in each group according to the lumbar bending range is shown in Table Ⅱ. The absolute value of the perceived LLD was smaller than that of the radiographic LLD in all the groups, and there was significant difference in mid group.

2) Sequential change of the perceived LLD and the radiographic LLD

The sequential change of the perceived LLD is shown in Figure 4. In 41 cases (70 %), the patients described they felt that the affected side was longer at the time of hospital discharge, and the postoperative perceived LLD decreased with time. The change with time was statistically significant ($p < 0.0001$).

In 12 cases (20.0%), the perceived LLD persisted at two years after the surgery (Table Ⅲ). In all of the 12 cases, the patients felt that the affected side was longer, and no case felt that the affected side was shorter. Eleven of 12 cases were osteoarthritis secondary due to dysplastic hip, and one case was traumatic osteoarthritis. No case of rapidly destructive coxarthrosis or idiopathic osteonecrosis of the femoral head felt LLD at two years after surgery.

In all the cases, there was no change of the postoperative radiographic LLD after three months to two years.

3) Relation between the postoperative perceived LLD and the preoperative lumbar bending range

In tilt-affected-side group, five of eight cases in rigid group perceived the LLD at two years postoperatively, and the average perceived LLD in rigid group was 4.6 (0-15.0) mm. In mid group, 2 of 15 cases perceived the LLD, and the average perceived LLD in mid group was 0.7 (0-5.0) mm. In flexible group, one of nine cases

Table 2. Relation between preoperative radiographic LLD and preoperative perceived LLD in each group according to lumbar bending range.

	n	preop. radiographic LLD (mm)	preop. perceived LLD (mm)	
flexible group	13	-13.0 ± 10.2	-10.8 ± 2.4	p = 0.56
mid group	34	-10.3 ± 9.2	-4.6 ± 5.6	p < 0.0001
rigid group	12	-9.3 ± 7.9	-6.9 ± 7.9	p = 0.18
		(average ± SD)		(paired t-test)

perceived the LLD, and the average perceived LLD in flexible group was 0.6 (0-5.0) mm. There was significant difference among these groups in the average perceived LLD (p = 0.013). Post hoc test revealed significant difference between rigid group and mid group (p = 0.023), and between rigid group and flexible group (p = 0.037) (Figure 5).

In horizontal group, no case perceived the LLD in flexible group (n = 2) and rigid group (n = 4) at two years postoperatively, and 3 of 18 cases perceived the LLD in mid group. The average perceived LLD in mid group was 0.7 (0-5.0) mm, and there was no significant difference among the three groups classified according to the lumbar bending range.

In tilt-unoperated-side group, there were two cases of flexible group and one case of mid group. One case of mid group perceived the LLD, and the postoperative radiographic LLD in the case was 5.5 mm.

4) Factors affecting the postoperative perceived LLD

In eight cases of tilt-affected-side and rigid group, there was no significant difference in the postoperative radiographic LLD between the cases with the perceived LLD postoperatively and the cases without the perceived LLD. The difference in the radiographic leg lengthening also was not significant between the two groups. On the other hand, the lengthening beyond perceived LLD was significantly greater in the cases with the perceived LLD (p = 0.025) (Table Ⅳ).

In 18 cases of horizontal and mid group, the differences in the postoperative radiographic LLD, in the radiographic leg lengthening and in the lengthening beyond perceived LLD were not significant between the cases with the perceived LLD and the cases without the perceived LLD, although the postoperative radiographic LLD tended to be greater in cases with the perceived LLD than in the cases without the perceived LLD (Table Ⅴ). For the three cases perceiving the LLD at two years postoperatively, the postoperative radiographic LLD was 5.1 mm or more (see Table Ⅲ).

In other subgroups, cases with the perceived LLD postoperatively were none to only two cases. Therefore, statistical analyses were not performed.

