The Use of 3D MRI Technology in the Evaluation of the Growth Plates of the Knee and Ankle

A. Stephen[a,b], R.J. Abboud[b], B. Ewing[d], B. Oliver[c] and S. Black[a]

Introduction

Throughout life, the human body continues to develop and adapt to an ever-changing environment. The influential growth spurt at puberty causes particularly widespread alteration to the longitudinal and circumferential expansion of bone, although little detail is known about the effect that the surge of hormones has on the growth plate. The epiphyseal plate (also known as the growth plate) is a specialised, discoid junction found in long bones and is depicted in **Figure 1**.

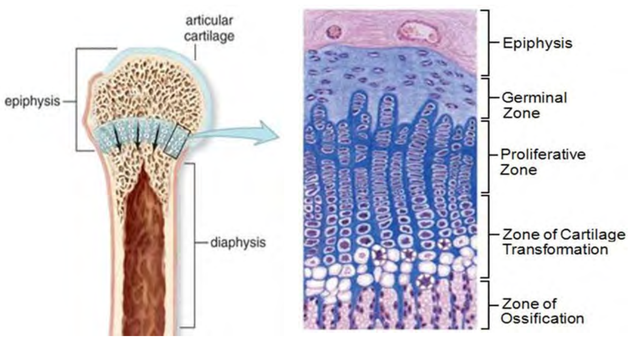


Figure 1 – The epiphyseal plate is the cartilaginous 'growing' area of long bone which consists of four conceptual zones (modified from McGraw-Hill (2010)).

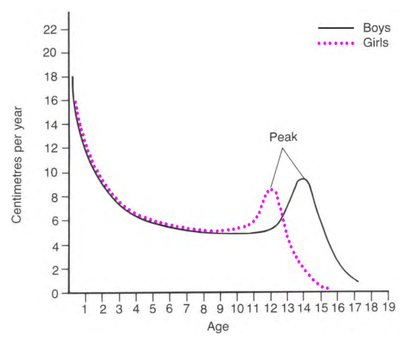


Figure 2 – The pubertal growth spurt is more precocious in girls, however, boys attain a greater peak (modified from Tanner *et al*., 1996).

During this time of peak growth, as displayed in **Figure 2**, the epiphyseal plate is already 2-5 times weaker than the surrounding skeletal structures and it is unclear whether significant shape or volume differences occur during this time of accelerated growth. The consequence of such structural changes may influence the ability of the growth plate to recover if injured through trauma; therefore the importance of being able to visualise the extent of damage is invaluable to clinicians. If the development of bone is inhibited, partial growth arrest could lead to long-term detrimental health risks which would require surgical treatment and this is dependent on the ability to define the precise area, location and appearance of the disrupted region.

Aim

To visualise the morphological nature and calculate the volume of epiphyseal plates from magnetic resonance imaging (MRI) scans.

Method and Materials

Twenty adolescent boys approaching the optimal age for the onset of the peak growth spurt (12-14 years), volunteered to have Dual Echo Steady State (DESS) scans of their dominant knee and ankle in a Magnetom Avanto MRI scanner (Siemens, Erlangen, Germany).

Previous studies in the literature (Craig *et al*., 2004; Sailhan *et al*., 2004) have noted the clinical importance of being able to discern the extent of ossified bridges of bone which highlight the disrupted region of longitudinal growth as in **Figure 3**. OsiriX© Imaging software is the only platform which is readily accessible and free to use in comparison to alternative workstations that are exceptionally expensive to license and install.

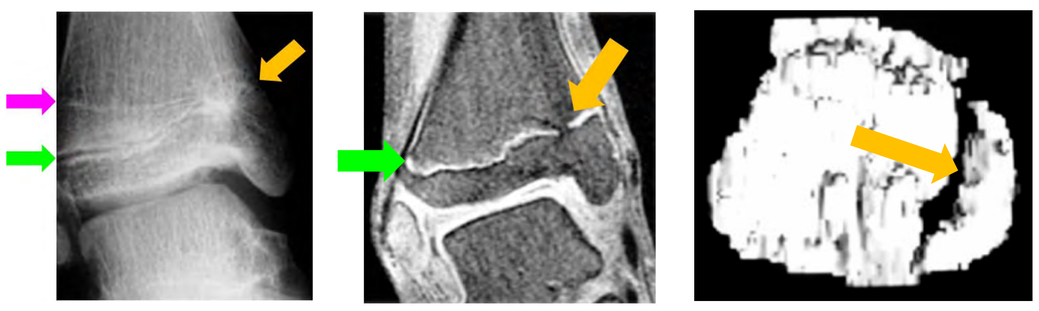


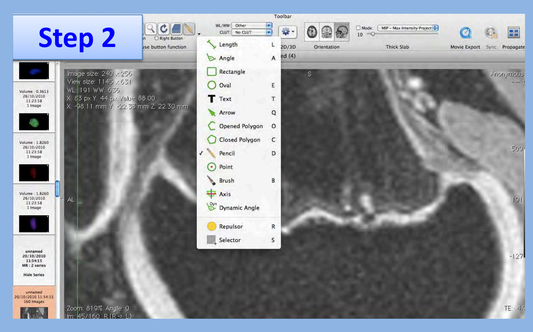
Figure 3 –This case is adapted from Sailhan *et al.* (2004) who reported a case of a 12 year old girl with 15° varus in her ankle and a distal tibial bony bridge (orange arrow) and a harris line (pink arrow). The radiograph on the left is not as detailed with regard to the growth plate (green arrow) as the MRI shown in the middle and by implementing the paintbrush tool in the Advantage workstation, the resultant 3D reconstruction of the tibia reveals the apparent osseous bridge causing partial physeal growth arrest.

