Computer-aided Preoperative Planning of Corrective Wedge Diaphysar Osteotomies of the Tibia – Simulation Model –

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1. INTRODUCTION

John Rhea Barton is best known as the originator of the corrective osteotomy for joint ankylosis. Computed Axial Tomography (CT or CAT) and Magnetic Resonance Imaging (MRI), also known as Magnetic Resonance Tomography (MRT) scans were first used in the early 1970s. (1,2) There are several deformities that can be corrected by tibial osteotomy: genu valgum, commonly known as “knock knees”; genu varum, in which the legs are severely bowlegged; crus antecurvatum; post-traumatic genu recurvatum, post-traumatic genu valgum, tibia vara (morbus Blaun); knee arthrosis; post-traumatic deformities of the tibia.

(3) Tibia is a bone, its mechanical (and anatomical) axis runs from the center of knee to the center of ankle. Mechanical axis passes through the center of the head of the femur, the center of the knee joint and the center of the ankle. In the sagittal plane the normal mechanical axis runs just behind the femoral head (because the femoral neck is anteverted) and just in front of the knee: At the knee the tibial joint orientation line in the sagittal plane is sloped about 10° posterior. The tibial plafond at the ankle has an anterior slope. (4,5)

Every deformity can be quantified in the following terms:
- Magnitude (degrees)
- Level (s) = apex or CORA (centre of rotation of angulation)
- Plane (coronal, sagittal, oblique or transverse.)
- X-ray in two planes

Osteotomy preparation includes: Clinical examination, determining the axis, length of lower limbs and orientation angles around the knee joint. Whole lower extremity radiographs in the standing position. Planning of surgery by preoperative drawing (6,7)

I Manual preoperative planning. After radiography of the whole lower extremity anatomical and physiological axes are drawn. The contour of the lower extremities is transferred onto the tracing paper. Angle of correction is measured and wedge drawn. Wedge head is tilted under the angle of 90°. Virtual osteotomy is performed.

II Subsequent or simultaneous planning can be realized as manual planning and elements of computer programming guidance can be entered, using universal type distraction-compression devices. (e.g. Ilizarov) (9)

III Computer-aided (PC) preoperative planning. It uses software programmes suitable for transforming bone image in the structure required for further mathematical processing. (10, 11)

2. GOAL OF RESEARCH

The goal of research for tibial deformities is to determine the exact osteotomy site, size of the wedge in the diaphyseal segment of tibia in the 2D simulation model with the discrepancy of the set parameters between the two studied methods, by means of manual and computer-aided planning of tibial osteotomy.

3. MATERIALS AND METHODS

First series – method I Thirty (30) preoperative drawings with different x-ray deformities of tibia diaphysis where preoperative manual planning is made on the tracing paper by the known methodology. Second series – method III Thirty (30) preoperative drawings of the same x-ray deformities for corrective osteotomy.

Tibia diaphysis, computer-processed – PC-programmed (MATLAB 6.5 version software). Research carried out by University of Sarajevo Clinical Centre Clinic for
Orthopaedics and Traumatology. Personal computer and scanner were used. MATLAB 6.5 version software was used for generating algorithm code, that is the basis of simulation model. It was also used for transforming bone image in the structure required for further mathematical processing.

4. RESULTS
For both studied methods, we established the following:
• discrepancy of correction angles in the AP and lateral planes in both series of preoperative drawings;
• resection site in the AP and lateral planes in both series of preoperative drawings;
• accuracy of cutting wedge, and postoperative axes of extremities in two planes (residual angularization of deformity, bone length)
• accuracy of both methods under all set parameters, inflection (H2 test, p)

5. DISCUSSION
Comparing own results in the correction of deformities it is visible that the significance of one method compared to the other is 5%, that is there is a minimum error. This is identical to the results of other authors, where the in vitro evaluation with a plastic bone model suggests that the error of deformity correction is less than 1.7 degrees in the frontal, and less than 2.3 degrees in the sagittal plane, respectively or Fujisawa in 80.7% (range 77.5-85.8%) and so on. (Kepler P. et al 2004.) (12, 13)

Analyzing and checking original Matlab version 6.5 software it is noticeable that not a minimum inflection was recorded at inserting fiducial marker which is anticipated in using the existing PC auxiliary surgical systems, primarily in using CT technique and correction of deformities in several planes (Phillips et al 2000) (14)

The studied groups and the application of simulation techniques used for osteotomies have not taken into consideration a fixation type, and loss of bone, being often the primary problem implying poor clinical results. (15) (Herniougu et al 1987, Odenbring et al 1991, Convetry et al 1993.)

Malcorrections are also possible subsequently and can escalate bone loss (Ivarsson and Larson 1989, maniaci et al 1989. Yasuda et al. 1992. Zuegel et al 1996.) Since this was not a set aim of research and since our future attention should be given to correlative parameters such as fixation type osteotomy site, multiplanar deformities, primary and/or subsequent bone loss where preoperative 3D PC preparatory techniques would be used, pointing to the consistency and predictability of surgical results. (Lotwin RS et al 1993, Ellis re et al 1999). Working on the MATLAB 6.5 version we noticed that in addition to the presented method of corrective osteotomy, we can carry out its alteration based on the optimum reduction in bone tilting, observing purely geometric parameters. (16, 17)

6. CONCLUSIONS
• Manual method of preoperative radiographic planning cannot be discarded as significance of this method compared with the other is 5% in the given parameters
  - Wedge base-to-apex distance
  - Lengthening after cutting of the wedge (AP, LL)
  - Numerical values – angles in the AP and lateral planes.
Interval of reliability of finding mean value of difference of angles is minimal for the two studied methods.

In manual preoperative planning, there is a minimum residual angulation after cutting of the wedge. There is no residual angulation in computer-aided, PC planning.

By computer-aided, PC preoperative planning we achieve the following:
- Retaining of ideal biomechanics
- Origin of possible poor results and complications is distinguished, since software can be used as Windows on the plain computer;
- Preoperative analysis and simulation of correction can be entered and stored into database, so there is a possibility of analysis and consultation with other specialized centers through the Internet;
- In case of bilateral osteotomies extremely important are data of previous osteotomies, which are stored and serve as basis for new corrective procedures;
- Introduction to the 3D preoperative planning;
- Postoperative control of results will be objective and detailed for corrective tibial osteotomies, contribution beyond the a.m. is expected. Multiple simulations will facilitate other surgeries as well, such as improving osteosynthesis technique, precise determination of fracture site, transplantates and so on;
- Since computer method is faster and simpler, it would replace the manual method;
- Shorter preoperative preparation;
- Preoperative planning requires multidisciplinary approach, modern computer equipment and educated personnel in the field of medical informatics;
- In addition to the medical advantage, the material profitability is also obvious.

REFERENCES

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