Characteristics of Hip Impingement Syndrome in patients with Multiple Hereditary Exostoses

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Research article

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Abstract

Backgrounds

This study aimed to investigate the characteristic deformities of the hip in multiple hereditary exostoses patients (MHE) and its association with the hip impingement syndrome.

Materials and methods

Between 2001 and 2019, total 51 patients (102 hips) were evaluated in this study. To assess the morphometry of the hip in patients with MHE, the femoral neck-shaft angle, Sharp’s acetabular angle and center-edge (CE) angle were evaluated. Hip impingement symptoms were classified to femoro-acetabular impingement (FAI) symptom group, ischio-femoral impingement (IFI) symptom group and non-impingement symptom group by comparing the symptoms, clinical signs and imaging studies. Alpha angle was evaluated to investigate the FAI. The minimum ischio-femoral distance was measured to evaluate for IFI using computed-tomographic study. Each measured morphometric study was compared according to gender, location and hip impingement symptom.

Results

Coxa valga and acetabular dysplasia were common with a mean femoral neck-shaft angle of 144.1°, mean CE angle of 27.9°, and mean Sharp’s acetabular angle of 42.0°. Each of the measured value for assessment of hip deformity was correlated significantly. Morphometric study on gender showed no significant difference except the alpha angle value. In addition, no significant difference was shown on comparison study by location of hip. On hip impingement symptom analysis, FAI symptom and IFI symptom were confirmed in 14 hip joints and 18 hip joints, respectively. The number of hip joints with IFI symptom was higher than those with FAI symptom in this study. Furthermore, both the FAI and IFI symptom group showed significant differences from the non-symptom group in the morphometric study. In addition, the minimum ischio-femoral distance was significantly decreased in the IFI symptom group, which seems to be associated with coxa valga deformity.

Conclusion

The results suggest that the characteristic deformities that occur in the hip joint of MHE patients affect the appearance of impingement syndrome. Therefore, it is necessary to carefully evaluate the characteristic deformities of the hip joint in patients with MHE and to set up the treatment modality accordingly.

Level of Evidence: Level III, retrospective comparative study

Introduction
Hip impingement syndromes were caused by abnormal conflict between the acetabulum and femur or between the ischium and femur. When two anatomical structures do not fit together perfectly or have insufficient distance to pass, these impingement syndrome can cause pain from the structures continuously rubbing against each other or soft tissue during movement. Over time these kinds of frictions can damage the joint, causing pain and limiting activity.

Among the hip impingement syndromes, femoro-acetabular impingement (FAI) caused by an abnormal contact between the acetabulum and femur has been more widely reported than ischio-femoral impingement (IFI) syndrome, which is caused by an abnormal conflict between the ischium and femur. In addition, recent studies have also reported that FAI syndrome caused by an abnormal morphology of the hip is associated with early-onset and rapidly progressive hip osteoarthritis [1, 2]. The prevalence of FAI has been reported to range from 6–35%, depending on the inclusion criteria for the population and the definitions of FAI [3]. Currently, the concept of FAI is well established, and its treatment has considerably evolved [1, 4–7]. However, studies on IFI syndrome are rarer than those on FAI syndrome. IFI as a clinical entity was first described in 1977 by Johnson [8], who reported on three patients with a complaint of pain after total hip replacement. Recently, the cause of IFI syndrome has been studied using various imaging techniques. Studies have reported that the dominant cause of IFI syndrome is the narrowing of the space between the ischial tuberosity and the lesser trochanter area, which can cause abnormal contact of the quadratus femoris muscle [8–13]. Although studies on IFI syndrome have been conducted recently, this syndrome has not been reported as much as FAI.

