ANTHROPOLOGIE • XXXVII/3 • pp. 257–264 • 1999

KURT W. ALT, CARLOS H. BUITRAGO TÉLLEZ, WINFRIED HENKE, HARTMUT ROTHE

DENTAL CT STUDIES IN ANTHROPOLOGY

ABSTRACT: CT studies enable non-invasive analyses of anthropological remains. Serial CT data permit 3D morphometry and computer-assisted reconstruction of skulls, jaws and bones. A qualitative and quantitative analysis of bone structures was performed using a new CT-software (DENTAL CT). The evaluation on skulls and dental remains included especially data from the thickness of jawbone, the relative location of dental roots, size and course of anatomical structures (maxillary sinus, alveolar canal, postorbital and ear region). Dental CT studies provide a broad perspective in primatology, palaeoanthropology, palaeopathology and other fields.

KEY WORDS: Dental CT – 2-D/3-D Reconstruction

INTRODUCTION

Teeth are the biological structures in which aspects of phylogenetic and ontogenetic development, all co-evolution of form and function, and also aspects of palaeopathology can be most accurately studied (Alt, Türp 1997, Alt *et al.* 1998). CT studies enable non-invasive analyses primarily of anthropological remains (fossil specimens, skeletons, mummies), but also of extant and extinct primates and other mammal species of interest. Dental CT studies provide a broad perspective in primatology, palaeoanthropology, palaeontology, prehistoric anthropology, and palaeopathology. Serial CT data permit 3D morphometry and computer-assisted reconstruction of skulls, jaws, and bones. A new CT-software (DENTAL CT with Somatom Plus S, Siemens) manages to do comprehensive qualitative and quantitative analyses of bone structures from dental remains.

METHOD

DENTAL CT makes reformation of panoramic views and paraxial slices of the lower and upper jaw possible. The special software was developed for the analysis of implantation surgery. A random curve generated by marking points along the mandibular arch defines the central panoramic slice, parallel to which up to 6 additional panoramic slices can be selected (*Figure1*). The paraxial slices are reconstructed perpendicular to the central curve based on thin 1–2 mm CT scans performed with the gantry positioned upright and parallel to the alveolar margin (*Figure 2*). The presentation of final images can be presented as a panoramic view or in multiimage display with reference markings (*Figures 3,4*).

DENTAL CT APPLICATION

The application of DENTAL CT in anthropology enables the display and measurement of the bone structure of the jaws, especially to evaluate the size of the maxillary sinuses, the thickness of the jawbone, and the course of the alveolar canal. Of further interest are aspects of dental development (crown formation, root extension, stages of deciduous and permanent dentition), quantitative analyses of crown and root dimensions, the interradicular distance, the topography and morphology of roots. In addition to

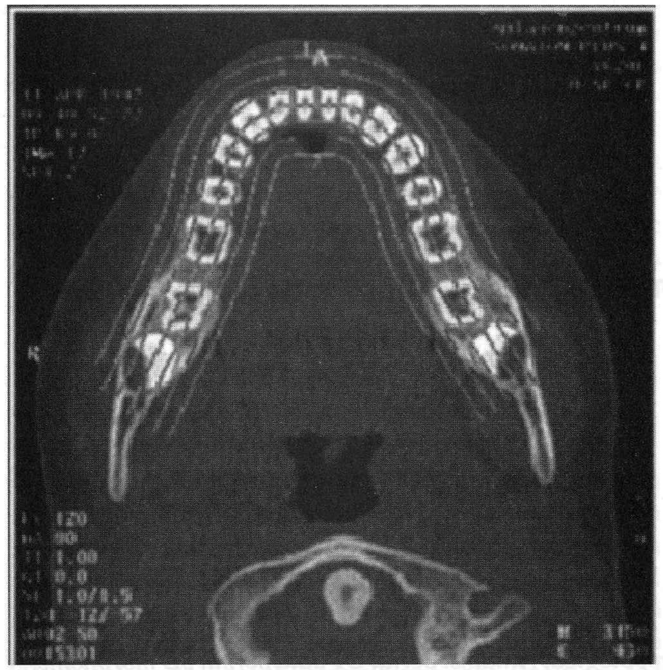


FIGURE 1. Transaxial slice with display of panoramic line.

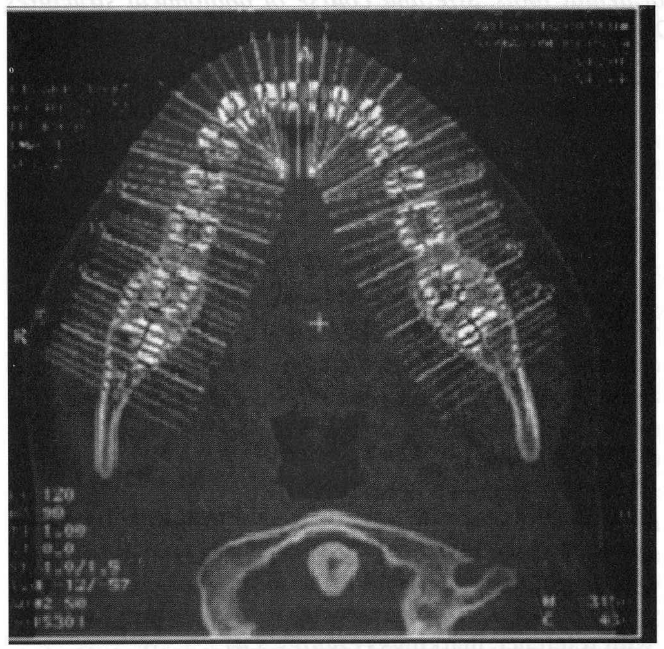


FIGURE 2. Transaxial slice with display of paraxial cutlines.

