Title: The Failing Medial Compartment in the Varus Knee and its Association with CAM Deformity of the Hip.

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None of the Author's have any conflict of interest to declare.

Abstract

Introduction: Since 2011, the knee service at the Nuffield Orthopaedic Centre has been offering a neutralising medial opening wedge high tibial osteotomy (HTO) to a specific group of patients with genu varum and early knee osteoarthritis. An observation was made concerning this group of patients and the presence of CAM deformity at the hip. The aim of this study is to establish whether or not any association exists between the OA phenotype shared by our HTO group and the incidence of CAM deformity at the hip.

Material & Methods: A cross-sectional study was designed to estimate the prevalence of CAM-type lesions across different groups of individuals. Our HTO group (n=30) was compared to a pre-arthroplasty group (n=20) and Control group (n=20). A total of 70 subjects were identified across the different groups all of whom had long-leg radiographs (LLRs) available for analysis. LLRs were analysed using an in house developed Matlab®-based (Matlab R2009b; MathWorks) software package for hip measurements and MediCAD® (Hectec GmbH, Germany) for lower limb alignment measurements.

Results: The HTO group had a significantly higher prevalence of CAM lesions (57%) than both the pre-arthroplasty (40%) and control (30%) groups. This difference was maintained when results were adjusted for potential confounding factors (Age, gender and laterality). Across the groups, individuals with tibia vara were more likely to have CAM-deformity of the hip (p=0.021).

Conclusion: Patients with symptomatic early knee OA and varus deformity of the knee have a high prevalence of CAM deformity in the hip.

Keywords: Knee, Hip, Osteoarthritis, CAM-deformity, Genu varum, Alpha angle

1.0 Introduction

Osteoarthritis (OA) of the knee is a major health concern with over 6 million people in the UK suffering from painful osteoarthritis in one or both knees [1]. Differences in pelvic geometry have been associated with compartment specific knee OA[2] and deviation from a neutral alignment at the knee has been linked to pathology in the hip[3].

The development of cam morphology is associated with intense sporting activity during adolescence[4]. The mechanism of CAM formation is proposed to be epiphyseal extension along the anterosuperior femoral neck as an adaptive response to physeal loading[5] (Figure 1). More recently, proximal tibia vara has been linked to disruption of the physeal growth plate in youth [6,7]. Despite common aetiology there is nothing in the literature to link proximal tibia vara with CAM-type lesions in the hip.

Surgery in the form of unicompartmental or total knee arthroplasty is an established effective treatment for end-stage ‘bone on bone’ osteoarthritis when conservative measures have failed. Whilst successful in patients with full-thickness disease, arthroplasty surgery is not routinely offered to those with less severe disease as it is associated with a worse outcome[8,9]. A re-alignment procedure around the knee, such as a high tibial osteotomy (HTO), has been shown to be effective in this patient group[10]. However, there is no agreement in the literature regarding surgical technique, patient selection or expected clinical outcomes[11].

Since 2011, the knee service at the Nuffield Orthopaedic Centre has been offering a neutralising medial opening wedge high tibial osteotomy to a group of patients presenting with the following characteristics:

1. Early osteoarthritis of the knee (Kellgren-Lawrence <3) isolated to the medial compartment
2. Pain and dysfunction for more than 2 years
3. A weightbearing axis (WBA) running through the medial compartment of the knee that could be corrected to neutral using an opening wedge high tibial osteotomy
4. No significant osteoarthritis affecting the lateral compartment or patello-femoral joint

During the development of this practice the following observation was made. There appeared to be an association between this phenotype of knee osteoarthritis and the presence of CAM deformity at the hip. We are not aware that this association has been made before.

The aim of this study is to establish whether or not any association exists between the OA phenotype shared by our HTO group and the prevalence of CAM deformity at the hip joint.

2.0 Materials & Methods

A cross-sectional study was performed with 70 participants divided into three groups. Ethical approval was granted by the local ethics committee (London Bloomsbury REC, ref: 15/LO/0701) and (NRES Committee South Central-Oxford A, ref: 12/SC/0006)

Power calculation

A power calculation was performed using previously published data by Lahner et al [3]. They described a mean difference in alpha angle of 7.86^0 between subjects with neutral and varus alignment and a maximum standard deviation of 5.55^0 across the groups. Therefore, with a statistical significance set at 0.05 and power of 0.9, a total of 24 participants were required, 12 in each group.

