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ORIGINAL ARTICLE

Comparison of Knee Angles in 2D and 3D EOS Imaging in Patients with Total Knee Arthroplasty

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ABSTRACT

Introduction: Stand-alone radiological images (Weight-Bearing) are commonly used to measure alignment in coronal and sagittal planes. Although its proportions and angles may not be correct, it shows us the vertical and horizontal divergence. In the present study, considering the ability of the EOS device to investigate angles in 3D, we investigated and compared the angular difference in 2D and 3D preoperative imaging in total knee arthroplasty. **Materials and Methods:** The present study is a cross-sectional analytical study. In this study, 50 patients with knee osteoarthritis who underwent knee replacement before EOS imaging of their lower extremities were enrolled. After obtaining patients' demographic data, the EOS was made from the hip, knee, and ankle area. The following angles (such as Varus and Valgus Knee angle, the lateral distal femoral angle, mechanical medial proximal tibial angle, and joint line convergence angle) in patients were reviewed and recorded once by an expert with the PACS software system, preoperatively. Then the data were analyzed by SPSS ver 21. **Results:** The results showed that there was a correlation between the angle of varus, lateral distal femoral angle, medial proximal tibial angle, and joint line convergence angle in 2D and 3D images (P<0.001), indicating that 2D and 3D EOS imaging is not different in examining mentioned angles. **Conclusion:** From this study, it can be concluded that the use of 3D imaging is not preferable to 2D imaging, and measurements of angles in each of these two methods are almost identical.

INTRODUCTION

Complete knee arthroscopy is a successful surgery as a treatment for osteoarthritis (1). The purpose of this procedure is to obtain stable and well-aligned tibiofemoral and patellofemoral joints and to achieve long-term patient satisfaction (2). However, 15 to 30 percent of patients are not satisfied with the results of the procedure after total knee arthroplasty (TKA) (3-5). The reason for this is that after complete joint replacement some patients experience several permanent complications such as pain, ankyloses, and joint clicks (5, 6). TKA efficacy is influenced by several factors, such as axial alignment of the lower limb, prosthesis rotation angle, soft tissue balance status, and patellofemoral tracking (7).

Previous studies have shown that the right angle of prosthesis placement plays a vital role in the rate of joint survival as well as the short, medium, and long term clinical efficacy (8-10). The optimal placement of the prosthesis during TKA joint replacement (TKA) is an essential part of the surgical procedure. Incorrect insertion of the knee prosthesis in the coronal plate causes the prosthetic loosening that made it be re-applied. A complete reverse knee replacement (rTKA) should be avoided, as this will fail the functional efficiency and lower prosthetic survival (11).

Proper prosthesis placement on the coronal plane has less pain, faster rehabilitation, and improved quality of life (12). The best orientation on the coronal plane is 3 degrees for varus or valgus deviations (11, 13). Stand-alone radiological images (Weight-Bearing) are commonly used to measure alignment in coronal and sagittal planes. Although its proportions and angles may not be correct, it shows us the vertical and horizontal divergence. Computer tomography (CT) scanogram can also be used to evaluate the alignment of the prosthesis in coronal, sagittal and rotary planes. However, due to the high radiation exposure and the cost of this scan, it can not be used regularly. Besides, in a CT scan, capturing the state of the image from the legs is not possible (14).

Ahead, the EOS system was developed to evaluate prosthetic positioning. This two-dimensional technique with low-dose X-rays can bring us two-dimensional radiology images, and three-dimensional rearrangements from the entire length of the leg. The main advantages of this technique are that the

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radiation is 800 to 1,000 times lower than the CT scan and 10 times less than the usual radiography (15). However, the software for 3D reconstruction is created for those lower limbs that do not have knee prostheses (16). As described in the measurement protocol, when the knee prosthesis is placed in an appropriate position, many anatomical reference points disappear or change. The reliability of this protocol has not yet been verified (17). Due to the lack of similar studies and the need for further study in this field, the present study aimed to examine the comparison of knee angles in 2D and 3D EOS imaging in patients with complete knee arthroplasty.

MATERIALS AND METHODS

The present study is a cross-sectional analytical study, which was conducted in Shahid Sadoughi educational hospital in Yazd. In this study, 50 patients with knee osteoarthritis who underwent knee replacement before EOS imaging of their lower extremities were enrolled. Besides, patients with a history of fractures in the femur, tibia, and knee of the ipsilateral side, as well as patients with congenital neuromuscular abnormalities were excluded from the study. First, patients' demographic data, including age, gender, height, weight, and body mass index (BMI), were obtained. All surgical procedures were performed by two surgeons. The EOS was made from the hip, knee, and ankle area. The following angles in patients were reviewed and recorded once by an expert with the PACS software system, preoperatively:

I. Varus and Valgus Knee angle: The angle between the center of the head of the femur to the center of the knee and the line from the center of the knee to the ankle's center in the coronal plane.

