Influence of leg length discrepancy on anterior acetabular coverage using false profile image

Abstract

Background Leg length discrepancy (LLD) occurs commonly in patients with osteoarthritis (OA) of the hip. Although some investigators argue that LLD in a weight-bearing position may influence lateral acetabular coverage, there have been no reports on the influence of LLD on anterior acetabular coverage and the relationship between LLD and VCA angle before and after LLD correction. Anterior acetabular coverage is an important index for diagnosis, treatment, and surgery for OA of the hip. Therefore, we investigated the influence of LLD in a weight-bearing position on VCA angle.

Methods Subjects were 154 patients with LLD in OA of the hip and 146 healthy individuals without LLD. The sole of the short-leg side in patients was adjusted with acrylic plate and the LLD revision value was calculated on anteroposterior (AP) view in a weight-bearing position. Calculated revision value was applied to subjects and VCA angles in false profile images before and after correction was measured. For healthy individuals, we corrected the sole of the non-examined side with acrylic plate to artificially increase LLD, and then measured VCA angles in false profile images before and after correction.

Results Significant difference was found in VCA angles between before and after LLD correction in patients and healthy individuals ($p < 0.05$). Difference in VCA angles before and after LLD correction in both patients and health individuals highly correlated with LLD level in both short- and long-leg sides.

Conclusions This study clarified that LLD in a weight-bearing position influenced VCA angle. Results suggested that comparison of images before and after correction increases the accuracy of diagnosis. Assessing anterior acetabular coverage before and after LLD correction is valuable in evaluating the need for surgery, suitable correction of osteotomised acetabular fragments in periacetabular osteotomy, and determining the angle of acetabular cup in artificial joint replacement.

Introduction

Leg length discrepancy (LLD) occurs with the progression of osteoarthritis (OA) of the hip, and the pelvis inclines on the short-leg side [1, 2]. This LLD may influence the measured values of acetabular coverage on plain X-ray image. OA of the hip is generally diagnosed by AP plain X-ray radiography in the supine position. For the diagnosis of acetabular dysplasia, lateral acetabular coverage is traditionally assessed by center edge (CE) and sharp angles [3]. X-ray images in the supine position, however, do not reflect the weight-bearing state. Since the hip joint is a weight-bearing joint, it should to be examined under weight-bearing conditions.

As a method to investigate anterior acetabular coverage, Lequesne et al. reported oblique imaging of the pelvis in the weight-bearing position as the false profile (FP) acquisition method [4]. Chosa et al. demonstrated that a three-dimensional evaluation was available through a combination of AP and FP images [5-7], and then modified the X-ray radiographic method using computed tomography (CT) images to develop a new FP acquisition method [8]. The number of studies on vertical center anterior margin (VCA) angle using FP images has increased recently [5-7, 9-14].

In this study, we focused on LLD in patients with OA of the hip. It has been reported that LLD in a weight-bearing position exerts an influence on patients with OA of the hip through lateral pelvic inclination [1, 2, 15-18]. It has also been reported that LLD in a weight-bearing position affects lateral acetabular coverage [15]. However, the influence of LLD on anterior acetabular coverage and the relationship between LLD before and after correction has not been reported.

The purpose of this study was to investigate the difference in VCA angles before and after correction by LLD level in a weight-bearing state in patients with OA of the hip, and quantitatively verify the influence of different levels of LLD on VCA angle.

Materials and Methods

Subjects were 154 patients (128 females and 26 males), aged 20 to 83 years (mean; 50 ± 15) who had been treated at the outpatient clinic at the Department of Orthopedics of our hospital, between July 2009 and March 2012, and 146 healthy females aged 22 to 35 years (mean; 25 ± 3) who were included in this study as clinical study volunteers between September 2010 and June 2011.

The Japanese Orthopedic Association sets the normal range of the Center Edge Angle (CEA) as 25 degrees or greater, the Acetabular Angle (ACA) as 5 degrees or less, 82% or more of the Acetabular Head Index (AHI), and the Vertical Center Anterior margin (VCA) as 25 degrees or more in Japanese adults through x-ray measurement.