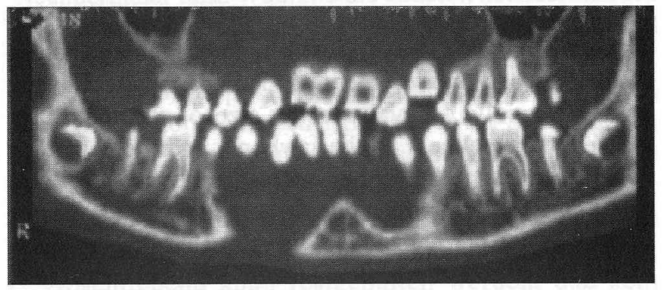


FIGURE 3. Panoramic view.

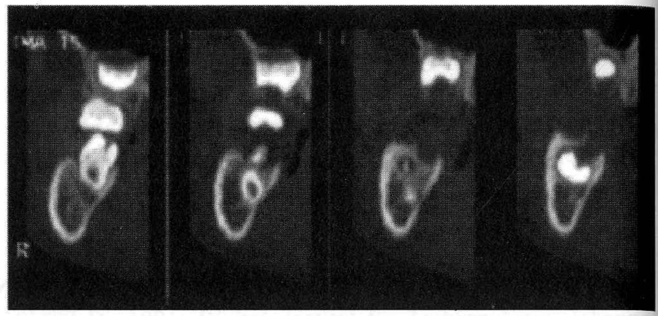


FIGURE 4. Multiimage display of paraxial cutlines (without reference markings).

studies of ontogeny and phylogeny, Dental CT is helpful for the extension and validation of results in palaeopathological diagnostics and also for the calculation of CT data for the preparation of 3-D stereolithographic duplicates, which is of especial interest for important finds.

PRIMATOLOGY

Dental CT on species Squirrel monkey (*Saimiri sciureus*)

In a cladistic analysis of the phylogenetic relationships between the New World monkeys (Platyrrhini) 21 dental and cranial characters of 16 taxa were analyzed. The aims of the study were

- to arrange the generic names of these taxa within natural phylogenetic units (monophyla)
- to formulate substantial hypotheses on the phylogenetic relationships between these genera and the Old World primates (Catarrhini)

The 3D non-invasive investigation of the skulls, especially of their postorbital and ear regions (*Figure 5 a,b*) as well as their sinus-systems (*Figure 6 a,b*), proved to be extremely heuristic for phylogenetic studies in the context of functional and evolutionary morphology of the primate skeleton (Wiesemüller, Rothe 1999).

PALAEOANTHROPOLOGY

The *Homo erectus* mandible from Dmanisi, East Georgia, Caucasus

In 1991 a well-preserved human mandible was found at the site of Dmanisi (85 km south-west of Tbilisi) by A. Justus, member of a German-Georgian excavation team. The human mandible has been dated by three independent methods to an age of max. 1.8 million years. First descriptions (see e.g. Gabùnia 1995) identify the mandible as *Homo erectus*. Though this taxon is known from contemporary sites on Java and the African continent, the earliest human fossils in western Eurasia were dated to 0.6 Myr or less (Henke, Rothe 1994, 1999). The Dmanisi mandible is therefore a key fossil in the discussion concerning the "taxon pulses" of early hominines.

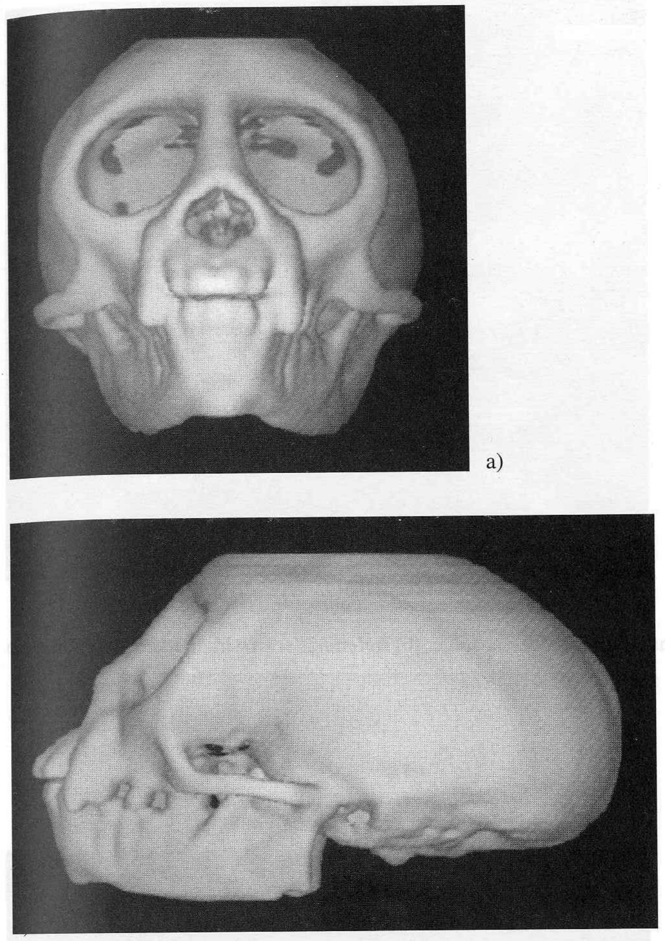


FIGURE 5. 3D-CT reconstruction of a *Saimiri*-skull using the surface rendering technique: (a) frontal view; (b) lateral view. Display of different anatomical bone structures (nasal, orbital, periorbital and postorbital regions).