Patient Selection

HTO group (n=30)*:* Since 2011, our knee service has been offering a high tibial osteotomy to patients with early to moderate knee OA. The surgical logbooks of two of the contributing authors (AJP, WJ) were retrospectively reviewed and all patients who underwent a medial opening wedge osteotomy were recruited. This included 30 patients undergoing 34 osteotomies. All patients had standing bilateral long leg radiographs (LLR) performed pre-operatively.

Control group (n=20): This group are the spouses of a high-risk osteoarthritis cohort recruited for a different study at our unit. The high risk OA cohort were siblings of patients with end-stage osteoarthritis who underwent arthroplasty surgery. Their spouses, the control group, were used to compare biomarkers for OA in previously unpublished work from our unit. The spouses were not selected based on the presence or absence of knee symptoms or based on their medical history. A total of 20 gender-matched subjects were identified and all had existing bilateral LLRs available for analysis.

Pre-arthroplasty group (PAG) (n=20): A consecutive group of patients, over a period of 7 months, who were listed for medial unicompartmental knee arthroplasty (UKA) (Dec 2014 to July 2015) and underwent an LLR as part of their clinical work up. Indications for UKA are 'bone on bone' medial compartment OA, an intact ACL and no lateral compartment disease.

In all groups patients were excluded if there was a history of lower limb trauma, congenital deformity or previous arthroplasty in their medical notes.

A total of 70 subjects were identified across the different groups (HTO n=30, PAG n=20, and Control n=20). Each subject contributed one limb for analysis. In the HTO and pre-arthroplasty groups this was the limb that underwent surgery. In the control group a limb was selected at random. If a subject had undergone an HTO on both legs then the leg that underwent surgery first was used.

Radiological Assessment

A standardised method is used for taking long leg radiographs in our institution. Bilateral standing AP radiographs are carried out with the patient centred on a wall stand with their patellae facing forward. The tube voltage is set between 70 and 80kV depending on the size of the patient and automatic exposure chambers ensure consistent radiographic images. The focus film distance is set at 180cm and a ruler is taped to the patient's leg for calibration. All radiographs were made using the GE Definium model 8000, which automatically tracks down the lower limb using pre-defined anatomical landmarks. The resulting images are then stitched together to produce a single image, which includes both lower limbs.

Radiological Analysis

Long leg radiographs were transferred as Digital Imaging and Communications in Medicine (DICOM) files from the Picture Archiving and Communications System (PACS version) into the Matlab®-based software package for hip measurements and MediCAD® (Hectec GmbH, Germany) for lower limb alignment measurements.

Hip deformity: Alpha angle was measured to describe the presence of a CAM deformity. This is the angle between the femoral neck axis and a line from the centre of a best-fit circle to where the femoral head-neck first exits this circle (figure 2).

DICOM Files were transferred to an in house developed Matlab®-based (Matlab R2009b; MathWorks) software package. All alpha angles were measured by a single observer (academic orthopaedic clinician). Repeat measurements were performed for the first 15 hips (intra-observer reliability) and a second reader (academic orthopaedic clinician) measured the alpha angle on the same 15 hips to assess inter-observer reliability.

Lower limb alignment: MediCAD (Classic version 3.0.2.2, MediCAD®, Hectec GmbH, Germany) is a commercially available planning software with high inter-observer reliability (ICC 0.89-0.97) [12] for assessing alignment in the coronal plane. Planning requires the operator to identify various anatomical landmarks that enable assessment of both anatomical and mechanical alignment. It includes three different measurements to describe a deviation from neutral lower limb alignment; Hip knee ankle angle (HKA), mechanical axis deviation (MAD), weight-bearing axis (WBA). Weight-bearing axis is derived from the point that the mechanical axis meets the knee joint line and is expressed as a percentage of the medial-lateral tibial plateau (Figure 3). Other measurements recorded include; mechanical proximal femoral angle (mLPFA), mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA) and mechanical lateral distal tibial angle (mLDTA) (figure 2). A single observer who was familiar with the software and experienced in its use for surgical planning performed all analyses (JP). A subset of ten radiographs had readings repeated by the same observer to calculate intra-observer reliability.