Cases of end-stage coxarthrosis as determined by the evaluation criteria for arthrosis of the hip established by the Japanese Orthopaedic Association and Grade IV on the Kellgren and Lawrence Grading Scale were excluded. Cases of advanced-stage coxarthrosis, Grade III with marked flexion, adduction and external rotation contracture of the hip, significant lumbar spondylosis, and scoliosis were also excluded.

Informed consent for this study was obtained from the subjects. This study was approved by the Clinical Ethics Committee of our hospital.

VCA angle was defined by Lequesne et al. in 1961 as the angle formed by a vertical line passing through the center of the femoral head and a straight line that connects the center of the femoral head and anterior edge of the acetabula on FP image [4]. The differences in VCA angles on FP image before and after correction are shown in Fig. 1 (A, C, D, and F).

LLD calculation method

The pelvis inclines toward the short-leg side when LLD is present on AP image in a weight-bearing position [1, 2, 15-19]. The short-leg side requires correction to reduce the inclination. We applied a 0.5 cm-thick acrylic plate to correct LLD. Using the lateral pelvic inclination in the first AP image in a weight-bearing position, we estimated LLD (Fig. 1B). Then, we added acrylic plate on the sole of the short-leg side to correct LLD and took another AP image (Fig. 1E). When the line connecting the bilateral teardrops (or ischial tuberosities) was horizontal, we measured the thickness of the acrylic plate, which was regarded as the LLD level (revision value). The LLD was measured at 0.5 cm intervals between 0.5 and 3.5 cm. We examined the width of the ilium and the symmetry of the obturator foramen on both left and right sides, and confirmed the absence of inclination.

VCA angle in patients

We investigated the relationship between LLD level and VCA angle. Subjects were 154 patients (128 females and 26 males), aged 20 to 83 years (mean; 50 ± 15), with LLD attributed to OA of the hip selected from among patients with AP images in a weight-bearing position (Table 1).

AP image in a weight-bearing position was acquired first. If LLD was observed, the short-leg side was adjusted by adding an acrylic plate on the sole and the revision value was calculated. Next, FP images before correction were acquired for both short- and long-leg sides. The calculated revision value was applied to the short-leg side, and FP images after correction were acquired for both short- and long-leg sides. VCA angles were measured with the FP images acquired before and after correction, and the gap was regarded as the difference in VCA angles. The impact on the long-leg side was also investigated in this study. Table 2 shows the mean values of VCA angles in patients.

VCA angle in healthy individuals

We measured VCA angles in healthy individuals with artificially induced LLD to examine the influence of LLD on acetabular coverage and pelvic movement. To compare VCA angles between patients and healthy individuals by LLD level, we investigated VCA angle in healthy individuals on the short-leg side. The subjects were 146 healthy females aged 22 to 35 years (mean; 25 ± 3) with no LLD (Table 1).

AP image in a weight-bearing position was acquired first to confirm the absence of LLD. Then, FP image for the examined side before correction was acquired. The sole of the non-examined side (long-leg side) was adjusted with acrylic plate to artificially create LLD to enable examination under the same condition as patients with LLD, and FP image for the examined side (short-leg side) after correction was acquired again. VCA angles were measured with the acquired FP images before and after correction, and the gap was regarded as the difference in VCA angles. Table 3 shows the mean values of VCA angles in healthy individuals.

Measurement analysis

VCA angle measurements were conducted by three investigators (two orthopedists and one radiological technologist) using the Images J 1.47i (National Institutes of Health) based on the methods established by Lequesne [4] and Chosa et al. [5, 6].

Statistical analysis

PASW Statistics 18 (SPSS, Tokyo, Japan) was used for statistical analysis. T-test was used for between-group comparison. Correlations were evaluated by the Pearson’s correlation coefficient. VCA angle concordance rates (Fleiss’ Kappa coefficient) among three investigators were 0.68 in patients and 0.75 in healthy individuals, both of which were substantial.

