Laser Projector Method for Measuring Postoperative Acetabular Anteversion After Total Hip Replacement

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Abstract

Introduction For patients undergoing total hip replacement (THR), measuring the postoperative acetabular anteversion precisely plays a pivotal role in the prognosis because anteversion of acetabulum cup determines the range of motion and stability after the THR. To date, the documented techniques for the accurate assessment encompass methods of two-dimensional (2D) and three-dimensional (3D). Our team has developed several 2D methods for precisely measuring acetabular anteversion after the THR, namely the trigonometric, the protractor, and the computerized ellipse method.

Despite multiple commercially available assessing tools, most mandate computerized equipment with corresponding software that is frequently in shortage in remote areas and developing countries. Therefore, we attempted to invent a laser projector that is able to measure the acetabular anteversion directly on the traditional plain film and to examine its validity and consistency by comparison with the Elliversion software.

Methods We invented a portable laser projector incorporating the ellipse method for the measurement of postoperative acetabular anteversion. We retrospectively collected 50 postoperative pelvis radiographs including acetabulum from our institution. One investigator first measured the anteversion of included radiographs through Elliversion software as the control group. Subsequently, two operators independently used the laser projector for measurements in two separate periods with 1-day intervals as the experimental group. Our analysis was comprised of intra- and inter-group comparisons, which investigated the consistency and validity, respectively, by using two-sample student's t-test. P-value < 0.05 suggests statistical significance.

Results There was no significant difference in measuring the anteversion through laser projectors between two operators (MD, -0.12; 95% CI, -0.52 to 0.27; p=0.54). The estimated effect in the anteversion measurement between the Elliversion and laser projector was also comparable (MD, -0.17; 95% CI, -0.38 to 0.04; p=0.12).

Conclusions Our study reported the consistency and validity of this laser projector as there is no significant difference in both intra- and inter-observer reliability, demonstrating real-time, intuitive, and convenient product design comparing to Elliversion. Most importantly, we look forward to helping elevate clinical acumen when doctors provide care to patients after THR, especially in remote areas.

Introduction

Total hip replacement (THR) is one of the most common elective operations in orthopedic field and it has been predicted that its annual volume will spike up to 572,000 by 2030.[1] For patients undergoing THR, measuring the postoperative acetabular anteversion precisely plays a pivotal role in the prognosis because anteversion of acetabulum cup determines the range of motion and stability after the THR.[2] To date, the documented techniques for assessing anteversion could be classified into two-dimensional (2D) and three-dimensional (3D) methods. Two-dimensional methods included the trigonometric,[3–5] the protractor,[2,6–10] and the computerized ellipse[11] method. The computerized tomography[12] (CT) method is an example of 3D method. For 2D methods, it is almost inevitable to confront deviations in measurement because there is no perfect angle and position in plain film radiograph. Although CT could be an excellent solution to this issue, it is clinically unpractical due to its high cost and risk of radiation exposure. We have published our results regarding the protractor and computerized ellipse methods. We verified and compared the accuracy between these methods using THR simulator[13] and concluded that exploiting computerized ellipse method conferred better precision than trigonometric method for radiographs of femoral head ($p < 0.01$).[11] Thus, our team primarily concentrated on 2D methods and we aimed to attain the maximal precision possible.

However, utilization of such method mandates computerized equipment with corresponding software. This equipment is frequently in shortage in remote areas and developing countries. There is also a lack of picture archiving and communication system (PACS). As a result, in order to overcome this limitation, we invented a laser projector method that is able to measure the acetabular anteversion directly no matter the radiographs were in the PACS or were traditional plain film. The projector system uses computerized ellipse method through our original software, Elliversion,[11] as the basis for measurement.

Methods

The aim of the present study is to investigate if the accuracy of measuring anteversion of acetabulum by the projector system is comparable to that by computerized ellipse method measuring software.

Anteversion measurement

Generally, both anatomic (true) and radiographic (planar) anteversion are acceptable for measurements. Based on Murray's definition,[14] true and planar anteversion could be acquired by projecting the acetabular axis on to the transverse plane and to the plane that is perpendicular to coronal plane as well as acetabular plane, respectively. Based on our prior research,[2] planar version is suitable for the evaluation of hip stability. Thus, in the present study, the mainstay measurement of acetabular anteversion is elliptical method, which concentrates on planar version.

