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Tools and Techniques in Preparation of Coloured Bones and Skeletons for Effective Teaching, Learning and Museums

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ABSTRACT

Background: Teaching veterinary osteology and arthrology has been performed with free bones collected from various animals after processing and preserving them for long duration. The profession of teaching Anatomy to undergraduate and postgraduate students in veterinary colleges not only requires the knowledge on Veterinary Gross Anatomy but also the methods of preparation of specimen for laboratory use. This article explains the methods and steps in preparation of coloured skulls, bones of forelimb, hindlimb, rib cage, digits and whole mounted skeletons, to be used in the anatomy laboratory to increase the efficiency of both teaching and learning.

Methods: A carcass of adult horse donated by a farmer was utilized for making complete coloured skeleton. The bones were collected from the carcass by natural maceration technique followed by cleaning with mild chemicals. The metallic paints and commonly available tools were used for colouring and mounting of horse skeleton. The parts of bones *viz.* process, fossa, articular area, foramen, the origin and insertion of various muscles were prepared with colours and labels on the surfaces of bones for teaching and museum purpose. The sequential step by step procedure for skeleton preparation in quickest possible time was standardized and explained using various tools.

Result: The natural maceration in open water tank was found to be most effective way of maceration of carcasses for collection of bones with their normal colour. The bones were processed mainly with washing soap powder and calcium carbonate followed by drying in natural sunlight which increased the brightness of the bone without any damage to the structure. The coloured skulls, bones of forelimb, hindlimb, rib cage, digits and whole mounted skeletons were prepared with available tools and chemical as this work consumes less time and cost and increases the students' learning efficiency, which will also be an asset and center of attraction for any Institution.

Key words: Coloured bones, Horse skeleton, Natural maceration, Teaching anatomy.

INTRODUCTION

The profession of Veterinary Practice is delivered in the forms of 1. Diagnosis and treatment of animals in the field conditions; 2. Minor and major Surgeries in field, government and private hospitals; 3. Teaching undergraduate and postgraduate students in various Institutions, that requires a sound knowledge in Veterinary Gross Anatomy. The subject knowledge in Veterinary Anatomy forms the basis for all those involved in these fields of services to livestock. The teaching of Anatomy has long been executed by giving much emphasis on practical demonstration, handling of bones, dissection of cadavers for body regions, organs of various domestic animals and birds as comparative veterinary anatomy. Teaching osteology has been performed with free bones collected from various animals after processing and preserving them for long duration. The availability of assembled or fully mounted skeletons of ox, horse, dog, sheep, goat, pig and fowl are highly essential in the anatomy laboratory and in museums for the students to refer and study the location, arrangement of bones and formation of joints in the body. The coloured skulls, long bones and mounted skeletons of various domestic animals and birds in the laboratory increase the efficiency of both teaching and learning osteology and arthrology. Most of the anatomy laboratories in various colleges in India have only plain bones for teaching due to the non-availability of staff and standard tools. The information on methods and procedures of preparation of coloured bones and skeletons are not available as published works. Hence, the current work was undertaken to standardize the methods in preparation of coloured bones and skeletons in quickest possible time for the purpose of teaching and museum.

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MATERIALS AND METHODS

Natural maceration or decomposition of carcass

A carcass of horse, 14 years of age was willingly donated to the department of Veterinary Anatomy by a private owner for the purpose of teaching. The bones of this animal were utilized for the preparation of complete coloured skeleton. In addition, bones of other domestic animals collected from slaughter house were also utilized for coloured bone specimen preparation and were routinely used in laboratory and museum for teaching and show purpose. The carcass was deskinned, visceral organs were removed from body cavities and the joints *viz.* hip, stifle were disarticulated to hasten maceration of ligaments and cartilages. The sternum was separated by cutting at all the costo-chondral junctions both on left and right side and processed separately to avoid maceration of cartilaginous portions of sternum. The cemented concrete tank measuring 8 feet × 5 feet × 5 feet over the ground level was used for maceration of carcass of horse and body parts of other animals. The cadaver and disconnected parts were immersed in the maceration tank containing water for 3 weeks to enable natural maceration. The tank was fitted with drainage outlet tap for easy cleaning and the top of the tank was kept open during the process of maceration. The tank was then filled with water upto 3-4 feet only, so as to expose few parts of the carcass for flies to feed and breed. The carcass attracted various flies *i.e.* domestic fly, blue and green bots (*Lucilia cuprina, Sarcophaga* sp.) and beetles (*Dermestes* sp.). These flies fed on fresh flesh and blood, laid their eggs (150-200 eggs at a time by a fly) on all over the exposed parts of carcass. The larvae of these files voraciously feed on the flesh for 10-15 days, eat away all soft tissues like flesh, tendons, cartilages and ligaments by moving one region to other regions in the water. All the bone became free from their joints and separated due this natural maceration.

