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OstAid: Digital Method for Preoperative Planning in High Tibial Osteotomy

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ABSTRACT

This Ostetotomy Aid was developed to help orthopaedic surgeons on digital preoperative planning specifically to define the center of rotation of angulation for osteotomy. The current problem facing by the surgeons is that even the radiograph use is in digital formats, but it only supports half the procedure required and the surgeons still need to complete other procedures manually. Therefore, new software will be developed to support all procedures digitally. This study will compare the mean of radiographic outcomes based on two weeks interval testing using the same data. Three raters are selected to test the current and the newly-developed software either by having the same or better results than the existing software in defining the center of rotation of angulation for osteotomy. Twenty-six digital radiographs from thirteen patients who underwent osteotomy with varus deformity were retrieved from Picture Archiving and Communications Systems at Universiti Kebangsaan Malaysia Medical Centre within 2016-2018. The result from the twenty-six images which used both software shows that there is no significance between them. It confirms that the results for correction angle using the new software were accepted and as good as the current software.

Key words: CORA; computer-aided; PACS, medical, image processing, x-ray, radiographic, 2D.

1. INTRODUCTION

High tibial osteotomy (HTO) is a surgical procedure that alters the weight-bearing axis of the lower extremity [1] on the sagittal plane. It is generally recommended for the moderately obese patient or for those who may have difficulty complying with weight-bearing restrictions [2]. While planning for high tibial osteotomy is crucial in achieving successful realignment [3], there are a lot research regarding preoperative planning before surgery such as for knee [4], [5], hip [6], ankle [7] and so on.

The current initiation in the medical industry to adopt the latest technologies sometimes encounter problems when the technology only supports some workforces at the hospital. Medical images as an example, which can be used to diagnose and analyze illness inside human body [8], [9] now are being transferred the printed radiographic image to digital. Medical image with DICOM (Digital Imaging and Communications in Medicine) format allows the integration of scanners, printers, workstations, servers and network hardware from multiple manufacturers [4]. However, they did not have the software that supports the manipulation process of the digital image. This causes the dedicated procedures back to the manual process.

Studies based on some of the available software in the market for osteotomy have been conducted in comparing the performed procedures. Software developers need to ensure that the system is reliable and user-friendly. It is important to enable the surgeon to make the right decisions about the design before performing surgery. The accuracy of the preoperative results can save time and can improve surgical procedure besides lowering the cost. Hence, new software needs to be developed to meet annual low patient demand.

2. RELATED WORKS

This paper discusses five software available in the market such as MedWeb which is currently being used in the hospital, Sectra, Adobe Photoshop which is an image-editing software, TraumaCad and MediCad. Since the demand for this software is low and the software price is too expensive, we propose to develop new software which can fulfil surgeons' requirement for preoperative planning.

2.1 MedWeb

MedWeb is a software that is in current execution at PPUKM. Figure 1 shows the interface. This software allows its users to measure the entire length of the patient's foot based on digital X-rays, displays the degrees of tibia tilt but it does not allow centre of rotations of angulations' (CORA) point determination and appropriate wedge selection planning [10].

2.2 Sectra

This is a software introduced by Sectra in Northern Ireland. It is used to mark, simulate corrections and establish a wedge angle for osteotomy correction. The software provides five guidance points: five steps used to determine the length of the foot (steps one and two), mark the resection line on the desired tibia (steps three and four) and simulate the selection of the wedge on the tibia (step five). Figure 2 shows the view.

