In this issue:
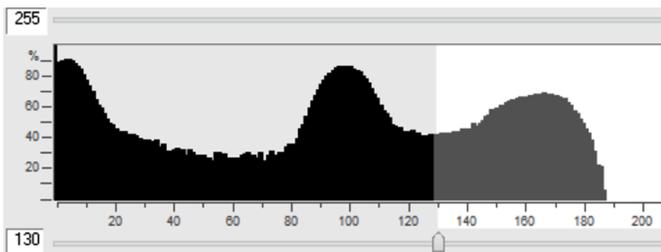- Segmentation of enamel and dentine
- Root canal segmentation
- Insertion of molar roots into the mandible
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● Welcome

Dental research employs microCT for a range of morphometric analyses of dental and associated bone tissues. This issue we will outline some essential microCT 3D analysis techniques for dental research. Teeth and their attachment in the jaw bone (mandible, maxilla) provide a complex morphology and well defined density phases – enamel, dentine (bone) and root canal.

● Segmentation of enamel and dentine

Enamel as the highest density material is straightforward to segment. A typical attenuation histogram of a tooth in the crown region (*figure 1*) shows the clear separation of the peaks corresponding to dentine and enamel (lower and higher greyscale respectively). Note that greyscale is an arbitrary number correlating with reconstructed attenuation coefficient, which relates to the x-ray opacity of the scanned material.


Figure 1. Attenuation histogram of a tooth crown shows clear peaks of enamel (right, highest density) and dentine, greyscale about 100. The furthest left peak is the low density ambient background (y axis in log scale).

Segmentation of enamel is therefore simply selection of the highest attenuation part of the histogram, in this case with a global threshold of greyscale 130. The resulting segmented enamel is shown as red in *figure 2*.
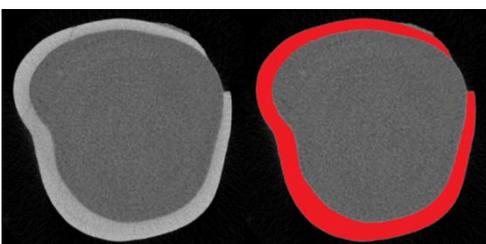
Figure 2. Enamel as the highest density material is simple to segment with a global threshold.

It is more complex to segment dentine, significantly less dense than enamel. Figure 3 shows the result of applying a global threshold (70-130) to segment a material of intermediate density, that is, where material is present in the cross-section of both higher and lower density than the selected greyscale range.
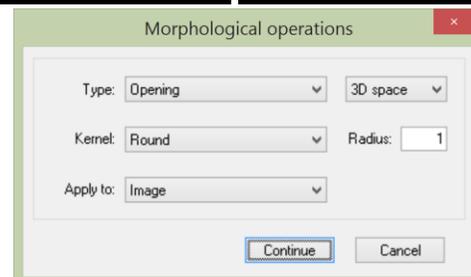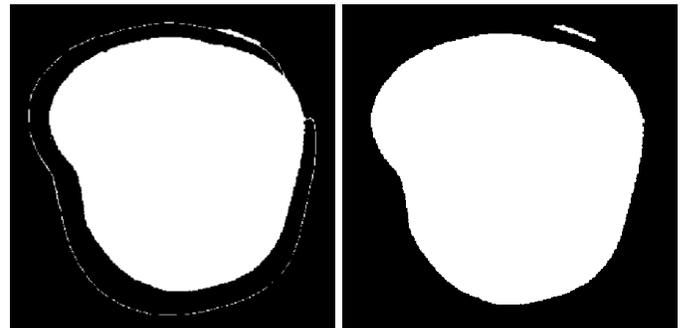
Figure 3. A "halo" always forms around high density materials (e.g. enamel) when an intermediate density material (dentine) is segmented, due to surface attenuation gradient (above left). A morphological opening procedure (below) can selectively remove such thin artefacts (above right).

The "halo" of binarised pixels at the boundary of the high density enamel is the inevitable artefact of the gradient of intensity from enamel to the ambient surroundings. The morphological operation "opening", which is erosion

followed by dilation, effectively removes any binarised object with thickness equal to or less than twice the opening pixel radius. In this case since no part of the object (dentine) is thin, opening deletes the enamel surface artefact without affecting the binarised image of dentine. When intermediate density objects are of more complex structure with thin components, such morphological operations should be done with care, to minimize artificial change to the analyzed structures

- Root canal segmentation

The root canal is a type of porosity, a low density space in the middle of the tooth that is of considerable interest – especially to endodontists. Ambient spaces can be binarised by threshold 0-70, but how do you separate the root canal from the surrounding space?

