

# The Restoration Of A Human Skeleton - As Scientific Specimen

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## Abstract

This paper describes the examination and restoration treatment of a male human skeleton that had long been used as a teaching specimen. The skeleton fell resulting in the brittle bone material shattering and bone fragment loss. The skeleton had been previously wired together, had steel inserts for rotation, as well as rods to facilitate weight balance. The treatment required reassembly and extensive repairs to broken bones due to a fall the skeleton suffered in the teaching context. Bones were first disassembled and catalogued, cleaned and then stabilized using adhesives. Damage to wire or metal-segments was addressed, weak areas of bone were reinforced with metal pins (stainless steel) and lost fragments from impact were replaced and secured with adhesive (using an isolating layer of dilute B72, consolidation and filling with PVA emulsion and Polyfilla as a polymer paste. A review of earlier work in the restoration of vertebrate skeletons is provided.

## 1.0 Introduction

A male human skeleton around 200 years old arrived in the Conservation Art Service and Antonetti Fine Arts Laboratories for examination. The skeleton had been used for instructional purposes in medical training, and was mounted on an unstable rolling frame. The remains were stored in an upright corrugated box with the torso and head attached, and the legs and arms detached.

A comprehensive examination of the skeleton was undertaken in order to develop a treatment strategy. All anatomical elements and fragments were inventoried (**Figure 1**). The examination of the skeleton revealed bone damage, old adhesive and varnish, missing patella and friable and weakened bone. The entire assemblage of hardware was examined in detail to assess for damage and loss. These problems presented a challenge, as most work in restoring vertebrate skeletons is done for display items where reinforcing hardware can be placed outside the bone. In the case of this specimen the skeleton was used for instruction and any hardware applied to the bone would be a visible distraction, and would also hide and/or damage bone material. The owner did not want any evidence of repairs to be visible as these would be considered distractions by instructors at the college.

There are a number of published works on the care of Natural History specimens, none of which address the issue of disassembly, repair and reassembly of damaged specimens (Carter & Walker, 1999; Rixon, 1976; Horie & Murphy, 1988). Most texts and articles are concerned with “fresh” specimens. This includes most taxidermy texts.



Figure 1: Setup for initial examination and inventory.

Others review the history of how specimens were displayed and used (Guerrini, 2003). Some have been written by archaeologists or paleontologists, for field workers or museum staff. They address problems of removing fossils and bones from matrix or geological contexts and processing the remains for laboratory examination, storage and eventual display (Hermann, 1908). Few of these provide directions for assembly as standing exhibits with the exception of paleontological display. Such display is mainly concerned with the physical properties of safe assembly. The hardware that has been developed in this field can be external and viewed by the public. This hardware is often painted the same as the bone or fossil material (Schultz & Reider, 1943; Bathel, 1966; Bessom,

1963; Majumdar, 1974; Carpenter, 1984; Converse, 1984; Leiggi & May, 1994). In fact, there are few reports of how fossil specimens are extracted from the field matrix and later prepared for exhibit. Rare passages appear of both conditions in separate publications, as for example the Shanidar I skull in situ (see Trinkaus & Shipman, 1993) prior to removal (**Figure 2**) and the after cleaning in Day (1986) (**Figure 3**). A similar problem faced the technicians who assembled the remains of the Arago fossil skeleton. Their task was more difficult in that they had to fabricate many lost bones.



Figure 2:

Shanidar I fossil skull in situ.