Discussion

Goodman et al. reported that preoperative accurate planning and a number of intraoperative cues to assess reproduction of the preoperative plan were helpful to prevent postoperative LLD [3]. Bose also described that the precise reproduction of the intraoperative position of the femur (abduction/adduction) and the use of an intraoperative measurement device assisted in equalization of leg length during surgery [5]. However, these articles aimed at radiographic equality of the leg length, and none of them mentioned the difference between the radiographic LLD and the perceived LLD. Konyves and Bannister revealed that the patients with the perceived LLD after THA had significantly lower hip function. However, they also aimed at the radiographic leg length equalization to avoid perception of the LLD [10]. In cases with the horizontal pelvis preoperatively where the compensatory lumbar scoliosis is none or minimum, radiographic equalization of the leg length would achieve satisfactory results. In fact, in horizontal group in the current study, all three cases who perceived the LLD postoperatively had the postoperative radiographic LLD greater than 5.0 mm, whereas no patient perceived the LLD if the postoperative radiographic LLD was 5.0 mm or less. On the other hand, in cases with preoperative pelvic tilting due to severe anatomical deformation such as secondary osteoarthritis due to developmental dysplasia of the hip, which is the commonest etiology of the osteoarthritis of the hip in Japan, the radiographic equalization of the leg lengthening cannot always

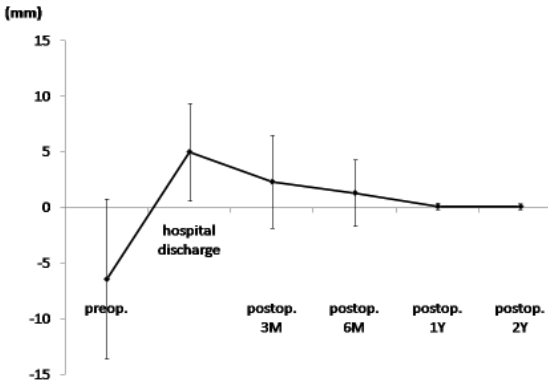

Figure 4. Sequential change of the perceived LLD.
The average perceived LLD at hospital discharge was 5.0 (0-20.0) mm, and the perceived LLD decreased with time. The data are given as average ± SD.

Table 3. Cases with perceived LLD at 2 years after surgery.

Age	Sex	pelvic tilting	lumbar lateral flexibility	preop. perceived LLD (mm)	preop. radiographc LLD (mm)	postop. radiographic LLD (mm)	radiographic leg lengthening (mm)	lengthening beyond perceived LLD (mm)	perceived LLD at 2 years postop. (mm)
51	F	tilt-affected-side	flexible	-10.0	-16.8	-0.9	15.9	5.9	5.0
67	F	tilt-affected-side	mid	0.0	-5.2	5.2	10.4	10.4	5.0
64	M	tilt-affected-side	mid	-5.0	-7.8	6.9	14.7	9.7	5.0
61	F	tilt-affected-side	rigid	-5.0	-5.3	6.2	11.5	6.5	10.0
75	F	tilt-affected-side	rigid	-5.0	-7.0	4.3	11.3	6.3	2.5
65	F	tilt-affected-side	rigid	-5.0	-6.9	5.2	12.1	7.1	5.0
67	F	tilt-affected-side	rigid	-5.0	-21.1	-0.9	20.2	15.2	15.0
86	F	tilt-affected-side	rigid	-2.5	-9.6	0.0	9.6	7.1	5.0
74	F	horizontal	mid	0.0	-2.5	5.1	7.6	7.6	2.5
72	F	horizontal	mid	-2.5	-4.3	5.2	9.6	7.1	5.0
65	F	horizontal	mid	-12.5	-11.5	7.1	18.6	6.1	5.0
61	F	tilt-affected-side	mid	0.0	-2.7	5.5	8.2	8.2	2.5

Table 4. Comparison between cases with perceived LLD and cases without perceived LLD in tilt-affected-side and rigid group.

	n	postop. radiographic LLD (mm)	radiographic leg lengthening (mm)	lengthening beyond perceived LLD (mm)	
perceived LLD (+)	5	3.0 ± 1.0	12.9 ± 1.7	8.4 ± 1.4	(average ± SD)
perceived LLD (-)	3	2.3 ± 0.3	11.6 ± 4.9	3.3 ± 1.3	
		p = 0.76	p = 0.46	p = 0.025	
		(Mann-Whitney test)			

Table 5. Comparison between cases with perceived LLD and cases without perceived LLD in horizontal and mid group.