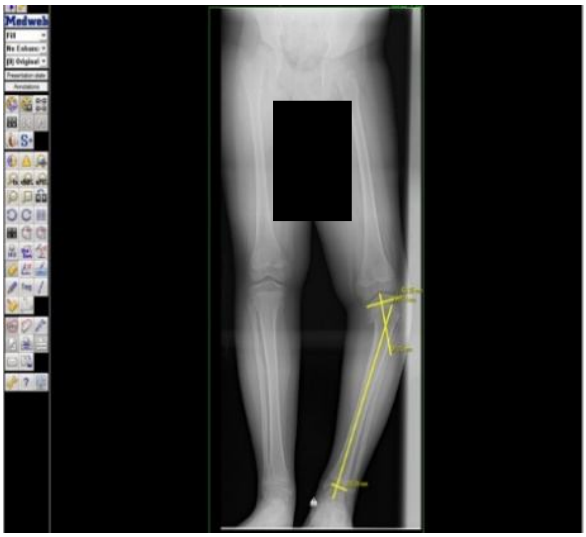

Figure 1: MedWeb Interface

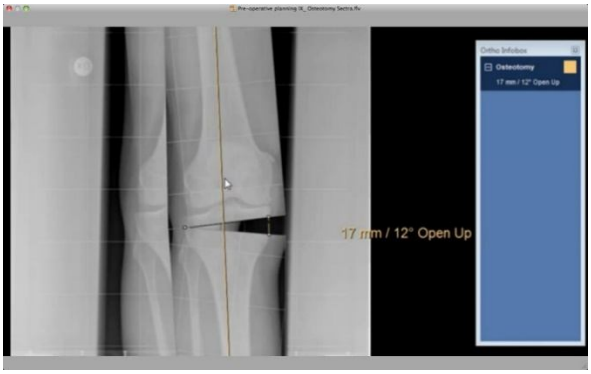

Figure 2: Sectra Interface

2.3 Adobe Photoshop

[11] discussed the advantages of using professional graphics editing software Adobe Photoshop 9 for osteotomy (see Figure 3). Reports from this study established that this software is capable of generating digital storage for project planning does not require multiple drawings and angles, is easy to copy for multiple planning purposes, easily compares pre-project planning and decision-making processes and able to display digital planning on a computer in the operating room.

2.4. TraumaCad

Austin Radiological Association in Israel introduced this software and used for pre-surgical planning in various areas of orthopaedic surgery such as joint replacement, treatment for fractures, limb defects in children and adults, spinal, foot and ankle surgery [12].

Patient management in pediatric orthopaedic surgery relies on radiographic interpretation and anatomical angular, and index skeletal measurements as an important addition to clinical examination. It has a customizable measurement tool template to measure osteotomy correction. This template can measure the length of a patient's foot, determine the CORA point, and visualize the correction [13]. Figure 4 shows the interface.

Figure 3: Adobe Photoshop interface

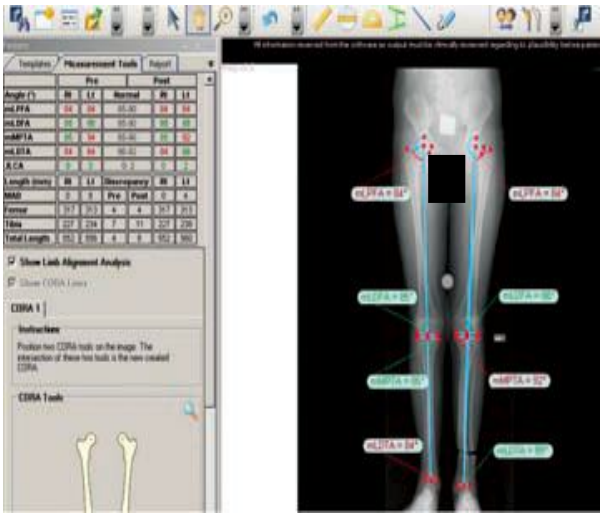

Figure 4: TraumaCad Interface

2.5. MediCad

Hectec GmbH located in Niederviehbach, Germany began their research in 1994 in search of digital solutions to help orthopaedic surgeons find reliable digital solutions and claimed to be the first in the world and recommended the name MediCad.

[14] used MediCad for computer-assisted analysis. It has features for analyzing alignment, joint orientation and leg length. It can automatically display the preview dimensions including relevant data (Hectec 2013). This software provides corrective suggestions based on the selection of lines made by software users. [15] presented a description of MediCad as shown in Figure 5.