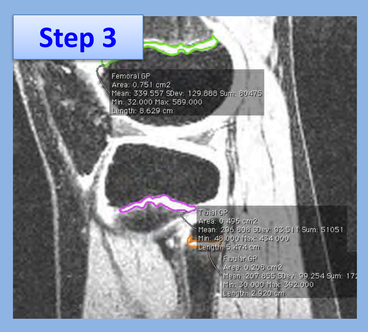
Step 1 The resultant 160 slice DICOM (Digital Imaging & Communications in Medicine) images are opened using OsiriX©.

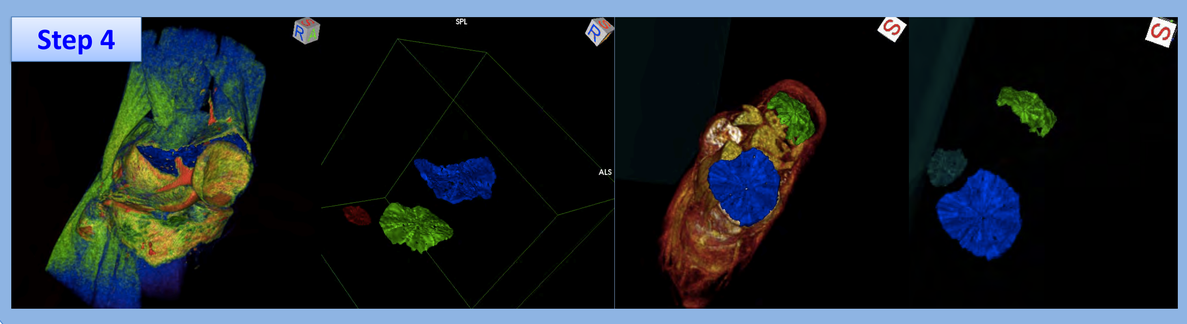
Step 2 The borders of each growth plate are discerned and outlined using the 'paintbrush' tool in the coronal view.

Step 3 All desired regions of interest (ROI) are labeled on each slice.

Step 4 3-dimensional reconstruction of the data permits visualisation of the morphology of the growth plates in addition to calculating the respective volumes.







Results

OsiriX© can be implemented to permit visualisation of the epiphyseal plates in 3D as well as calculate the respective volumes. The functional capabilities are numerous and although volumes are generated from the specified regions of interest, **Figure 4** demonstrates the importance of applying the correct reconstruction filter. In the case of visualising the undulating surface of a distal tibial growth plate, the power crust filter is essential for morphological accuracy when compared with the delaunay filter.

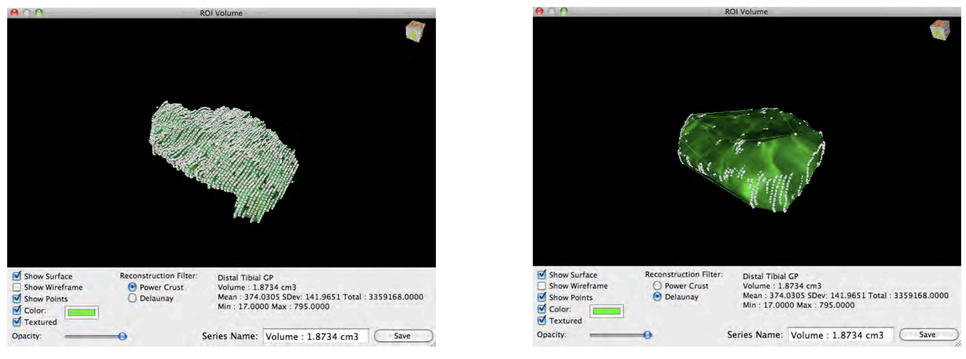


Figure 4 – Screen shots of the volume calculation of the same distal tibial growth plate. The left demonstrates a reconstruction using the Power Crust Filter and the right depicts the Delaunay Filter, which obscures the finer morphological details vital to interpreting the undulating surface of .

Conclusion

OsiriX© is a free, open source software package that has the additional advantageous ability to access and review MRI DICOM files using mobile devices (e.g. iPhone or iPad) which could significantly aid in the communication between practitioners and clinicians. **Figure 5** displays an easy to create, interactive, surface rendered view of the knee that can be exported as a movie.

Advanced, non-invasive imaging techniques may enable us to prevent possible long-term health risks following trauma of the growth plate by providing a better understanding as to how growing bones adapt to changing lifestyles and the influential advancement of surgical techniques.

Figure 5 – 3D surface rendered reconstruction of the knee.

a Centre for Anatomy & Human Identification (CAHID), University of Dundee, DD1 5EH.
b Institute of Motion Analysis & Research (IMAR), TORT Centre Ninewells Hospital & Medical School, Dundee, DD1 9SY.
c Tayside NHS Hospitals, Radiology Department, Ninewells Hospital and Medical School, Dundee, DD1 9SY.
d Institute of Sport & Exercise (ISE), University of Dundee, DD1 4HN.

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