There are several ways to do this in CTAn custom processing, such as to first make a shrink-wrapped ROI then exclude the non-ROI space. However a simpler way to do this is to use one of the options in the "Despeckle" plugin called "remove outer objects". If white binarised objects are present both inside and outside an ambient (pore) black space, this function will remove the outer part. Note that this is run in 2D. In this case, shown in figure 4, the binarised outer space is removed leaving only the root canals and some disconnected artefact objects, which are easy to remove by another despeckle (3D sweep) operation ("remove all except the largest object").
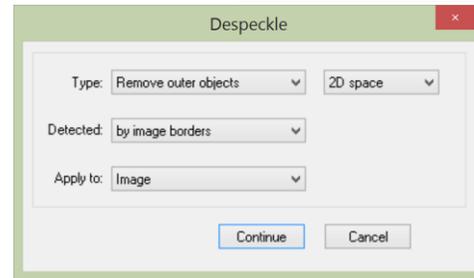

Figure 4. Inverse binarisation (above left) segments both the root canal and the surrounding space; the despeckle / "remove outer objects" operation removes the surrounding space, leaving the porous spaces only such as the root canal

The result of these three procedures outlined for binarising respectively the enamel, dentine and root canals, is a separate and accurate segmentation of all three phases of the tooth, allowing both quantitative analysis and visualization, as shown in *figure 5*.
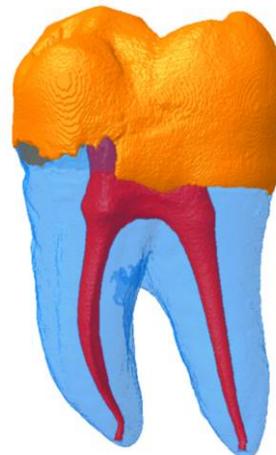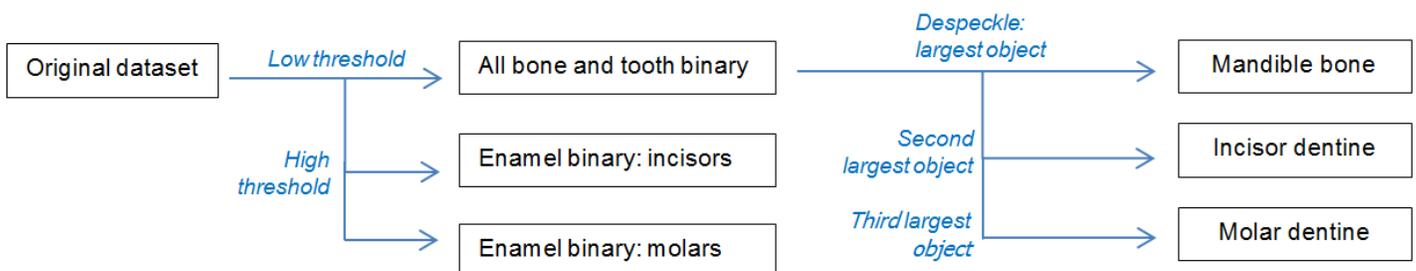

Figure 5. Surface rendered image of 3D models of enamel, dentine and the root canals of a molar tooth, displayed in CT-Volume.

Innovation with Integrity

- **Insertion of molar roots into the mandible**

The rat or mouse mandible and molar teeth are important in a number of research models in periodontics and other dental related fields. Here once again, the range of segmentation and image processing tools in CTAn (especially in custom processing) allow the automatic delineation and separation of the essential components – enamel from dentine and bone, and molars (including roots) from adjacent mandibular / maxillary bone. In this case, as with the human molar, global thresholding will separate enamel from dentine (with opening to remove edge artefacts). An important feature of the molar teeth is the periodontal ligament separating the molar roots from the neighboring alveolar bone. Thus in scans of sufficient resolution and quality, the molars plus roots represent a distinct binarised object and can be separated from mandible bone using the despeckle plugin (sweep option). These straightforward steps to separate the incisor and molar teeth from the jaw bone are illustrated in the following flow chart and in *figure 6*.

Figure 6. Surface rendered models of the rat mandible, and molar and incisor dentine and enamel (CT-Volume).

Both figures 5 and 6 show multiple surface rendered models made using CTAn and displayed using CTVol. For more details, we refer you to the method note "MN017_Basic 3D surface rendering".

- **Upcoming events**

Bruker microCT will participate with an exhibit in the forthcoming conferences. Please click the link below for more information. We hope to see you there!

Metfoam	Aug.31 - Sep.02	Barcelona, Spain
WMIC	Sep. 02-05	Hawaii, USA
XNPIG	Sep. 08-11	Maryland, USA
ASBMR	Oct. 09-12	Seattle, USA
BCEIA	Oct. 27-30	Beijing, China
MRS	Nov.29 - Dec.04	Boston, USA

- **Image of the Month**

Volume rendering (left) and 3D morphometric analysis (right) of a rat bone scanned with SkyScan 1174 at 26µm pixel.

structure thickness
53µm   905µm

structure separation
53µm   905µm