3.0 Calculation

The mean, standard deviation, maximum and minimum values were calculated for all measurements.

Alpha angle has a bimodal distribution[13]. We sub-divided the alpha angle into two groups; alpha angle$<65^0$, alpha angle$>=65^0$. In so doing it was possible to determine the prevalence of significant CAM deformities between the groups i.e. those CAM deformities associated with a future risk of OA or total hip replacement [13–15]. Given its bimodal distribution there will be relatively few patients who have an alpha angle in close proximity to this threshold[13] reducing the risks associated with defining such a cut-off.

In the absence of any definition for tibia vara, a threshold was created to define this group. Subjects with a medial Proximal Tibial Angle (mPTA) one standard deviation towards varus from those values described in a healthy population[6] were considered to have tibia vara (mPTA; male<84.33^0 female<85.76^0).

Logistic regression was performed to determine whether a significant difference in the frequency of cam-deformity (alpha angle >65) was observed between the groups. The model was adjusted for potential confounding factors; age, gender and laterality.

A 2x2 chi-squared table was used to compare the counts of individuals with proximal tibia vara with or without CAM-deformity in the ipsilateral hip.

A Wilcoxon-Mann-Whitney test was performed to identify between group differences for the lower limb alignment variables.

Pearson correlation determined the relationships between lower limb alignment measurements and measurements at the hip. This would establish if any variables associated with mal-alignment were correlated with the presence of CAM deformity.

All statistical analyses were performed using Stata/IC 13.1 (StataCorp, Inc). A *p*-value <0.05 was considered significant.

4.0 Results

Group Characteristics

A total of 70 limbs from 70 subjects were available for analysis (HTO n=30, Pre-arthroplasty n=20, Control n=20). 67 subjects were male and 3 subjects were female. There was no significant difference in gender across the groups. The pre-arthroplasty group were older than both the control and HTO groups [Pre-arthroplasty (Avg 66.4(±10.5)), Control (Avg. 49(±8.13), HTO (Avg. 44.6(±6.9)). (Table1)

Observer reliability

Intra-observer reliability was very good for all the recorded measurements [Intraclass correlation coefficient (ICC); Medicad® Classic =0.84-0.99, Matlab®-based (Matlab R2009b; MathWorks) software package = 0.99]. Inter-observer reliability was also very good for alpha angle measurements [ICC; Matlab®-based (Matlab R2009b; MathWorks) = 0.83].

K/L Grade

The HTO and control groups had lower K/L grades than the pre-arthroplasty group (Table 1).

Alpha angle

Higher alpha angle values were seen in the HTO group compared to both the pre-arthroplasty and control groups (Figure 3). The prevalence of CAM lesions defined by a mean alpha angle of >65^0 was greater in our HTO group than the remaining two groups [HTO (18/30 = 63%) vs Control (6/20= 30%) *p*=0.001; HTO vs Pre-arthroplasty

(8/20=40.0%) (p=0.011) (Table 2). Variables including age, gender and laterality did not influence the presence of cam-deformity.

Hip and knee measurements

Differences in lower limb alignment were observed between the three groups and are summarised in Table 2.

Pearson Correlation demonstrated no significant correlation between any lower limb alignment measurements (HKA, MAD, WBA, MPTA, mLPFA, mLDFA, mLDTA, JLCA) and alpha angle.

Across the groups, individuals with tibia vara (MPTA 1SD towards varus) were more likely to have a CAM-deformity (Alpha angle>65^0) of the hip (p=0.02) (see Table 3).

5.0 Discussion

The results of this study confirm that our HTO group have a higher prevalence of CAM lesions defined by an Alpha angle >65^0 than both the pre-arthroplasty and control groups [HTO vs Control, *p*=0.021; HTO vs Pre-arthroplasty, *p*=0.046] (Figure 4). Furthermore, across the groups, individuals with proximal tibia vara were more likely to have CAM-deformity at the hip (*p*=0.02) (see Table 3).

