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Original Article

# Intraobserver and intermethod reliability for using two different computer programs in preoperative lower limb alignment analysis

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ABSTRACT

*Background and objective:* Professional graphics editing programs can be used in the preoperative planning of lower limb deformity correction surgery. This study was conducted to test the reliability of using such programs versus FDA approved medical planning software.
*Materials and methods:* Thirty long standing lower limb radiographs had been selected. Two different computer programs (Adobe Photoshop) versus planning software (MediCAD) were used in the analysis of lower limb alignment. The following angles were measured twice:Lateral Proximal Femoral Angle (LPFA), mechanical Lateral Distal Femoral Angle (mLDFA), Joint Line Convergence Angle (JLCA), Medial Proximal Tibial Angle (MPTA), Lateral Distal Tibial Angle (LDTA) and Mechanical Axis Deviation (MAD). Intraclass correlation coefficient (ICC) was used to assess the intraobserver and intermethod reliability and the mean differences between measurements were calculated.
*Results:* Intraobserver and intermethod reliability scores were very good (>0.95) for all measurements. The highest reliability was for MAD (0.999). LPFA and LDTA had the highest variability and a range of intraobserver absolute difference up to 4.8° and 3.7° respectively.
*Conclusion:* Computer assisted lower limb alignment analysis is reliable whether using graphics editing program or specialized planning software. However slight higher variability for angles away from the knee joint can be expected.


## 1. Introduction

Computer assisted analysis of lower limb alignment offers many advantages including reduction of the total time required for planning, higher reliability and digital storage of images [1]. However, specialized FDA approved planning programs are not available in many institutions and are expensive [1]. On the other hand, reports describing the use of professional graphics editing programs (PGEPs) as Photoshop program do exist and may represent a good alternative [2–4]. None of these reports had already discussed the accuracy of using these graphics editing programs in the medical field.

Furthermore, many studies have tested the intraobserver and interobserver reliability of measuring the

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tibiofemoral angle using either manual or computer assisted methods [5–10]. Nevertheless, identifying the source and magnitude of lower limb deformities requires separate evaluation of different joint orientation angles. Few studies have discussed the intraobserver and interobserver reliability of manual and computer assisted lower limb alignment analysis with regard to the individual assessment of joint orientation angles [1,11]. Furthermore, sources of possible errors and variability in lower limb deformity analysis were not completely discussed.

### *1.1. Aim of the work*

The aims of this study were twofold. The first was to evaluate the reliability (intraobserver and intermethod) of computer assisted lower limb alignment analysis using a professional graphics editing program (Adobe Photoshop version 9.0, Adobe System Incorporated, CA, USA) versus FDA approved medical planning software (MediCAD version 2.0, Hectec GmbH, Altfraunhofen, Germany). The second aim was to identify possible sources of error during digital methods of lower limb alignment analysis.

## 2. Materials and methods

Thirty long standing lower limb anteroposterior digital radiographs (14 right and 16 left sides) were chosen from our electronic database and were pasted directly to the planning software using standard Picture Archiving and Communication System (PACS) workstations. These radiographs were preoperative imaging studies used for planning of either deformity correction surgeries or total knee replacements. Two different computer programs were used for lower limb alignment analysis: Adobe Photoshop version 9.0 (Adobe System Incorporated, CA, USA) and MediCAD version 2.0 (Hectec GmbH, Altfraunhofen, Germany). The following angles were measured in each radiograph: LPFA, mLDFA, MPTA, JLCA and LDTA as well as measuring the MAD (Table 1) [12,13]. All measurements were repeated twice on 2 different occasions for each computer program. No two sessions of measurements had been done within the same day to avoid memorization of the results. The analysis was performed by a single orthopedic surgeon who has a special interest in dealing with professional graphics editing programs and who is also experienced in the field of deformity correction surgery (MK). All radiographs were taken using the same protocol. The X-ray tube was positioned 300 cm from the film. The hip and knee joints were fully extended while the patient was full weight bearing on both legs. The X-ray beam was centered at the level of the knee joint with the patella facing directly forward, centered between the femoral condyles. A spherical metal X-ray marker, 30 mm in diameter positioned at the same level of the bone, was used to calibrate the radiographs to the actual bone size.