On the basis of studies reporting that hip impingement syndrome is caused by an abnormal contact around the hip joint, this study postulated that the possible risk of developing hip impingement is higher in patients with multiple hereditary exostoses (MHE) exostoses around the hip. MHE, with an estimated frequency of at least 1 per 50,000, is one of the most common bony dysplasia occurring in the metaphyseal area of bones due to endochondral ossification [14, 15]. The characteristic symptom of MHE is a palpable mass around the extremities causing limitation of joint motion. However, there have been no studies on FAI, which is more common in the general patient group, in patients with MHE. Rather, a few reports have been published on IFI, which has not been considerably reported in general patients. In addition, there have been no reports on hip impingement syndrome in patients with MHE and its association with characteristic deformities in the hip joint.

This study, therefore, was conducted to investigate the characteristic hip deformities in MHE, and to evaluate the correlation of each of characteristic deformities association with the hip impingement syndrome.

Materials And Methods

This study retrospectively reviewed the patients diagnosed with MHE from January 1, 2001 to January 1, 2019. Patients with MHE who had plain radiographs of the hip joints (those who had plain radiographs before surgical intervention or those who had not undergone any surgical intervention around the hip
joints) were included. Patients with poor quality of radiographic images, those who underwent surgery elsewhere, and young patients without tri-radiate cartilage closure for the evaluation of mature hip joints were excluded.

Between 2001 and 2019, plain radiographs of 188 hips in 94 patients diagnosed with MHE were retrospectively reviewed. Among them, 28 patients (56 hips) who had no lesion around the hip joint were excluded. Although 132 hips in 66 patients (70.2%) were identified as having lesions around the hip joint, 15 young patients without tri-radiate cartilage closure were further excluded. Therefore, a total of 51 patients (102 hips) with tri-radiate cartilage closure were included.

**Morphometric analysis**

Radiographic analysis was conducted using the last follow-up radiographs in patients who had not undergone any surgical intervention, and the last preoperative radiographs in those who had undergone surgical treatment around the hip joints. For the morphometry of the hip joint in patients with MHE, the femoral neck-shaft angle of Muller [16] was evaluated to assess proximal femur deformity, and Sharp's acetabular angle [17] and the center-edge (CE) angle [18, 19] were evaluated to assess acetabular dysplasia (Fig. 1). In addition, the correlation between each of the values examined for deformities of MHE hips was also investigated.

**Comparative analysis according to sex, and the right/left sides of the hip**

All hips were classified according to sex, and evaluated to confirm the differences in morphometric parameters between the sexes. In addition, all hips were classified as right and left, and comparative analysis of morphological differences between the right and left hip was performed.

**Impingement analysis**

According to hip impingement symptoms, patients were classified into the FAI and IFI symptom groups to compare the triads of symptoms, clinical signs and imaging studies.

The FAI symptom group included patients who complained of groin discomfort during the hip flexion and internal rotation physical examination and had corresponding imaging findings with alpha angle measurements (Fig. 2). Whereas, the IFI symptom group included the patients who showed a significant reduction of the minimum ischio-femoral distance on computed-tomography (CT) evaluation (Fig. 3), and complained of hip discomfort during hip extension, adduction, and external rotation in a physical examination test.

For FAI evaluation, the alpha angle of all hips was measured and morphometric analysis was conducted to compare the FAI symptom group and the non-FAI symptom group.
For IFI evaluation, regardless of the presence or absence of symptoms, all hip CT studies in patients with MHE were performed in the neutral supine position. Minimum ischio-femoral distance was compared between IFI symptom and non-IFI-symptom groups based on CT findings, and a morphometric study of the IFI symptom and non-IFI symptom groups was performed using plain radiographs.

**Statistical analysis**

Statistical analysis was performed using the SPSS version 21.0 software. The correlation between the characteristic deformities was determined using Kendall's coefficient of rank correlation. A t-test was applied to compare the sex differences, and the right/left side hip joint differences. The Mann-Whitney U-test was applied to compare the two differences according to the presence or absence of hip impingement symptoms. Further, statistical significance was set at $P<0.05$.

