Segmentation of trabecular jaw bone on CBCT and µCT datasets

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Aims

The term bone quality is used often in a dentomaxillofacial context. It needs to be assessed prior to implant placement, or in the evaluation of disease processes. Nevertheless a clear definition of bone quality is lacking (Ribeiro-Rotta et al 2010). A quantitative evaluation can be done with histomorphometry. This evaluation, however, strongly depends on segmentation performance. The aim of this research was twofold: 1) to compare segmentation performance of 9 CBCT systems, using µCT images as the ground truth; 2) to compare morphometry using global and adaptive segmentation (Burghardt et al 2007).

Method

Four human formalin-fixed jaws including soft tissues were scanned with 9 different CBCT devices at clinical settings and with Skyscan 1173. The CBCT devices were 3D Accuitomo 80 (Morita, Japan), Galileos (Sirona, Germany), I-Cat (ISI, USA), Illuma (3M, USA), Newtom (QR, Italy), Picasso-trio (E-Woo, Korea), Promax 3D (Planmeca, Finland), 3D Scanora (Soredex, Finland), Skyview (MyRay, Italy).
Registration was performed in a Maximum Mutual Information sense, which is fully automatic and well suited for dental CBCT datasets, of which the pixel (voxel) values have not yet been calibrated in a standardized manner. In this procedure, linear interpolation is applied when necessary. The computational streamline was implemented by C++ programming with the ITK software tool (www.itk.org) of the National Library of Medicine. Image sets from all scanners for each sample were co-registered under a universal voxel resolution of 0.2 x 0.2 x 0.2 mm^3, which is assumedly sufficient for comparative quality evaluation.
In CT-analyser, a region of interest for each jaw was chosen. This region was selected to contain trabecular bone only and in a continuous way. Because of the pre-processing, the regions for all scans were identical. The regions of interest were segmented for each scan, first using global thresholding, second based on adaptive thresholding.
All binary images were then analyzed for the following morphological 3D parameters: %BV, BS, iS, TbTh, TbSp and TbN. For each of the devices, these morphological parameters were compared to the parameters extracted from the µCT images. Furthermore, overlap between the VOI of all CBCT images and the VOI on µCT was calculated.

Results

Based on the mean morphometry results for each scanner over the different regions of interest, the overall percentage error was calculated, compared to the Skyscan results. This overall error, together with the percentage error in overlap, is shown in table 1.

Table 1: Overall percentage error and overlap error for CBCT vs. µCT using global thresholding.

Device	Overal %error	Overlap %error
Accuitomo	35.9	29.3
Galileos	30.7	26.6
i-Cat	37.4	29.5
Illuma	44.7	33.7
Newtom	39.6	30.0
Picasso	30.2	23.8
Promax	39.1	35.1
Scanora	11.9	24.2
Skyview	74.8	39.0

We compared the percentage error from the ground truth (Skyscan) for global and adaptive segmentation. The result is shown in table 2.

Table 2: Overall percentage error for CBCT vs. µCT using global and adaptive thresholding.

	Rms error	
Device	Global	Adaptive
Accuitomo		30.0
Galileos	75.1	28.0
i-Cat	77.7	33.5
Illuma	75.7	34.7
Newtom		39.2
Picasso	81.2	25.6
Promax	81.4	26.0
Scanora	86.0	22.0
Skyview	73.1	42.2

Based on the overlap results from the adaptive thresholding technique, we constructed the following graph (Figure 1).

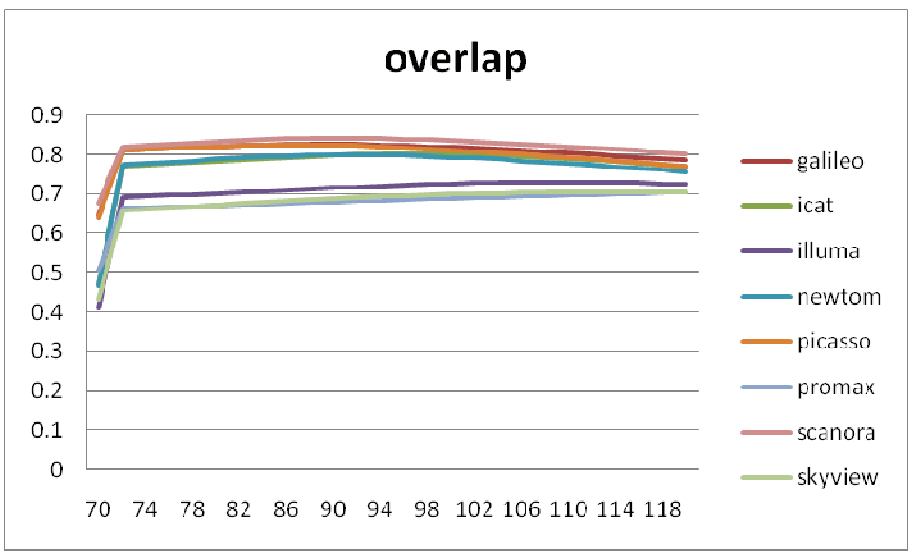

Figure 1: Overlap of CBCT scans with µCT ground truth after adaptive thresholding.

As such, a classification of CBCT scanner performance could be made. This classification could be compared to the subjective perception of the images. Below, 2 examples of a well and less performing CBCT device are depicted (Figure 2).

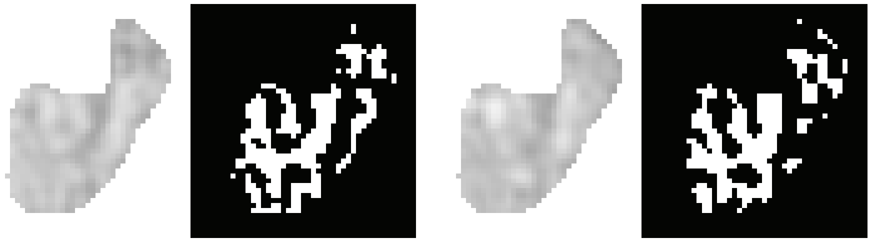

Figure 2: Good segmentation ability (L) and worse segmentation ability (R), as calculated by overlap

Conclusions

We have analyzed and compared the trabecular structure of several skulls scanned with dental CBCT, using µCT images as the ground truth. As such, we were able to quantify the segmentation accuracy of the different devices under evaluation. We found the parameter of overlap to be the most robust parameter to compare devices. This parameter was least influenced by the choice of threshold value for bone.

In the comparison of global and adaptive thresholding, we found the adaptive technique to be less sensitive to the threshold value. In addition, the adaptive technique resulted in segmentations closer to the ground truth. Therefore, we concluded that adaptive thresholding was a large improvement over global thresholding in jaw bone images made with dental CBCT.

Based on the overlap of CBCT images with µCT images, a ranking could be made between the scanners, that had great similarity with the intuitive classification of an observer. In a later stage, this intuitive classification will be compared in a systematic manner to the quantitative analysis through CT-analyser.

References:

1. Ribeiro-Rotta RF, Lindh C, Pereira AC, Rohlin M. "Ambiguity in bone tissue characteristics as presented in studies on dental implant planning and placement: a systematic review. Clin Oral Implants Res, e-pub ahead of print, 2010
2. Burghardt AJ, Kazakia GJ, Majumdar S. "A local adaptive threshold strategy for high resolution peripheral quantitative computed tomography of trabecular bone. Annals of Biomedical Engineering, 35, 1678-1686, 2007