**Table 1**
Nomenclature of joint orientation angles in the frontal plane mechanical axis planning [1,9].

| Nomenclature of joint orientation angles | |
|---|---|
| LPFA | *Lateral Proximal Femoral Angle*<br>The angle between the mechanical axis of the femur and a line between the tip of the greater trochanter and the center of the femoral head |
| mLDFA | *Mechanical Lateral Distal Femoral Angle*<br>The angle between the mechanical axis of the femur and the distal femoral knee joint orientation line |
| MPTA | *Medial Proximal Tibial Angle*<br>The angle between the mechanical axis of the tibia and the proximal tibial knee joint orientation line |
| LDTA | *Lateral Distal Tibial Angle*<br>The angle between the mechanical axis of the tibia and the ankle joint orientation line |
| JLCA | *Joint Line Convergence Angle*<br>The angle between the tangent through the two most convex distal points of the femoral condyles and a line along the flat portion of the subchondral bone of the tibial plateau |
| MAD | *Mechanical Axis Deviation*<br>The distance between the mechanical axis of the whole lower limb and the knee center |

### *2.1. PGEP assisted analysis*

The details of using the Photoshop program in the analysis of lower limb alignment were already described by Shiha et al. [4] and we followed these same steps. The femoral head was elected using the elliptical selection tool and its center was identified with the free transform option. The distal femoral and proximal tibial knee joint orientation lines were drawn. The apex of the intercondylar notch and the midpoint between the tibial spines were used as references for the knee joint line midpoints, the femoral and tibial sides respectively. The ankle joint orientation line was drawn and its center was identified by the midpoint between the edges of the medial and lateral shoulders of the talus. The different lines of mechanical axis planning were drawn and the required angles were measured using the ruler tool. The diameter of the spherical metal marker was then measured and the magnification factor of the radiograph was calculated. MAD was measured and calculated according to the magnification factor (Fig. 1a).

### *2.2. MediCAD assisted analysis*

For digital analysis using the MediCAD program, the radiographs were firstly calibrated using the spherical metal marker as a reference for the actual bone size. The center of the head of the femur was identified using (the 3 point circle) option of the program and the tip of the greater trochanter was marked. The distal femoral and the proximal tibial knee joint orientation lines and the ankle joint orientation line were drawn. The mid condylar point of the distal femur, the mid plateau point of the proximal tibia and the midpoint of the ankle joint were identified by the program at the same time. The program automatically generates all angles required for mechanical axis planning: LPFA, mLDFA, MPTA, LDTA, JLCA as well as MAD (Fig. 1b).