**Results**

**Demographic data and morphometric evaluation**

The mean age of 51 patients (102 hips) was 24.0 (14.0 to 54.0) years. Among them, 27 patients (54 hips) were men and 24 patients (48 hips) were women. The mean values of deformity measures in 102 MHE hips are listed in Table 1. In femoral neck-shaft angle analysis for the evaluation of proximal femur deformity, coxa valga with a mean angle of 144.1° was common. In the evaluation to confirm the deformity of the acetabulum and femoral head coverage, the mean CE angle and Sharp's angle was found to 27.9° and 42.0°, respectively. To determine the correlation of each value, an additional investigation was conducted on the distribution of the measured values. Figure 4 shows the distribution of MHE hips according to CE and femoral neck-shaft angles. As the CE angle value increased, the value of femoral neck-shaft angle tended to decrease. Figure 5 shows the correlation between Sharp's angle and the femoral neck-shaft angle, demonstrating that the value of the femoral neck shaft angle tended to increase as Sharp's angle increased. As shown in Fig. 6, the change in Sharp's angle was confirmed to show a reverse relationship to the CE angle change pattern. In addition, a further survey was conducted to determine whether the correlation of each value was significantly related to each other. As shown in Table 2, it was confirmed that the correlation was significant (CE angle vs femoral neck-shaft angle; $P = 0.004$, Sharp's angle vs femoral neck-shaft angle; $P = 0.027$ and CE angle vs Sharp's angle; $P < 0.001$).
Table 1
Morphometric study of 51 patients (102 hips) with multiple hereditary exostoses using plain radiographs

| Morphometric study of 102 hips using plain radiographs |
|-------------------------------------------------------|
| Femoral neck-shaft angle (°)                          | 144.1 (127.9–166.3) |
| Sharp’s angle (°)                                     | 42.0 (34.0–60.5)    |
| Center-edge (CE) angle (°)                            | 27.9 (4.0–41.1)     |
| Alpha angle (°)                                       | 59.7 (38.3–88.4)    |

Table 2
Correlations of measured values for morphometric study using Kendall’s coefficient test (tau)

| Two parameters                  | Kendall's tau | P value |
|---------------------------------|---------------|---------|
| Center-edge angle vs femoral neck-shaft angle | -0.197        | 0.004   |
| Sharp’s angle vs femoral neck-shaft angle       | 0.149         | 0.027   |
| Center-edge angle vs Sharp’s angle             | -0.419        | < 0.001 |

Morphometric study according to sex, and the right/left sides of the hip

All MHE hips were classified according to sex, and a morphometric study was conducted to evaluate the sex differences. No significant difference was found except for the alpha angle between male and female hips. On alpha angle evaluation, the hips of male patients showed significantly higher values (P = 0.002) than the hips of female patients (Table 3).
Table 3
Comparison of morphometric parameters according to sex

| Radiographic parameters       | Men (n = 54) | Women (n = 48) | P value |
|------------------------------|-------------|----------------|---------|
| Femoral neck-shaft angle (°) | 145.8 (± 9.6) | 142.9 (± 7.1) | 0.085   |
| Sharp's angle (°)            | 41.2 (± 3.9)   | 42.9 (± 4.8)   | 0.057   |
| Center-edge angle (°)        | 28.1 (± 7.1)   | 26.5 (± 7.4)   | 0.059   |
| Alpha angle (°)              | 63.1 (± 11.2)  | 56.0 (± 11.6)  | 0.002   |

On the comparative analysis between the right and left sides of the hip, no significant difference was found (Table 4).