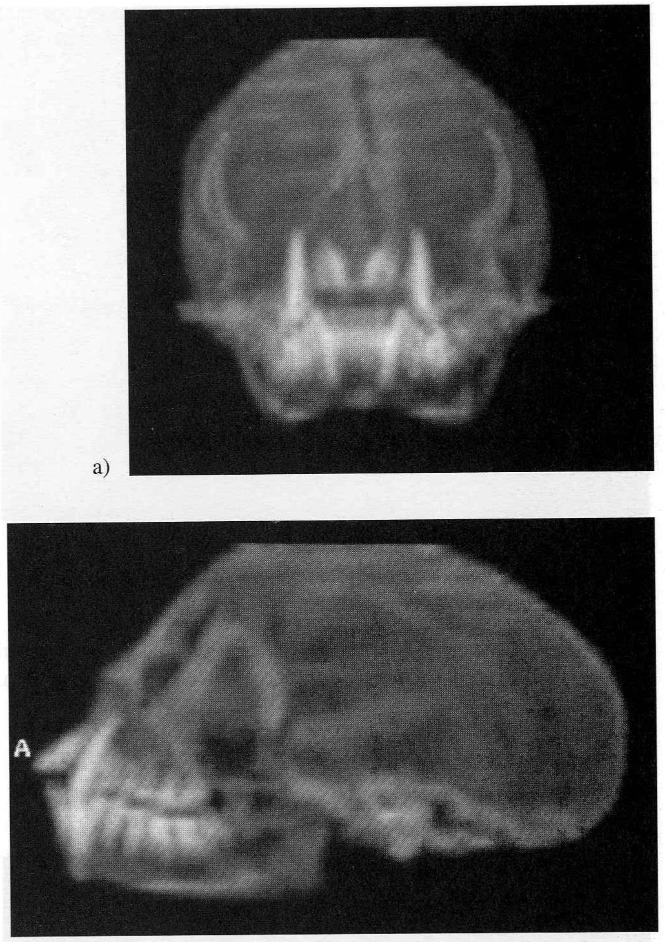


FIGURE 6. Maximum-Intensity-Projection (MIP)-Reconstruction: (a) frontal view; (b) lateral view. This technique allows the depiction of the highest density values of the 3D data volume, especially to evaluate the incidence and size of the maxillary sinus and to show the shape and position of the canine teeth.

The Dmanisi hominin exhibits a completely preserved dentition and a virtually complete corpus while *rami* are broken off and missing. The comparison of morphological tooth features and the mandible allows a clear distinction of the Dmanisi fossil from the genus *Australopithecus* and its definite classification as a member of the genus *Homo*. Within the *Homo*-taxon there are much stronger affinities to the Asian and African *H. erectus*/*H. ergaster* mandibles than to *H. habilis* fossils and those which are attributed to *H. heidelbergensis* and *H. neanderthalensis*.

CT-studies on the cast of the Dmanisi mandible

The CT investigation of the Dmanisi fossil was done on a precise plastic cast because there was no possibility of studying the original in Georgia using this method. This pilot study should indicate whether CT studies on casts, which are much more easily available than original fossils, give adequate and informative morphological and metrical results. Especially the detailed information on the shape of the corpus (e.g. chin, *tubera*) and the CT data for the stereolithograph will be helpful for further morphological comparisons (Henke *et al.* in print).

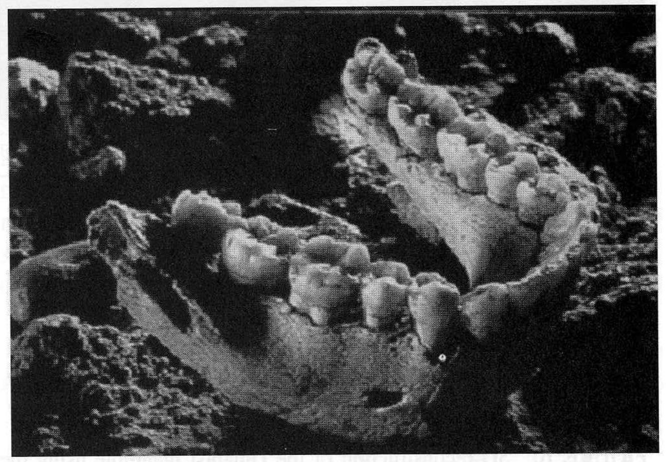
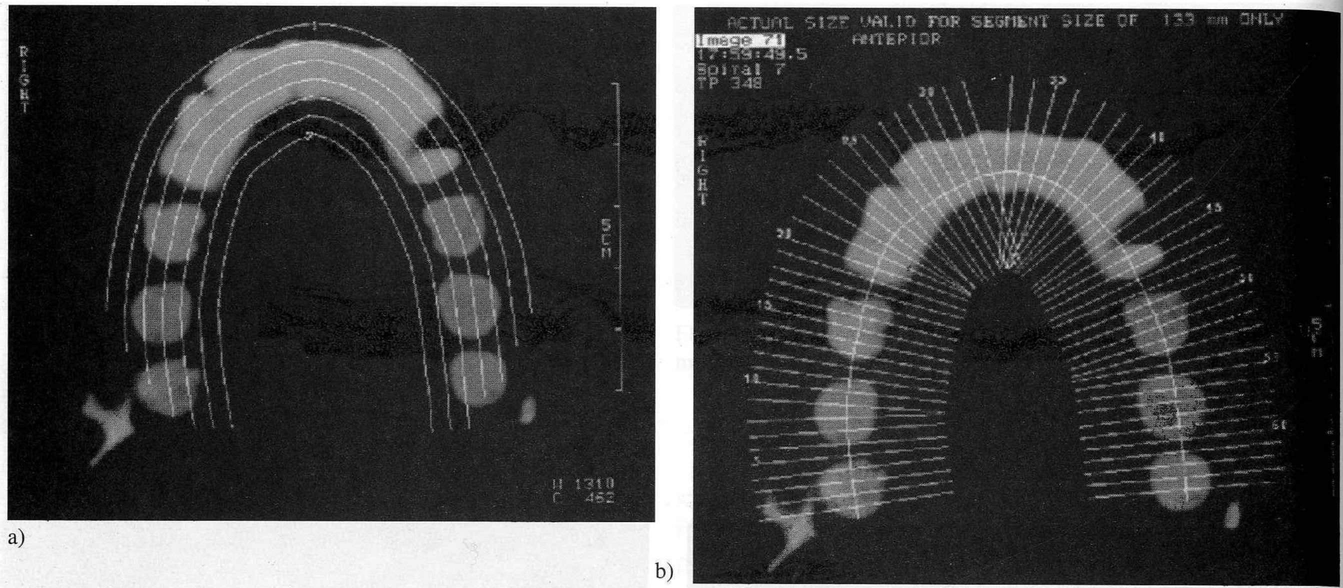