	n	postop. radiographic LLD (mm)	radiographic leg lengthening (mm)	lengthening beyond perceived LLD (mm)	
perceived LLD (+)	3	5.8 ± 1.1	12.0 ± 5.9	6.9 ± 0.8	(average ± SD)
perceived LLD (-)	15	3.8 ± 4.2	9.4 ± 4.4	6.2 ± 4.1	
		p = 0.40	p = 0.51	p = 0.95	
		(Mann-Whitney test)			

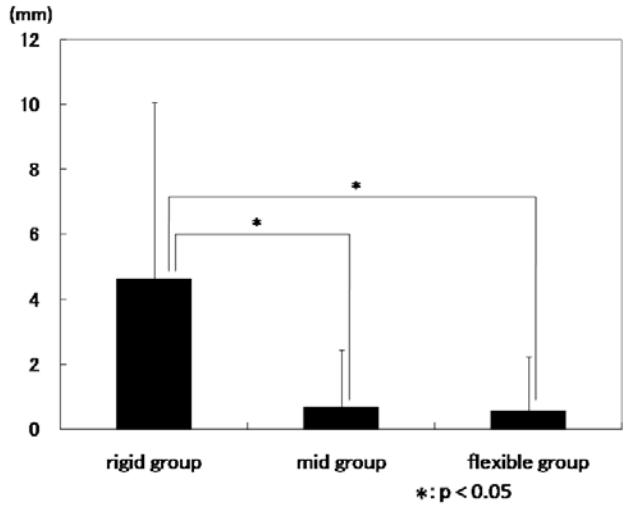

Figure 5. The postoperative perceived LLD in tilt-affected-side group by the group of the preoperative lumbar bending range. The data are given as average ± SD.
The perceived LLD of rigid group was significantly greater than those of other groups.

achieve the satisfactory result. In tilt-affected-side group in the current study, there were three cases of which the perceived LLD was 5mm or more although the radiographic LLD was within 1mm (see Table Ⅲ). The current study suggested that the preoperative perceived LLD works as a reference to determine the amount of leg lengthening in THA.

The factors related to the perceived LLD include the radiographic LLD, the contracture of the hip joint, the inclination of the pelvis due to the scoliosis of the lumbar spine, and the flexion contracture of the knee joint. In THA, leg lengthening and release of the contracture of the affected side is possible, and the pelvic inclination is expected to be more horizontal postoperatively. By predicting the degree of postoperative pelvic inclination, it would be possible to determine the adequate amount of leg lengthening. The lumbar spinal lateroflexion to the affected side taken preoperatively in this study is a simulation of the situation where a pelvis becomes horizontal in connection with the leg lengthening and the release of the contracture of the affected hip after THA. Cases with high lumbar flexibility to the affected side seem to have high reversibility of the pelvic inclination, so the pelvis becomes horizontal due to leg length equalization, resulting in the disappearance of the perceived LLD. On the other hand, cases with low lumbar flexibility to the affected side seem to have low reversibility of the pelvic inclination, so the inclination of the pelvis remains after THA; thus resulting in a situation where the perceived LLD remains (Figures 6 and 7). In this study, cases with rigid lumbar spine felt LLD at a high rate after THA, and cases with flexible lumbar spine felt LLD at a lower rate. The results can be explained by the abovementioned mechanisms.

The reason that most of the patients felt the affected side was longer immediately after THA would be related to the pelvic inclination. Adduction restriction of the affected side hip joint due to tight hip abductors, which is often seen immediately after THA, accelerates

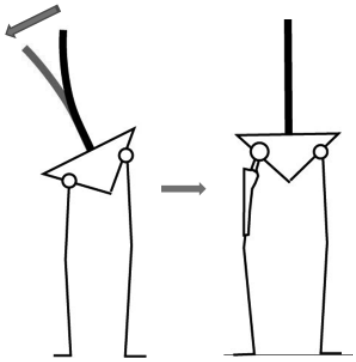

Figure 6. Cases with high flexibility to the affected side of lumbar spine.
The pelvis becomes horizontal due to leg length equalization, resulting in the disappearance of the perceived LLD.

