A Comparative Study of Computer Aided System Preoperative Planning for High Tibial Osteotomy

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Abstract. We discuss five softwares commonly used for preoperative planning for high tibial osteotomy, namely MedWeb, TraumaCad, MediCad, Sectra and Photoshop. Each software has their own specialty and specification based on surgeon requirements. Detail of methods for each software is discussed. This paper aims to highlights the strength and weaknesses of the softwares. Our comparison shows that the selection of method to be used depends on the needs of the surgeon. The different software suitability discussed are axis used, users' control capability, automatic wedge selection, CORA's point, tibial slope, automatic measurement, and visualize correction. The results obtained from the comparative analysis are expected to aid in development innovative software for preoperative osteotomy planning, based on the strengths of each software discussed.

Keywords: Software · Preoperative planning · Tibial slope · Center of rotation of angulation (CORA) · Mechanical axis · Image dimension · Visualize correction

1 Introduction

Osteotomy is an operation performed by orthopaedic surgeon to correct bone deformity. It happens when the human long bones are bent toward (valgus) or away(varus) from the midline of the human body. The bones that are commonly operated upon to are tibia, femur abd humerus (Fig. 1) The goal of an osteotomy is to realign the mechanical axis of the affected limb by shifting the eccentric loading forces back to its mechanical axis alignment. Shifting the loading forces to its normal mechanical axis is an important factor in determining the long-term outcome for patients' satisfaction and relief [1]. This paper will only focuses on osteotomy of tibia, known as high tibial osteotomy or HTO.
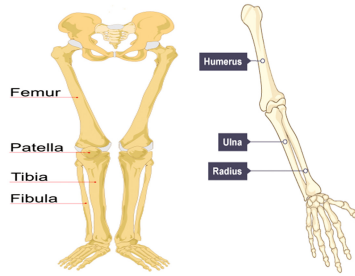
Fig. 1. Femur, tibia and humerus location

2 High Tibial Osteotomy

High tibial osteotomy (HTO) is one of the most reliable methods for the correction of proximal tibial deformity [2, 3]. This method has been used by surgeons all around the world in resolving tibia deformity where the tibia is sloping closer or away from the vertical plane of the human body. The deformity may occurs during childhood such as idiopathic tibia vara or due to malalignment following fracture malunion.

Manual pre-operative planning for HTO requires the surgeons to have a ruler, scissor, goniometer and the radiograph. As technology advances, many hospitals have changed their radiographic film to digital format. Hence, there is a need for software to handle the digital format.

Preoperative planning with computer aided process for HTO is an area where the technical design and development of human-computer interaction is a critical success factor. Careful preoperative planning for proximal tibial osteotomy is essential if the desired correction of alignment with long term satisfactory outcome is to be achieve [4, 5]. The existence of software that has a user-friendly interface and easy to meet surgeon's specific requirements will facilitate a quicker and more efficient preoperative planning.

3 Methods of Study

This study is based on previous literature acquired by researchers. Researchers decided to discuss further five softwares with namely MedWeb, TraumaCad, MediCad, Photoshop and Sectra. Detailed features were selected based on the needs of preoperative planning of high tibial osteotomy's routine such as the preparing of 2 and/or 3 dimension image, providing the mechanical or anatomical axis, how far users have control capability, selecting wedge, presenting CORA's point on the image, displaying degree angle tibial slope, calculating for femoral-tibia is automatic, visualizing correction and either they providing computer navigation or not. Details will discuss further in different topics.

