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RESEARCH ARTICLE

Comparison of 3D alignment of knee between normal and osteoarthritis subjects by measuring the femoral tibial angle (FTA) using, 3D bone model image fitting technique.

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Abstract

In the field of orthopedic surgery, lower extremity alignment is generally assessed 2D (two dimension) on plain radiographs. However 2D radiographic measurements have some limitations. Therefore in this study we used 3D (three dimension) bone model image fitting technique, to assess and compare the 3D alignment of lower extremity of normal and osteoarthritis subjects by measuring femoral tibial angle (FTA). Frontal AP (antero posterior) and 60^0 oblique CR (computed radiography) images of 20 subject's lower limb were taken. After obtaining bi-planner radiographic images, several bony reference points were digitized as follows, 3 points on the counter of the femoral head, 3 points on the counter of the medial and lateral femoral condyle, medial and lateral most points on the proximal joint surface and medial and lateral points on the top of the taler dome. Using above digitized reference points, anatomical coordinate systems of the tibia and femur were established on each of CR images and femoral and tibial X,Y,Z axis were defined. 3D digital models of reference bones already were created earlier by the CT (computed radiography) scans of dried femur and tibia. Then the images of the 3D digital models were projected onto CR images of the subject's tibia and femur using the projection matrix. Then projected images of reference bones were mathematically superimposed and deformed by an image fitting technique. Thereafter using the inverse projection matrix, 3D digital model of the subject's lower limb was created. By using this technique we could able to measure the FTA of each subject. Results indicates significant difference (P=0.002) in FTA value between normal and osteoarthritis subjects. We assume the 3D bone model image fitting technique can be used to determine and evaluating treatment for knee osteoarthritis, with more developments in future.

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Introduction:-

Evaluations of knee alignment are useful in the diagnosis of arthritic conditionsaffecting the knee joint, serving also as a guide for conservative management and surgical planning.In the field of orthopedic surgery, lower extremity alignment is generally assessed two dimensionally (2-D) on plain radiographs.

The vertical axes is a vertical line that in normal AP RX weight bearing goes from the center of the pubic symphysis to the ground. (Dossett et al., 2012)The mechanical axis of the lower limb is a line extended from the center of the femoral head to the center of the ankle and in normal condition it crosses the center of the knee joint (Luo et al., 2000)

The femoral part of this line that goes from the center of the femoral head to the center of the knee (the intercondylar notch of the distal femur) is called femoral mechanical axis while the distal or tibial part that goes from the center of the tibial proximal epiphysis to the center of the ankle joint is called tibial mechanical axis. In normal condition the two axes, femoral and tibial one describe a straight angle or more precisely a medial angle slightly less than 180° (Hernigou et al .,1987; Sikorski et al., 2008)

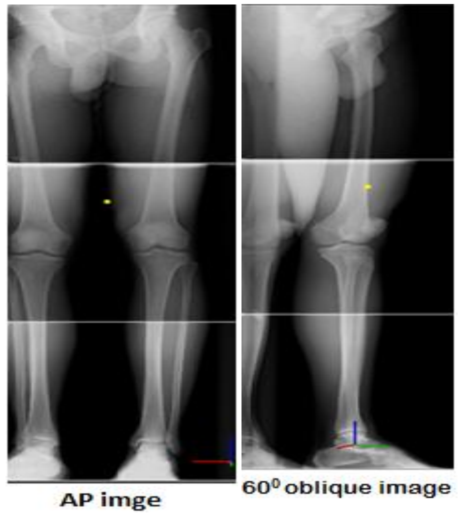
The femoral and tibial anatomical axes are identified within the intramedullary bone canal and may be drawn with a line bisecting both the femur and tibia in an one half or, less precisely, drawing a line connecting the center of the femoral or tibial shaft to point 10 cm above or below the knee joint respectively. On anteroposterior evaluation the femoral anatomical axis has a 5–7 degree of inclination difference than his mechanic axis while in normal condition the tibial anatomical axis coincides with the mechanical one and as consequence these 2 anatomical axis of femur and tibia describe a lateral angle called femorotibial angle (FTA) whose range depends on sex, height, femoral hip offset, rotation and physical anthropology. The FTA is approximately 178° and 175°–176° in Caucasian men and women respectively while slightly less in Asian people but may markedly deviate in case of associate torsional or flexion deformity (Bellemans et al., 2010).

