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Quality Assurance in Medical 3D-printing: A Dimensional Accuracy Study of Patient-specific 3D-printed Vascular Anatomical Models

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Purpose

3D printing enables the rapid manufacture of patient-specific anatomical models that substantially improve patient consultation and offer unprecedented opportunities for surgical planning and training. Here, we sought to validate the dimensional accuracy of vascular anatomical models manufactured using common 3D printing modalities including Fused-Deposition Modelling (FDM), Stereolithography Apparatus (SLA), Selective Laser Sintering (SLS), and MultiJet (MJ) 3D printing.

Methods

3D models of patient anatomy were produced by segmentation of computed tomography angiography (CTA) scans using Materialise Mimics, followed by the addition of measurement reference points and digital processing in Materialise 3Matic. Models were then manufactured via FDM, SLA, SLS and MJ 3D printing, respectively, using standard settings. The dimensional accuracy of the digital and 3D-printed models was assessed and compared to original CTA data to investigate errors introduced at different steps of the medical 3D printing process.

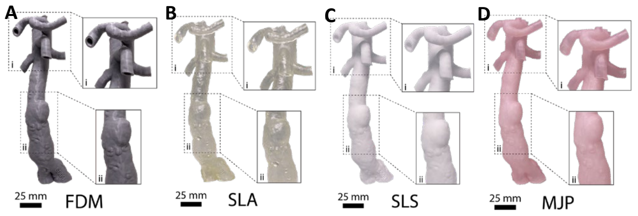


Figure 1 Abdominal aortic aneurysm models representative of each printing modality. A. FDM. B. SLA. C. SLS D. MultiJet

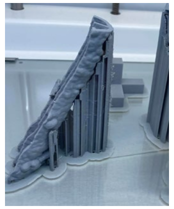
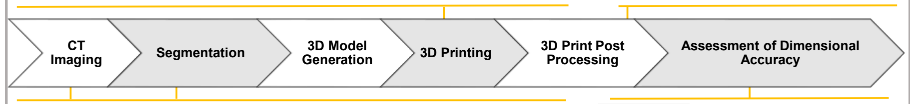


Figure 3 FDM Printed model with support material attached to underside.



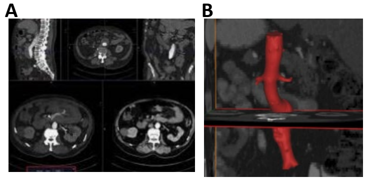


Figure 2 A. Abdominal aorta is imaged via CT angiogram. B. The Aorta (red) has been segmented from the CT image.

Figure 4 Heat map representation of dimensional accuracy of printed models compared to original CT scans.

Results

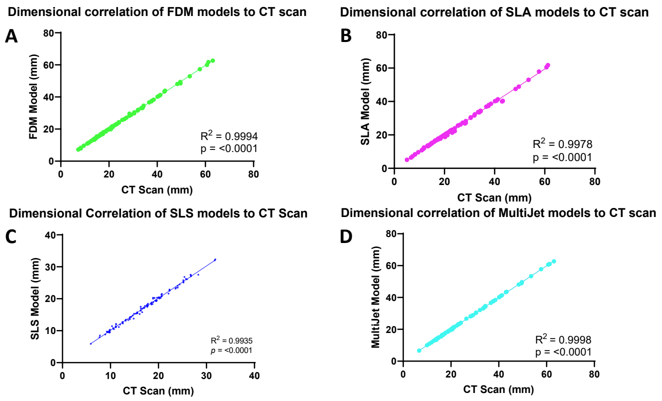


Figure 3 A-D Depict strong correlation between digital models and 3D printed models for all printing modalities with all R^2 >0.99

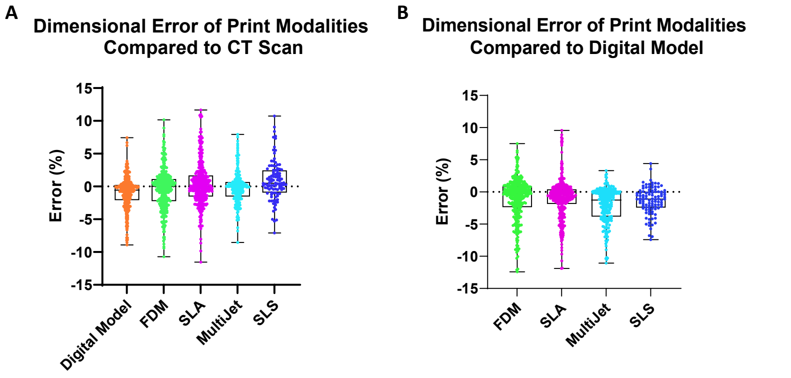


Figure 4 Comparison of the percentage error of each printing modality compared; A. CT scan data and B. as corrected for error occurring during digital processing.

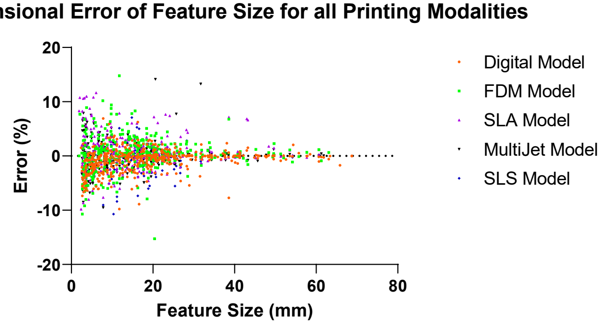


Figure 5 Error of 3D printed models compared to original CT scans depicting increasing error present in all 3D printing modalities as dimension approaches zero.

Quantitative assessment revealed an overall printed model deviation of -0.41 ± 0.71% (MEAN ± STDEV), +0.39 ± 0.58%, +0.88 ± 0.64% and -0.15 ± 0.44% for FDM, SLA, SLS-printed models and MultiJet, respectively, compared to unmodified CTA data.

Comparison of digital 3D models to CTA data revealed a mean error of -0.97% ± 0.08%, resulting from digital anatomical segmentation and processing.

Therefore, deviations resulting from the print modality alone were -0.99 ± 0.71%, +0.99 ± 0.62%, -1.35 ± 0.64% and -2.04 ± 0.46% for FDM, SLA, SLS and MultiJet printed models, respectively.

Conclusions

This study established novel quality assurance procedures and revealed a high level of dimensional accuracy of 3D-printed patient-specific vascular anatomical models, suggesting they meet the requirements for clinical applications.

Griffith University Queensland, Australia · Menzies Health Institute Queensland · QIMR Berghofer Medical Research Institute – The Future of Health · Pathology Queensland · QUT · The University of Queensland Australia – Create Change · Herston Health Precinct · RBWH Foundation · Metro North Health · Queensland Government