4   Computer Aided for Preoperative Planning Osteotomy

Since radiographic film has been digitized, preoperative planning with computer aided for this was created for the purpose of replacing manual methods and speed up the work procedures with more efficient results. Some of the strengths and issues of this study will be discussed.
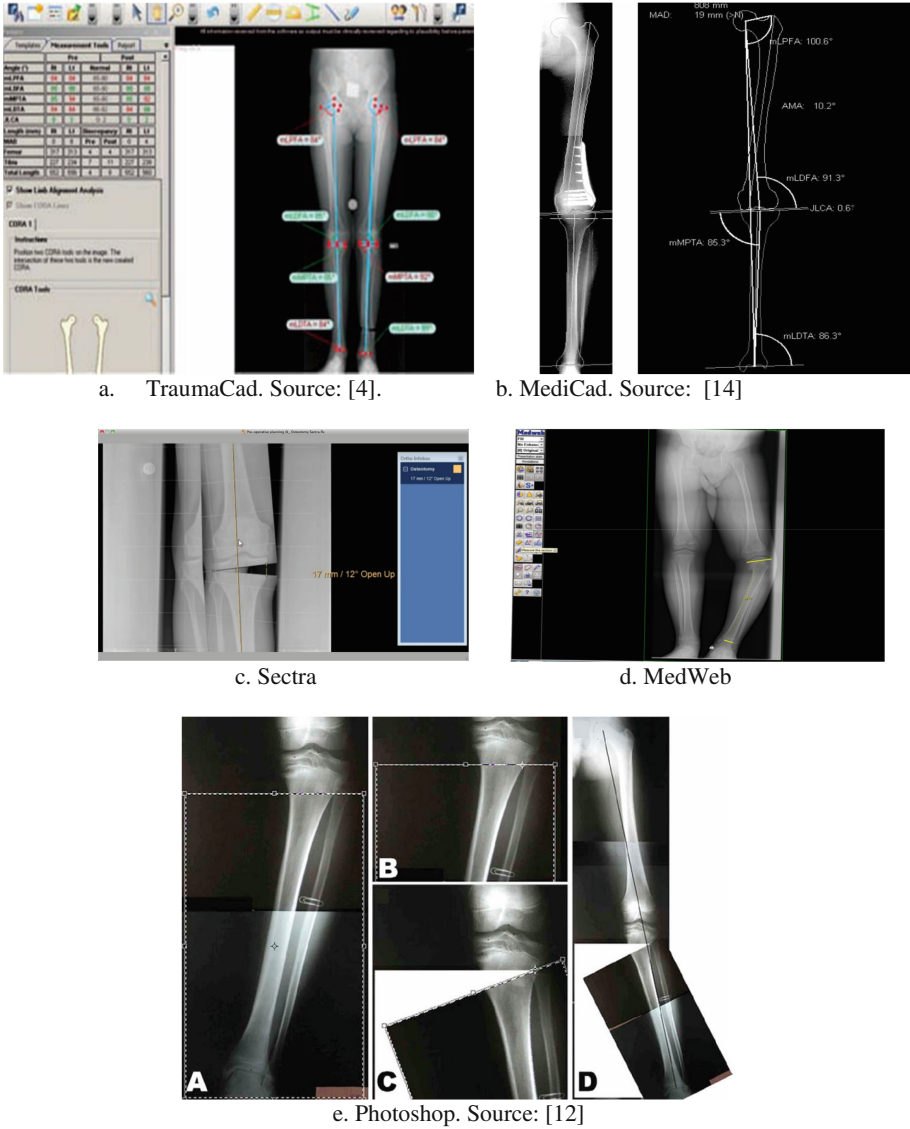
4.1   TraumaCad

Austin Radiological Association in Israel introduced TraumaCad. This software is used for preoperative planning in various areas of orthopedic surgery, such as joint replacement, treatment of fractures, limb deformities in a population of children and adults, spine surgery, foot and ankle [6]. Patient management in pediatric orthopedic surgery depends on the radiographs interpretation and anatomical frame size measurement, angle, and index as an important adjunct to clinical examination. This software has a template of variable measurement tool to measure the correction osteotomy. The template is capable in measuring the length of the patient's leg, the exact point of center of rotation of angulation (CORA), and also visualizes correction [7]. Figure 2(a) shows the interface of TraumaCad software.

This software is capable of reading three-dimensional medical images [8], loaded for the purpose of scaling and magnification of the image automatically [9], and is the standard approach with two sizes of deformity correction template for osteotomy [6]. Tests were made by [6] on 57 patients using first size, it produces an accuracy of 87 % while the testing on 65 patients using second size produces an accuracy of 96 %.

Whereas according to the study of [9], the median error expansion in two size groups is 1.14 % when calculated automatically. The median size of a single error is 5.98 %. Relationship between actual and forecast growth is stronger in the double marker with a very good relationship (r = 0.91). Reference [10] in their study stated that TraumaCad was useful in preoperative hip template where it successfully predicts the components of the prosthesis within ±1 size in most waist studied. However, it should not be used as an absolute measurement for the size of the prosthesis to be used. This software is usually provided together with computer navigation to enhance the process in intra-operative.

4.2   MediCad

References [11, 13] were using the MediCad which was introduced by Hectec GmbH, Niederviehbach, German for the computer-aided analysis. This software has features to analyze alignment, joint orientation and long legs. It can also display the preoperative dimension automatically including related data [14]. MediCad provide corrective recommendations based on the line selection. Figure 2(b) shows a MediCad software. MediCad also has the measurement template, which is able to read two-dimensional and three-dimensional medical image for osteotomy correction. This software is also provided together with computer navigation to enhance the process in intra-operative.

a.   TraumaCad. Source: [4].   b. MediCad. Source: [14]

c. Sectra   d. MedWeb

e. Photoshop. Source: [12]

Fig. 2. (a-e) Software interface as discussed.

4.3   Sectra

Sectra is the software, which was introduced by Sectra in Northern Ireland. This software is used to signify, simulate correction and creates a wedge angle for osteotomy correction. It provides five-point guides that will be used to determine the length of the foot (two-step), marking the resection line at the desired tibia (two steps), and simulate the selection of the wedge on the tibia (the fifth step). However, researcher found that

there was no CORA point displayed to guide the surgeon. Display of the software is shown in Fig. 2(c). Sectra also has specific guidelines for completing the preoperative planning process.

4.4 MedWeb

This software allows the user to measure the total length of the patient's leg on digital X-rays and shows the degree of the slope angle of the tibia, however the software does not allow determination of point of wedge center of rotation and angulation (CORA) and planning appropriate selection is made [15]. Figure 2(d) shows the interface of MedWeb.

