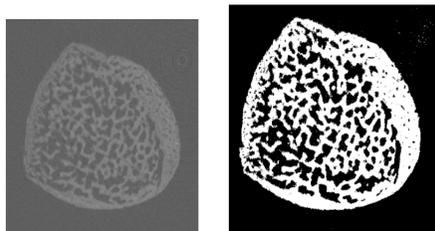


The use of medical imaging technologies such as computed tomography are becoming increasingly common in forensic investigations and can be employed in post-mortem analysis to facilitate a non-invasive assessment of the body. More specifically, micro-computed tomography (μ CT) has been investigated as a non-destructive alternative to histological sampling, which can enable microscopic visualization of bone without the requirement for expensive and time consuming sample preparation and processing. Moreover, μ CT can provide a full 3D visual representation of the specimen scanned. However, poor image quality can prevent a true reflection of the internal structure of a bone thus compromising its analysis. Due to the paucity of quantitative research regarding digital noise reducing techniques, this study aims to investigate the effectiveness of some of the algorithms the computer program ImageJ offers with regard to reducing noise in high-resolution micro-computed tomography (μ CT) scans.

Materials

- μ CT scans of the right ischia of 4 neonates from the Scheuer Collection, CAHID, University of Dundee
- Open source software ImageJ
- Plug-in 'BoneJ'



Methods

STEP 1: Image stacks were calibrated to reflect scanning resolution and datasets were binarised

STEP 2: Two regions of trabecular bone were selected for analysis from each specimen one in the inferior region and one in the superior portion of the ischium.

STEP 3: **Median, Minimum, Maximum, Open+Close, Erode+Dilate** and **Remove Outliers** algorithms were applied to each of the specimens.

STEP 4: Using BoneJ, trabecular parameters including Bone Volume Fraction, Trabecular Thickness, Trabecular Separation, Structural Model Index and Degree of Anisotropy were calculated before and after the application of each of the filters.

STEP 5: A statistical evaluation of the parameters calculated against a control sample carried out using the program SigmaPlot.

Results

Qualitative observation of the changes induced by the algorithms relative to the control (Figure 1 – 6)



Figure 1 shows the changes Median algorithm (right) performed on the control image sequence (left).



Figure 2 allows for the comparison between the control dataset (left) and the images after Minimum algorithm was applied (right).



Figure 3 highlights the differences between the control image stacks (left) and the alteration produced by Maximum algorithm (right).



Figure 4 is a representation of the control dataset (left) and the effects algorithms Open and Close created on the image stacks.



Figure 5 presents the control image sample (left) and the same sample after Erode filter followed by Dilate were applied (right).

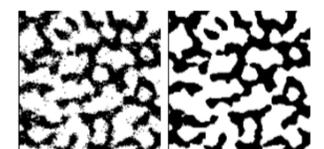


Figure 6 displays the appearance of the datasets used as control (left) and how Remove Outliers filter altered it (right).

Quantitative Analysis – Changes observed in the parameters after the application of the algorithms (Table 1)

| | Bone Volume Fraction | Trabecular Thickness | Trabecular Separation | Structural Model Index | Degree of Anisotropy |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Desired Changes | Little to no change | Increase (Significant) | Increase (Significant) | Decrease (Significant) | Increase |
| Median | Little to no change | Increase (Significant) | Increase (Significant) | Decrease | Increase (Significant) |
| Minimum | Increase | Decrease (Significant) | Decrease (Significant) | Increase | Increase & Decrease |
| Maximum | Increase (Significant) | Increase (Significant) | Decrease | Decrease (Significant) | Increase & Decrease |
| Open+Close | Little to no change | Increase (Significant) | Decrease | Decrease | Increase |
| Erode+Dilate | Decrease | Increase (Significant) | Increase | Decrease (Significant) | Increase & Decrease |
| Remove Outliers | Little to no change | Increase (Significant) | Decrease (Significant) | Increase | Increase (Significant) |

Table 1 shows the trend of the changes observed in the parameters studied and the effects the algorithms had on the control sample.

Discussion

- The median algorithm appears to be the most successful algorithm in terms of noise reduction as it has the least influence on trabecular bone parameters. The use of the Median algorithm as a successful noise reductive algorithm has been implemented before (Pontzer et al., 2006; Cooper et al., 2007), which supports the findings obtained from this study.
- Minimum and Maximum algorithms affected the control dataset quite notably. These two filters appear to have failed to reduce the amount of noise pixels in the images. Therefore, they would not be recommended for the purpose of digital image noise reduction.
- Open+Close are a combination of Erode and Dilate filters, so there is no surprise in having obtained similar results in the two datasets. The only difference detected was in the SMI values: both algorithms succeeded in causing a decrease of the index value, but only changes applied by the single application of Erode and Dilate (Erode+Dilate) produced a statistically significant change. Taking into account the changes observed, the use of these two filters is not advisable.
- Remove Outliers induced changes for most parameters, thus it doesn't appear to be suitable when attempting to enhance image quality by noise reduction.

Conclusion

The quantitative analysis of the trabecular bone distribution following the application of algorithms demonstrated that the best-suited filter for noise reduction is Median. The results obtained show that it was possible to improve the quality of the image by reducing noise pixels.

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