Table 4
Comparison of morphometric parameters according to the side of the hip

| Radiographic parameters       | Right (n = 51) | Left (n = 51) | P value |
|------------------------------|---------------|--------------|---------|
| Femoral neck-shaft angle (°) | 144.6 (± 8.1) | 144.2 (± 9.1) | 0.796   |
| Sharp's angle (°)            | 42.0 (± 4.9)   | 41.9 (± 4.0)   | 0.906   |
| Center-edge angle (°)        | 27.0 (± 8.0)   | 28.4 (± 6.9)   | 0.344   |
| Alpha angle (°)              | 59.2 (± 11.7)  | 60.3 (± 12.0)  | 0.645   |

Morphometric study with FAI

On FAI evaluation, although 62 MHE hips with an alpha angle of ≥ 55° were observed in this study (Fig. 7), only 14 MHE hips showed FAI symptoms. As a result, the incidence of FAI symptoms in MHE hips confirmed to be 13.7% in this study. The result of the comparative analysis of morphometric parameters according to the presence or absence of FAI symptoms are shown in Table 5. The FAI symptom group showed significantly higher coxa valga deformity presented by femoral neck-shaft angle (P < .001), significantly higher acetabular dysplasia presented by Sharp’s angle (P = 0.027) and significantly lower femoral head coverage presented by CE angle (P = 0.017) as well as higher alpha angle (P < 0.001) than the non FAI symptom group.
Table 5
Comparative analysis of morphometric parameters between the femoro-acetabular impingement (FAI) symptom group and the non FAI symptom group

| Radiographic parameters | FAI symptom group (n = 14) | Non FAI Symptom group (n = 88) | P value |
|-------------------------|---------------------------|-------------------------------|---------|
| Femoral neck-shaft angle (°) | 153.9 (143.8–161.1) | 142.6 (127.9–166.3) | < 0.001 |
| Sharp's angle (°) | 45.0 (31.5–60.5) | 41.5 (34.0–53.6) | 0.027 |
| Center-edge angle (°) | 21.1 (4.0–41.1) | 28.8 (9.3–38.8) | 0.017 |
| Alpha angle (°) | 76.7 (60.7–88.4) | 57.9 (38.3–83.4) | < 0.001 |

Morphometric study with IFI

A total of 18 of 102 MHE hips (17.7%) presented IFI symptoms in this study. A morphometric study of hip deformities was conducted using plain radiographs, and the results were compared between the IFI symptom group and the non IFI symptom group. Table 6 shows significant differences in morphometric parameters between the two groups (femoral neck shaft angle; P < 0.001, Sharp’s angle; P = 0.013, CE angle; P = 0.002 and alpha angle; P < 0.001). Additionally, the IFI symptom group was compared with the non IFI-symptom group, and the correlation with the ischio-femoral distance was evaluated on the basis of CT findings. A total 52 MHE hips with CT findings were identified. Among them, 34 hips were classified into the non IFI symptom group. The ischio-femoral distance was compared between the IFI symptom group and the non IFI symptom group on the basis of CT findings, and a significant difference (P < .001) was found (Table 7).
Table 6
Comparative analysis of morphometric parameters between the ischio-femoral impingement (IFI) symptom group and the non IFI symptom group

| Radiographic parameters | IFI symptom group (n = 18) | Non IFI Symptom group (n = 84) | P value |
|-------------------------|---------------------------|-------------------------------|---------|
| Femoral neck-shaft angle (°) | 150.9 (138.4–161.1) | 142.7 (127.9–166.3) | < 0.001 |
| Sharp's angle (°) | 44.7 (31.5–60.5) | 41.4 (34.0–53.6) | 0.013 |
| Center-edge angle (°) | 21.1 (4.0–40.2) | 29.3 (9.3–41.1) | 0.002 |
| Alpha angle (°) | 73.3 (56.0–88.4) | 56.8 (38.3–83.4) | < 0.001 |

Table 7
Comparative analysis of computed-tomography (CT) findings between the ischio-femoral impingement (IFI) symptom group and the non-IFI symptom group

| CT based parameter | IFI symptom group (n = 18) | Non IFI symptom group (n = 34) | P value |
|-------------------|---------------------------|-------------------------------|---------|
| Minimum ischio femoral distance (mm) | 6.6 (2.4–9.7) | 16.4 (10.2–25.2) | < 0.001 |

