Leg Length Measurement with Smartphone Application during Surgery: Useful, Easy and Reliable Method

Ameliyat Sırasında Akıllı Telefon Uygulaması ile Bacak Uzunluk Ölçümü: Kullanışlı, Kolay ve Güvenilir Yöntem

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ABSTRACT

Introduction: Leg Length Discrepancy (LLD) is one of the main problems in Hip Arthroplasty. During surgery, despite a lot of defined methods, the gold-standard method has not existed yet. The purpose of this study was to evaluate the application program as a measurement method in hip arthroplasty operations and compare the application measurement methods.

Methods: Between December 2018 and December 2019, 166 consecutive patients who had operated for primary coxarthrosis were included in the study. Two methods (sterile tape and application program) were used during the surgery to equalize the leg length difference. These methods were compared with each other and with preoperative and postoperative orthoroentgenography.

Results: There was no statistically significant difference between the values measured with the preoperative and intraoperative application and the values measured with the preoperative and postoperative orthoroentgenography ($p<0.05$). There was a statistically significant difference between the values found as a result of measurement with sterile tape and the results found with the application ($p<0.05$).

Conclusion: The application method is easy cheap and a reliable method for evaluating LLD during surgery. With this method, measurements can be made correctly. This method can be used as an additional or primary method in evaluating LLD.

Key words: Leg Length Discrepancy; Measurement with Application; Intraoperative Measurement; Coxarthrosis

ÖZET

Giriş: Bacak Uzunluk Eşitsizliği (BUE), Kalça Artroplastisindeki ana problemlerden biridir. Ameliyat sırasında tanımlanmış birçok yönteme rağmen altın standart yöntem henüz mevcut değildir. Bu çalışmanın amacı, kalça artroplastisi ameliyatlarında bir ölçüm yöntemi olarak akıllı telefon uygulama programını değerlendirmek ve uygulama ölçüm yöntemlerini karşılaştırmaktır.

Yöntemler: Aralık 2018 ile Aralık 2019 tarihleri arasında primer koksartroz nedeniyle opere edilen ardışık 166 hasta çalışmaya dahil edildi. Ameliyat sırasında bacak uzunluğunu eşitlemek için iki yöntem (steril mezura ve uygulama programı) kullanıldı. Bu yöntemler birbirleriyle ve ameliyat öncesi ve sonrası ortoröntgenografi ile karşılaştırıldı.

Bulgular: Preoperatif ve intraoperatif uygulama ile ölçülen değerler ile preoperatif ve postoperatif ortoröntgenografi ile ölçülen değerler arasında istatistiksel olarak anlamlı fark yoktu ($p<0.05$). Steril mezura ile yapılan ölçüm sonucu bulunan değerler ile uygulama ile bulunan sonuçlar arasında istatistiksel olarak anlamlı fark bulundu ($p<0.05$).

Sonuç: Uygulama programı kullanımı, ameliyat sırasında BUE'ni değerlendirmek için kullanılan kolay, ucuz ve güvenilir bir yöntemdir. Bu yöntemle ölçümler doğru bir şekilde yapılabilmektedir. Bu yöntem, BUE'ni değerlendirmede ek veya birincil yöntem olarak kullanılabilir.

Anahtar Kelimeler: Bacak Uzunluk Eşitsizliği,, Aplikasyon ile Ölçüm, İntraoperatif Ölçüm, Koksartroz

INTRODUCTION

Leg Length Discrepancy (LLD) is one of the main problems in Hip Arthroplasty. Generally, it is related with patient satisfaction (1-4). In literature, lots of articles report that 1 cm difference is acceptable and discrepancy up to 1 cm does not affect the patient's functional outcomes (5-10). It is generally accepted that if LLD is over 1.5 cm, it can cause lower back pain, gait disorders and general dissatisfaction (11-13). Not only patient depended factors, but also lawsuit is a big

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problem about this issue. Failure to the restoration of leg length is leading cause of litigation after joint arthroplasty in USA and UK (14,15).

There are a lot of described techniques about the measurement of the leg length during hip arthroplasty surgery, including intraoperative equipment, intraoperative measurement devices, and computer navigation systems (16-20). But these devices and systems are not cost-effective and useful.

The aim of this study was to evaluate the application program as a measurement method in hip arthroplasty operations and compare the application measurement methods with the other conventional methods. Further, we wanted to find out whether this measurement method is useful and reliable.

