Further evidence of periodontal bone pathology in a juvenile specimen of *Australopithecus africanus* from Sterkfontein, South Africa

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The dentition and alveolar bone of a maxilla of a juvenile Australopithecus africanus *have been examined using a high energy X-ray computed tomography scanner. Results indicate the presence of previously undetected severe alveolar bone loss, localised around the roots of deciduous molars. The high energy X-ray capability of the industrial scanner (not available on conventional medical scanners) has the potential to reveal morphological details of fossil specimens.*

Plio-Pleistocene hominid remains from cave deposits of the Blaauwbank Valley at Sterkfontein, Swartkrans and Kromdraai (in the former Transvaal, now Gauteng, South Africa) have been the subject of extensive studies to establish the nature of evolutionary developments in the lineage from *Australopithecus* to *Homo*.[1–4] Cases of dental pathology in South African Australopithecinae are rare. With the exclusion of reports of carious lesions in three *Australopithecus robustus* specimens from Swartkrans,[5,6] palaeopathology has been confined to alveolar bone alterations consistent with a case of pre-pubertal periodontitis,[7] as well as alveolar bone loss in adult individuals of both *A. africanus* and *A. robustus*.[8,9] It was previously reported that the fossil remains of a juvenile *A. africanus* specimen, Sts 24a from Sterkfontein Member 4, temporally confined on faunal grounds to an age of 2.5–3.0 million years before the present, showed pathological alterations of the periodontal alveolar process suggestive of a case of pre-pubertal periodontitis.[7] This diagnosis was based on macroscopic features of the distribution of alveolar bone loss, on the pattern of periodontal bone destruction, migration of the affected deciduous molars, and on stereo-microscopic and scanning electron microscopic evidence of alveolar bone destruction.[7] The macroscopic and stereo-microscopic examination of the alveolar bony housing of teeth dm^2 and dm^1 suggested that a pre-existing vertical bony defect might have been present, which was gradually replaced by calcite during the process of fossilisation. The depth and severity of the vertical pattern of alveolar bone loss remained unknown, however, and the total extent of the periodontal attachment loss was purely speculative.[7]

To gain further insight into the morphology and severity of the vertical pattern of bone loss, X-ray computed tomography (CT) images of Sts 24a were generated using an Actis+ industrial tomography system (Bio-Imaging Research Inc., Lincolnshire, Illinois), and a Philips 320-kV X-ray tube with 0.8-mm focal spot size. A linear array solid state detector was used, having 2048 detectors in a 50-mm length and an entrance slit approximately 0.2 mm wide, enabling high resolution images to be obtained. For the examination of Sts 24a, the source was operated at 300 kV, 2 mA, with a 3-mm copper filter in the beam. Sagittal images were taken at 1-mm intervals. Figure 1 shows the unprecedented resolution achieved on a heavily mineralised fossil specimen, with details of the alveolar bone, enamel–dentine interface, periodontal ligament space, root morphology and associated endodontic space. The previously inferred vertical bone loss can be clearly observed affecting the distal root of dm^2, extending towards the apex of the root. It is noteworthy that the high resolution of the image allows the visualisation of the stage of root morphogenesis of the mesio-buccal and disto-buccal roots of M^1, as well as of the periodontal ligament space along the furcation, and the lamina dura of the inter-radicular alveolar bone.

Beside investigations into alveolar bone pathology, as outlined in this report, the use of an industrial CT scanner with high energy X-ray capability can be expected to yield morphological details of hominid fossils. In particular, the high resolution of images of root morphogenesis may prove invaluable in re-classifying the eruption stages of the Australopithecinae and early *Homo* specimens.

