Conservation assessment of the Neanderthal human remains from Krapina, Croatia and its implications for the debate on the display and loan of human fossils

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Summary
In 2005, the Ethiopian government’s decision to offer the fossilized remains of a three million-year-old human ancestor for an exhibition tour of the United States provoked condemnation from many palaeoanthropologists. In response, the council of the International Association for the Study of Human Palaeontology passed a resolution stating that such remains should not be endangered by loan and exhibition but preserved for qualified scientific access only. This report summarizes the findings of a detailed conservation assessment of the collection of Neanderthal remains from Krapina Cave, Croatia. Examination showed that damage had occurred due to the incorrect application of resins as preservatives and adhesives, and the moulding of specimens for casting. Resin coatings had discoloured and contracted making it difficult to study surface features as well as resulting in surface loss. Adhesive joins were often inaccurate and join edges had not been strengthened by consolidation prior to adhesion, leaving them vulnerable to damage and further breakage. The use of casting materials such as plaster, wax and rubber had resulted in loss of the fragile surface and new breaks, or further breaks along old joins. The report concludes that human fossils may be as much at risk from researchers as when on loan to exhibitions.

INTRODUCTION
The discovery of human remains more than 10000 years old is always a cause for scientific celebration. Such finds are rare and valuable, as each new sample or technique may reveal threads of evidence in our understanding of human evolution. Consequently, there is a persistent requirement to measure, cast and sample from existing and newly discovered human bones. As a result many palaeoanthropologists, among them the curator of the Neanderthal human remains from Krapina Cave, Croatia, Dr Jakov Radovčić, have noted regrettable damage and distortion to specimens. In response to these concerns, and at the request of Dr Radovčić and American colleagues Professor Milford Wolpoff of Ann Arbor University, Michigan and Professor Alan Mann of Princeton University, New Jersey, the British Museum agreed to support a conservation survey of the Krapina material.

THE SURVEY
The survey examined the largest known sample of Neanderthal human remains from Krapina Cave, north of Zagreb in Croatia. Excavated between 1899 and 1906 by palaeontologist Dragutin Gorjanović-Kramberger, the collection, curated at the Croatian Natural History Museum in Zagreb, consists of approximately 830 bones or fragments, including cranial and postcranial elements of individuals who lived between about 120000 and 60000 years ago. The bibliography of over 3000 papers in 20 languages written on these remains over the last century is a mark of their considerable importance to international research and debate on human evolution [1]. It also reflects the intense pressure placed on the collection by four generations of scientists, each seeking to answer new questions using the latest techniques.
Method

In May 2007 the authors examined every bone and bone fragment in the Krapina collection in Zagreb with the exception of the phalanges and separate teeth. In the case of the phalanges and teeth, representative samples of about 10% of each were examined so that an estimate of the condition and conservation requirements could be determined for all the specimens. Each specimen was checked against the collection catalogue [2]. This ensured the correct identification of the specimens and their numbers, as well as showing up changes in their condition that have occurred over the last 20 years. Dr Radovčić was on hand throughout the work and provided the invaluable guidance and information that can only be acquired by long acquaintance with a collection.

Following identification, every item was examined by eye and using a ×2.75 Optivisor headband magnifier. As each specimen was inspected, notes on its condition and conservation requirements were recorded in an Excel spreadsheet. Photographs were taken to record the deterioration noted on particular specimens, or types of alteration affecting the collection generally. Additional, higher-resolution, digital images of surfaces made during previous research by one of the authors (JC) were also utilized. As the work progressed, some basic solvent tests were carried out on the resins and glues that have been used on the remains over the last century in order to determine their composition, state of degradation and potential ease of removal. Samples of these resins were also taken for further analysis in the laboratory at the British Museum.

As the specimens were examined, each was categorized based on the approach developed by the British Museum for regular auditing of the conservation requirements of its own collections. Each piece was placed in one of the condition categories listed in Table 1.

By the end of the survey, even before the data collected had been analysed, the method already indicated the conservation requirements. Around a third of the collection is a high or medium priority and the rest requires attention in the near future. The remainder of this contribution summarizes the data, outlines the conservation requirements and suggests the actions required.