METHODS

Patients

After the institutional review board approving, this prospective study started. Between December 2018 and December 2019, patients who had operated for primary coxarthrosis were included in the study. Our inclusion criteria are all patients aged 18-85 who underwent primary total hip arthroplasty. We excluded patients with a history of THA or revision THA on the same side, dysplasia responsible for hip dislocation and tumours.

Preoperative evaluation

Before the operation day, the patients were evaluated on their bad. We did a physical examination and measured the LLD of patients. We used three methods for every patient. The first method was tape measure, the second method was a smartphone application (Measure; 2018 Apple Inc.) and the third method was orthoroentgenography. Firstly, we measured leg length for both lower limbs using the midpoint of the femoral head and the mid-tibial plafond from the weight-bearing orthoroentgenography (Fig. 1-2). Then, we marked the anatomic landmarks for measuring. We marked Spina Iliaca Anterior Superior (SIAS) and Medial Malleoli (MM). After that, we measured with a tape measure from the anatomic landmarks for the left and right lower limb and we noted the LLD. Finally, we measured using smartphone application from the same anatomic landmarks for left and right lower limbs in the operation room and we noted the LLD (Fig. 3A,B). In order to increase the reliability, measurements made with tape measure and application methods, each measurement was made by two different surgeons. The two values found for each measurement method were averaged and noted. None of the surgeons knew the patient's other measurement results. Measurements were recorded by an assistant.

Figure 1. Preoperative Radiography.

Surgical technique and intraoperative measurement

All the patients were operated by the same surgeon and at the same institute. We operated the patients at supine position on the standard operation table. We used direct anterolateral approach for all patients. We

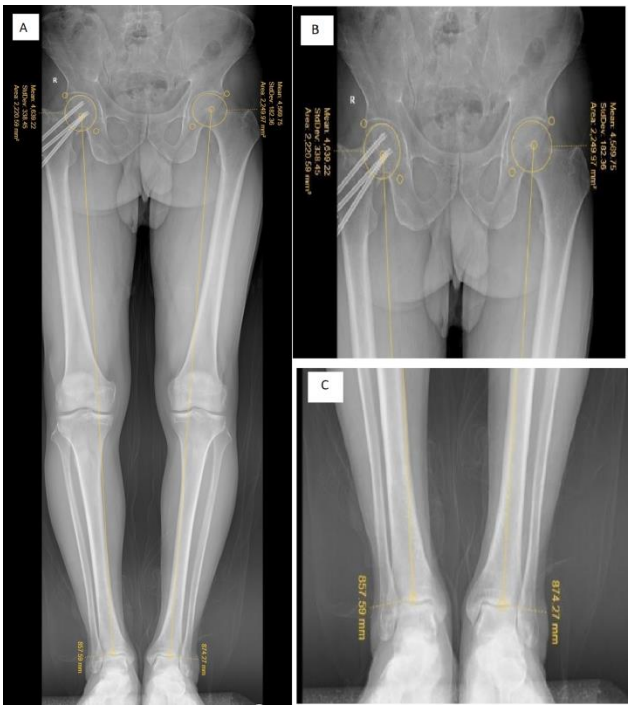

Figure 2a. Preoperative Orthoroentgenography With Measurement Lines. **2b.** Preoperative Orthoroentgenography With Measurement Lines (Pelvic Part). **2c:** Preoperative Orthoroentgenography With Measurement Lines (Ankle Part)

used sterile drape either for surgery site or for cover the foot. Before covering with drape, we marked with the sterile surgical pen the bone landmarks where SIAS and Medial Malleoli. After placing the prosthesis, AP images of both hips were taken by fluoroscopy to evaluate the position of the implants and leg length. In addition, the senior surgeon himself used the leg-to-leg method to evaluate leg length. After these evaluations, he ended the operation. On the operation table, two different surgeons from the operation team measured the leg length with sterile tape. Finally, two different surgeons who are unsterile, measure the leg length with smartphone application from the landmarks (Fig. 3C). The values measured by different surgeons were recorded by taking their averages. A different surgeon recorded the LLD by measuring from the orthoroentgenography taken on the 2nd postoperative day (Fig. 4). Preoperative and postoperative orthoroentgenography measurements were taken as a reference. The application method and tape methods were compared in terms of their accuracy and reliability.