FIGURE 7. Cast of the Dmanisi mandible (from GEO).



a) b)

FIGURE 8. (a) Reference scan with marked parasagittal 2D reconstructions along the alveolar ridge; (b) Reference scan with marked panoramic 2D reconstructions (displayed on a cast of the original Dmanisi mandible).

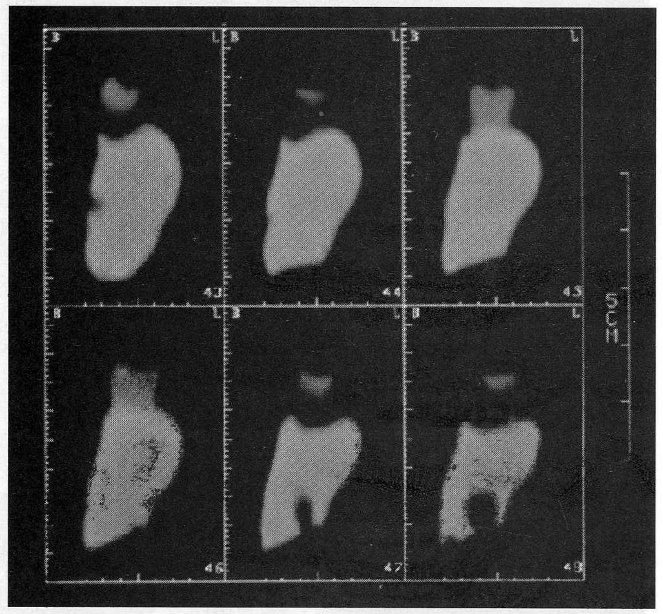
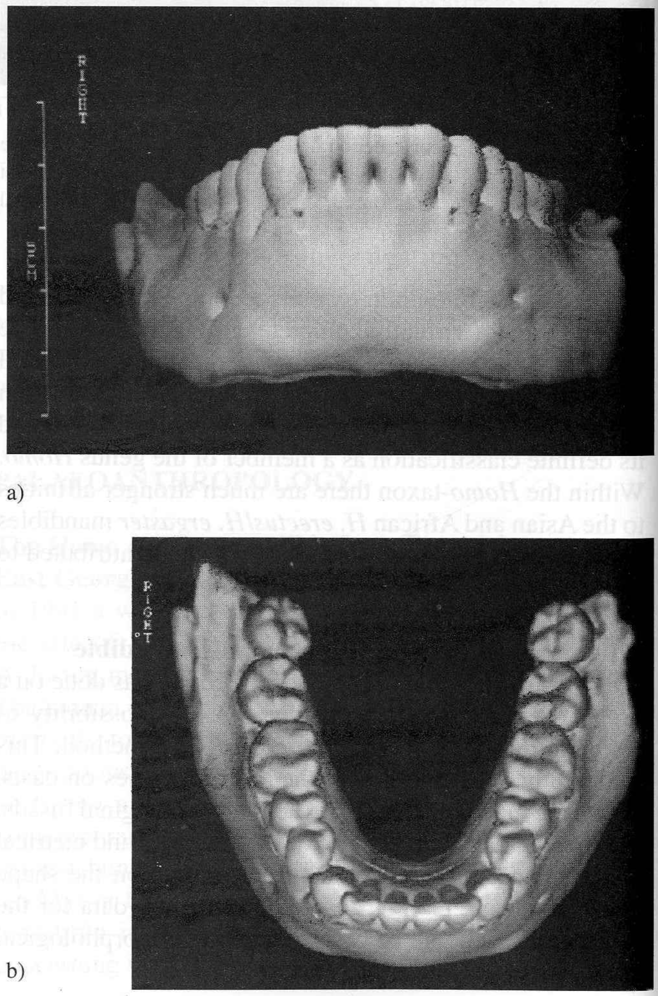


FIGURE 9. Parasagittal orthoradial 2D reconstructions of the Dmanisi mandible cast showing the shape of the mandible and indicating bucco-lingual measurements.



a) b)

FIGURE 10. 3D reconstruction of the Dmanisi mandible using the surface rendering technique: (a) frontal view; (b) occlusal view.