## *The Shanidar Remains*

IRAQ SHANIDAR

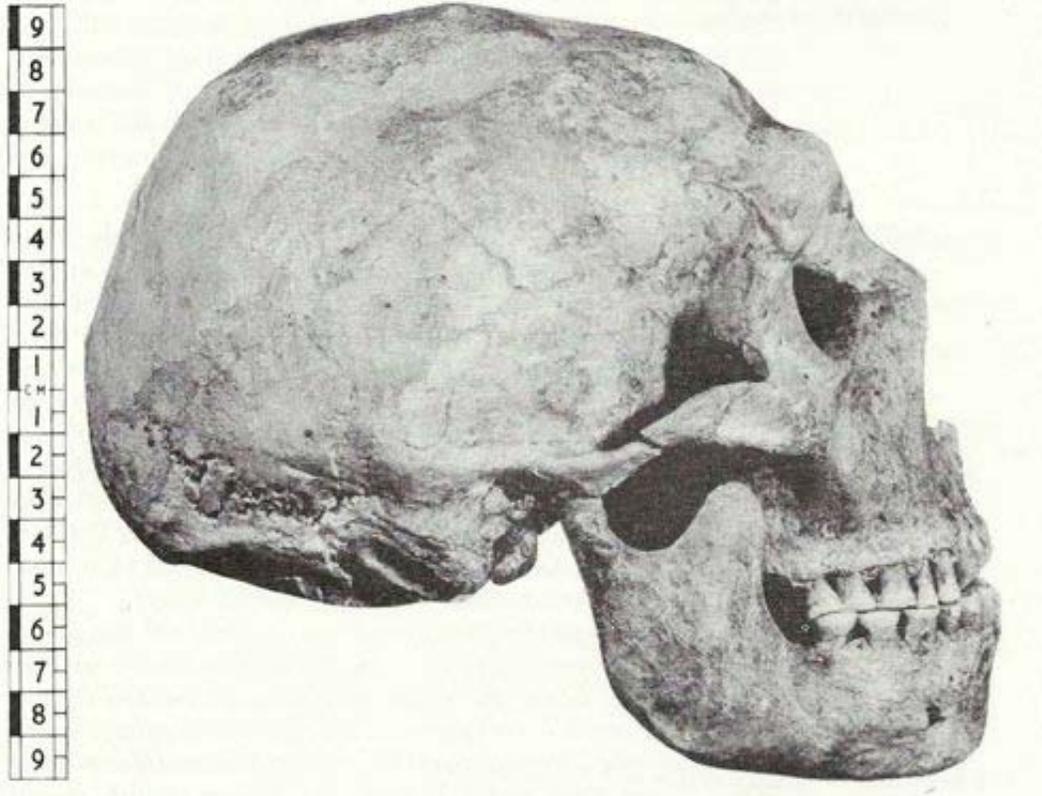


Figure 3: Shanidar I fossil skull after removal of matrix.

In the early 1970s The California Academy of Sciences had a carbon copy of a manual by Adele Panofsky, which was available as a guide for work with fossil skeletons. Panofsky worked at the Stanford Linear Accelerator Center and her experience was published as a technical note of that institution. Again, the adaptation of techniques was for external support of the fossil material and could not be applied to our problem. Our supports had to be minimal and leave the skeleton as it had originally appeared for display in a medical school at the turn of the 20th century. The central goal was to repair all damaged areas to produce a visual integrity and structural stability while adding a foundation that would not be externally visible.

### **2.0 General Appearance and Condition**

The damage to the skeleton was reported to have resulted from the skeleton falling over. This fall resulted in numerous broken bones with accompanying loss of bone fragments. The lack of cushioning material (flesh, etc.), and the general brittle nature of bone that has been treated to

remove flesh were factors in the extent of the damage. Even in lightly treated cadavers where the flesh has been removed in a mechanical fashion and then treated by cold-water maceration we find a loss of bone density. Bone loss can often be attributed to the use of chemicals, including bleaches, and drilling into the bone to allow for the removal of marrow. While there are holes drilled into this skeleton, they appear to be related to the process of rearticulation. These drill holes and the hardware associated with them have impacted the bone in adjacent areas (**Figure 4**).



Figure 4 1: Abrasion of femur around a wingnut at articulation point. Tape was wrapped around both tibia.