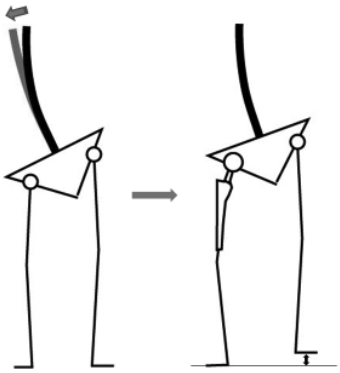

Figure 7. Cases with low flexibility to the affected side of lumbar spine.
The inclination of the pelvis remains after THA, resulting in a situation where the perceived LLD remains.

pelvic inclination and causes this perception of LLD [7]. As the hip abductors are stretched and relaxed by postoperative rehabilitation, the pelvic inclination would decrease and the perceived LLD found immediately after the surgery would diminish. In fact, 70% of the cases felt the LLD at the time of hospital discharge, and only 20 % of the cases felt the LLD at two years after surgery in this study.

In patients with hip joint disease, the affected hip is usually restricted in abduction [11], and tends to be adducted in the supine position. However, this study showed that, in standing position, the pelvis tended to incline the affected side downward and the affected hip tended to become abducted in the majority of the cases. This is explained as compensation for the leg shortening of the affected side. In such cases (tilt-affected-side group), the perceived LLD was smaller than the radiographic LLD. In only three cases (tilt-unoperated-side group), even in standing position, the pelvis inclined towards the contralateral side downward, and the affected hip was in adduction.

The present study has some limitations. First, it is not a randomized study. We started this study after we hypothesized that the preoperative lumbar lateral flexibility would be helpful as a guideline of the optimal amount of leg lengthening. As a result, we took care not to lengthen the leg too much in some cases with rigid lumbar spine. Secondly, although the morbidity period may be a factor of the reversibility of the pelvic inclination, it was not evaluated in the current study. Finally, the ideal amount of the lengthening beyond perceived LLD could not be decided in the current study. However, the lengthening beyond perceived LLD in the cases with the perceived LLD was 8.4 ± 1.4 (6.3 to 15.2) and that in the cases without the perceived LLD was 3.3 ± 1.3 (-0.9 to 5.4) in tilt-affected-side and rigid group (see Table Ⅳ). Furthermore, all 12 cases with the postoperative perceived LLD received the leg lengthening beyond perceived LLD of 5.9 mm or more (see Table Ⅲ). Therefore, the leg lengthening beyond perceived LLD within 5 mm might be acceptable.

There is no publication, to our knowledge, that addresses the adequate amount of leg lengthening in planning of THA in order to avoid postoperative perceived LLD. Our study suggested that the preoperative evaluation of lateral flexibility of lumbar spine and perceived LLD is helpful in determining the optimal amount of leg lengthening in THA. In cases with preoperative pelvic inclination downward to the affected side and with rigid lumbar spine, amount of leg lengthening should not be excessively greater than preoperative perceived LLD. In other cases, lengthening the leg to the same length as the contralateral side rarely results in postoperative perceived LLD.

References

1. Hofmann AA, Skrzynski MC. Leg-len edics 2000;23:943-4.
2. Maloney WJ, Keeney JA. Leg length discrepancy after total hip arthroplasty. J Arthroplasty 2004;19 Suppl 1:108-10.
3. Goodman SB, Huene DS, Imrie S. Preoperative templating for the equalization of leg lengths in total hip arthroplasty.

Contemp Orthop 1992;24:703-10.
4. Woolson ST, Hartford JM, Sawyer A. Results of a method of leg-length equalization for patients undergoing primary total hip replacement. J Arthroplasty 1999;14:159-64.
5. Bose WJ. Accurate limb-length equalization during total hip arthroplasty. Orthopaedics 2000;23:433-6.
6. Eggli S, Pisan M, Muller ME. The value of preoperative planning for total hip arthroplasty. J Bone Joint Surg Br 1998;80:382-90.
7. Jasty M, Webster W, Harris W. Management of limb length inequality during total hip replacement. Clin Orthop 1996;333:165-71.
8. Offierski CM, MacNab I. Hip-spine syndrome. Spine 1983;8:316-21.
9. White TO, Dougall TW. Arthroplasty of the hip: leg length is not important. J Bone Joint Surg Br 2002;84-B:335-8.
10. Konyves A, Bannister GC. The importance of leg length discrepancy after total hip arthroplasty. J Bone Joint Surg Br 2005;87-B:155-7.
11. Arokoski MH, Haara M, Helminen HJ, et al. Physical function in men with and without hip osteoarthritis. Arch Phys Med Rehabil. 2004 Apr;85(4):574-81.