The first Australopithecine (RC 911) from the Hominid Corridor in South East Africa (Malema/Malawi)

In 1996 members of the **H**ominid-**C**orridor-**R**esearch-**P**roject (headed by F. Schrenk, Darmstadt/T. Bromage, New York) discovered a 2.5 Mya old maxilla fragment of a hominin fossil (RC 911; *Figure 11*) in Malema (Malawi). Following the mandible UR 501 (1991) the maxilla fragment from Malema provided further proof of the existence of hominines from the corridor between East and South Africa (Kulmer *et al.* 1999). The measurements of the teeth showed significant affinities to the taxon *P.* (*A.*) *boisei*. Morphological observation regarding function by REM studies of microwear features such as enamel pits and scratches do not reveal a specific wear pattern which would support the classification. Due to the poor preservation of the occlusal surfaces it was not possible to reconstruct the enamel thickness. At 5–6 mm the diameter of the enamel prisms lies within the variation range of modern humans.

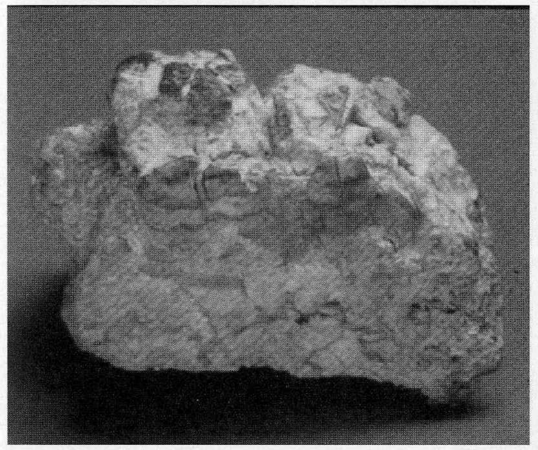


FIGURE 11. Latero-occlusal view of the maxilla fragment of RC 911 from Malema, Malawi.

Results of CT-studies on the RC 911

The maxilla fragment RC 911 was examined by computerized tomography on axial levels of 1–2 mm distance (Alt *et al.* in prep). The first two pictures show the transaxial slices displaying paraxial cutlines (*Figure 12a*) and the transaxial slices displaying panoramic lines (PAN 1–7) (*Figure 12b*). PAN 3 is a panoramic view of the jaw which runs directly through the alveoli of the four buccal roots and shows their shape and size (*Figure 12c*). The tomogram displaying the panoramic lines further documents the topography of the three molar roots through a medial slice in the root area. (*Figure 12d*). The compact bone is substantially thicker on the palatinal side as opposed to the vestibular side. Out of the paraxial slices, which generate 50 paraxial reformations (PR 73–123), *Figure 12e* shows the situation in the root region of the second molar. The palatal and disto-buccal roots are represented. The interradicular distance between the root tips measures 15 mm, the length of the disto-buccal root (measured from the root tip to the bifurcation) 17 mm, that of the palatinal root 16 mm, the diameter of the roots measures 7 mm disto-buccal and 8 mm palatal (at the bifurcation). All the measurements of the third molar (not pictured) are lower. The 3D reconstruction presents the preservation of the maxilla and provides an impression of the shape, size and the decomposition processes on the fossil. The 3D data can be used to prepare a stereolithograph of the original find.

PALAEOPATHOLOGY

Odontogenic infection of the mandible – osteomyelitis

Even today, more than 80% of all osteomyelitis cases definitely have an odontogenic origin (odontogenic infection, jaw fracture, tooth extraction). Acute osteomyelitis occurs six times more frequently in the mandible than in the maxilla. The oral cavity is physiologically colonized with microbes (e.g. *Staphylococcus aureus*). In healthy individuals, the oral mucosa works as a sufficient barrier membrane that prevents penetration and infection. However, in the presence of a deep carious lesion or an open pulp caused by excessive attrition and subsequent pulpitis, the odontogenic infection may spread along the pulpal cavity to the periapical region involving the alveolar bone (local osteitis). Osteomyelitis starts if the microbes penetrate the cancellous (medullary) portion of the bone. The infection may be localized or it may spread diffusely through the entire medullary structure. Three parameters influence the clinical course of the infection: the anatomic region, the patient's resistance, and the virulence of the microorganisms.