Normal FTA is slightly more valgus in women than men. In general the normal knee joint alignment is 2°–3° of varus compared with the mechanical axis although healthy nonarthritic patients may have different values. In fact obesity, activity and muscle strength, all play a crucial role in the development of arthritis also with a perfect aligned knee. Several studies have shown the prevalence of a constitutional varus knee with a significant percentage of valgus morphology moreover even individuals characterized with different alignment between left and right knee.(Coventry; 1985; Fahlman et al., 2014; Gheno et al., 2012)
Recent studies were done on three-dimensional (3D) measurements of the lower extremity using a biplanar low-dose X-ray device in children and adolescents. 3D measurements of eight dried bones were analyzed by a biplanar low-dose X-ray device (LDX) using stereoscopic software and compared with 3D computed tomography (CT).Secondly, lower limbs of children and adolescents were studied using LDX two-dimensional (2D) and 3D measurements. Both parts were evaluated for femoral and tibial lengths and mechanical angles, frontal and lateral knee angulations, and the femoral neck-shaft angle, wherethe 3D specimen comparison between LDX and CT measurements showed no significant differences (Zheng G et al., 2009)

3-D reconstruction of a surface model of the proximal femur from digital biplanar radiographs were done and the experimental results demonstrated that biplanar reconstruction technique could accurately reconstruct the surface models of both nonpathologic and pathologic femurs (average error distance is 0.9 mm) (Cooke and Sled; 2009)
Therefore in this study we used 3-D bone model image fitting technique, to assess and compare the 3-D alignment of lower extremity of normal and osteoarthritis subjects by measuring femoral tibial angle (FTA).

Materials and Method:-

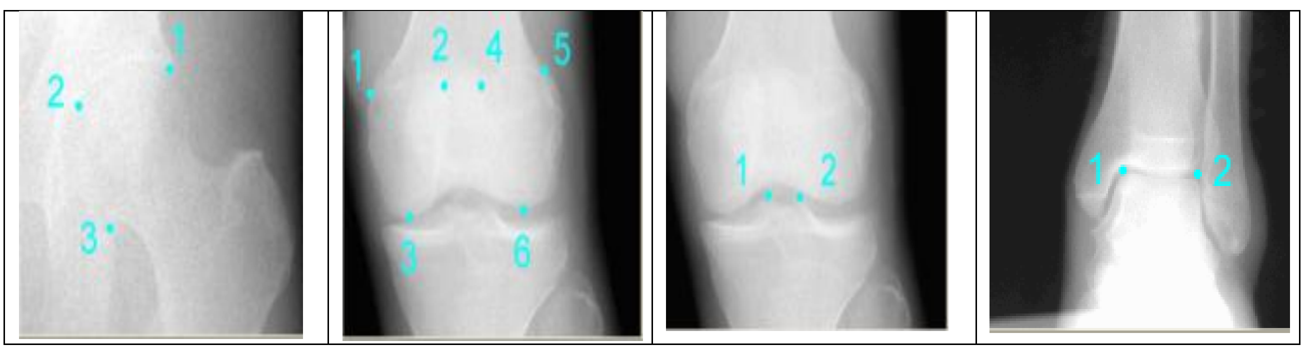
Twenty (20)volunteer patients were selected for this experimental study as follows;
The subject stood in a specially designed cassette holder and faced the X-Ray tube. The frontal CR image (AP) and the 600 oblique CR image of subject’s lower limb was taken.



Camera calibration technique was used to determine the 3-D position space of objects from CR images.After obtaining the bi-planner radiographic images of the subject's lower extremity, several bony reference points were digitized in each CR view as follows;

Femur:-
Femoral Head-> 3 points on the counter of the femoral head.
Femoral Condyle-> 3 points on the counter of the medial and lateral femoral condyle.

Tibia:-
Joint surface-> medial and lateral most points on the proximal joint surface.
Taler dome-> medial and lateral points on the top of the taler dome, were digitized



Using this digitized reference points, anatomical coordinate systems of the tibia and femur were established on each of the Computed Radiography (CR) images and Femoral X,Y,Z and tibial X,Y,Z axis were defined. Three dimensional (3-D) digital models of the reference bones were created earlier with the use of the Computed Tomography (CT) scans of dried femur and tibia (reference bones). The images of the 3-D digital models were projected onto CR images of the subject's tibia and femur using the projection matrix. The projected images of the reference bones were then mathematically superimposed and deformed by an image fitting technique.Using the inverse projection matrix, 3-D digital model of the subject's lower limb was created. By using this technique we could measure the FTA (Femoral Tibial Angle) of the subjects.