Processing of bones

The loose bones were washed several times in the maceration tank itself with free flow of water to remove the decayed soft tissue debris. The free bones after several washing from the maceration tank were collected carefully without leaving even small bones like phalanges, sesamoids *etc.* for making complete skeleton. The foul smelling bones were immersed in 30 liters of water containers mixed with 1 kg of washing soap powder for 7 days. The bones were washed several times with running water and kept in 30 liters of water mixed with 5 kg of calcium carbonate (common lime powder) for 7 days to remove further fat and also to increase the brightness of the bone. The free bones were dried in sunlight in open place for 3 days to remove water and traces of fat content, if any.

Tools used for coloured skeleton making

A list of tools and chemicals used for processing, colouring and mounting of skeleton are listed in Table 1 (Fig 1).

RESULTS AND DISCUSSION

Collection of bones by natural maceration

The bones were collected by the process of natural maceration in open water tank. The removal of skin and visceral organs from body cavities of carcass has increased the maceration process. The cadaver was partially immersed in water which acts as a medium of transport for larvae to reach various body parts and few parts exposed over the water for files to breed has also hastened the maceration

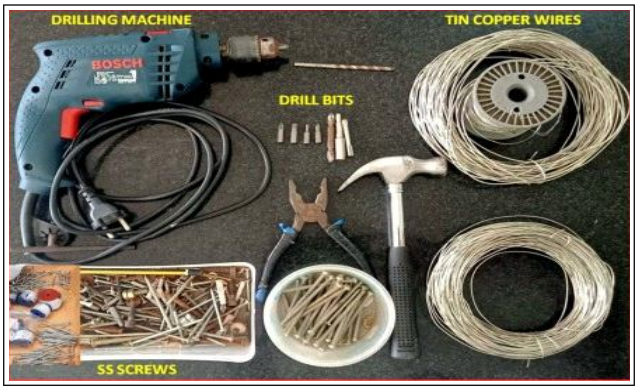


Fig 1: Tools required for making coloured skeleton.

Table 1: Tools and chemicals used for coloured bones and skeleton making.

Tools and chemicals	Purpose and size
Drilling machine with drill and screw bits	For inserting tin-copper wires and screws.
Screw drivers, cutting pliers	For tightening the screws and wires in desired length.
Tin copper wires	Various thickness in Nos.: For tightly fixing/tying the bones.
MS steel rods, square plates, bolts	7-8' square rod : For axial skeletonPlates and bolts: For fixing the SS pipes with wooden base.
Stainless steel pipes	3" Pipe : For holding the skeleton.
Stainless steel screws	1" - 3" : For fixing the extremities of adjacent bones and bones with wooden base.
Stainless steel rods	8-10 mm thick round: For welding the axial rod with SS pipe.
Araldite and anabond	For binding bones at their joints, fixing the teeth in their alveoli.
Wooden planks	3' × 8' : As a base of the skeleton.
Paints, thinner and brushes	Metallic multicolours (red, blue, green, orange, gold, silver, black).
Washing soap powder	2.0-5.0 kilograms for cleaning all bones of large animal.
Lime (Calcium carbonate)	5.0-10.0 kilograms for removing grease and fat.

process. This lasted for 2-3 weeks and the larvae died and putrefied along with the carcass leaving only bones in the maceration tank. This is the most effective way of maceration of carcass for proper cleaning of flesh, ligaments and tendons in shortest possible time.

