# The Significance of Conventional Radiographs in Physical Anthropology

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## Introduction

Digital and conventional radiography provide many benefits in the field of physical anthropology. Individual studies that have used radiographs have showcased the vast capabilities of information developed from using them, such as, analyzing mummified remains (Conlogue, Nelson, and Guillén, 2004), identifying skeleton lesions (Ortner, 2003), and three dimensional CT imagery of hominid fossils (Mafart, Guipert, Lumley, and Subsol., 2004). The Repatriation Osteology Laboratory, at the Smithsonian Institution, has implemented conventional radiographs into the standardized protocol for the archival recording of their large collection of Native American remains. Including conventional radiographs as a part of the protocol, provides that visual aid is needed for the study of pathology, age, and health and nutrition. Unfortunately, the use of conventional radiographs has not been widely practiced in physical anthropology for diagnostic use. But, since the advancement of digital technology, there has been a wave of research articles promoting the newer technologies as a way of studying human remains. In this report, I will discuss when radiography was first practiced in physical anthropology, the information to be gained with the use of the study of radiographs in studying human remains, the protocol for gathering information using conventional radiographs at the Smithsonian Institution, and the advantages and disadvantages of using a digital or conventional x-ray machine.

## The Beginning of Radiography in Physical Anthropology

Since the discovery of the cathode rays in 1895 by Dr. Wilhelm Conrad Röntgen, radiographs have been used in physical anthropology. In 1902, only seven years after the discovery, Dr. Gorjanovic-Kramberger used conventional radiographs for studying early hominids discovered in the Krapina Cave in Croatia. Standard two-dimensional radiographs of the Krapina Neanderthals were taken producing a collection of 884 radiographs. These early radiographs became one of the earliest documentations of benign bone tumors, the possible surgical amputation of a hand, and several examples of osteoarthritis.[1] Aside from this rare early documentation, early radiographs were used mostly as evidence in court cases. These beginning radiographs, although non-anthropological, greatly influenced the later use of radiographs in forensic anthropology. Around Christmas of 1895, George Holder shot Tolson Cunning in the leg. Luckily, Mr. Cunning was not badly injured by the incident, but the bullet was still lodged in his leg after the wound healed. Mr. Cunning's surgeon, Dr. R.C. Kirkpatrick asked John Cox, a professor of physics at McGill University, to x-ray the extremity of Mr. Cunning's leg. The exposure time took 45 minutes and the finished image showed the bullet lying between the tibia and fibula. Dr. Kirkpatrick surgically removed the bullet from Mr. Cunning's leg and the radiograph was submitted to court where Mr. Holder was sentenced to 14 years in the penitentiary.[2]

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[1] Mann, Alan; PHD & Monge, Janet; PHD, *First Comprehensive Radiographic Study of Famous Krapina Neandertal Fossil Collection Reveals Health of Early Hominids (of 130,000 years ago)* **www.museum.upenn.edu/new/research/Exp_Rese_Disc/PhysicalAnthro/neanderthals**

[2] Brogdon, B.G., eds., (1998) *Forensic Radiology*. Massachusetts, CRC Press LLC

By the early 1980's, new discoveries in biomedical radiology offered more potential in visual imagery by becoming digital. MRIs, CT scanners, 3D digitizers, scanning electron microscopies, and digital fluoroscopies expanded the capabilities of conventional radiography machines and two dimensional images. Now, computer programs opened a virtual world where an exact copy of the bone could be enhanced by the researcher, remains could be protected from potential damaging and misplacement, new landmarks could be discovered, and bones with a higher density had the opportunity to have a clearer image.

## New Information Derived from Radiographic Analysis

Particularly in the fields of paleoanthropology and forensic anthropology, the use of radiography has become essential to the process of data collecting. With gross examinations capable of showing only what is available on the surface, radiography allows a transparent look inside, expanding the scope of data collection to a more complete analysis of certain topics, such as, examining nutrition and health in past populations, determining age and oral pathological conditions, general pathological conditions, and observing embedded objects and adhering material.