According to McLaren equation,[15] planar version = arc sin (short axis/long axis), where short and long axes represented the axes of elliptical outline of the acetabular shell. However, a femoral head could easily eclipse the needed ellipse, resulting in difficult portraying. Therefore, we invented our own Elliversion software, through which we could estimate the ellipse under most circumstances.[11] Our newly design laser projectors (Fig. 1) used the same elliptical method for measuring the anteversion as well, through converting computer-generated JPEG. image to projectable AVI. file. Three mode has been designed, including Rudimentary mode: 1 degree per frame, Standard mode: 0.1 degree per frame and Precise mode: 0.05 degree per frame. The following data were analyzed through Precise mode.

Study population

We collected 50 postoperative pelvis radiographs in anteroposterior (AP) view, which included acetabulum retrospectively. Eligible patients were aged 18 or older and had undergone either unilateral or bilateral THR. Those who suffered from hip fractures or congenital hip anomalies were excluded.

Data collection

We measured every acetabular anteversion of the included 50 pelvic radiographs using both Elliversion and the laser projector. Initially, W.C.C completed measuring radiographs with Elliversion as the control group. Subsequently, two investigators (W.C.C and K.Y.C) independently used the projectors for measurements in two separate periods with 1-day intervals as the experimental group (Fig. 2). Eventually, we measured 50 anteversion from Elliversion in control group and 200 from laser projectors in experimental group.

Statistical synthesis

Our analyses comprised of intra- and inter-group comparison using two-sample student's t-test. A p-value < 0.05 was considered statistically significant. For intra-group comparison, we aimed to examine the 'consistency' of our laser projector, to see if the measured results remain consistent when used by operators in different circumstances. On the other hand, regarding inter-group comparison, we scrutinized the 'validity' of the projector, to see if there were statistical differences compared to Elliversion.

Results

All 50 postoperative pelvis AP radiographs with their corresponding anteversion measurement from both Elliversion and Laser projectors were presented in details in the supplementary file. Among included radiographs, all acetabular cups are clear to identify.

The intra-group reliability was summarized in Table 1. Laser A1 and A2 represented the mean anteversions measured by W.C.C in the first and second time, respectively, with a certain interval of period. There was no significant difference in measurements between A1 and A2 (MD, 0.25; 95% CI, -0.10 to 0.61; p = 0.15). On the other hand, Laser B1 and B2 accounted for mean measurements acquired by K.Y.C. in two independent periods. The difference between B1 and B2 was little (MD, 0.18; 95% CI, -0.05 to 0.42; p = 0.12). Moreover, Laser A and B were the mean anteversion of A1, A2 and B1, B2. The results acquired by two investigators (A vs B) were comparable (MD, -0.12; 95% CI, -0.52 to 0.27; p = 0.54).

The inter-group reliability was outlined in Table 2. The estimated effect in the anteversion measurement between two Elliversion and Laser were similar (MD, -0.17; 95% CI, -0.38 to 0.04; p = 0.12).

Discussion

Due to advanced surgical techniques and increased endurance of hip prostheses, the long-term survival after THR has improved a lot. The primary reason for hip reoperation falls into instability, dislocation and mechanical loosening.[16,17] Although the causes of dislocation are multifactorial, the most recognized one is associated with acetabular orientation, including inclination and anteversion. Erroneous orientation will result in femoroacetabular impingement syndrome (FAI) leading to dislocation.[18] Inadequate and excessive anteversion of acetabulum will increase the respective risk of anterior impingement in sitting position and posterior impingement in standing position.[18] On the other hand, a high inclination of hip cup could possibly lead to FAI by posing detrimental edge-loading and contact pressure that accelerated overall wear.[19] Though the best orientation of acetabulum is still debated with Charnley et al.[20] suggesting no absolutely perfect value, an angle between 15 ~ 30 degree[21,22] for anteversion and 40 ~ 55 degree[23,24] for inclination are generally recommended. Compared to acetabular anteversion, the measurement of inclination could be easily achieved on plain radiographs. As a consequence, precisely measuring postoperative anteversion is challenging and crucial in patients receiving THR.

Over the past decades, computer-aided diagnosis has evolved rapidly and grown from a state of infancy to certain maturity.[25] To date, there are various computer-aided 2D methods for directly measuring postoperative acetabular anteversion upon plain radiographs and each method carried its own advantages and disadvantages. Although there is still no gold-standard measurement of acetabular orientation, a variety of methods have been proposed to identify the postoperative position, such as methods of Lewinnek et al.[26], Widmer et al.[10], Hassan et al.[27], Ackland et al.[3], Woo et al.[28] and Liaw et al.[2] Among these verified methods, Nho et al.[29] compared their accuracy utilizing CT as a reference standard and found out that Lewinnek et al., Hassan et al., Liaw et al., and Woo et al. possessed higher reliability and validity. Furthermore, Park and colleagues[30] concluded that the method proposed by Liaw et al. was more accurate than others while utilizing plain films for measuring the acetabular anteversion after THR, with the PolyWare programme as the reference standard. In fact, Liaw's team has created many new modalities in pursuit of better precision and convenience. The primary concept of Liaw et al. that was compared in Park's study was trigonometric, which would be an ideal method for measuring radiographs without femoral heads. However, for those with femoral heads, it is more appropriate to utilize elliptical method which conferred better precision if femoral heads were included because the outline of the shell tends to be obscured.[11] Moreover, during our daily practice, it is almost inevitably to include femoral heads in the postoperative radiographs. As a result, we selected the ellipse as the measuring basis in our laser projectors.