Areas of abrasion on the surface of the bones could be the result of cleaning with jets of water or compressed air, but other agents are also possible. The use of heated water and detergents,

especially those containing chlorides, has been associated by Carter & Walker (1999), with similar features and loss of soluble components of bone, mostly where simmering is utilized. Mahoney (1973) reports the frequent addition of washing soda to simmering baths to quickly remove fats. In this skeleton the chalky quality of the bone is more reminiscent of bone treated by simmering with sodium perborate as opposed to the more destructive process using sodium bicarbonate, ammonia and sodium hypochlorite. Wire was used to maintain the position of the ribs and steel inserts were covered with epoxy to unite the ribs to the sternum (**Figure 5**). Shellac was used at the clavicles (**Figure 11**).

## 2.1 Losses

Neither knee had patellae. Tape was on each of the areas of articulation of the knee (**Figure 4**). Information about the lost patellae was not available. College authorities indicated that all parts had been collected. The tape may have held the joint together at some point for instructional purposes, but apparently did not act as a temporary means of securing the lost patellae. There was no evidence of patellae in the bone fragments sent to the laboratory for restoration.

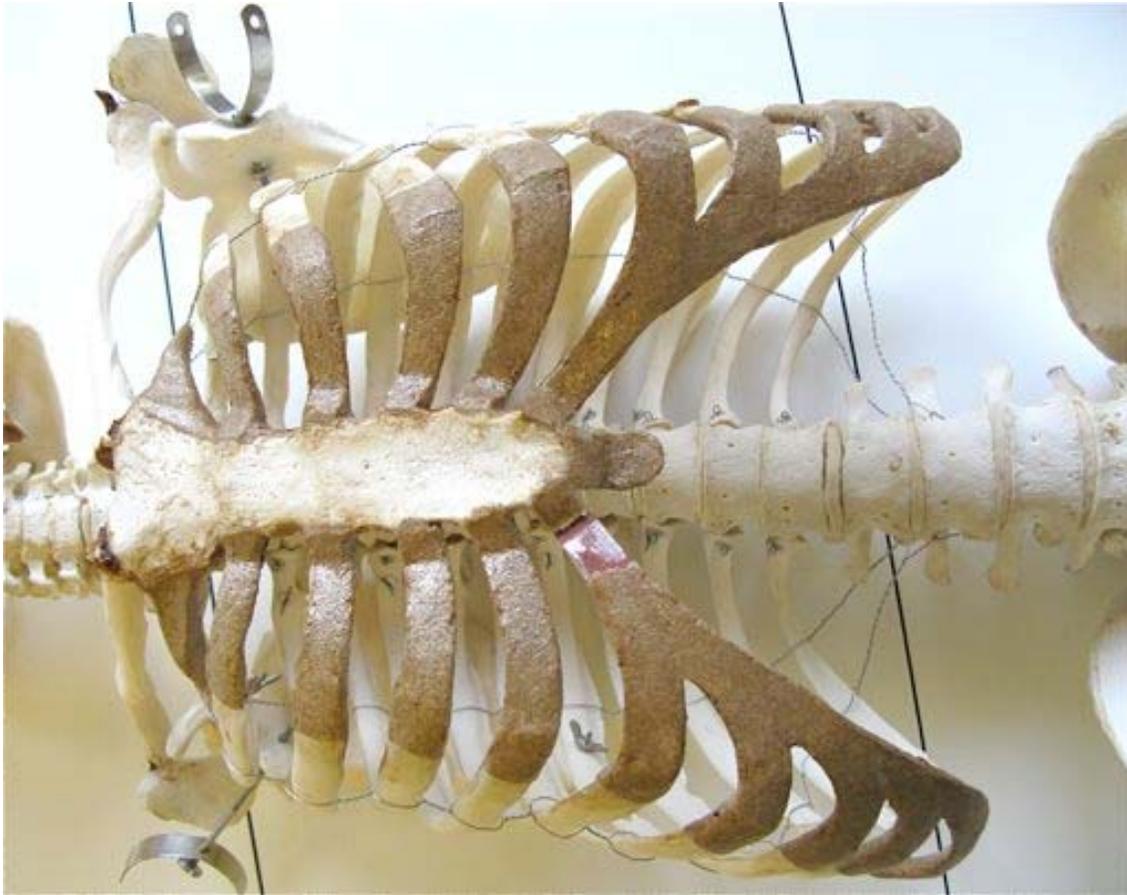


Figure 5: Various structural supports for torso.