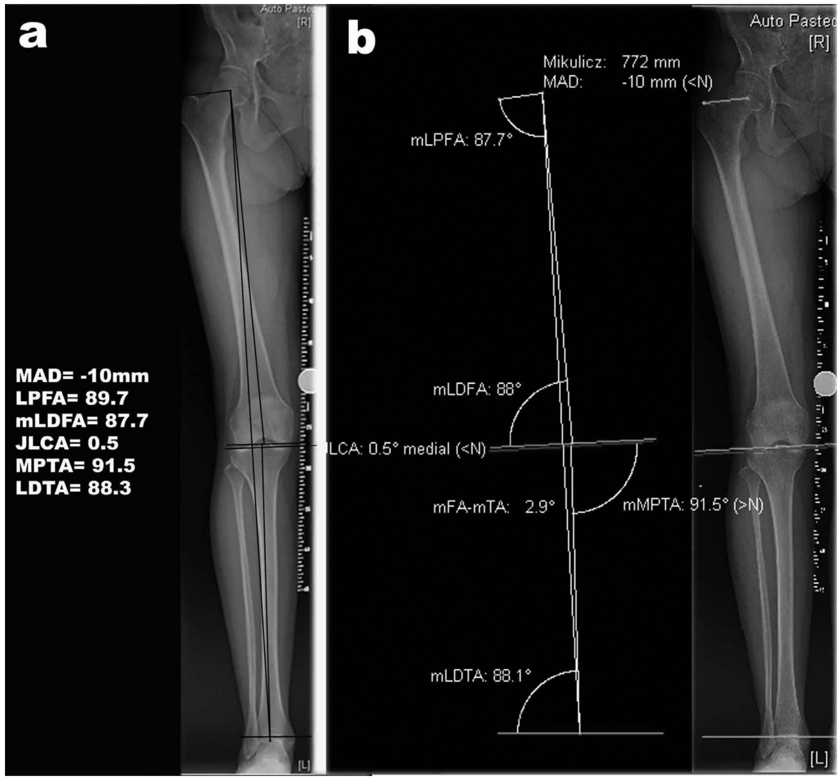


**Fig. 1.** Preoperative lower limb mechanical axis planning. (a) PGEP assisted analysis. (b) MediCAD assisted analysis.

### *2.3. Statistical analysis*

Intraobserver reliability for each method was evaluated using the intraclass correlation coefficient (ICC) [11,14]. The means of the two measurement sets in the PGEP assisted analysis and those of the MediCAD assisted analysis were calculated. The intermethod reliability (the reliability of using the first method versus the second method for lower limb geometry analysis) was quantified with the ICC [11,14] reliability analysis. Reliability was scored: very good (0.81–1), good (0.061–0.8), moderate (0.41–0.6), fair (0.21–0.4) or poor (⩽0.2) [14]. Differences between the two measurement sets of both methods were calculated to evaluate the intraobserver variability. For measurements using the first versus the second programs, differences were calculated between the mean values of the first and the second methods respectively. Range, mean and standard deviation of these differences were calculated for all data sets as well as the 95% confidence intervals for intraobserver and intermethod reliability analyses. The SPSS program (SPSS 15.0, SPSS Inc., Chicago, IL, USA) was used for the statistical analysis.

## 3. Results

The intraobserver reliability was very good for all measurements using either of the two computer programs. Intraobserver ICC scores ranged from 0.964 to 0.999. MAD had the highest ICC score of 0.999 and the lowest scores 0.964 and 0.966 were for mLDFA and LDTA, in the PGEP and MediCAD methods respectively (Table 2). Regarding the intermethod reliability analysis for using one computer program versus the other, the ICCs were very good for all measurements. The ICC scores ranged from 0.955 to 0.999. MAD had also the highest reliability score of 0.999, while LDTA had the lowest reliability score of 0.955 in the intermethod ICCs. The intermethod ICC scores were slightly higher than the intraobserver scores for all measurements except MPTA and LDTA (tibial side measurements) (Table 2).

**Table 2**
ICC scores with 95% confidence intervals for intraobserver and intermethod reliability analyses. Professional graphics editing program (PGEP).

| | Intraobserver reliability | | Intermethod reliability |
|---|---|---|---|
| | PGEP | MediCAD | |
| MAD | 0.998 (0.996–0.999) | 0.998 (0.996–0.999) | 0.998 (0.996–0.999) |
| LPFA | 0.945 (0.887–0.973) | 0.95 (0.899–0.976) | 0.953 (0.903–0.977) |
| mLDFA | 0.931 (0.86–0.967) | 0.934 (0.866–0.968) | 0.947 (0.892–0.974) |
| MPTA | 0.949 (0.896–0.976) | 0.952 (0.901–0.977) | 0.952 (0.902–0.977) |
| LDTA | 0.947 (0.892–0.974) | 0.933 (0.865–0.968) | 0.914 (0.827–0.958) |
| JLCA | 0.982 (0.964–0.992) | 0.948 (0.944–0.987) | 0.975 (0.947–0.988) |

The intraobserver mean absolute difference for angles in the PGEP assisted analysis ranged from 0.4 ± 0.4° to 1.2 ± 0.8°. The LPFA and LDTA had the highest mean absolute differences: 1.2 ± 0.8° and 1.1 ± 0.9° respectively. For the intraobserver data set in the MediCAD method, the mean absolute difference ranged from 0.7 ± 0.3° to 1.2 ± 0.8°. The LPFA and LDTA had also the highest mean absolute differences: 1.1 ± 1° and 1.2 ± 0.8° respectively. The intermethod mean absolute differences had a range between 0.5 ± 0.5° and 1.5 ± 1°, with the highest values that were 1.5 ± 1° and 1.2 ± 1.1° for LPFA and LDTA respectively (Table 3).