To evaluate the radiological differences between the FAI and IFI symptom group, hips with both FAI and IFI symptoms were excluded and only hips with isolated FAI or IFI symptoms were compared. No significant difference was observed between these two groups (Table 8).
Table 8
Comparative analysis of morphometric parameters between the isolated femoro-acetabular (FAI) symptom group and the isolated ischio-femoral impingement (IFI) symptom group

| Radiographic parameters | Isolated FAI symptom group (n = 4) | Isolated IFI symptom group (n = 8) | P value |
|-------------------------|-----------------------------------|-----------------------------------|---------|
| Femoral neck-shaft angle (°) | 153.2 (148.5–158.3) | 150.1 (138.4–153.0) | 0.089 |
| Sharp's angle (°) | 42.7 (40.3–46.2) | 43.2 (40.2–47.7) | 0.734 |
| Center-edge angle (°) | 25.8 (9.3–41.1) | 23.4 (13.7–31.6) | 0.865 |
| Alpha angle (°) | 73.9 (60.7–82.2) | 67.6 (56.0–76.1) | 0.234 |

Discussion

As impingement syndrome in the hip joint can be caused by an abnormal contact between bony and soft tissue structures, this study postulated that the risk of hip impingement syndrome is higher in patients with MHE around the hip joints.

FAI symptoms have been reported to be more common than IFI symptoms in general patients who do not have MHE, however, IFI symptoms have been reported more than FAI symptoms in patients with MHE of the hip. The characteristic deformities of MHE hips with coexisting exostoses around the proximal femur may have a crucial role. Therefore, this study was conducted to investigate the deformities of the hip in patients with MHE and their relationship to hip impingement syndrome.

In general, the main characteristic deformities of MHE hips have been reported to be coxa valga in the proximal femur and occasional features of acetabular dysplasia [20]. Moreover, the presence of coxa valga has also been reported as a developmental consequence associated with acetabular dysplasia [18]. Consistent with previous studies [18, 20], the main characteristic deformities of MHE hips in this study were also identified to be coxa valga and acetabular dysplasia. Furthermore, as shown in Table 2, each deformity measure was confirmed to have a significant correlation.

In the comparison of right and left MHE hips, coxa valga and acetabular dysplasia were found as in the overall MHE hips; however, there was no significant difference between the right and left hips. In the classification according to sex, similar to common deformities of MHE hips, coxa valga and acetabular dysplasia were found, although there was no significant difference. However, the sex comparison according to the alpha angle value showed a significantly higher increase in the male hip joint. This study
can be assumed to be similar to a report [21] showing that MHE as a genetic disease is more deformed in men. However, in this study, as only the alpha angle showed a difference, more detailed studies according to sex are needed.

This study also investigated the relationship between impingement syndrome in MHE hips and the development of deformities. Considering the two measured values of Sharp’s angle and the CE angle, which indicate acetabular dysplasia, the coverage of the femoral head would be reduced. Therefore, pincer-type FAI caused by over coverage of the femoral head seems less likely in patients with MHE. In contrast, FAI in patients with MHE is likely to appear as a cam-type owing to the exostoses around the femoral head-neck junction. According to reports on cam-type impingement syndrome in general patients, the possibility of FAI is high when the alpha-angle value is > 55° [22]. Although 62 MHE hips with an alpha angle of ≥ 55° were observed in this study (Fig. 7), only 14 of 62 MHE hips had FAI symptoms. The reason why only a few hips presented with FAI in patients with MHE is that the increased alpha-angle value had been compensated by other characteristic deformities of the MHE hip. Coxa valga and acetabular dysplasia, for example, could increase the working distance between the proximal femur and the acetabulum. The schematic illustration in Fig. 8 proposes an explanation for this possibility. FAI symptoms in MHE hips occur as a result of the interaction between these compensating values and conflicting values.