A previous study using LLRs from patients being evaluated for knee pathology demonstrated that with greater mechanical axis deviation (MAD) away from neutral an increased alpha angle at the hip was observed[3]. The authors of this study concluded that patients presenting with significant varus/valgus alignment should be carefully examined for symptomatic hip pain consistent with femoro-acetabular impingement[3]. The study comments on the presence of OA in these patients but not the severity of disease. Our study suggests that the association between lower limb alignment and CAM deformity at the hip may be more complex than this. If the mechanical axis deviation (MAD) were strictly connected with alpha angle it would follow that our pre-arthroplasty group would also have a high prevalence of CAMs, as there MAD was greater than the control and HTO groups. This was not the case. Furthermore, Pearson correlation did not demonstrate any significant relationship between MAD and alpha angle. This may in part be due to the bimodal distribution of the alpha angle.

A further cross-sectional study using long leg radiographs demonstrated that variations in hip and pelvic geometry were associated with compartment-specific knee OA[2]. Specifically, a reduced abductor angle and a more varus neck-shaft angle in the hip were associated with medial compartment OA at the knee [2]. We found no correlation between our mechanical lateral proximal femoral angle (mLPFA) and the presence of cam-deformity.

A wide-range of values have been reported in the literature for the prevalence of CAM deformity. This is due to differences in the definitions used to define the deformity and the population of interest. In a healthy population using a threshold alpha angle of $>50.5^0$ Hack et al reported a prevalence of CAM-deformity of 14%[16]. They noted that the majority of CAM lesions occurred in males (79%), which may explain the higher prevalence seen in our control group (30%).

The use of comparator groups in this study, permitted multiple variables to be compared simultaneously enabling the relationships between different variables to be recognised. Our groups demonstrated variation with regard to lower limb alignment (see Table 2). The most varus alignment was seen in the pre-arthroplasty group (Avg. HKA= -8.5) who also demonstrated a higher incidence of proximal tbia vara (MPTA; 1SD towards varus). Undoubtedly, this reflects a group with more severe OA who have drifted further into varus as their intra-articular pathology has progressed. Boney attrition of the medial tibial plateau will have exaggerated the varus angulation of the MPTA in this group.

The HTO group were more varus than the control group but were similar in terms of severity of OA. The significantly lower MPTA but similar mLDFA, seen in the HTO group compared to controls, suggests that it is a higher incidence of proximal tibia vara that has led to the overall varus alignment. They reflect a group of patients who have early OA in the presence of a ‘constitutional varus’[6] deformity i.e. their varus deformity is due to tibio-femoral geometry as opposed to lateral compartment opening as a result of lateral soft tissue laxity[17]. The HTO group represent a potentially interesting subgroup of patients with tibia vara and osteoarthritis.

Varus mal-alignment at the knee is associated with both incidence and progression of medial compartment knee OA [18,19]. CAM deformity at the hip is causative of osteoarthritis of the hip [20] and in particular severe CAM-type deformity (alpha angle >65^0) is strongly associated with end-stage OA of the hip and progression to THR[14,15]. Our HTO group, therefore, demonstrate independent predictors for progression of OA in both the hip and the knee. Interestingly, both CAM deformity in the hip and varus deformity in the knee have been linked to disruption of the physeal growth plate in youth. There is growing evidence to support this. Disruption of the growth plate has been found to precede CAM-type deformity in elite basketball players [5], and higher levels of sporting activity in youth are associated with the ‘constitutional varus’ phenotype[6] and in particular high levels of sporting activity in youth are associated with a more varus proxima tibia[7]. A high prevalence of CAM lesions has also been reported in elite ice hockey players[21] and American Football players[22]. Joint preservation surgery is increasingly adopted in the hip to restore the femoral head-neck concavity and repair associated joint pathology [23](Palmer 2016 BMJ Open Sport Exercise). Surgery for femoroacetabular impingement has been shown to provide symptomatic benefit beyond five years, but is significantly less effective in the presence of osteoarthritis[24]. This highlights the importance of identifying individuals at risk of cam morphology and intervening at an early stage.