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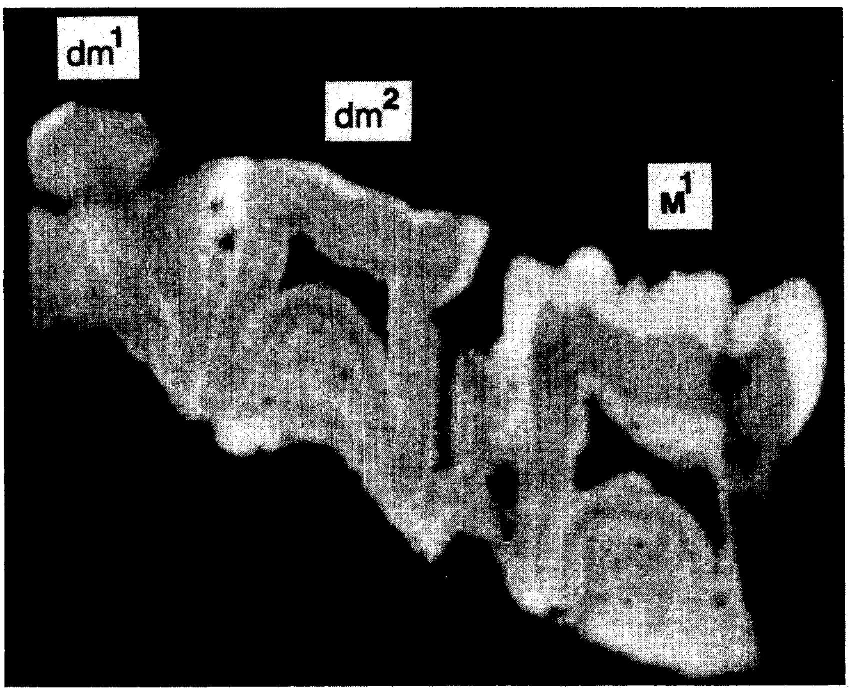

Fig. 1. CT scan of dm^1, dm^2 and M^1 of Sts 24a, representing *A. africanus* from Sterkfontein. The erupting maxillary M^1 is capped by a thick layer of enamel; below the enamel and subjacent dentine, the pulp chamber and the mesio-buccal and disto-buccal root canals are clearly discernible; note also the lamina dura of the inter-radicular bone and the periodontal ligament space of the furcation, and the apices of the developing mesio-buccal and disto-buccal roots of M^1. Root morphogenesis is still occurring as judged by the evidence of an open apex (compare the apex of the distal root of dm^2). The well-preserved dm^2 shows wear of the occlusal enamel and a large pulp chamber; a vertical defect of alveolar bone loss has affected the distal root. There is also loss of alveolar bone affecting the furcation of dm^2.

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CT scans of Sts 14 provide the potential for manufacturing casts

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Sts 14 is a partial skeleton of Australopithecus africanus, *discovered in 1947 at Sterkfontein by Broom and Robinson.*[1,2] *It represents the South African counterpart to 'Lucy', a partial skeleton of* Australopithecus afarensis. *Although casts have been made of the pelvic bones and sacrum of Sts 14, the fragility of most of the vertebrae has prevented the manufacture of moulds of the vertebral column. Here we report the results of a feasibility study, using an industrial X-ray computed tomography (CT) scanner to manufacture a cast of one vertebra (Sts 14e), which could be used as one of many master positives for the mass production of casts of Sts 14.*

CT images of Sts 14e were generated using an Actis+ industrial tomography system (Bio-Imaging Research Inc., Lincolnshire, Illinois), and a Philips 320 kV X-ray tube with a 0.8-mm focal spot size. A linear array solid state detector was used, having 2048 detectors in a 50-mm length and an entrance slit approximately 0.2 mm wide, enabling high resolution images to be obtained. For the examination of Sts 14, the source was operated at 250 kV, 2 mA, with a 1.8-mm copper filter in the beam. Images were taken at 0.5-mm intervals with a slice thickness of 0.2 mm. Figures 1 and 2 show two images which were used as part of the three-dimensional reconstruction of Sts 14e. The use of dilute acetic acid during preparation has led to the partial dissolution of lime in the centre of the vertebra. The fragility of this vertebra is most noticeable in areas where calcite has been dissolved. The master positive was produced using a Stratsys fused deposition modeller (Fig. 3).

Fig. 1. (*Left*) CT scan of Sts 14e, a vertebra of *Australopithecus africanus*, discovered in 1947 by Robert Broom and John Robinson at Sterkfontein. Imaging with a slice thickness of 0.2 mm has revealed detail of trabecular bone with unprecedented high resolution. Fig. 2. (*Right*) Another CT scan of Sts 14e.

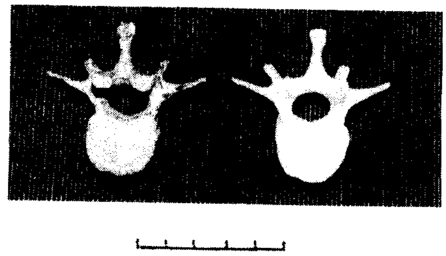

Fig. 3. The original and cast of Sts 14e. The cast (on the right) was obtained by means of high resolution CT scanning. Scale in centimetres.

The production of casts of other elements of Sts 14 (or indeed of other fragile and valuable fossils) by means of CT scanning clearly is an advantage over conventional moulding techniques, which require direct contact with the fossils. Readers interested in obtaining such casts should contact J.F.T.

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