Some studies [9, 12, 13, 20] have reported that IFI syndrome may result from the abnormal contact due to the reduced distance around the ischium and lesser trochanter area. Similarly, IFI in MHE hips has been reported to be caused by the shortening of the ischio-femoral distance due to exostoses around the lesser trochanter area and coxa valga deformities. As shown in Table 6, the IFI symptom group showed a much higher incidence of coxa valga than the non IFI symptom group in this study. The deformities observed in the IFI symptom group showed significant differences from those in the non IFI symptom group. Although significant increases in coxa valga deformity and acetabular dysplasia were observed, they were conflicting factors in the FAI symptom group. However, in the IFI symptom group, only coxa valga deformity was a risk factor for IFI and acetabular dysplasia does not have an association with IFI. Rather, it seemed that the risk of developing IFI symptoms increased when exostoses occurred around the lesser trochanter. In a study on MHE deformities, Porter et al. [20] reported that the occurrence of exostoses was more prevalent in the medial side of the proximal femur. In the IFI symptom group in this study, the minimum ischio-femoral distance measured with hip CT was significantly decreased (P < 0.001) as described in Table 7 and coxa valga was significantly increased (P < 0.001) as described in Table 6. As a result, these characteristic deformities in MHE hips may explain why more IFI symptoms appear in patients with MHE.

To compare the symptomatic hips between FAI and IFI, isolated FAI and IFI symptom hips were additionally sorted, however, no significant difference was found between the two groups (Table 8).

Although this study performed a CT study in patients strongly suspected to have IFI symptoms, there have been limitations in comparative analyses in that CT studies were not performed in all asymptomatic
patients. In addition, there may be limitations in distinguishing soft tissue impingement or bony impingement owing to the use of CT rather than magnetic resonance imaging.

However, this study is meaningful in that it investigated the association between the characteristic deformities of MHE hip joints and impingement syndrome. Furthermore, this study also showed that the most characteristic deformity in MHE hips was coxa valga regardless of the impingement type, often accompanied by acetabular dysplasia. Further, this study confirmed that the characteristics of the deformities act as differently in each type of impingement syndrome.

Conclusions

The increased incidence of hip impingement syndrome in patients with MHE was mainly caused by exostoses occurring around the hip joint. In this study, however, fewer incidences of FAI were observed, and IFI syndrome was more frequently noted in patients with MHE than in the general populations, because the characteristic deformities of the MHE hip itself have a compensatory effect on the occurrence of FAI symptoms. However, IFI syndrome, which is rare in the general populations, is had a relatively high incidence in patients with MHE, because of the characteristic deformities of the MHE hip.

It is important to note that the hip impingement syndromes that can cause hip pain in patients with MHE of the hip may differ from those that often occur in the general populations. Therefore, it is necessary to carefully evaluate the characteristic deformities of the hip joint occurring in patients with MHE and to plan the treatment modality accordingly.

Abbreviations

MHE
Multiple hereditary exostoses
CE
Center-edge
FAI
Femoro-acetabular impingement
IFI
Ischio-femoral impingement
CT
Computed-tomography

Declarations

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Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors contributions

YSA, STJ, WJK, HSO and YSK participated in the analysis and interpretation of the data, drafting, and final preparation of the manuscript. YSA participated in the conception and design of the study, acquisition of the data, analysis and interpretation of the data, drafting, and final preparation of the manuscript. STJ participated in the conception and design of the study, acquisition of the data, analysis and interpretation of the data, drafting, and final revising of the manuscript. WJK, HSO and YSK participated in correction of grammar, also analysis and interpretation of the data. All authors have read and approved the final manuscript

Ethics approval and consent to participate

Chonnam National University Hospital Institutional Review Board approved the patient record review and all data collected. The reference number for the project was CNUH-2020-019. For this type of study, formal consent was not required, and the Chonnam National University Hospital Institutional Review Board approved this.