In researching the dietary and health patterns of past populations, researchers have analyzed "harris lines", cortical thickness, and dental wear. Harris lines are an indicator for a metabolic disorder where normal growth development is interrupted and can only be detected and examined by radiographic analysis. In an article by Bruwelheide *et al.* (2001), "harris lines" in long bones were stated as "transverse radiopaque markers" explored by a group of researchers. In the same article, Bruwelheide (2001) mentions an article written by D. Owsley (1991) in which the cortical thickness of femora were measured in North American Plains populations. When examining dental wear, diet can be analyzed using a scanning electron microscopy. This can provide a closer examination of the dental wear on the enamel. Walker and Teaford (1981) used scanning electron microscopy to analyze the dental wear of recent and extinct mammals to determine whether they follow a mostly frugivorous or folivorous diet.

In addition, radiographs provide a clearer and more visible image into the dental development of sub-adult remains. With the constant change of our teeth, the eruption and formation of permanent and deciduous teeth can only be observed using radiographs. Ubelaker (1978) studied the dentition of Native Americans and created a standard chart that showed a diagram for each year of dentition beginning with 5 months gestation to 35 years of age. Displaced dentition and pathological conditions are also better observed using radiographs. For example, a displaced second molar found in an adult right maxilla was positioned horizontally and could not be seen externally. This common condition often went undetected and could be fully viewed only under radiographic analysis (Bruwelheide, 2001). Periodontal disease, dental hypoplasia, and fibrous dysplasia can be identified and described from radiographs. In the advanced stages of periodontal disease, the surface layer of the alveolar crest erodes to the point where the roots begin to detach from the periodontal ligaments, becoming loose from the sulcus (Poyton, 1982).

The study of pathological conditions relies on radiographic analysis for the identification and description of antemortem and postmortem bone abnormalities, such as, fractures, diseases, and cultural practices. In *The Human Bone Manual*, a photograph of a left clavicle shows only a postmortem fracture, on the inferior side, recognized by gross examination. However, the radiograph shows an antemortem fracture that healed with the medial end rotated counterclockwise causing a misalignment of fractured pieces (White and Folkens, 2006). Bone diseases that also cause abnormalities are commonly seen in radiographic examination. Osteomyelitis occurs when bacteria, entered from a wound, infect the medullary cavity and cause swelling. By gross examination, two tibia were diagnosed with osteomyelitis by the cloaca and localized reactive bone. But, through radiographic analysis, a greater reaction to the infection in the medullary cavity could be seen (White and Folkens, 2006). Some bone observations can easily be missed by gross examination. Rothschild and Rothschild (1995) studied mestastic cancer in post-crania of individuals from the Hamann-Todd collection. In past examinations, blastic lesions were overlooked because they occur in the inner structure of the bone. From the collection, thirty out of thirty-three individuals had lesions found in the ilium.

Information pertaining to objects embedded or adhering to the bone is enhanced greatly in radiographic examination. An unknown skeleton found in the Cheyenne River had an embedded metal projectile point in the inferior aspect of the ramus and pubis of the ischium. The radiograph showed the orientation of the point and bone growth around the object (Bruwelheide, 2001). Also, observing embedded objects in bone can help with determining burial lots with multiple individuals missed by gross examination. For example, a tibia brought in from the Sully site in South Dakota revealed a distal and proximal finger lodged in the mid-shaft (Bruwelheide, 2001).

**Standard Protocol for Conventional Radiography at the Repatriation Osteology Laboratory**

The x-ray facility is located in the Department of Anthropology. A portable radiograph machine, a Porta Ray Model 1100, is sealed off by walls covered by lead to protect the technician from the constant exposure of harmful rays. Located in the area are foam wedges used for positioning the bones in the standard views and small lead plates used to block off portions of the cassette. The control panel, placed outside the area, controls the amount of kilovoltage (kVp), milliamperge (mA), and exposure time (s). During the exposure the technician is protected and safe from exposure to the radiation. Also, in the facility, a darkroom with a high speed automatic processor, a Kodak M35A X-OMAT, develops the film in approximately 3 minutes. Kodak single lanex and X-omatic film cassettes take two specific sizes of film, the 24 X 30 centimeter Kodak Min-R film for skull and sub-adult long bones shots and the 35 X 43 centimeter Kodak Ektascan B/RA for adult long bones.