An envelope of fragments accompanied the skeletal parts. The larger of these were matched to their respective losses, but the smaller fragments could not be matched to specific broken areas. In general, breaks in bones showed a fair degree of matched ends. The most severe damage was presented in the vertebrosteral ribs 3 to 7 of the right side, and the vertebrochondreal ribs notably 9, 10 and 11 of the left (**Figures 6 & 7**).



Figure 6: Five fractured ribs. Proper left side.



Figure 7: Three fractured ribs. Proper right side.

Some losses are present in the right scapula break and at the attachment of the 7th cervical vertebrae and rib, one exhibits stress with losses. This stress is also present in many of the dorsal attachments of ribs to vertebrae. In several locations there is general cracking and torsion evident with missing fragments. In some cases these may be old, and predate the accident, but in general, most appear new.

Breaks and losses also appear in the armatures joining the ribs to the sternum (**Figure 14**).

## **2.2 Distortion and Damaged Hardware**

As mentioned above, many of the losses were accompanied by impact distortion of the bone where twisting and compression had resulted in a dislocation of position of the bone from that expected, given the anatomical norm. Careful consideration was given to potential individual variation or pathological conditions, in each consideration of potential abnormal positions, or incomplete locations by reference to standard texts (e.g., Bass, 1987; Ortner & Putschar, 1981; Steele & Bramblett, 1988; Steward, 1979; Wells, 1964).

## **3.0 Treatment Plan**

The goal of treatment was to return the skeleton to a normal anatomical condition and to retain or restore the historical organization and materials used in the original assemblage. The treatment was organized in several stages. Each stage was evaluated at the conclusion to determine if modifications of the treatment plan should be made. The single most important element in the restoration, other than stabilizing the overall structure as a functional object, was that the skeleton could not show any evidence of support repairs, like metal armatures on the exterior of the bone or obvious filled in places where the original material was lost. All reinforcement had to be interior and not visible. We did use some outer reinforcements, such as replacing wire hole felt pads. Also, the polyfilla/pva fills changed the appearance of the skeleton by making the bone less transparent.

The first stage was to organize the fragments and disassemble the skeleton. All parts were separately identified/labeled and numbered so that they could be associated during reassembly.

Each bone or fragment was examined and any cracks or loose areas were noted.

Each bone or fragment was cleaned in three ways: First it was dry cleaned using a soft brush and Hoover vacuum, then cleaned using alcohol and finally with an aqueous surfactant (**Figure 8**).

The bones were repaired

The skeleton was reassembled with the replacement of felt pads and realignment of wire

A new stand was acquired



Figure 8: Cleaning bone material.

### Methods

Fractures and loose areas were coated with a PVA emulsion, AYAA in alcohol (ISOH) 5%. Broken pieces were reattached with the same adhesive. Dilute B72 was used in harder to adhere, complete breaks. **Figure 9** shows materials and set-up of the workstation.



Figure 9: Initial rib repair, fragments with notations in the foreground and materials assembled for treatment.

Some areas of articulation were also separated either by wear before the fall or due to it, though they contained wire holding them together (**Figure 10**). Originally the wire connecting the clavicle to the sternum was supported by a mass of adhesive, which appeared to be a natural resin such as shellac. The brown color of this resin may be an artifact of aging.. We were unable to remove this mass of old adhesive. The mass was insoluble and we preferred not to risk disturbing the bone with aggressive mechanical removal. We applied BEVA D-8 or PVA AYAA onto the areas of articulation to reinforce the wire



Figure 10: Clavicles at sternum originally joined with wire and adhesive.