Regarding measurement of distances, intraobserver and intermethod ICCs showed nearly perfect reliability for MAD and were the same in all data sets (0.999). The intraobserver mean absolute difference was 1.1 ± 0.7 mm and 0.8 ± 1 mm for the PGEP and MediCAD assisted analysis respectively and 0.9 ± 0.7 mm for the intermethod analysis.

## 4. Discussion

Accurate correction of lower limb deformities is important to restore normal function and to prevent adjacent joint degenerative changes [15]. The steps of the preoperative planning of corrective surgeries are well known and well described [12,15]. However, inherent intraobserver and interobserver variability do exist for different joint orientation angles [1,11]. Computer assisted lower limb geometry analysis has been shown to facilitate the process of preoperative planning and to increase the intraobserver and interobserver reliability [1,7,9].

The main limitation of our study is the single observer analysis. No other observers were involved and therefore interobserver variability was not assessed. Unfortunately, one of the main limitations for the use of programs such as Photoshop in preoperative planning is the need for special knowledge and expertise in the work with these programs. That is why only one orthopedic surgeon was involved in this analysis because of his interest in graphics programs in addition to his experience in the field of deformity correction surgery.

**Table 3**
Mean ± SD and range of absolute differences of the intraobserver and the intermethod values for each measurement. Professional graphics editing program (PGEP).

| | Intraobserver absolute difference | | Intermethod absolute difference mean ± SD (range) |
|---|---|---|---|
| | PGEP mean ± SD (range) | MediCAD mean ± SD (range) | |
| MAD | 1.1 ± 0.7 (0.1–2.5) | 0.8 ± 1 (0–5) | 0.9 ± 0.7 (0–2.5) |
| LPFA (°) | 1.2 ± 0.8 (0–4) | 1.1 ± 1 (0–4.8) | 1.5 ± 1 (0.1–3.3) |
| mLDFA (°) | 0.8 ± 0.6 (0–1.8) | 0.8 ± 0.5 (0.1–2) | 0.6 ± 0.5 (0–2.2) |
| MPTA (°) | 0.6 ± 0.5 (0–1.9) | 0.7 ± 0.3 (0.1–1.5) | 0.6 ± 0.6 (0–2.6) |
| LDTA (°) | 1.1 ± 0.9 (0–3.7) | 1.2 ± 0.8 (0.1–2.9) | 1.2 ± 1.1 (0–4.1) |
| JLCA (°) | 0.4 ± 0.4 (0–1.5) | 0.7 ± 0.7 (0–2.6) | 0.5 ± 0.5 (0–1.7) |

Our results showed very good reliability regarding the intraobserver data for both methods of computer assisted analysis. The intermethod reliability was very good for all values of the head of the femur. The LDTA showed also high intraobserver and intermethod variability. Intraobserver differences for LDTA may be as high as 3.7° and 2.9° for the PGEP and MediCAD assisted analyses respectively and 4.1° for the intermethod values (Table 3). This difference can be explained by the wide range of variability of tibial torsion. Therefore, the lateral part of the talus may be overlapped by the distal fibula making it difficult to identify accurately the center of the talus and even the joint orientation line (the ends of the tibial plafond line) (Fig. 2). Also, the presence of a very short arm on one side for this angle (which is the line connecting the two ends of the tibial plafond line) may add some variability in this measurement. Hankemeier et al. [1] had also the JLCA variability in the third position after LPFA and LDTA for the conventional measurements and in the second position after LPFA for the computer assisted measurements.