Statistical Analysis

Analysis of the data was done using the IBM SPSS 22.0 statistical package program. Descriptive statistics for numerical variables were expressed as mean and standard deviation. Kolmogorov Smirnov test was performed for normality analysis. The t-Test in Independent Groups, One-Way Variance Analysis, t-Test in Independent Groups, Variance Analysis in Repeated Measurements were performed to determine the relationships between parameters. Tukey was used in post hoc analysis. Intraclass and concordance correlation coefficients were used to determine reliability and correlation. The results were evaluated within the 95% confidence interval and $p < 0.05$ was considered significant.

Ethical review committee statement

This investigational protocol was conducted with the approval of the university ethical committee. In accordance with the requirements of this review, all subjects provided informed consent. (No: E-18-2360 Date: 27/12/2018)

RESULTS

Totally 171 patients evaluated prospectively. 5 of 171 patients did not agree to participate in the study. The study included 166 patients, comprising 77 (46.4%) males and 89 (53.6%) females with a mean age of 64.2 (range 25 to 79) years. Pathology of 129 (77.7%) patients was primary coxarthrosis and pathology of 37 (21.7%) patients were posttraumatic coxarthrosis.

In the evaluation based on the orthoroentgenography, preoperative mean LLD of patients was 1,018±0,927 cm (range 0 - 4.2 cm) and postoperative mean LLD of patients was 0,304 ± 0,439 cm (range 0 - 1.7 cm).

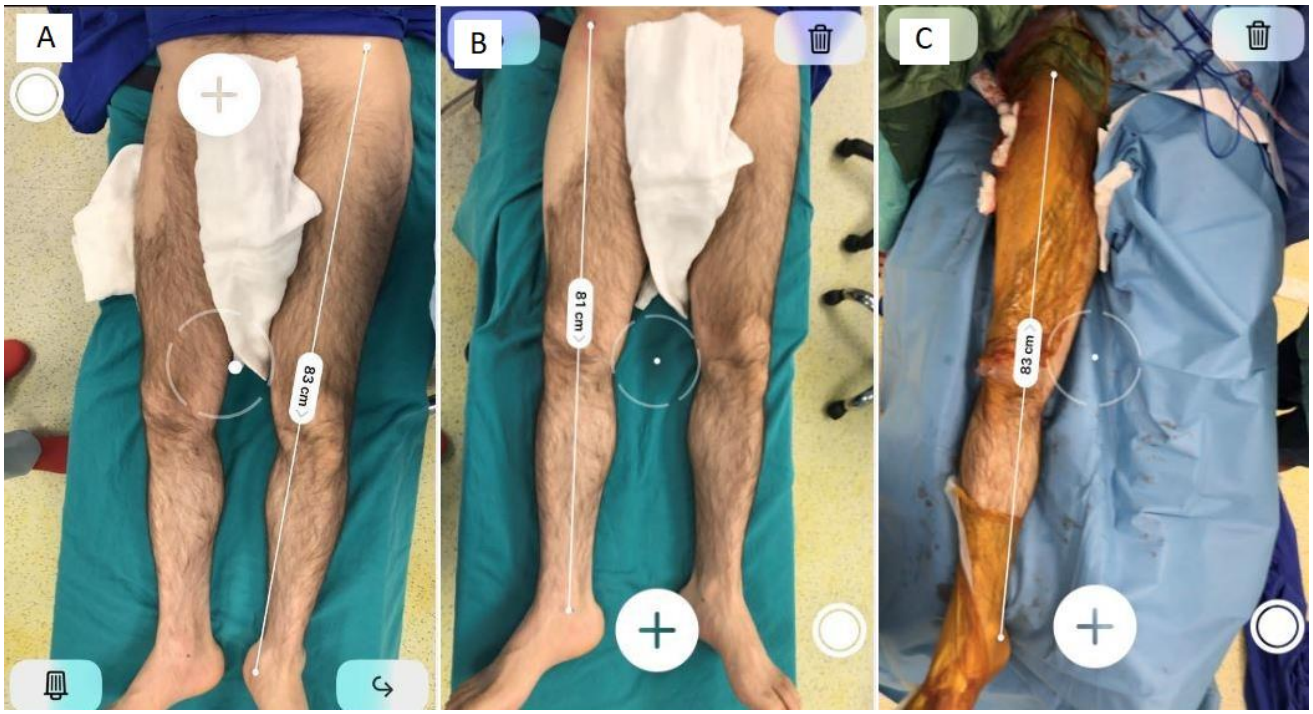

Figure 3a. Preoperative Smartphone Application Measurement (Left Leg). **3b.** Preoperative Smartphone Application Measurement (Right Leg). **3c:** Intraoperative Smartphone Application Measurement (Right Leg)