As standard protocol, the skull and specific long bones, the humerus, femura, and tibia, are regularly x-rayed. Arrows along the borders of the film cassette as well as crosshairs in the light field create an x-y axis that helps with centering the crania following skeletal landmarks. The following are the views for the skull: mediolateral, posterior-anterior (PA), superior-inferior (SI), and left and right oblique-lateral of the maxilla and mandible. For the mediolateral view, Figure 1 and 1a, the film cassette is placed longitudinally with the description box in the top left-hand corner. The cranium is positioned along the Frankfurt Horizontal plane with the auditory meatus and floor of orbit aligned with the x-axis. The pre-molars and molars of the left maxilla overlap the opposing antimeres. For the posterior-anterior view, Figure 2 and 2a, the cranium is placed in the center of the film plane in the *Norma occipitalis* view with the cranium pushed slightly forward to allow the maxillary dentition to be visible in the light field. If a mandible is present, it is positioned in the posterior-anterior view with the interior dentition parallel to the plane of the film. For the superior-inferior view, Figure 3 and 3a, the cranium is placed upright with the occlusal surface maxillary dentition aligned with the plane of the film. If the mandible is present, place the mandible inferior side down on top of the cassette, arranged diagonally in front of the cranium. This arrangement, Figure 4 and 4a, should have the mandible in the top left corner lined up with the cranium to create a diagonal line intercepting the origin of the x-y axis. For the left and right oblique-lateral views of the maxilla and mandible only one sheet of film is necessary. The layout of the film is in split-screen format, Figure 5, 5a, 6, and 6a, with a lead sheet blocking one half of the film while permitting x-ray exposure of the other half.

The x-ray protocol for post-crania (pc) includes these certain bones: humerus, tibia, and femur. These bones are positioned in the posterior-anterior view. Due to the number of post-cranial lots involving many individuals, we try to place as many bones as possible onto one sheet of film. However, that tends to become difficult with femora. Special requests, which are views in addition to the protocol, can be made by individuals examining the remains for studying suspected pathological conditions, anomalies, and other abnormal features. The requests are entered into the database where the technician can easily retrieve the requests. A list is printed out specifying the catalog number, bone, positions and views, and a short, detailed description explaining the examination (Bruweldheide, 2001).

To produce the best radiographs, the radiographic technician requires an appropriate kilovoltage (kVp) and exposure time (s) to produce the clearest images. The control panel allows the technician to make adjustments by estimating the density of the bone. The kVp has three settings of 60, 80, and 100 kVp, but the machine is mostly set on 80 kVp. The density of the remains dictates the exposure time which is adjusted by tenths of seconds ranging from 0.1 to 1.9 seconds. Determining the correct exposure time and kilovoltage is based entirely on judgment of the technician who must understand how much of the power output from the kilovoltage and seconds, the affect of the intensifiers in the film cassette, and the correct estimation of bone density are all important for producing a clear image of the remains. Certain remains have a greater density because of certain disease or burial condition. For example, remains from Florida tend to be denser because of the sand or mineralization of the remains.