II. Mechanical lateral distal femoral angle (LDFA): Angle between the mechanical axis of the femur and the line between the distal femoral condyles

III. Mechanical medial proximal tibial angle (MPTA): The angle between the mechanical axis of the tibia and the line drawn from the tibial plateau in the coronal plane.

IV. Joint linear congruence angle (JLCA): The angle between the two lines of the knee joint orientation

After that, All data were analyzed by SPSS software ver 21. Chi-square, ANOVA, and Paired T-test were used to analyze the data.

RESULTS

In this study, 50 patients undergoing knee replacement surgery were evaluated. Of this 82 % of patients were female and 18% were male. 52% of patients underwent surgery on the left knee, and 48% of patients underwent surgery on the right knee. The mean age of patients was 64/84, with a minimum age of 48 and a maximum age of 79 years. The mean BMI of patients was 28/60, with a mean BMI of 22.32 and a maximum of 42.66 (Table 1).

The mean Varus angle was 14.04 ± 6.49 in a 2D view, and the mean of the Varus angle was 13.67 ± 6.46 in a 3D view. Also, the mean of the LDFA was 91.58 ± 3.32 and 92.07 ± 3.18 in 2D and 3D views, respectively. The mean MPTA was 81.06 $\pm$ 4.81 in a 2D view, and its average angle for a 3D view was 82.04 ± 4.81. The mean JLCA in a 2D view was $6.15 \pm 2.\ 54$, and its average angle for a 3D view was 6.82 ± 2.60 (Table 2).

In the evaluation of correlations between varus correlations in patients, there was a significant difference between the two types of measurements (2D and 3D) measurements (*P* <0.001), meaning that there is no significant difference between 2D and 3D EOS imaging for evaluation Knee varus (Table 3).

Same to the knee varus angle measurement, it also has been shown that there is no significant difference between 2D and 3D EOS imaging for evaluation other Knee angles (*P* <0.001) (LDFA, MPTA, JLCA)

Also, the coefficient of agreement between the angles in the 2D and 3D images in terms of Blant-Altman diagrams showed that all points are within a standard deviation from the mean, and this means that the results of the angular measurements in the 2D and 3D images are consistent (Figure 1).

DISCUSSION

In this study, we compare the use of EOS as 3D imaging and simultaneous 2D imaging. Subsequent investigations revealed that none of the parameters measured had a preference for 3D imaging over 2D imaging. In the present study for the varus angle, it was found that there was no difference between 2D and 3D measurements.

In the study of Meijer MF et al. (17) about computed assisted surgery and the use of EOS on patients undergoing knee arthroplasty, it was found that there was no difference between the two imaging modalities. Angles do not help improve knee surgery. However, the study concluded that the 3D method was more reliable than the 2D one. In another study, Meijer MF et al. (18) two years after the previous study found that the use of 3D imaging was not appropriate to 2D imaging, but it can be used as a modality to examine more closely the aspects of knee prostheses. Ros Wade et al., in a systematic review of various studies, concluded that despite better efficacy and more comfortable use of EOS, this knee arthroplasty surgery tool has no practical advantage over 2D imaging (19). On the other hand, the benefits of using EOS have been studied by Melhem E et al. In this study, it was shown that the use of EOS in the evaluation of lower limb angles is not preferable to 2D measurement, but because of the low radiation exposure in this implement, it is recommended to use in the therapeutic process (15). In the other study which Meijer FM et al. examined the variations of LDFA angles between 3D EOS and computer-assisted surgery (CAS), they found that there was no significant relationship between these two measurement methods, but the Varus and Valgus angle and MPTA are more preferred than CAS measurements. Although the present study shows that 3D and 2D imaging are no different in measuring these angles, Studies to evaluate these angles and compare them in these two measuring instruments are very limited, and no definitive conclusion can be reached (17-19).

The MPTA in the present study did not differ significantly in the two measurement methods, which were the same as Sgroi M.'s study result (20). Another study reviewed by Wybier M et al. found that using the EOS tool was not preferable to 2D measurements at these angles, but using EOS as a safer and more accurate tool for tracking patients was recommended (21). The absence of any difference between the two measurement methods indicates that EOS is not superior to 2D imaging for MPTA measurement (17).

CONCLUSION

This study showed that 3D imaging is not preferable to 2D imaging and the lower extremity angles are the same in both methods and two-dimensional imaging can be used with confidence.

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None

AUTHOR CONTRIBUTIONS

All authors contributed in present study.

CONFLICT OF INTERESTS

None.

ETHICAL STANDARDS

Written informed consent obtain from all subjects.