Losses were filled using Golden Paste, usually aided by the use of microballoons, or Polyfilla in PVA emulsion, also varying concentrations of PVA emulsion and polyfilla as a bulking agent and filler were used as appropriate where microballoons did not smooth as desired. Where pieces were lost they were either molded in plaster, or a piece of Japanese paper was cut to shape and saturated in BEVA D-8. IN some areas we used card stock to begin with for structural support. Then Golden Paste or Polyfilla was built up to compensate for the loss (**Figure 11**).



Figure 11: Building up of material to fill loss.

Where breaks required reinforcement, we added new aluminum or stainless steel implants fabricated to custom fit each unique break. Implants had to be cut, formed, notched and bent to repair every loss. **Figure 14** shows the original flat implants in the sternum-rib connection. The new implants were fabricated in our laboratory from metal rod blanks, purchased from a local craft store. Customization required bending the blanks into specific shapes that had been determined by placing a blank in near position and then estimating the angle of most effective insertion given the mass of bone present. The blank was bent to fit using pliers. Implants were embedded in the bone using B72 set in a PVA reinforced bed, or as in the case shown in **Figure12**.

It was essential that the implants be able to bridge short distances, while being easy to twist and manipulate. In the case of the ribs, narrow round, hollow tubular implants were best. The hollow tubular type was easier to bend, while the solid round held weight better.



Figure 12: Insertion of PVA after pins were installed. The pins can be seen on either side of the syringe.

After the pins were secured, the pre-matched fragments could be set into place with PVA-AYAA (Figure 13).

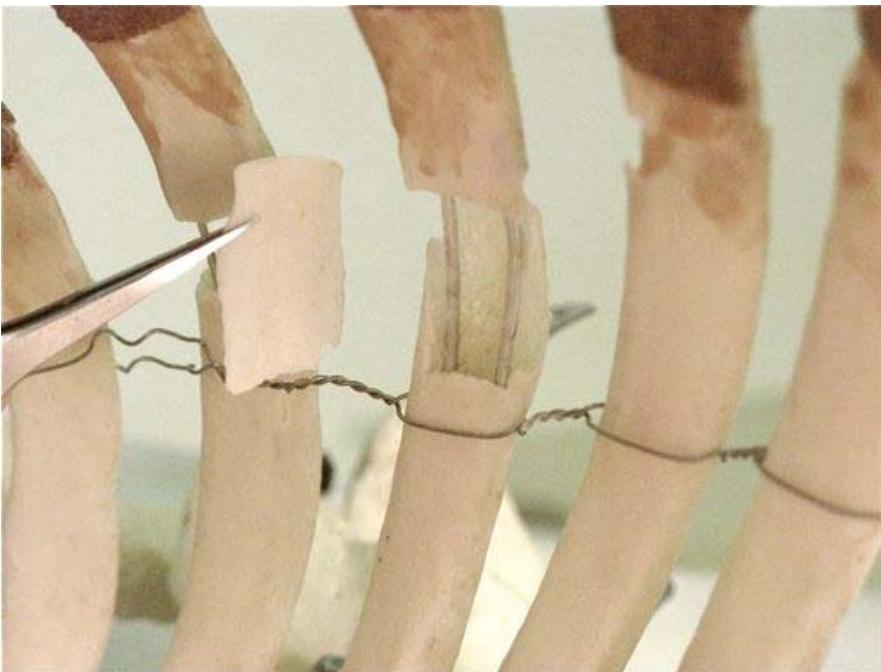


Figure 13: Pins set into ribs being covered with retrieved fragments.

Araldite was used to repair the original epoxy adhesive beds around the original flat metal inserts (**Figure 14**). The area where the Araldite would be applied was coated with either B-72 or PVA emulsion.



Figure 14: Original steel insert had been covered with epoxy, which cracked and broke during the fall.

The original wire supporting the ribcage was reused. We unwound the wire, made the repair and rewound the wire as the adhesives were drying. This allowed the repaired areas to rejoin while the repair adhesive was still flexible (**Figure 15**).