This intraobserver difference is relatively large for an angle with a narrow range such as the JLCA (normal range 0–2°) [12]. In some patients with advanced knee osteoarthritic changes, marked bony attrition and marginal osteophytes may cause difficulties in the localization of the femoral and tibial joint orientation lines. Another explanation for difficulties with the proximal tibial knee joint orientation line, may be the variability of the tibial plateau slope angle and so the variability of the appearance of the medial and lateral tibial condyles. A third point is that the two arms forming this angle are very short arms which add more variability. Feldman et al. [11] studied the intraobserver and interobserver reliability of manual lower limb deformity measurements in the frontal and sagittal planes. Intraobserver ICC scores were very good for all measurements in the frontal plane and ranged from 0.86 to 0.93. The anatomic medial proximal femoral angle (aMPFA) and LDTA had an average median intraobserver absolute difference of 2.2° and 2° respectively. Intraobserver difference in the aMPFA, MPTA and LDTA as high as 23°, 30° and 26° was reported respectively. In comparison with our data, our highest intraobserver differences were 4.8° and 3.7° for the LPFA and LDTA respectively. Myers et al. [16], in their study for associated distal femoral and tibial deformities in patients with Blount's disease, reported intraobserver ICC scores for anatomical Lateral Distal Tibial Angle (aLDTA) and anatomical Lateral Distal Femoral Angle (aLDFA) of 0.62 and 0.97 respectively. This also confirms the presence of higher intraobserver variability for measuring the LDTA. Furthermore, the presence of tibial torsional deformities in patients with Blount's disease may also explain this wide intraobserver variability for aLDTA in the study of Myers et al. and therefore supports our explanation [17].

In conclusion, computer assisted analysis of lower limb alignment parameters is a highly reliable tool for preoperative planning in cases with lower limb deformities. The use of professional graphics editing program may be a good solution in the absence of specialized medical plan-

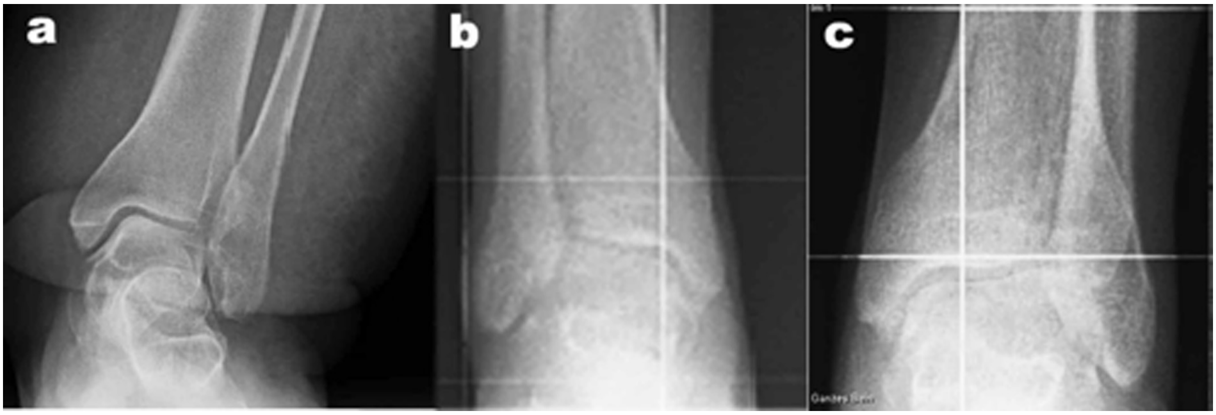


**Fig. 2.** Wide range of tibial torsion may explain the high intraobserver and intermethod variability of LDTA measurements. (a) The lateral and medial shoulders of the talus can be clearly identified. (b) & (c)The lateral shoulder of talus is overlapped by the distal fibula.

ning software. It facilitates the process of planning and has high reliability similar to specialized medical planning software. Inherent intraobserver variability for measurements away from the knee joint (LPFA and LDTA) may be expected. However, measurement of distances is highly reliable using digital analysis.

## Conflict of interest

We have no conflict of interest to declare.


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