The present study successfully identified the consistency and validity of our newly designed laser projectors, demonstrating real-time, intuitive, and convenient product design comparing to Elliversion. We found that there was no significant difference in measured anteversion between Elliversion and the projector. In addition, distinctions in two separate operators utilizing the projector were negligible. Some orthopedic surgeons may question the necessity of this projector in the presence of Elliversion. Indeed, in most developed countries or modern cities where hospitals are equipped with PACS, the projector is superfluous. However, in hospitals located in developing countries or in the remote regions that are either geographically isolated, socioeconomically unequal or of indigenous health inequity, PACS could be luxurious. In addition, one of the eight key features of remote medical practice, 'increased clinical acumen', mandates remote doctors to have high level of clinical acumen to make the diagnosis and cope with the diseases because hospitals where they are practicing often lack of diagnostic support,[31] not to mention PACS. Thus, we believe that our projectors are able to aid clinical acumen whenever doctors confront patients with operation history of THR in remote areas.

Conclusion

We invented a portable laser projector using the elliptical method for orthopedic surgeons to feasibly and conveniently measure postoperative acetabular anteversion. Our study reported the consistency and validity of this laser projector as there is no significant difference in both intra- and inter-observer reliability. Most importantly, we look forward to helping elevate clinical acumen when doctors provide care to patients after THR, especially in remote areas.

Declarations

Conflicts of interest

The authors have no conflicts of interest relevant to this article

Ethics approval and consent to participate

The above study has been approved by expedited review process of the TMU-Joint Institutional Review Board in meeting #108-10-3(TMU-JIRB No: N201910002, date:2019/10/22), duration of validity is from 2019/10/10 to 2020/10/09, and must be monitored by TMU-JIRB.

Waiver of informed consent was approved in the certificate of IRB approval (TMU-JIRB No: N201910002, Protocol version/Date: Version 1.4/20190912, Informed consent forms: Waiver of informed consent, Case report forms: Version 2/07 October 2019)

The certificate of IRB approval was provided in related files (English version in page 2).

All the work was performed in Shuang Ho Hospital, New Taipei City, Taiwan.

All methods were carried out in accordance with relevant guidelinesand regulations.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and analysed during the current study were listed in supplementary file

1. Elliversion measured data and Laser project measured data

2. Supplementary-file

Competing interests

The authors declare no competing interests

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Authors' contributions

CWC: Conception of the work, the acquisition of data, interpretation of data, drafting the work, and final approval of the version to be published.

TYW: Supervision of the research and final approval of the version to be published.

KYC: The acquisition of data and final approval of the version to be published.

PWW: Interpretation of data, revising draft critically for important intellectual content, and final approval of the version to be published.

YMH: The acquisition of data prepared figures 1- 2a/b and final approval of the version to be published

FHL: Interpretation of data and final approval of the version to be published

CKL: Design of the work and software, the acquisition of data, analysis, interpretation of data, revising draft critically for important intellectual content, and final approval of the version to be published.

All authors reviewed the manuscript

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Tables

Table 1

Intra-observer reliability

Mean	SD	Mean	SD	MD	95% CI	p-value
Laser A1		Laser A2		A1 versus A2		
15.49	5.92	15.24	5.95	0.25	[-0.10 to 0.61]	0.15
Laser B1		Laser B2		B1 versus B2		
15.58	5.79	15.39	5.97	0.18	[-0.05 to 0.42]	0.12
Laser A		Laser B		A versus B		
15.36	5.91	15.49	5.82	-0.12	[-0.52 to 0.27]	0.54

Abbreviation: SD, standard deviation; CI, confidence interval; Laser A1 represents the first measurement by the W.C.C; Laser A2 represents the second measurement by the W.C.C; Laser B1 represents the first measurement by the K.Y.C; Laser B2 represents the first measurement by the K.Y.C

Table 2

Inter-observer reliability

Elliversion		Laser		Elliversion versus Laser		
Mean	SD	Mean	SD	MD	95% CI	p-value
15.26	5.84	15.42	5.82	-0.17	[-0.38 to 0.04]	0.12

Abbreviation: SD, standard deviation; CI, confidence interval;

Figures

Figure 1

The portable laser projector that was used in the present study for the measurement of postoperative acetabular anteversion.