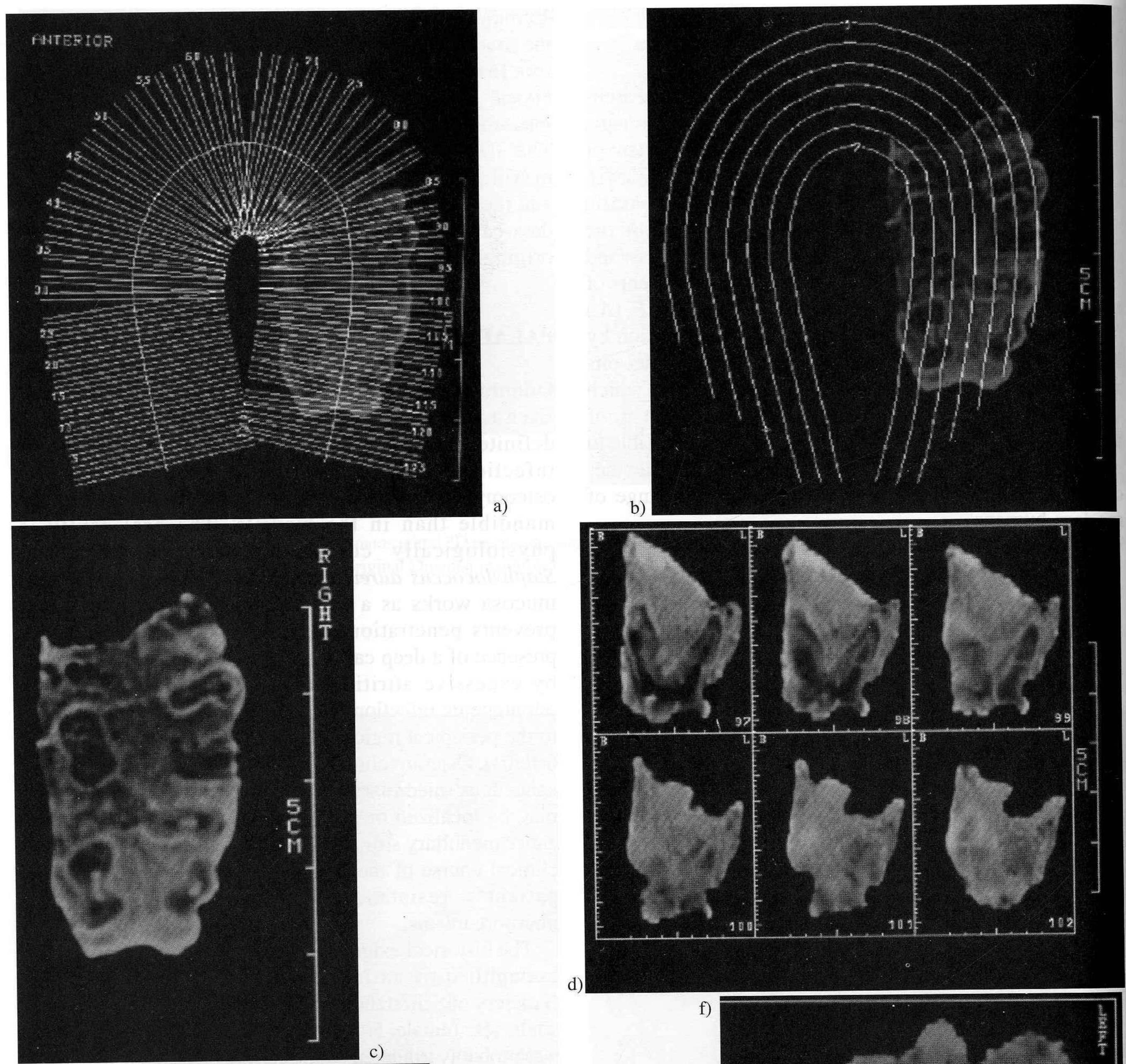
The historical evidence of chronic osteomyelitis is here exemplified by an individual from the early Medieval cemetery of Schretzheim (South Germany, grave 570, age: adult, sex: female, 5th–7th cent. A. D.). The osteomyelitis was probably triggered by the carious teeth in the mandible. The macroscopic and radiological features are shown in *Figures 13 a–d.*

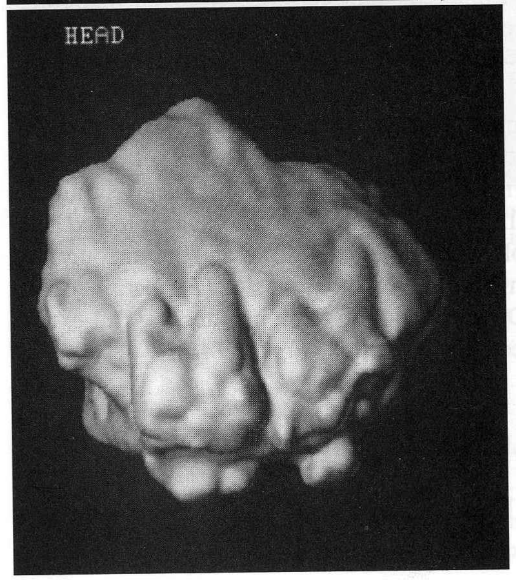
Dental CT and 2-D reconstruction

Dental CT and secondary 2D reconstructions revealed clear signs of a surrounding chronic osteomyelitis affecting the alveolar canal. The panoramic scan shows the infected area of the mandible with periapical lesions and the surrounding radiolucent involucrum on the right side (*Figure 14a*). The secondary 2D reconstruction demonstrates the full extent of the advanced osteomyelitis (*Figure 14b*).

ACKNOWLEDGEMENTS

We thank Hilary Dannenberg, Freiburg, for language revision, and SIEMENS, Germany, for the co-operation.





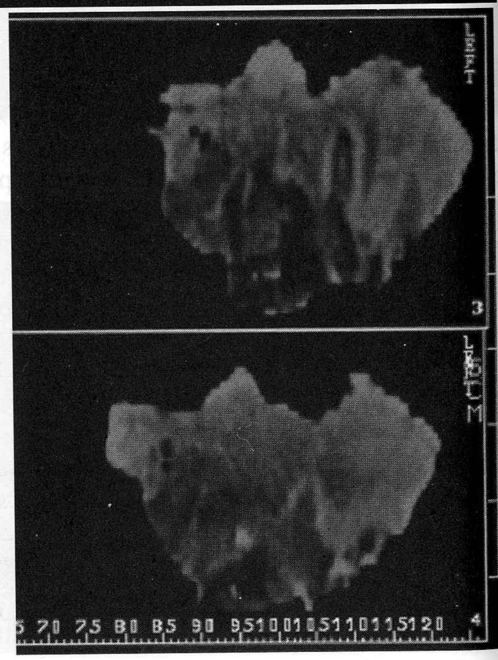


FIGURE 12. (a) Reference scan with marked parasagittal 2D reconstructions along the alveolar ridge; (b) reference scan with marked panoramic 2D reconstruction; (c) panoramic view of the maxilla, axial slice of the roots (buccal view); (d) parasagittal orthoradial 2D reconstructions; (e) axial slice through the molars; (f) 3D reconstruction using the surface rendering technique (buccal view).