**Figure 16** shows how areas of loss and breaks were filled with Polyfilla in BEVA D-8. Ethafoam spacers were used in the repair of the ribs. They were cut to the precise size needed to achieve the correct anatomical position of the ribs, this was also restrained by the earlier folds of the reinforcing wire placed on the skeleton originally. It appeared that the original wire reinforcements cut into the bone of the ribs during impact causing considerable bone loss. The previously mentioned consolidants and fillers were also used to repair this damage.

To the right top of **Figure 16** one can also see a screw head that is seated in a “washer” of felt. Most of the original hardware was installed with these “washers”. Such “washers” of felt were originally placed on both sides against the bone between the vertebra, to protect the bone from rubbing against bone and hardware. Some of the felt was lost during the accident. Other areas never

had washers. In all cases, we replaced lost and missing washers with newly cut felt of the same thickness as the original.



Figure15: One of two implants placed within this broken rib.



Figure 16: Implants covered with filler.

The rib cage had been originally reassembled in the sternal-end ossification site using an epoxy. Where there were cracks or losses in this adhesive mass, PVA was used to adhere epoxy fragments. Where substantial losses had occurred or where adhesion had failed a new epoxy was added and painted to match. In some cases, as seen in **Figure 14**, new epoxy was added over the old steel inserts.

**Figure 17** illustrates the completed frontal area of the skeleton featuring the repaired sternum and ribs, using original wires.



Figure 17.

Inpainting was done using Gamblin or gouache painting materials over PVA coated original surfaces, and then coated with PVA and/or a matte varnish.

**Figure 18** is a detail of a repaired area of one of the scapula with the felt washer and nut in place. The repair has been inpainted to reduce the contrast of the fill materials, but not completely hide the area of repaired damage.



Figure 18.

Some thin bones of the skull were repaired with Japanese tissue coated in PVA or BEVA D-8 and applied to the broken or missing bone with tweezers and lightly manipulated into place with a scalpel. The paper was brushed into tight and even contact to remove wrinkles and cover the missing spaces completely. These paper repairs were so difficult to notice that in most cases no inpainting necessary (**Figure 19**).

In some cases, such as surrounding the teeth, the adhesive had darkened with age and could not be removed. After consultation with the owner, we decided not to remove the material. In some cases, it was painted to soften its appearance material. Figure 16: Area of repair with Japanese tissue of the right nasal bone. New Patellae were fabricated, and added using aluminum wire (**Figure 20**).



Figure 19: Area of repair with Japanese tissue of the right nasal bone.



Figure: 20

A new stand was researched. We consulted the owner and came up with a design that was more stable and less likely to be tipped over. As the original stand was considered unsafe, the new stand had to adhere to strict requirements of stability and ease of use. The process of locating an appropriate support was difficult. Dozens of sites were visited and distributors interrogated. Of the available manufacturers only two produced support systems. The two available manufacturers' products were rejected, as they either had no rolling system that was stable (plastic wheels, and plastic frame with thin top heavy design), or had no rolling system at all. The stand that met most of our requirements was manufactured in China but had to be purchased in batches of 100. The next most desirable unit could not be obtained as it was out of stock.

We gave all the information we collected to the owner who had decided to purchase the stand we recommended directly from the manufacturer.

The skeleton had to hang as it did originally from a hook set into the skull. This hook was reinforced with a new metal design and with new felt washers. The completed skeleton is shown in **Figure 21**, hanging from one of our laboratory stands originally designed for holding photo lights. We had modified this stand with a piece of Bunsen burner ring-stand equipment for the specific

purpose of assembling the skeleton. The skeleton was returned to the owner with only the original hook to be used with whatever new mounting system they chose.



Figure 21: Reassembled skeleton after treatment with new patellae.

## 4.0 Conclusion

The conservation treatment of this skeleton presented substantial challenges, both from a scientific and a conservation perspective. The repair had to retain the appearance of the early 20th century technology of the original assembly and had to be able to continue to be used as a teaching tool. Reinforcement had to be hidden and this made the choice of treatment very difficult, as there were no existing publications that addressed such a conservation ethic. Treatment reversibility had to be weighed against the necessity of the object continuing to be a functional, composite object. All other discovered treatments of reassembly used external repair supports.