The radiographs are entered into a data entry application program, designed by the director of the Repatriation Osteology Lab, Dr. Stephen Ousley. The database is located and managed at the Repatriation Office and the Automatic Data Processing Center of the National Museum of Natural History. The radiographs are put into acid-free, unbuffered envelopes to prevent staining that was evident along the seams on older radiographs. Then, the radiographs are placed into customized film cabinets, S&S Vertifile metal cabinets for the easy storage and access.[3]

## Advantages and Disadvantages to Digital and Conventional Radiography

When deciding that the best archival preservation option is either continuing the use of only conventional radiographs or digitizing the images, certain factors should be taken into consideration. The human remains, managed through the Repatriation Osteology Laboratory, will either eventually be sent back to their affiliated cultural tribe/group or become apart of the museum collection at the National Museum of Natural History. Therefore, choosing the best system for preserving the radiographs is important. When considering the best option for the long term preservation of these radiographs, the Repatriation Osteology Laboratory decided to continue the use of conventional radiographs as an archival base with the intention of scanning and storing each image digitally. By digitally storing the images, they could upload a large number of images onto CDs, DVDs, disks, or a database for easy access to any image. Although, converting to digital storage tends to be expensive, the results in the long run are worth the cost. For example, when building the proper facility to store a conventional radiograph machine, you need a separate area to x-ray the remains, a dark room to insert new film and process the exposures without exposing them to harmful light, a storage facility for chemicals, film cassettes, film, etc., and another storage facility for the completed radiographs. Then, more money will be needed to hire a radiographic technician, who will purchase supplies, provide maintenance for the equipment, and the continual upkeep of the radiographs. However, with a digital radiography machine, only one room is needed for digital equipment, enough to fit the equipment, the researcher, and a computer system to store backed-up data. More space might be required if hard-copies are preferred. Since, the computer system stores the originals, the exact copy can be enhanced multiple times allowing different aspects to be accentuated through one image. The copies can be adjusted by the shadows, brightness, contrast, and sharpening features, clarifying features less easily seen from the original. Otherwise, under the use of conventional radiography, the image would have to be x-rayed multiple times under different settings. But, with the option to enhance the originals, the researcher enhancing the image would make adjustments depending on his/her own perception of the appropriate corrections, taking data from the actual image. Also, having a form of computer digital storage for saving the digitized images eliminates the risk of only one which can copy become misplaced, damaged, or lost forever.

There is a cost-effective method of digitizing two-dimensional radiographs and retaining the original hard-copies. It would be necessary to invest in a professional scanner to scan the radiographs without altering the original depiction of the image. For example, the radiographs presented in this report were scanned using an Epson

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[3] Bruwelheide, Karin S., *et al.* (2001). "Standardized Protocol for Radiographic and Photographic Documentation of Human Skeletons." *Human Remains: Conservation, Retrieval, and Analysis*

Expression 1640 XL scanner with a 12.2-inch by 17.2-inch large format color flatbed, 1600 X 3200 dpi resolution, and 42-bit internal and external color depth, resulting in identical digitized images from the two-dimensional radiographs. However, by using Adobe Photoshop 8.0, the radiographs were modified to enhance lesions and illuminate internal skeletal landmarks not evident in the original image. Another example of digitizing items was researched at Simon Fraser University in the Department of Archaeology. A professional scanner and computer program, Adobe Photoshop, were used as a simpler, less expensive technique for digitizing images (Odwak and Schulting, 1996).

**Conclusion**

In conclusion, radiography is an important part of the visual documentation in Physical Anthropology. Without radiographic analysis, a large amount of information would continue to be misdiagnosed or overlooked. The use of digital radiographs in anthropology opens up a whole new world of visual data, making it more readily available for the anthropological community. For example, virtual anthropology is a 3-D digital computer program changing the way researchers will examine fossils and modern hominids. Instead of studying tangible remains, a laser scans the remains, converting the image to an exact copy. Besides a limited spatial resolution, the computer program will be able to access hidden skeletal landmarks, virtual objects become more easily seen, and advanced morphometric analysis for fragmented remains (Weber, 2001).

Physical anthropology has continued to expand in the capabilities of researching human remains both past and present. The Repatriation Osteology Laboratory has widely practiced their radiographic data collecting for over a decade and has helped in redefining traditional forms of collecting information. As they continue to adhere to an extensive protocol of data collection, new improvements will continue to be made on radiographic equipment allowing better archival preservation of these radiographs to continue for researchers in the distant future.

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