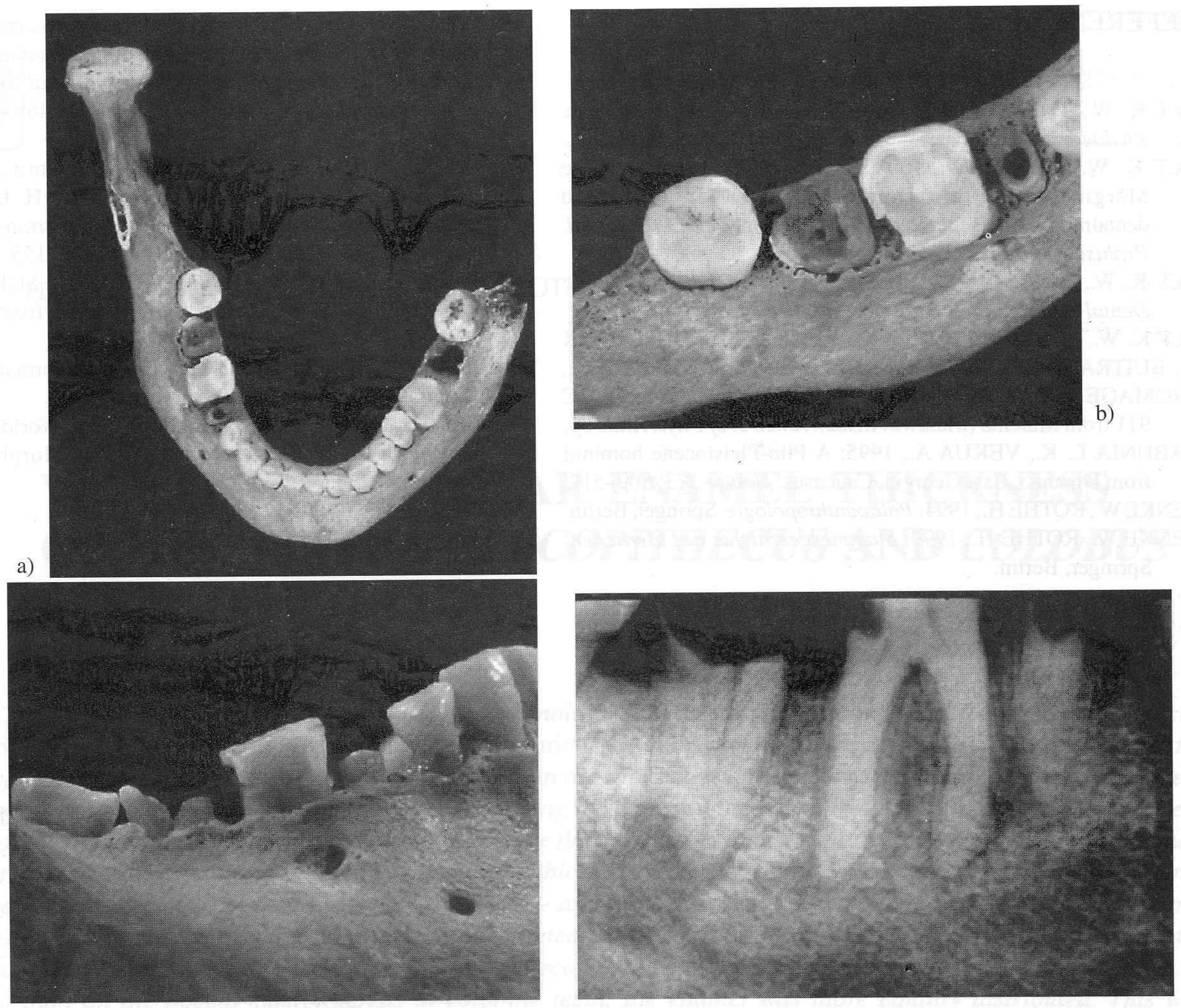


FIGURE 13. (a) Mandible of an adult female from Schretzheim (top view) with chronic osteomyelitis. Post mortem loss of left second molar. Bone lesions by radicular cysts or periapical granulomas on second premolar, first and second molars on the right, approximal caries on the right first molar; (b) Occlusal view of the mandible with destroyed crowns of both second premolar and second molar. Alveolo-buccal bony outgrowth; (c) Right side of the mandible with alveolar fistula (alveolar abscess on the second premolar and/or first molar); (d) X-ray of the right side of the mandible. Radiolucency without radiopaque margin and resorption on the root tip suggest the incidence of dental granulomas.