We would like to enter into conversation with other conservators and preparators who are actively engaged in this type of work to share experiences and discuss problems.

## 5.0 Sources of Materials

PVA AYAA: Resin acquired in bulk from Conservation Materials in the 1980s B-72 copolymer: Resin acquired in bulk from Conservation Materials in the 1980s Polyfilla: Acquired from Conservation Materials in 1980s BEVA D-8: Dispersion from Conservation Support Systems Artificial Saliva: Roxan Laboratories CMC: Process Materials Corporation Alcohol: Reagent grade absolute from Mallinckrodt Toluene: Reagent grade from Mallinckrodt Stainless Steel blanks: Cliff's Hardware, San Francisco Araldite: Conservation Resources International, LLC Microballoons: Conservation Support Systems Golden Paste: Golden Artist Colors Pigments: Gamblin Artists Colors, Gouache Winsor & Newton Matte Varnish: Daler-Rowney

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### Bibliography

Bass, William M., *Human Osteology: A Laboratory and Field Manual*, 3rd Edition, Missouri Archaeological Society, Special Publication, N. 2, Columbia, Mo, 1987.

Bathel, K., "Mounting a skeleton of *Smilodon californicus* Bovard," *Curator*, v. 9, 1966: 119-124.

Bessom, L., "A technique for mounting skeletons with fiberglass," *Curator*, v. 6, 1963:231-239.

Carpenter, K., "Skeletal reconstruction and life restoration of *Sauropelta* (Ankylosauria: Nodosauridae) from the Cretaceous of North America," *Canadian Journal of Earth Sciences*, v. 21, 1984:1491-1498.

Carter, David and Walker, Annette K., *Care and Conservation of Natural History Collections*,

Oxford, Butterworth & Heineman, 1999. Converse, H., Handbook of Paleo-preparation Techniques, Gainesville, Florida Paleontological Society, 1984.

Day, Michael H., Guide to Fossil Man, 4th edition, Chicago, The University of Chicago Press, 1986.

Guerrini, Anita, "Duverney's Skeletons," *Isis*, v. 94, n. 4, Dec. 2003: 577-603. Hermann, A., "Modern laboratory methods in vertebrate paleontology," *American Museum of Natural History Bulletin*, n. 26 of the Manchester Museum, 1988. Leiggi, Patrick & May Peter, *Vertebrate Paleontological Techniques*, Vol. 1, Cambridge, Cambridge University Press, 1994.

Mahoney, R., *Laboratory Techniques in Zoology*, 2nd edition, London, Butterworths, 1973.

Majumdar, P., "A free-standing mount of an Indian rhynchosaur," *Curator*, v. 17, 1974:50-55.

Ortner, Donald J., *Identification of Pathological Conditions in Human Skeletal Remains*,

*Smithsonian Contributions to Anthropology*, n. 28, Washington, D.C. 1985.

Panofsky, Adele I., *Current Techniques for Fossil Skeleton Mounting*, Mimeo, SLAC-TN-737, August 1973. Rixon, A., *Fossil Animal Remains: Their Preparation and Conservation*, London, Athlone,

1976. Schultz, C. & Reider, H. "Modern methods in the preparation of fossil skeletons," *Compass*, v. 23, 1943:268-291. ,

Steele, Gentry D. & Bramblett, Claude A., *The Anatomy and Biology of the Human Skeleton*,

Texas A & M University Press, 1988. Stewart, T.D., *Essentials of Forensic Anthropology*,

Springfield, Charles C. Thomas, 1979. Trinkaus, Erik & Shipman, Pat, *The Neanderthals*, New

York, Alfred A. Knopf, 1993. Wells, Calvin, *Bones, Bodies and Disease: Evidence of Disease and Abnormality in Early Man*, New York, Frederick A. Praeger, 1964.