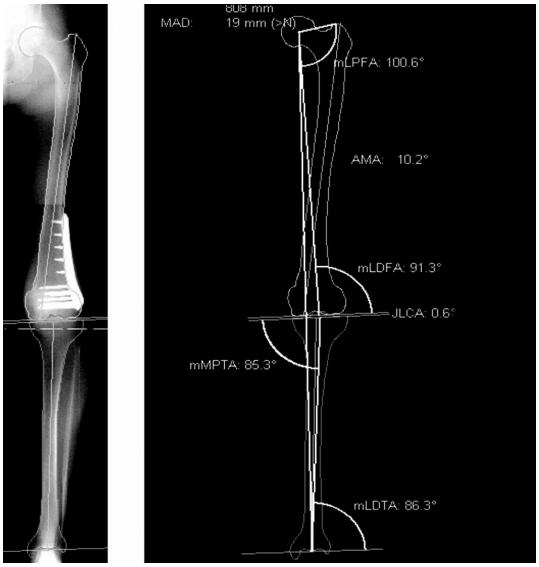

Figure 5: MediCad interface

2.6 Justification

MedWeb does not provide a proper location for the CORA's point. MedWeb also did not provide visual correction that results in the difficulty for the surgeons to evaluate and to anticipate the expected outcome. Sectra also have the same problem with MedWeb, that is not provide CORA's point and make it difficult to surgeon defining the location to cut the tibia. In Photoshop, researchers find it quite difficult to automatically record the angle of correction resulting in the necessary information needs to be entered manually into the image. While for TraumaCad and MediCad, this software are provided with computer navigation which costing too much and not affordable to development country to have them [16]. So based on these limitations, researcher aims to develop a new software that will fulfil those weaknesses.

3. PROPOSE SOFTWARE

As the current software (MedWeb) cannot display forecast result, surgeons find it difficult to visualize the final solution. Ostetotomy Aid (OstAid) was developed to enable the visualization. OstAid is a new software developed using MATLAB to enable surgeons to plan more efficiently and achieve more effective results. This proposed development software should be considered with the trend of the technology and long-term planning of the organization in order to be sustained in the software development industry. This phase discusses the general algorithm used to support the whole process and also the user interface (UI) functionality.

3.1 Algorithm

Figure 6 describes the process that should involve pre-operative planning for high tibial osteotomy. Images need to load from the driver. Marker-based on two T shapes was used to determine the intersection as well as the correction angle. The angle formed by the intersection of both markers determines the degree of correction required for realignment of the mechanical axis [17]. Those markers will be allocated at the top and the bottom tibia with both rotations can be made for each marker using arrow keys on the keyboard before confirming the angle produced. Based on the defined correction angle, new images will be displayed as planned.

1. Load image from the storage device
2. The medical image will display in the left box
3. Change brightness if necessary
4. Apply marker one
5. Rotate the marker based on the desired angle
6. Move the marker based on the desired location
7. Apply marker two
8. Rotate the marker based on the desired angle
9. Move the marker based on the desired location
10. Correction angle will display based on the intersection
11. Display the result of correction based on correction angle

Figure 6: Algorithm

3.2 User Interface Design

OstAid was developed using MATLAB while the interface was designed using Graphical User Interface Development Environment (GUIDE). Screen display, functional buttons and text fields were imported using the provided tools. MATLAB codes can be generated automatically or added as needed. The interface will be stored in *.fig format and will be called along with MATLAB code itself which is using *.m format file.

Figure 7 shows an example of an empty interface and Figure 8 shows the result of the interface that has been designed. The left box displays images obtained from PACS while the right box displays the image to be manipulated based on the decided correction angle. Figure 9 shows the example of the preoperative planning as conducted by the rater.