A compelling hypothesis is that some of our HTO group has experienced epiphyseal disruption at the proximal tibia and at the proximal femur leading to early onset OA of the knee and a future risk for development of OA in the hip. Such individuals would share an OA phenotype that has not been described before and is distinct from the general population. A conclusion supported by the fact that subjects with tibia vara in our cohort were more likely to have a CAM-deformity at the hip ($p<0.006$). The aetiology may be a congenital or acquired growth plate disruption either of which could be contingent on a genetic predisposition. Recognising such phenotypes is highly relevant to the prevention, progression and treatment of OA[25]. Tibia vara (assessed using the tibia bone varus angle, TBVA) has been shown to predict successful outcomes in osteotomy surgery[26]. The phenotype described in this study may also have implications for outcomes in surgical practice.

Future work should focus on applying these findings to the general population and determining how deformity around the knee relates to pathology in the hip. Larger longitudinal studies in healthy individuals are required to establish the temporal relationship between these two pathologies. Establishing whether or not the phenotype described in this study influences outcomes for surgery such as hip arthroscopy and high tibial osteotomy would be of value. Furthermore, it is not clear whether tibia vara in the presence of knee OA represents a subgroup of the typical early anteromedial OA phenotype[27] or whether they represent a distinct group in themselves which has differences in terms of both evolution and progression of disease.

There are limitations inherent to this study. Sampling bias may have occurred when generating the comparator groups. However, subjects were selected before any radiographs were reviewed reducing the possibility of them being selected 'in' or 'out' based on the appearance of their radiographs. Observer bias was limited by separating hip and alignment measurements between two observers. The observer viewing the hip scores was blinded to the lower limb alignment scores and vice versa.

The majority of subjects were male. All subjects who underwent a high tibial osteotomy were included. The procedure is offered to both males and females but in our practice we have found many more males presenting to the clinic with symptomatic early to moderate OA, varus deformity and a willingness to proceed with osteotomy surgery. Gender differences were then kept equal across the remaining groups to avoid bias.

The pre-arthroplasty group were selected to reflect an end-stage osteoarthritis cohort. Although this group is older they are an important inclusion. They have a similar prevalence of CAM deformity to controls. As such the higher prevalence of CAM deformities seen in the HTO group cannot simply be explained as an underlying propensity for this group to develop lower limb OA. If this were the case one would expect a similar prevalence in the pre-arthroplasty group. Cam deformities do not resolve as age progresses.

An important point to note is that long-leg radiographs are not routinely requested for patients undergoing UKA and the specific reason for requesting the investigation was unknown. However, the medical notes were reviewed and patients were excluded if there was a history of lower limb trauma, congenital deformity or previous arthroplasty. Furthermore, the selection criteria for UKA at our unit is strict; ‘bone on bone’ anteromedial OA, an intact ACL and no lateral compartment disease. Accordingly the phenotype of OA across the pre-arthroplasty group should be consistent.

As expected the higher K/L grade in the pre-arthroplasty group indicates greater radiological evidence of knee OA compared to the HTO and control groups. It is important to note that some subjects in the control group had established OA in one or both of their knees. The control group represent a cross-section of the general population with a variety of lower limb alignment values, a range of osteoarthritis severity and an age range that matches our HTO group.

The use of LLRs to measure the alpha angle may have underestimated the true prevalence of CAM lesions, which could be improved by the use of lateral radiographs, a 45-degree Dunn view radiograph or MRI. LLRs are vulnerable to positioning error and the measurements obtained may vary depending on how the leg is positioned. Furthermore, it is important to note that the increased varus seen in our HTO and UKA group may in and of itself have affected the positioning of the leg leading to an increased observation of CAM lesions. However, inaccuracies caused by positioning error should have been consistent across the three groups and a reciprocal increase in CAM deformity was not seen in the UKA group who were also in significantly varus alignment.

Despite the limitations described, this study has much strength. It is important to note that we did not set out to discover the association between our HTO group and CAM deformity. The clinical observations were made and then validated using comparator groups. The high prevalence of CAM lesions in our HTO group is a finding supported by the fact that similar results are not seen in either the control or the pre-arthroplasty groups.

6.0 Conclusion

This study confirms that patients undergoing HTO for symptomatic early knee OA and varus deformity of the knee have a high prevalence of CAM deformity in the hip. It is the first study to identify a link between the presence of proximal tibia vara and the presence of CAM-deformity in the hip. Disruption of the physeal growth plate in youth, described in the literature, is a plausible aetiological basis on which to support this finding.