Mean LLD of preoperative measurement with the application was 1,021 ± 0,931 (range 0–4 cm) and mean LLD of intraoperative measurement with the application was 0,286 ± 0,451 (range 0-2 cm). (Table 1) The reliability and agreement between postoperative orthoroentgenographic versus intraoperative app and sterile tape measurements were good and moderate respectively (ICC = 0,753 and 0,617 respectively). (Table 2) There was statistically significant difference in terms of postoperative and intraoperative values in both orthoroentgenography and application ($p<0.05$). Tukey results were given in table. (Table 3)

In terms of intraoperative measurements, there was a statistically significant difference between the values found as a result of measurement with sterile tape and the application methods ($p<0.05$). The reliability and agreement between intraoperative measurements were given in table. (Table 2)

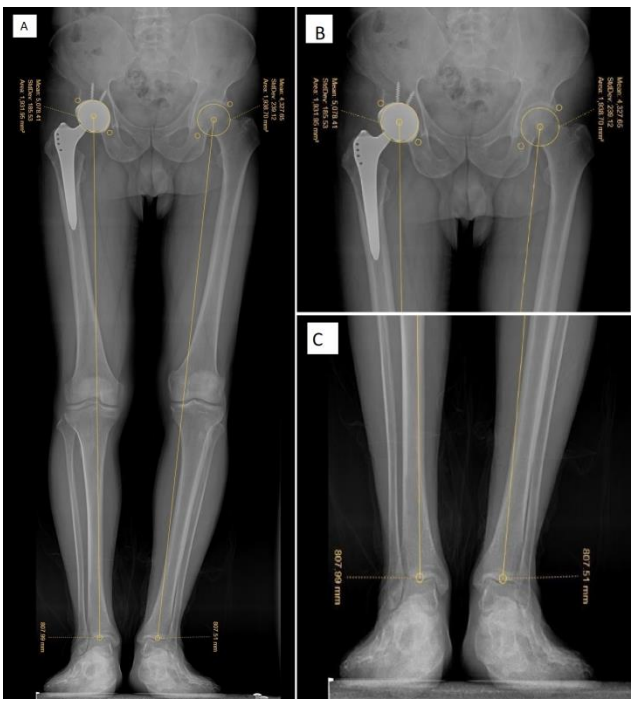

Figure 4a. Postoperative Orthoroentgenography With Measurement Lines. **4b.** Postoperative Orthoroentgenography With Measurement Lines (Pelvic Part). **4c:** Postoperative Orthoroentgenography With Measurement Lines (Ankle Part)

Table 1. Comparison of application method and orthoroentgenography measurements

		Mean ± Standard Deviation	p
Orthoroentgenography measurement	Preoperative	1,0181 ± 0,92751	**0,001**
	Postoperative	0,3042 ± 0,43961	
Application measurement	Preoperative	1,0211 ± 0,93152	**0,001**
	Intraoperative	0,2861 ± 0,45165	
Preoperative comparison	Orthoroentgenography	1,0181 ± 0,92751	0,971
	Application	1,0211 ± 0,93152	
Final comparison	Orthoroentgenography	0,3042 ± 0,43961	0,900
	Application	0,5241 ± 0,50395	

Depended simple t test for paired samples

DISCUSSION

The most important finding of this study was that leg length measurement using intraoperative application is a simple, convenient and reliable method. Considering the current orthopaedic literature, there is no other study using this method. At the same time, this study is the first and only prospective and largest patient series study using this method.

Table 2. The reliability and agreement between methods.