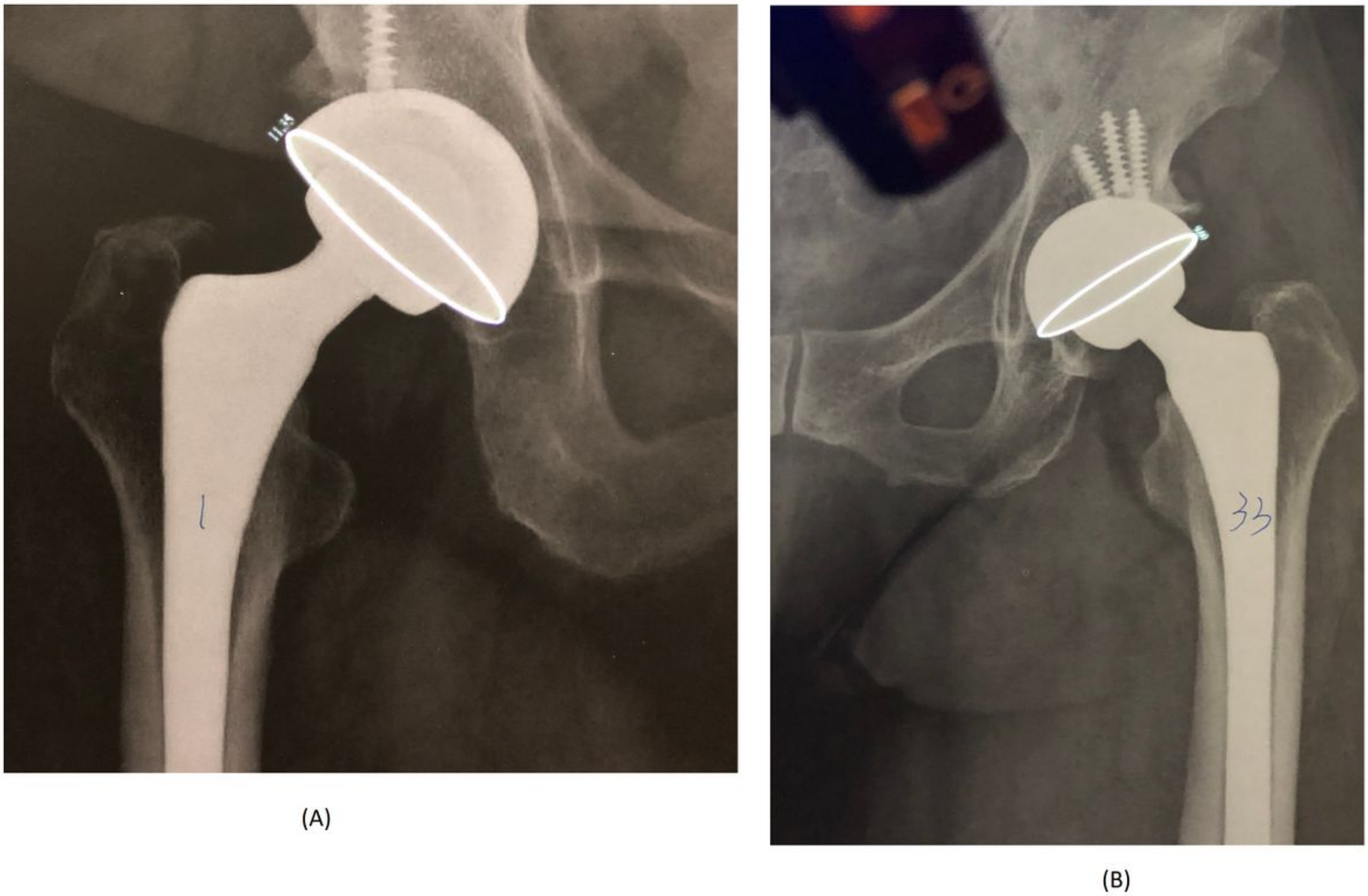

Figure 2

Post-operative radiographs of united total hip arthroplasty. Acetabular anteversion was measured using a portable laser projector. (A) A participant of right total hip arthroplasty with clear ellipse for measurement. (B) A participant of left total hip arthroplasty with a half of ellipse being obscured by femoral head, which is an example of poor-quality radiographs.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementaryfile.pdf