7.0 Declaration of Interests

Conflicts of interest: none

8.0 Acknowledgements

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knee. J Bone Joint Surg Br 1991;73:582–6.

List of Figures

Figure 1: Anteroposterior radiograph demonstrating epiphyseal extension that results in loss of the antero-superior head-neck concavity and cam morphology

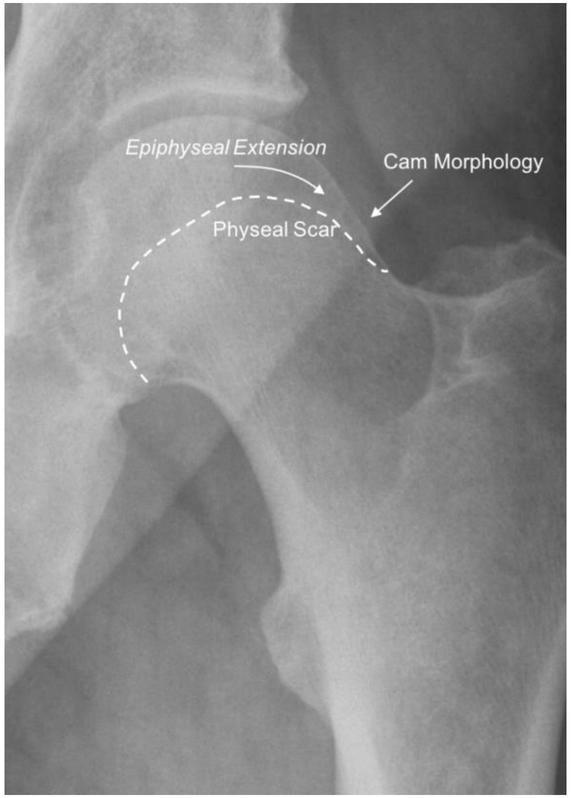
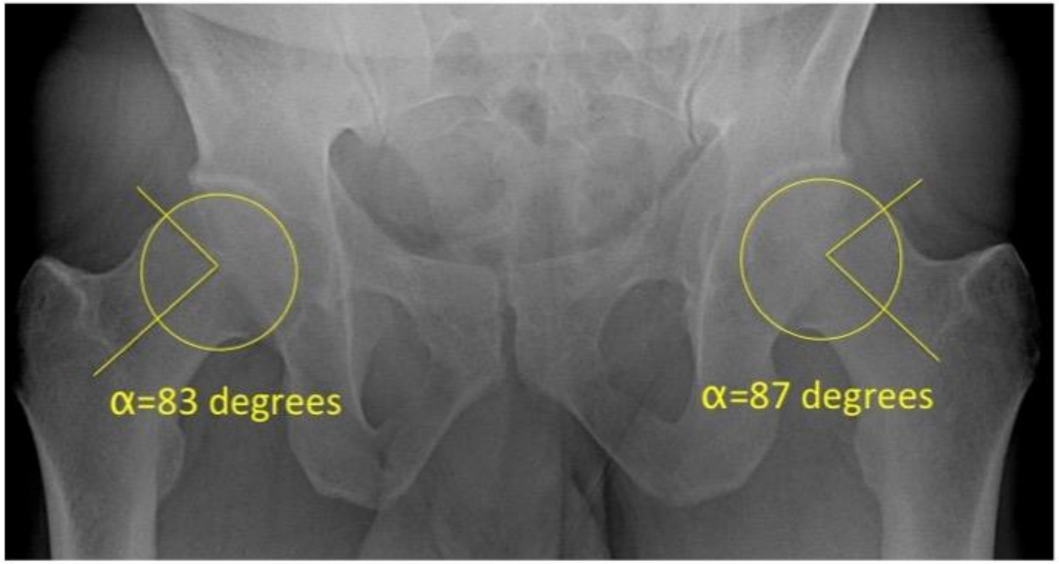
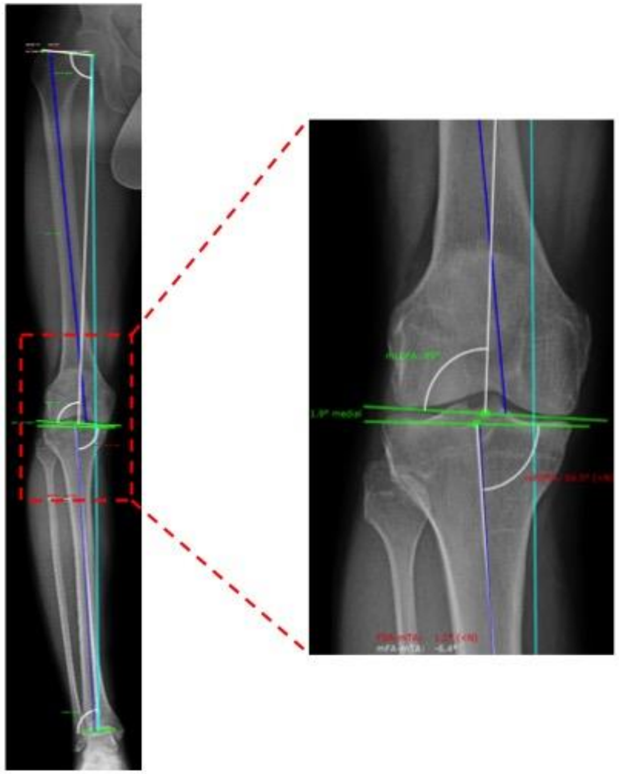