Results

VCA angle in patients

Fig. 2 shows mean VCA angles and the difference before and after correction by LLD level in patients. Significant differences were found in VCA angles between before and after correction on both short- and long-leg sides ($p < 0.05$). The difference in VCA angles before an after correction correlated with LLD level (the short-leg side [$\gamma = 0.994$], the long-leg side [$\gamma = 0.985$]). The difference in VCA angle on the long-leg side was greater than that on the short-leg side.

VCA angle in healthy individuals

The results showed that VCA angles in healthy individuals change before and after artificially induced LLD. Fig. 3 shows the mean VCA angles and the differences on short-leg side before and after correction by LLD level in healthy individuals. Significant difference was found in VCA angles on short-leg side between before and after correction ($P < 0.05$). Difference in VCA angles on the short-leg side before and after correction correlated with LLD level ($\gamma = 0.998$).

Comparison between VCA angles in patients and healthy individuals

Changes in VCA angle on the short-leg side in healthy individuals before and after artificially creating LLD revealed a tendency similar to that in VCA angle on the long-leg side in patients with OA of the hip (Fig.4). VCA angle in patients with OA of the hip tended to decrease as LLD increased, whereas VCA angle on the short-leg side increased in healthy individuals with artificially created LLD (Fig.5).

Discussion

Acetabular coverage is an important element in OA of the hip; and it is also important to examine coverage in a standing position because the weight-bearing area in hip joint varies while walking. LLD in walking has a significant impact on the weight-bearing area. Many studies have focused on lateral coverage, and anterior and posterior pelvic inclination in AP images; however, none of these include examination with FP images. In this study, we examined the relationship in LLD between before and after correction to consider the impact of LLD in a weight-bearing position on the anterior coverage of hip joint in a weight-bearing position.

It is noted in the guidelines for the treatment of OA of the hip that LLD affects pelvic inclination, spinal alignment and lateral acetabular coverage. LLD level of the coxarthrosis group (12.2 ± 9.3 mm) was higher than that of the control group (3.3 ± 4.6 mm), and the lateral pelvic inclination angle of the coxarthrosis group (1.6° ± 2.1°) was significantly greater than that of the control group (0.8° ± 1.2°), (HF11689, EV level R-III) [20].

The pelvis reportedly inclines toward the affected side in OA of the hip [1, 2, 15-18], and the influence of functional LLD is assumed to be the cause of this [19, 21]. The burden to the hip, knee, and low back are occasionally abated by correction in patients with LLD in OA of the hip [15, 22-24]. In our study, hip joint and low back symptoms were reduced in some patients with correction at X-ray examination. Since LLD is not observed in the normal pelvic position, measurement with corrected LLD is clinically necessary.