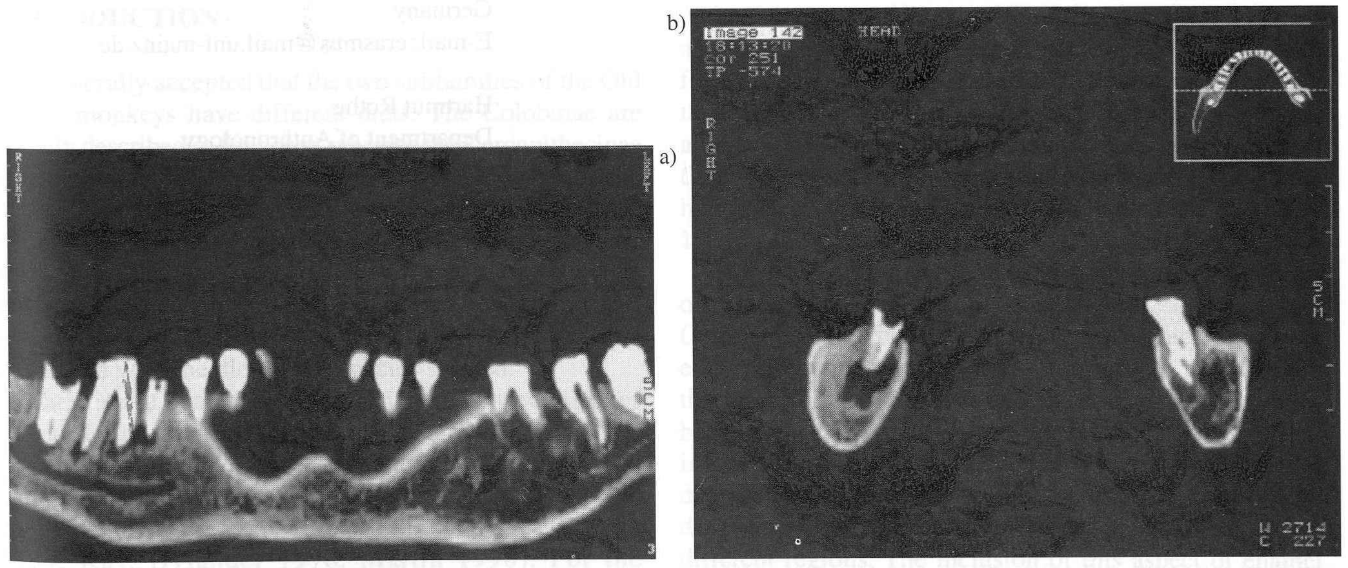


FIGURE 14. (a) Panoramic reconstruction through the alveolar canal with direct communication to the root of the second molar on the right. Periapical lesions on the root tips of the right second premolar and first and second molars; (b) Secondary coronal 2D reconstruction based on a 3D reference image showing the osteolytic periapical lesion with involvement of the mandibular canal on the right.

REFERENCES

ALT K. W., TÜRP J. C., Eds. 1997: *Die Evolution der Zähne. Phylogenie – Ontogenie – Variation.* Quintessenz, Berlin.

ALT K. W., HENKE W., ROTHE H., 1997: Taxonomische Marginalien zum Dmanisi-Unterkiefer aufgrund dentalmorphologischer Vergleichsanalysen. *Beitr. Archäozool. Prähist. Anthrop.* 1: 124–133.

ALT K. W., RÖSING F. W., TESCHLER-NICOLA, Eds. 1998: *Dental Anthropology*. Springer. Wien.

ALT K. W., SCHRENK F., HENKE W., GÖTZ H., DUSCHNER H., BUITRAGO TELLEZ C. H., KULLMER O. SANDROCK O., BROMAGE T. G., JUWAYEYI Z. M., in prep.: Dental fossil RC 911 from Malema (Malawi/Africa). *Amer. J. of Phys. Anthrop.*

GABUNIA L. K., VEKUA A., 1995: A Plio-Pleistocene hominid from Dmanisi, East Georgia, Caucasus. *Nature* 373: 509–512.

HENKE W., ROTHE H., 1994: *Paläoanthropologie*. Springer, Berlin.

HENKE W., ROTHE H., 1999: *Stammesgeschichte des Menschen.* Springer, Berlin.

HENKE W., ROTH H., SIMON C., 1995: Qualitative and quantitative analysis of the Dmanisi mandible. In: R. Radlanski, H. Renz (Eds.): *Proceedings of the 10th International Symposium on Dental Morphology, Berlin 6–10, 1995.* Pp. 459–471. Brünne, Berlin.

HENKE W., ROTHE H., ALT K. W., 1999: Dmanisi and the early Eurasian dispersal of the Genus *Homo*. In: H. Ullrich (Ed.): *Hominid Evolution. Lifestyles and survival strategies.* Edition Archaea, Gelsenkirchen/Schwelm, pp. 138–155.

KULMER O., SANDROCK O., ABEL R., SCHRENK F., BROMAGE T. G ., 1999: The first *Paranthropus* from the Malawi Rift.. *J. of Hum. Evol.* 37: 121–127.

fy. SIEMENS A. G.(o.J.): Dental CT – Product information. Medical Engineering Group, Erlangen.

WEISEMÜLLER B., ROTHE H., 1999: New World Monkeys – A Phylogenetic Study. Zeitschrift für Morphologie und *Anthropologie*. 82: 115–157.

Kurt W. Alt
Department of Anthropology
Mainz University
Mainz
Germany
E-mail: erasmus@mail.uni-mainz.de

Carlos H. Buitrago Téllez
Department of Radiology
Basel University
Basel
Switzerland

Winfried Henke
Department of Anthropology
Mainz University
Mainz
Germany
E-mail: erasmus@mail.uni-mainz.de

Hartmut Rothe
Department of Anthropology
Göttingen University
Göttingen
Germany