Figure 2: Antero-posterior radiograph of the pelvis demonstrating the alpha angle of the hip



Antero-posterior pelvis portion of limb-alignment radiograph performed on a patient who underwent a right knee opening wedge high-tibial osteotomy. There are bilateral cam deformities with elevated alpha angle measurements. Measurements shown were taken using an in house developed Matlab®-based (Matlab R2009b; MathWorks) software package.

Figure 3: Long-leg radiograph illustrating lower limb alignment measurement



Long leg radiograph taken from a subject within the HTO group. Image shows the mechanical lateral distal femoral angle (mLDFA = 89^0), medial proximal tibial angle (MPTA=84.5^0) and joint line convergence angle (JLCA = 1.9^0). Light blue line indicates the mechanical axis (a line from the centre of the hip joint to the centre of the ankle joint). The weight bearing axis (WBA) is derived from the point that the mechanical axis meets the knee joint line and is expressed as a percentage of the medial-lateral tibial plateau. All measurements taken using MediCAD© Classic Version 3.0.2.2.

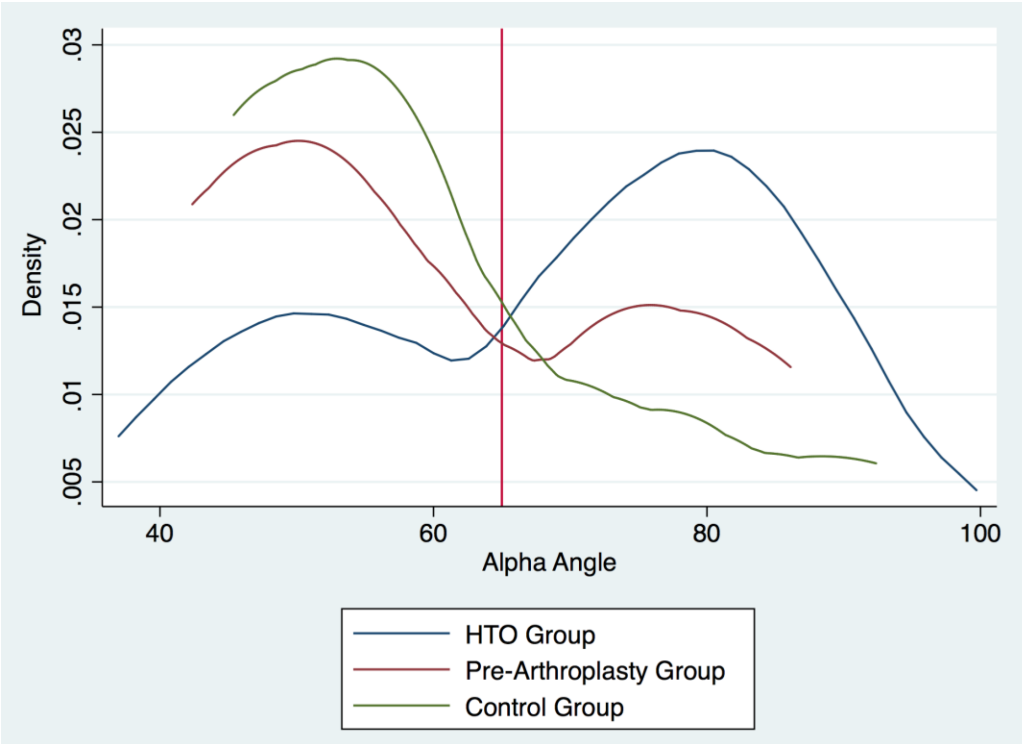


Figure 4: Kernel Density Plot Graph illustrating the bimodal distribution for alpha angle in the observed population groups. The graph demonstrates the higher prevalence of subjects with a larger alpha angle in the HTO group compared to the other two groups.

List of Tables

	Age (yrs) Mean Avg. (SD, min-max)	Gender (M=Male, F=Female)	Kellgren Lawrence Grade
Control	**49** (±8.1, 31.8-62.5)	M=19, F=1	**0=25% 1= 15%, 2=50% 3=10% 4=0%**
HTO	**44.6** (±6.9, 25-56.8)	M=29, F=1	**0=0% 1= 7%, 2=83% 3=10% 4=15%**
Pre-arthroplasty	**66.4** (±10.5, 46.2-80.7)	M=19, F=1	**0=0% 1= 0%, 2=0% 3=10% 4=90%**