This study revealed that patients with OA of the hip developed anterior pelvic torsion toward the short-leg side and posterior torsion toward the long-leg side through the measurement of VCA angles before and after correction for both short- and long-leg sides. Anterior acetabular coverage decreased after correction on the short-leg side in patients (Fig. 2A), while it increased on the long-leg side after correction of LLD (Fig. 2B). We believe the decreasing VCA angle on the long-leg side at 2.0 cm of LLD shown in Fig. 2B was a result of the inclusion of the smaller anterior acetabular coverage on the normal side in the patient group. In healthy individuals, anterior acetabular coverage on the examined short-leg side increased with the increase of artificially created LLD, which led to the assumption that healthy individuals also develop pelvic torsion if LLD is artificially created (Fig. 3). Changes in VCA angle on the short-leg side in healthy individuals before and after artificially creating LLD revealed a tendency similar to that in VCA angle on the long-leg side in patients with OA of the hip, which probably occurred because the longer the leg on non-examined side becomes, the more the pelvis on the examined side twists forward (Fig.2B, 3 and Fig. 4) [25]. We analyzed VCA angle on the short-leg side in patients with OA of the hip before correction and in healthy individuals after correction (Fig. 5). VCA angle in patients with OA of the hip tended to decrease as LLD increased, whereas VCA angle on the short-leg side increased in healthy individuals with artificially created LLD, and correlation was found in VCA angles in patients with LLD level between 0.5 and 2.5 cm ($p < 0.05$). In healthy individuals, the pelvis inclines forward and rotates to maintain balance. As a result, the anterior coverage increases as a physiological response. Conversely, in the patients with OA of the hip, because the short-leg side is affected, anterior coverage is insufficient and contractured. In addition, we believe that anterior coverage decreases in association with the severity of acetabular dysplasia and coxarthrosis. VCA angles in patients with an LLD level greater than 3.0 cm increased. The reason was assumed to be that all patients with an LLD level greater than 3.0 cm have an OA of the hip with highly elevated greater trochanter, which was thought not to have been caused by acetabular dysplasia, but by anatomical and mechanical impact due to the highly elevated greater trochanter. Correction of LLD is necessary to enable measurement of the actual VCA angle, and to offer more effective treatment. Correcting and evaluating LLD before surgery enables a better understanding of the condition of the hip joint (including contracture on the affected side, which would be helpful in determining the need for muscle release surgery) in assessing the suitable correction of osteotomised acetabular fragments in periacetabular osteotomy, and in calculating the angle of the acetabular cup in artificial joint replacement. VCA angle on the long-leg side in patients was analyzed (Fig. 2B). VCA angle on the long-leg side increased after LLD correction to the same degree as in healthy individuals. This indicated that correction of LLD led to a physiological response in patients. This result suggested that LLD in patients with OA of the hip strongly influences VCA angle on the long-leg side as well. Measuring VCA angles before and after LLD correction along with CE angle, and evaluating the mechanism of physiological compensation are important in examining the condition of patients with OA of the hip accompanied by LLD and in preventing its progression.

Periacetabular osteotomy is a treatment for OA of the hip. If VCA angle on the long-leg side improves with LLD correction, the LLD has to be corrected concomitantly with periacetabular osteotomy, and a shoe lift is required to prevent the progression of coxarthrosis on the normal side (the long-leg side). In contrast, if LLD correction does not provide improvement in VCA angle on the long-leg side, surgical therapy should be considered because conservative therapy may be inadequate for the maintenance of balance or the prevention of progression of coxarthrosis for both the affected (short leg) and normal (long leg) sides.

The findings of this study are clinically important. LLD correction in the treatment of OA of the hip attributed to acetabular dysplasia or subluxated OA of the hip reduces the acetabular coverage on the affected side; however, correction is necessary to prevent the progression of coxarthrosis on the normal side. Correction of LLD in conservative joint surgery, such as periacetabular osteotomy or femoral osteotomy, is important for both the surgical and non-surgical sides. Pelvic inclination and VCA angles before and after correction in the weight-bearing state, therefore, provide important data in clinical practice. In particular, VCA angle in a weight-bearing position varies before and after LLD correction in correlation with the level of LLD. For this reason, when LLD is observed on AP view, further examination and evaluation with LLD correction may be useful in deciding treatment.

A wide range of LLD measurement methods have been reported [26-29]. The calculation of LLD in a weight-bearing position utilizing acrylic plate was accurate; however, there was a limitation in the measurement. Investigators must estimate LLD subjectively with the first AP X-ray radiography, and make corrections. If the initial correction is not accurate, investigators must adjust again with acrylic plate, which is troublesome. Calculation of LLD by applying Spina Malleollar Distance (SMD) [30] or lateral pelvic inclination angle (inclination of the line connecting the bilateral teardrops or ischial tuberosities) would yield significant results. Establishment of a simple and accurate method of calculating LLD in a weight-bearing position is a future task.

Conclusions

We have concluded that LLD in a weight-bearing position influenced VCA angle of the hip joint in OA of the hip. When LLD is present, it is crucial to acquire FP images, as well as AP images of hip joint, for both the affected and normal sides, before and after LLD correction for further evaluation. Surgical therapy has been suggested for cases in which no improvement is observed in VCA angle on the long-leg (normal) side. Therefore, comparison of the images acquired before and after LLD correction leads to better diagnosis and more effective treatment.

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