Consent for publication

Not applicable

Competing interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br. 2005;87:1012–8.

2. Eijer H, Hogervorst T. Femoroacetabular impingement causes osteoarthritis of the hip by migration and micro-instability of the femoral head. Med Hypotheses. 2017;4:93–6.

3. Fukushima K, Uchiyama K, Takahira N, Moriya M, Yamamoto T, Itoman M, Takaso M. Prevalence of radiographic findings of femoroacetabular impingement in the Japanese population. J Orthop Surg Res. 2014;9:25.

4. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip. Clin Orthop Relat Res. 2008;466(2):264–72.

5. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003;417:112–20.

6. Leunig M, Beaulé PE, Ganz R. The concept of femoroacetabular impingement: current status and future perspectives. Clin Orthop Relat Res. 2009;467(3):616–22.

7. Tannast M, Goricki D, Beck M, Murphy SB, Siebenrock KA. Hip damage occurs at the zone of femoroacetabular impingement. Clin Orthop Relat Res. 2008;466(2):273–80.

8. Johnson KA. Impingement of the lesser trochanter on the ischial ramus after total hip arthroplasty: report of three cases. J Bone Joint Surg Am. 1977;59:268–9.

9. Ali AM, Teh J, Whitwell D, Ostlere S. Ischiofemoral impingement: a retrospective analysis of cases in a specialist orthopaedic centre over a four-year period. Hip Int. 2013;23:263–8.

10. Patti JW, Ouellette H, Bredella MA, Torriani M. Impingement of lesser trochanter on ischium as a potential cause for hip pain. Skeletal Radiol. 2008;37:939–41.

11. Safran M, Ryu J. Ischiofemoral impingement of the hip: a novel approach to treatment. Knee Surg Sports Traumatol Arthrosc. 2014;22:781–5.

12. Taneja AK, Bredella MA, Torriani M. Ischiofemoral impingement. Magn Reson Imaging Clin N Am. 2013;21(1):65–73.

13. Tosun O, Algin O, Yalcin N, Cay N, Ocakoglu G, Karaoglanoglu M. Ischiofemoral impingement: evaluation with new MRI parameters and assessment of their reliability. Skeletal Radiol. 2012;41:575–87.

14. Noonan KJ, Feinberg JR, Levena A, Snead J, Wurtz LD. Natural history of multiple hereditary osteochondromatosis of the lower extremity and ankle. J Pediatr Orthop.
15. Schmale GA, Conrad EU 3rd, Raskind WH. The nat. 2002;22:120-4. ural history of hereditary multiple exostoses. *J Bone Joint Surg Am.* 1994;76:986 – 92.

16. Muller ME. Ischiometric radiologique. Rev Chir Orthop Reparatrice Appar Mot. 1956;4(1):124–33.

17. Sharp IK. Acetabular dysplasia: the acetabular angle. *J Bone Joint Surg Br.* 1961;43(B):268–72.

18. Tonnis D. Congenital dysplasia and dislocation of the hip in children and adults. *Berlin: Springer-Verlag;* 1987.

19. Wiberg G. Studien uber das normale arthrografiebild des huftgelenks bei kleinkindern. *Z Orthop.* 1941;72:35–47.

20. Porter DE, Benson MK, Hosney GA. The hip in hereditary multiple exostoses. *J Bone Joint Surg Br.* 2001;83(B):988–95.

21. Perdini E, Jennes I, Tremosini M, Milanesi A, Mordenti M, Parra A, Sgariglia F, Zuntini M, Campanacci L, Fabbri N, Pignotti E. Wuyts w, Sangiorgi L. Genotype-phenotype correlation study in 529 patients with multiple hereditary exostoses: Identification of “Protective” and “Risk” factors. *J Bone Joint Surg Am.* 2011;93(24):2294–302.

22. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head–neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br.* 2002;84:556–60.