Table 1:Demographic characteristics for the three groups including Age, Gender and Kellgren Lawrence (K/L) Grade.

Variable [mean (range)]	Patient group		
	Control	PAG	HTO
HKA	**-2.6^0** (-10.2^0 – 3.3^0)	**-8.5^0*** (-14.3^0 – -0.4^0)	**-5.2^0*#** (-10.9^0 – -0.4^0)
MAD	**10.4** (-11 – 41)	**29*** (1 – 52)	**18.2*#** (1 – 42)
WBA	**35.9** (0 – 64.5)	**12.0*** (-11.4 – 46.4)	**24.9*#** (-2.4 – 47.1)
mLPFA	**86.2^0** (71.1^0 – 94.5^0)	**89.2^0** (76.9^0 – 100^0)	**91.1^0*** (83.8^0 – 102^0)
mLDFA	**87.7^0** (85.3^0 – 90.6^0)	**88.6^0** (85.4^0 – 91^0)	**88.3^0** (84.4^0 – 90.6^0)
MPTA	**86.2^0** (81.3^0 – 89.9^0)	**85.2^0** (81.2^0 – 88.2^0)	**85.1^0** (81.4^0 – 89^0)
mLDTA	**83.4^0** (71.2^0 – 89.9^0)	**86.3^0** (78.2^0 – 97.4^0)	**85.8^0** (74.8^0 – 95.5^0)
JLCA	**1.1^0** (-1^0 – 4.6^0)	**5.0^0*** (1.8^0 – 10.1^0)	**2.1^0*#** (-0.2^0 – 6.4^0)
Alpha angle (>65 degrees)	**6/20** (30%)	**8/20** (40%)	**17/30** (57%)
Proximal tibia vara (MPTA >1SD varus)	**4/20** (20%)	**7/20** (35%)	**8/30** (27%)

Table 2: A summary of lower limb alignment values for the three different groups.
Indicates a significant difference compared to the control group ($p<0.05$*)
#Indicates a significant difference compared to the pre-arthroplasty group (*$p<0.05$*)

		CAM-deformity (Alpha>65^{0})	
		No	Yes
Tibia Vara (MPTA >1SD varus)	No	32	19
	Yes	6	13

Table 3: 2x2 contingency table showing the counts of individuals with a CAM-deformity defined by an Alpha angle of >65^{0} and tibia vara defined by an mPTA that is 1SD towards varus from the mean value described in a healthy population[6]. Individuals with tibia vara are more likely to have have CAM-deformity of the hip (p=0.02)