Results:-

Table 1-Key

Key	
OA	Osteoarthritis
FTA	Femoral tibial angle
M	Male
F	Fe male
R	Right
L	Left

Acquired results for osteoarthritis positive patients:-

Table 2-OA Positive

OA	Age	Sex	Side	Grade	FTA
1	70	F	R	2	183.81
2	62	F	L	4	192.62
3	72	F	R	4	185.75
4	73	F	L	3	183.45
5	60	F	R	4	185.52
6	67	F	L	3	185.86
7	76	F	L	3	188.25
8	67	F	L	2	184.64

Acquired results for non osteoarthritis patients:-

Table 3-OA Negative

NON-OA	Age	Sex	Side	Grade	FTA
9	70	M	R	1	171.43
10	64	F	R	1	172.21
11	22	M	R	1	173.25
12	24	M	R	1	173.32
13	23	M	R	1	172.38
14	76	M	R	1	171.16
15	61	F	R	2	174.23
16	42	F	R	1	173.27
17	39	M	L	1	171.34
			R	1	172.16
18	24	M	L	1	172.46
			R	1	175.47
19	25	M	L	1	173.31
			R	1	171.23
20	67	M	L	2	172.4

Data Analysis:-

SPSS software used for analyzing the data. Following shows the methods used;

Group statistics:-

Analyzed dataillustrate Mean of FTA (Femoral Tibial Angle)among normal subjects is 186.2375 and among the patients FTA value is 172.6413. Calculated standard deviations in normal and osteoarthritis positive patients were 2.973607 and 1.198892 respectively and the standard error between the groups were 1.05133 and 0.30955.

Table 4-Statistical analysis

	Subject	Number	Mean	SD	SE
FTA	Patient	8	186.2375	2.973607	1.05133
	Normal	15	172.6413	1.198892	0.30955

Independent Samples test:-

Levene's test (Levene, 1960) is used to test if k samples have equal variances. Equal variances across samples is called homogeneity of variance. Some statistical tests, for example the analysis of variance, assume that variances are equal across groups or samples. The Levene's test can be used to verify that assumption. By the test it is calculated significance value of 0.048.

The two-sample t-test (Snedecor and Cochran, 1989) is used to determine if two population means are equal. From the t test for equality of means it is given (t)- statistic value of Equal variance assumed and Equal variance not assumed15.714, 12.406 respectively. Degree of freedom (df) given 21 and 8.235 both groups and finally significance value 0.002.

Table 5-Independent Samples test

	Levine's test for Equality of Variance		T-test for Equality of Means		
FTA	F	Sig	t	df	Sig(2-tailed)
Equal variance assumed	4.413	0.048	15.714	21	0.002
Equal variance not assumed			12.406	8.235	0.002

Discussion:-

During osteoarthritis, the cartilage of the knee is gradually damaged, which causes a change in the axial alignment of the lower limb, therefore the femoral tibial angle (FTA) is increased. According to the statistical analysis P=0.002 therefore as P < 0.05Significant difference between two groups.Femoral tibial angle (FTA) is higher in osteoarthritis patients (calculated mean value of OA positive is 186.2375) than normal subjects(calculated mean value of OA negative is 172.6413).3-D bone model image fitting technique can be used todistinguish between normal and osteoarthritis patients.Some limitation of this study are the number of subjects were relatively small; as the radiation dose delivered during this examination is relatively higher we were unable to find volunteers as normal subjects patientswho came for knee X-ray examinations and did not have any abnormal findings in the radiographs were considered as normal subjects.According to the results, it indicates there is a significant difference in FTA value between normal and osteoarthritis subjects when using 3-D bone model image fitting technique.We assume that the 3-D bone model image fitting technique can be used to determine and evaluating treatment for knee osteoarthritis, with more developments in future.

Conclusion:-

Measured FTA (femoral tibial angle) by 3 D bone model image fitting technique can be used to distinguish between normal and osteoarthritis patients. This technique will reduce the CT (Computed tomography) reconstruction time of knee joint and same time reduces the acquired patient radiation dose by CT.

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