Table 1. The frequency distribution of demographic variables in patients undergoing complete knee arthroplasty

Variable		Number	Percentage (%)
Sex	Female	41	82
	Male	9	18
Knee	Left	26	52
	Right	24	48
Mean ± SD		Min	Max
Age	64.84±5.701	84	97
BMI	28.6±4.05	22.32	42.66

Abbreviations;
SD: standard deviation, Min: minimum, Max: maximum, BMI: body mass index

Table 2. Average measurements of the available parameters

Variable	Mean ± SD	Min	Max
Varus angle in 2D	14.04±6.49	3	70/27
Varus angle in 3D	13.67±6.46	10/3	70/28
LDFA in 2D	91.58±3.32	85	103
LDFA in 3D	92.07±3.18	25/85	101
MPTA in 2D	81.46±4.81	46/70	30/90
MPTA in 3D	82.04±4.81	80/70	80/91
JLCA in 2D	6.15±2.54	1	20/12
JLCA in 3D	6.82±2.60	1	59/12

Abbreviations;
SD: standard deviation, Min: minimum, Max: maximum, LDFA: lateral distal femoral angle angle, MPTA: mechanical medial proximal tibial angle, JLCA: Joint linear congruence angle, 2D: two-dimentional, 3D: three-dimentional

Table 3. Correlation between 2D Varus and 3D Varus angle in patients undergoing total knee arthroplasty

Dimensional varus	2D	3D
2D	r=1	0/997=r $P < 0.001$
3D	-	r=1

Abbreviations;
2D: two-dimentional, 3D: three-dimentional

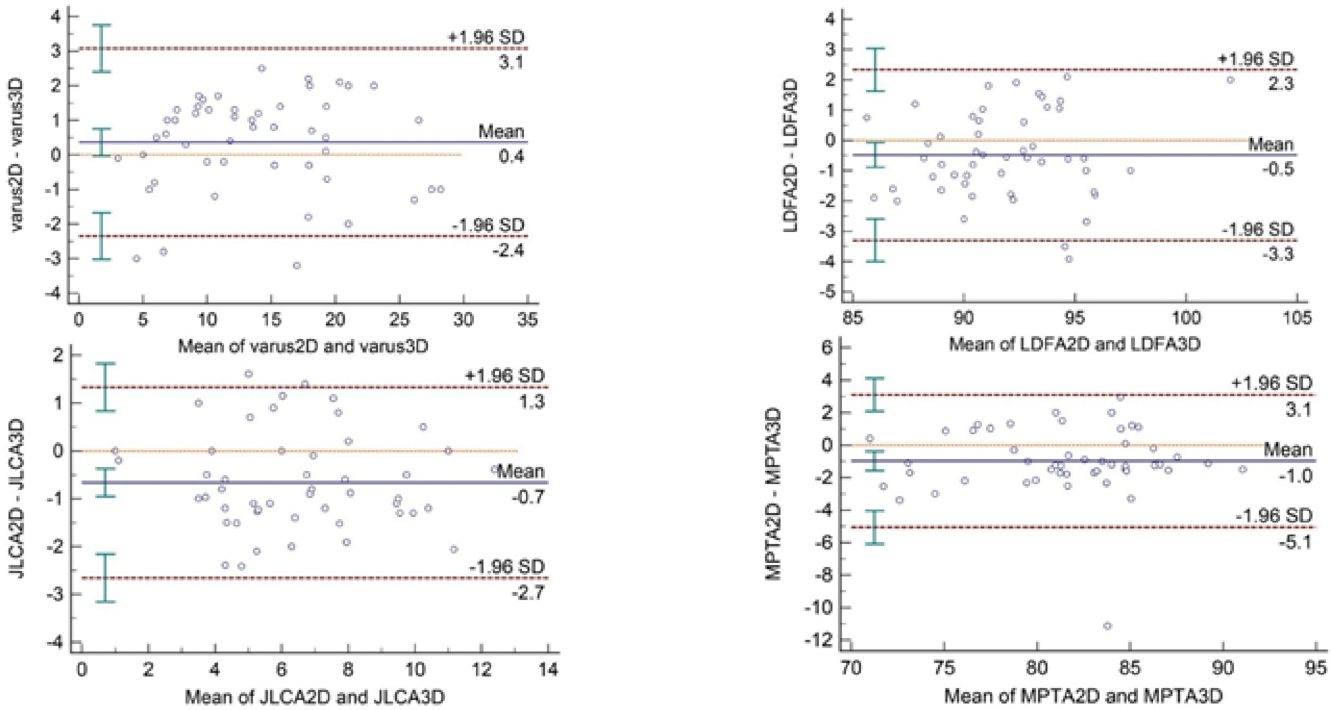

Figure 1. The coefficient of agreement between the angles in the 2D and 3D images in terms of Blant-Altman diagrams in patients undergoing TKA
(Abbreviations; 2D: two-dimentional, 3D: three-dimentional, TKA: total knee arthroplasty)

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