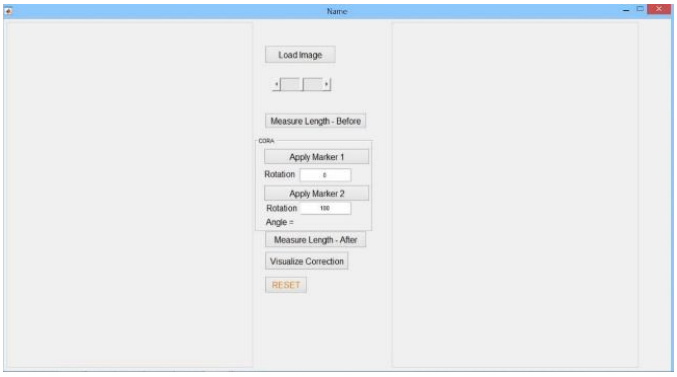

Figure 7: OstAid Interface

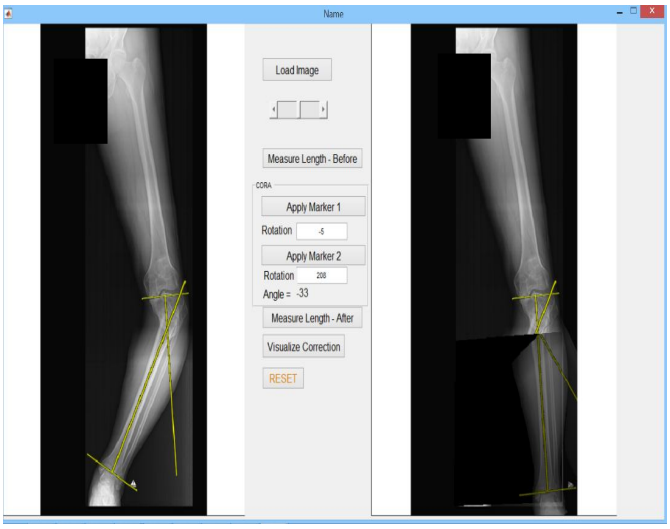

Figure 8: OstAid interface with the images

4. MATERIAL AND METHODS

After the development is complete, reliability testing was performed to ensure that the results obtained are the same or better than the current software. This study accessed medical images from PACS and did not involve patients directly. Thirteen patients who have already undergone high tibial osteotomy in Universiti Kebangsaan Malaysia Medical Centre (UKMMC) from 2016 to 2018 were included in this study. All had medial compartment arthritis with varus alignment. Long-leg weight-bearing radiographs were obtained for each patient. This method described by Davis has been modified for open wedge osteotomy and for application to digital images viewed using a PACS system. Images from PACS can be accessed and downloaded for manipulation.

Three raters from UKMMC who have direct involvement in osteotomy would be given the list of MRN to test the images from both software. The second round of observation was also performed within two weeks to generate mean values for comparison. For current software, raters need to access those images directly from PACS and measure the angles, while for the new system, raters need to access those images from storage. All raters will record the measurement angles in degrees for all images.

5. RESULT AND ANALYSIS

This part will discussed about results based on testing that has been done by three raters from Orthopaedic Department at UKMMC within two weeks interval.

5.1 Demographic Results

Table 1 shows a total of thirteen patients consisting of children and adolescents between the ages of two and sixteen had both leg defects and underwent osteotomy at UKMMC from 2016 to early 2018. All of these patients had osteotomy on both legs, so tests were performed on all the affected legs, making the total number of the tested tibia was 26. The gender of the patients was relatively balanced: 46 percent male and 54 percent female.

Table 1: Demographic Result

Item	Number
Patient	13
Tibia	
- Left	13
- Right	13
Patient Age	2-15
Sex	
- Male	6
- Female	7

5.2. Radiographic Results for correction angle

Based on the preoperative planning for high tibial osteotomy as shown in Table 2, there were no significant differences in mean correction angle between two weeks of interval testing (P=0.100 and P=0.433, respectively). Mean for Test 1 and Test 2 is slightly different with 0.6 with MedWeb and 0.36 with OstAid. There was no significant difference in the mean correction angle for both software.

Table 2: Correction angle's result

Parameter	Test 1	Test 2	Mean Difference *	*P*-Value
MedWeb	**18.50**	**19.10**	**0.60**	**0.100**
OstAid	**21.41**	**21.77**	**0.36**	**0.433**

* *(95% confidence interval)*

6. DISCUSSION

Computer graphics involve the representation of image data using a computer for the better understanding and interpretation of data [18], [19]. Preoperative planning for high tibial osteotomy is vital for the surgeon in planning the location for cutting the tibia, defining the angle and preview the forecast result. OstAid provided fast, precise, easy and reproducible results. OstAid also can provide and support the whole procedure for preoperative planning of high tibial osteotomy, which are from defining mechanical axes of the tibia, defining the CORA until the visualization of the forecast correction, where current software cannot supply the features for whole processes. This new software also was developed and can be maintenance in low cost only.

In this study, similar results were obtained between the two software, which means that new software also can provide the efficient result in determining CORA such as current software. This also proves that new software can be used as an option or a substitute for HTO benchmarking. Based on that, analysis done based on comparing mean (±SD) for first and second testing within two weeks. This study was motivated from a few studies that compare mean. An example, [20] comparing the mean for pre- and post-operative, as well as conventional versus navigated system, [21] also determined the accuracy of tibial-slope measurements, calculated as the mean differential between the two measurements, which are before and after.

7. CONCLUSION

In summary, there are no significant difference in the mean correction from both software. This supports the objective of the study stating that the results obtained from MedWeb are similar to OstAid, and this proves that OstAid software can be used for high tibial osteotomy prognosis planning purposes with user-friendly interface. In future, further detailed clinical studies will also be designed to ensure the reliability of this new software.

Ethics Preoperative planning is a routine practice. The activity of this study was equivalent to an audit of practice and so ethical approval was not sought.

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