The bones collected from maceration tank were processed mainly with washing soap powder and calcium carbonate (common lime powder) to increase the brightness of the bone without any physical and chemical damage. Reports on the use of various chemicals like gasoline (95%), trichloroethylene and hydrogen peroxide used for degreasing and bleaching purpose have indicated the disadvantages mainly discolouration (Gram, 2006; Hussain *et al*., 2007 and Allouch, 2014). The free bones were dried in natural sunlight in open place for 3 days that removed water and traces of fat content. The bones obtained from natural maceration appeared bright white in colour unlike the bones obtained using chemicals which were creamy or yellowish in colour with many cracks as reported by Onwuama *et al.* (2012).

Colouring the bones

The cleaned bones were assorted according to the regions *viz*, skull and mandible, vertebrae (cervical, thoracic, lumbar, sacrum, coccygeal), forelimb and hindlimb. Metallic paints were used for colouring all the bones due to its additional metallic lustre on the surface appeared pleasing. All the bones of skull are painted with different colours but same colour was used for paired bones of both sides. Various colours are used for cervical, thoracic, lumbar, sacrum and coccygeal vertebrae to distinguish their respective regions. Bones of the limbs were coloured with multiple colour combinations keeping bilateral similarities to enable easy identification of various bones. The hoof of all the limbs were kept intact along with 3rd phalanx and painted with black colour for additional attraction. The sternum which was dissected carefully to remove extra muscle and fibrous tissue was processed in sunlight and also stained with black colour. The coloured bones were dried for 2 days before assembling to prepare a complete skeleton. The coloured bones in a laboratory or museum usually attracts the interest of the students and visitors and enable better understanding on arrangement of bones in various body regions. Mounting a skeleton requires a sequential step by step procedure (Fig 3) which results in completion of the work in quickest possible time. A full length photograph of a horse in standing position with its head held in right position may be used as model for preparing the skeleton as that of the standing horse. The steps followed in preparation and mounting of coloured skeleton is as given below,

Step 1: Assembling vertebral column

The groups of bones of vertebral column were arranged according to their actual locations first on a clean floor (Fig 2). The length was measured up to the sacrum for choosing the length of steel rod (1-inch-thick square rod) which is going to act as axis through vertebral foramina of all vertebrae. The angle of the head, neck, body of the horse in standing position was brought out in the SS rod by making sufficient bends in its full length. Around one foot of rod was kept free anteriorly to fit the skull through the foramen magnum. The posterior end of the steel rod was trimmed gradually to fit the vertebral foramina up to first 3-4 coccygeal vertebrae.

Step 2: Assembling limbs

The carpals and tarsals were first tied up with tin-copper wires using small drilled holes. The bones of proximal and distal rows were carefully tied up as per their location followed by attaching them additionally with araldite ensured their stability. Steel screws of adequate sizes in combination with tin-copper wires were used for attaching other long bones with appropriate angles between bones at their joints. The alignment between the bones of shoulder, arm and forearm in forelimbs and between thigh bone, leg bone in hindlimb were done carefully based on the required posture of the horse skeleton.

Step 3: Fixing the height

The vertebral column inserted with SS rod and the two forelimbs and two hind limbs were held as that of the standing animal by using minimum 6 persons, so that the length between forelimbs and hindlimbs and height of the SS pipe as support from the wooden base to ventral aspect of vertebral column were measured. Two stainless steel pipes were fitted on wooden planks (3 feet × 8 feet) using square steel plates and bolt and nuts. The vertebral column using SS rod was joined with two SS pipes, one located in front (at the level of 7th Cervical vertebra) and another at back (at the level of middle of Sacrum). The finishing work on wooden base and welding work with steels were done by trained professional as per our requirement and direction. The wooden base was also painted using a mixture of metallic gold paint mixed with wood polish that gave the base a golden glossy luster (Fig 3).

Step 4: Fixing the ribs

All 13 ribs of both sides were identified and arranged on table. The holes were made in the head and tubercle of each rib correspondingly in centrum and transverse process



Fig 2: Coloured vertebrae, mandible and hip bone of horse for making skeleton.

of thoracic vertebrae for fixing the ribs at their proximal ends using tin copper wires. Starting from 1st rib all 13 ribs of one side were properly tied to the ribs. The distal extremities of ribs were attached with the corresponding sternebra and costal cartilages using tin-copper wires and additionally supported with araldite binding for extra stability.

