Rapid Prototyping in Forensic Odontology

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Abstract
High-resolution CT scans of the head are routinely and pre-emptively undertaken at Queensland Health Forensic and Scientific Services (QHFSS) where dental diagnosis or identification is likely to be an issue. Whole-body CT scans are also routinely undertaken as part of the routine post-mortem examination. Rapid prototyping of bony remains has been undertaken using this CT data as a source for 3-dimensional printing of exhibits for analysis and possible court presentation, as well as for ongoing reference. This process is illustrated and the outcomes discussed.

Introduction
Rapid prototyping involves creating a Real-world physical 3D model from a computer model. Five types of rapid prototyping exist: STL, fused deposition modelling, multi-jet modelling, selective laser sintering, and the technique we have used in this study, 3-D printing. All depend on the ability represent data as 3-Dimensional models. In 3-D printing, a special printer expels tiny increments of a photopolymer-based resin much like an inkjet printer and this is cured using UV light. Areas in the printed object which require physical support during printing, such as overlaps, are completed with a support material that can later be washed away to reveal the finished printed shape.

When printing from CT data, CT slices can be printed sequentially as 2-D layers, building these up to create the 3-D model. This is termed “additive layer” printing. The smaller the thickness of the slice, the better the resolution of the completed model.

Preparing CT Data for 3-D Printing
The MDCT (Multi-Detector Computed Tomography) scanner at QHFSS is capable of segmenting and exporting items in Surface Resolution Language (STL) format, which represents surfaces as a mesh of triangular facets. The greater the number of triangles used, the more detail can be encapsulated in the final model, and this depends not only on the resolution of the CT scan undertaken, but also on the software used to create the STL file.

The software on the Vibe Workstations we possess appears to export only low-resolution STL files, as shown in Figure 2 below. Third-party software, such as MIMICS (www.materialise.com) are capable of more accurate image segmentation and much higher resolution.

The Three-Dimensional Printer
The printer we use is an Objet Eden 260V printer, which has an X-axis and Y-axis resolution of 1000 dpi (dots per inch), and a Z-axis resolution of 1800 dpi. This printer is capable of printing very high-resolution models, and this crucially depends on the quality of the initial STL file, with which it is provided.

It can print objects with maximum dimensions of 255 mm x 255 mm x 200 mm, and can print using materials ranging from rigid opaque and transparent resins, rubbery material, and high-temperature resistant material. More than one material can be used in any single model. The support material is a non-toxic gel-like photopolymer which is easily removed by a high-pressure water jet.

The typical dimensional accuracy of a printed object is 20 – 85 μm for features below 50mm, and up to 200 μm for full model size. The dimensional accuracy on smaller items is therefore within the range of some common impression and casting material combinations, and might be expected to suffice for most forensic purposes involving objects within its size range.

The costs of printing are moderate. The resin shown in the printed working wrench shown in Figure 4 costs approximately 57 cents per gram. Support material currently costs approximately 33 cents per gram, and the material costs are the major contributor since the printer has been purchased or leased in the same way that ink is a refill cost to inkjet printers. In the case of 3-D printers, however, no substrate such as paper is required, and the results are therefore dependent on the material used, the size, and the quality of the STL dataset. The wrench shown as specified the required use of 42 grams of resin and 31 grams of support material.

Time taken to print is also an issue, and is dependent on the resolution chosen. For example, the wrench illustrated below took one hour and 50 minutes to print at the resolution shown, but would require only 28 minutes at the lower-resolution setting.

Conclusion
While 3-D computer models can be built from any appropriate source, CT data in the mortuary setting permits us to segment data to extract specifically models of bone and teeth. This may be useful to Forensic Odontologists in both analysis and as exhibits in evidence, adding a new dimension to the clarity of communication in the courtroom. As increasing resolution and better software become available, and as costs fall as this technology is taken up by more users in all fields, it is likely that the ease of making models and quality of the results will improve greatly.

As Forensic Odontologists should be aware that this technology exists, and explore the array of new opportunities it opens for us.

References