Methods	ICC	Interpretation*
PO orthoroentgenography - IO Application	0,753	Good
PO orthoroentgenography - IO sterile tape	0,617	Moderate
IO sterile tape – IO Application	0,712	Moderate

ICC: Intraclass Correlation Coefficient Test IO: Intraoperative PO: Postoperative
** Below 0.50: poor, between 0.50 and 0.75: moderate, between 0.75 and 0.90: good, above 0.90: excellent*

There are many studies to search for reliable and easy measurement methods (4,5,18,21,22). Nossa et al (21) compared three intraoperative measurement methods (1. Leg/leg method 2. Compass-like system 3. Trochanteric/joint ratio device) in their study. They found that the use of the devices improves the results, but it would not be enough to use the single method. Papadopoulos et al. (18) used the suture technique to sixty patients during surgery. Despite their limitations, they found that the suture technique is quite accurate technique for measuring leg length during surgery. Ian et al. (22) used 3 intraoperative methods (1. Abductor shuck (AS) 2. Trans osseous pins with a calibrated calliper, 3. Patella electrocardiogram leads) for measuring leg length and compared with the postoperative radiography. They found that the AS method best correlates to postoperative radiographic LLD among the three techniques, although all methods were positively correlated. At the same time, they mentioned that clinical measurements of LLD correlate poorly with radiographic measurements and may be of limited utility. Ogawa et al. (17) compared manual measurement device and computer navigation and Licini et al. (23) compared with and without computer navigation, they found that the computer navigation method is not superior to other methods. All of these studies needed to use an instrument to measure during surgery, sterilize these instruments, and/or make an extra surgical intervention (suturing, drilling or inserting Steinman/K-wire) to the patient's skin or bone. In the current study, measurements were made without any extra surgical intervention and the need for extra surgical sterilization. There was no statistically significant difference between the values measured with the application and the values measured with the orthoroentgenography ($p>0.05$).

In studies to evaluate LLD objectively; Tipton et al. (24) compared pelvic radiography and orthoroentgenography to evaluate LLD. They suggested that orthoroentgenography and did not recommend only pelvic radiography to predict the true LLD. Piyankumala et al. (25) compared three measurement methods (1. Block test to assess patient's perception, 2. Pelvic radiography 3. Weight-bearing orthoroentgenography) to evaluate LLD and they found that the best accurate method is Weight-bearing orthoroentgenography. In the current study, we used orthoroentgenography to evaluate real LLD and There was no statistically significant difference between the values measured with the application and the values measured with the orthoroentgenography ($p>0.05$).

Table 3. Comparison of postoperative orthoroentgenogram measurement with intraoperative methods.

Measurement Methods (I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
PO ortho-roentgenogram	IO sterile tape	**-,21988***	,05089	***0,000****	-,3510	-,0888
	IO application	,01807	,05089	*0,985*	-,1130	,1492

Tukey test results (Multiple Comparisons).
*The mean difference is significant at the 0.05 level.

Keršič et al. (5) compared four measurement methods (absolute, relative, trochanteric, standardized-trochanteric) to evaluate the impact of LLD on the clinical outcome of THA. They found that within the 10 mm range of mean postoperative leg length discrepancy in the studied series, its impact on the overall clinical satisfaction was detectable but not considerable. Mcwilliams et al. (6) reviewed 79 papers about LLD and they found that 10 mm LLD is acceptable. There is no agreement over an upper limit. Loughenbury et al. (26) did a survey study with British Hip Society members. They found that 89% of surgeons agree that 15 mm of LLD after primary uncomplicated THA was always acceptable and 90% of surgeons think that LLD more than 22.74 mm was never acceptable. They also found that over %50 surgeons use two or more tests. In the current study, the LLD average between preoperative orthoroentgenography and postoperative orthoroentgenography was 7.14±0.62 mm and between preoperative application and intraoperative application was 7.35±0.69 mm. There was no statistically significant difference between two methods ($p>0.05$). However, there was a statistically significant difference between the sterile tape method and the other two methods. ($p<0.05$)

Our study has some limitations. Unlike other measurement methods, only integers can be measured, and the decimal part cannot be seen in the application method. Another limitation is that the application method can only be used in operations performed in the supine position. Finally, not every surgeon may have a smartphone with this application.

CONCLUSION

Despite simple techniques such as leg length comparison and complex devices such as computer navigation device, a gold- standard method does not exist. We have defined a new measurement method. For this method, no extra materials, sterilization, surgical intervention or expensive electronic equipment are required. With this method, leg length can be measured accurately and reliably. This method can be used as an additional or primary method in evaluating LLD. At the same time, we hope that this study will pave the way for technological developments that will increase the comfort and safety of surgeons in the future.

Informed Consent: Informed consent was obtained from patients who participated in this study.

Conflict of Interest: No conflict of interest was declared by the authors.

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