Step 5: Mounting the head, hip bone and tail

The coloured upper jaw of the skull was fitted anteriorly by inserting the 6 inches of square rod projecting in front, into the foramen magnum. Copper wires were used to tie the skull with steel rod by making many holes for binding wires. Additional long SS plate was placed under the skull at bony palate and the other end was welded with the front side of anterior SS pipe. Mandible was fitted with skull with wires tied between mandibular condyle and temporal bones on either side; between body of the mandible and supporting SS plate placed at the bony palate.

Step 6: Fixing limbs

The hipbone was attached with the sacrum by SS screws and tin-copper wires and additional support was provided to this bone at the level of pubis by welding SS round rods to the posterior SS pipe. The full set of bones assembled in hind limb was attached to the acetabulum with head of femur using SS screws maintaining appropriate angle. Attach the forelimbs by wires or screws at the level of shoulder bone. The shoulder bone or scapula was attached with 3rd and/or 4th ribs with proper angle by placing the 3rd digit on wooden base. The hoof of each limb at the distal end was fixed with wooden base using SS screws.

Step 7: Finishing work

After attaching assembled bones of each region, the gap space in vertebral column between bodies and articular processes was filled with araldite to avoid shaking rib cage. In addition, the wire netting was carried out binding adjacent ribs and adjacent dorsal spines to give extra stability. Finally the extra-length of tin copper wires were cut after tightening the grip over bones. The complete work of making a coloured skeleton was done along with routine works of the department and it took nearly less than 45 days only but this skeleton may last for long period resisting mechanical damage.

Coloured bones and skulls for teaching

The class room teaching of anatomy can be made easy for the teacher and student by using coloured bones and their parts *viz*. process, fossa, articular area, foramen *etc*., marked with various colours (Fig 4).

The practical laboratory must have at least one number of coloured skull of ox, horse, dog, pig and fowl to understand the anatomy of individual bones of skull. The flat bones of skull are usually fused with adjacent bone at many places and the demarcation is indistinct in many species. Hence, by adding multiple colours to

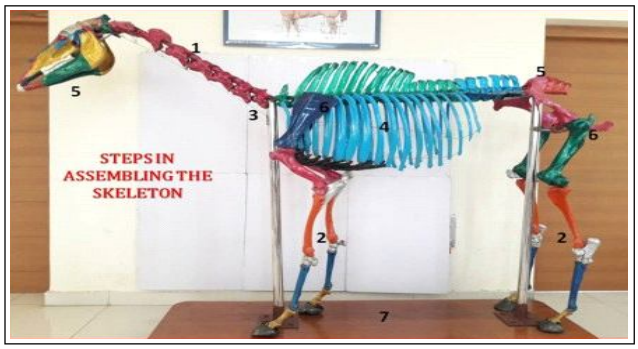


Fig 3: Steps in mounting of coloured skeleton of horse.



Fig 4: coloured bones for teaching in practical laboratory.



Fig 5: Coloured skulls (ox, buffalo, pig, horse) and rib cage of Horse.

individual bones in skull exhibited the boundaries clearly. The students can easily understand and remember individual bones of skull due to their added colours and demarcated boundaries (Fig 5). The course and supply of major blood vessels and nerves, foramina for nerve blocks and bony prominences in the skull can also be drawn with various colours for creating interest and better understanding among students. Coloured rib cages of ox, horse, dog and fowl were prepared to teach various joints between thoracic vertebrae, ribs, sternum, boundaries of thoracic cavity and location of visceral organs in thorax and abdomen.

CONCLUSION

The current work suggested that the coloured skeletons and bones for teaching and museum purpose can be readily

prepared by natural maceration and processing in low cost. In addition to good stock of bones and skeletons in our laboratory, preparation of coloured bones, skulls and whole coloured skeletons will be an additional aid for efficient learning to students. We have practically noticed higher levels of learning and interest among the students when they observe and handle the skeletons and bones that are coloured. In conclusion, we recommend that the coloured skulls, bones of forelimb, hindlimb, rib cage, digits and whole mounted skeletons can be prepared with available resources as this work consumes less time and cost and increases the students' learning efficiency, which will also be an asset and center of attraction for any Institution.

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Conflict of interest

All authors declare that they have no conflict of interest.

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