4.5 Adobe Photoshop

Reference [12] discusses the advantages of using Adobe Photoshop 9, a professional graphics editing software for preoperative osteotomy. The study reported is that the software is able to create digital storage for preoperative planning, does require some line drawings and angle, easy to copy for the purpose of a few times planning but easy to compare between the process of preoperative planning and intraoperative decision, as well as it has the ability to display digital plan on the computer in the operating room. Nonetheless, researchers have found it quite difficult to record the angle correction automatically in which the required information must be entered manually in the image. Figure 2(e) shows the preoperative planning using Adobe Photoshop by [12].

5   Software Comparisons

See Table 1.

Table 1. Comparison for each software.

Item studied	TraumaCad	MediCad	Sectra	Medweb	Photoshop
Image dimension	2D&3D	2D&3D	2D&3D	2D	2D
Axis provided	Mechanical axis	Mechanical and anatomical axes	Mechanical axis	Not provided	Not provided
Template	Provide 2 size of deformity correction template for osteotomy	Provided 1 template only	Did not provide any template. However user are guided based on five click guide	Did not provide any template to user	Did not provide any template
Control capability	Based on the template given, user can freely modified the position of a part the template	Based on the template given, user can freely modified the position of a part the template	User defined based on guided steps provided	User are freely to define line and measurement	User are freely to define line and measurement
Wedge selection is automatic defined	This TraumaCad provide open wedge selection based on the Cora defined	Open wedge is automatic defined	Provide automatically selection for open and close wedge osteotomy	MedWeb did not provide any wedge selection	User is freely select and rotates the area for wedge
Cora's point is presented on the image	TraumaCad is automatically defined Cora. However, user are freely modify the location of Cora to	This software did provide Cora. User can freely determine base cut for rotational center	Did not provide point of Cora. Software automatically determines cut line and user need to define the straight anatomical axis of the leg	This MedWeb is not capable to display Cora	Did not provide point of Cora

(Continued)

Table 1. (*Continued*)

Item studied	TraumaCad	MediCad	Sectra	Medweb	Photoshop
Tibial slope	Automatically defined from the template provided. Proper planning is where the rotation display of the tibial slope is become 0°	Automatically defined from the template	Automatically defined from the small window provided in the same screen	Cannot be defined	Undefined
Calculation for femoral-tibia is automatic	The calculation is based on the template given or modification template	The calculation is based on the template given or modification template	Define based on 1st and 2nd guided click	Measurement is provided when the user determine the two points of femoral-tibia	Define by the user's clicks
Visualize correction	User need to define area to visualize correction	Automatically provide suggestion for open wedge osteotomy	Visualize correction based on 5th click which is the user need to click over and simulate the knee area on femoral tibia to simulate correction	Medweb did not provide any visualization of correction	Manually define by select the area for wedge, and manually rotate the area
Computer navigation provided	Yes	Yes	No	No	No

6 Discussion

The use of computed tomography (CT) for three dimension (3D) image is capable of producing clear and detailed images, but it will expose the patient to ionizing radiation at a relatively high dose [16], which is less suitable for children. Magnetic resonance imaging (MRI), which is said to produce similar quality images with CT, and has another advantage that is free of radiation, which is much safer for patients [17]. Nonetheless, the sedative should be given to the child in order for him to remain static until the completion of the imaging process. This is due to the range of time for as session is within an hour [18]. To that end, the researchers propose to use X-ray images using a two-dimensional (2D), offering advantages such as lower exposure dose per frame and a wider dynamic range [19].

Many established softwares are provided with axis to comfort users in planning process. However, it is not a big problems to expert users in determining the axes manually. Provision of software templates are very helpful in preoperative planning. Coupled with the convenience of auto-flexi, it really helps the surgeon to plan fast, precise, effective and more productive.

An Open or closed wedge osteotomies are the most commonly practiced. CORA is important in determining the angle of correction for tibial slope. While auto-visualise for corrective osteotomy is useful in helping surgeons in explaining to their patients on what happening before, during and after surgery. All these functions give advantages to the surgeon before performing the surgical correction. Computer navigation is a device which provided together with dedicated preoperative planning software, such as TraumaCad and MediCad. However, with the high cost compared to the number of patients per year, most hospitals in development countries cannot affort to buy this software.

The bones of each individual is unique and different from each other depending on gender, population, age, and body mass index (BMI) [20–23]. Reference [24] state that there is no way to be accurate and reliable in preoperative control towards the correction angle, the tibia slope, and the changes produced by osteotomy rotation. The tibia slope is not static and will constantly change from birth until a bone reach its maturity. This slope is also strongly influenced by differential among dominant or not of each person [25].

7 Conclusion

The study focuses in brief, five common softwares used for preoperative planning of an osteotomy. The comparison made was to study the different specification applied to implement preoperative planning for an osteotomy. The strength for the software will guide us to develop a better method, while the weaknesses will be avoided and overcome. Our future research will concentrate on the selection of the best method based on the preoperative planning for high tibial osteotomy.

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