Present condition of the fossils

Most of the collection consists of fragments of bone that have been rejoined since excavation. Many of the joins were made years apart, so a single specimen may have been reconstructed by various researchers using a number of different techniques and adhesives. There is no documentation recording these reconstructions or the materials applied. Whether the specimens are complete bones, rejoined or fragmentary, all but a few have been covered with a thick coat of resin. In most cases this would appear to have been applied soon after the initial excavation and in many instances has been applied over sediment. This was usual practice at the turn of the twentieth century; in 1905 Rathgen recommended the application of natural resins such as dammar, shellac, isinglass or/and animal glues in appropriate solvents as a method of preservation for fossil bone [3]. These coatings have embrittled and discoloured with time, covering and damaging signifi-

<table>
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<th>Condition category</th>
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<tr>
<td>A</td>
<td>Good</td>
<td>No conservation required</td>
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<tr>
<td>B</td>
<td>Stable but at risk of degrading within 10 years</td>
<td>Low</td>
<td>Conservation required within 10 years</td>
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<tr>
<td>C</td>
<td>Unstable</td>
<td>Medium</td>
<td>Conservation essential as soon as possible</td>
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<td>D</td>
<td>Actively deteriorating</td>
<td>High</td>
<td>Conservation urgent</td>
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Figure 1. Photomicrograph of incised lines on Krapina skull 6. Evidence of post-mortem modification of the skull is obscured by the deteriorating resin coating, which is flaking off with fragments of the periosteum.

Figure 2. Photomicrograph of cut marks in the area of the mylohyoid line on the interior of juvenile mandible Krapina 53. The resin coating has a crazed surface and is flaking away.
In contrast, post-mortem markings on the bone surfaces, Figures 1 and 2. The internal structure of the bone is fragile and usually unconsolidated, causing a difference between the hard outer surface and fragile interior that sets up long-term stresses within the bones and may eventually result in surface loss. This is already visible on some fragments, particularly where moulding for replication has taken place. Tests on the coatings using acetone (propanone), ethanol, isopropanol (propan-2-ol) and water were inconclusive, although in some cases there appeared to be a slight softening with hot water, suggesting the presence of animal glue. Recent DNA tests have revealed the presence of bovine DNA, which could have resulted from the use of animal glue [4]. Samples of these resins were also taken for laboratory analysis at the British Museum, where subsequent testing revealed the presence of polyvinyl acetate, cellulose nitrate, proteinaceous material and components derived from conifer resin [5].

Figures 3 and 4 show some of the criteria that put a number of specimens on the critical list of pieces requiring urgent attention. Both illustrations show how newly discovered joins have been stuck together using a variety of adhesives over the years. As the 'preservatives' that have been used only coat and harden the surface, without consolidating the bone, the interior remains soft and fragile. When two such pieces are joined, any adhesive will form a hard line along the join. This will eventually result in further breakage and loss of bone. A succession of repairs to such separated joins repeats the problem, causing further damage with worse and ever more inaccurate reconstructions. In many cases adhesive has spilled out onto the surface of the joins. This excess adhesive may contract as it degrades resulting in surface damage and even loss. Tests on the adhesive suggest that there may be cellulose nitrate present. Recent joins have been made with an acrylic, Paraloid B48N, dissolved in acetone [4].

The use of small wooden sticks glued in place to hold fragments in position was undoubtedly intended to support and strengthen some joins, Figure 3. Unfortunately, this has compounded the problems of excess adhesive and poor joins. The sticks do not give adequate support to the fragments and in several cases they have detached, removing the bone surface, leaving the bone unsupported and the join unstable. Dimensional changes in the wooden sticks due to environmental variations may also have contributed to this movement. The distortion in form that may be caused could result in the collection of misleading measurements and provide poor bases for the comparison of specimens.
On fragments of limb bones there is often a hard fill or consolidant material present on the exposed cancellous tissue, Figure 5. This appears to be stable, but is thick and obscures the surface of the tissue. The few bones that are uncoated are fragile but otherwise well preserved. The teeth are in relatively good condition and in general do not appear to have been coated with resin.

During a century of research the Krapina bones and teeth have been extensively moulded for the production of casts. Surfaces and joins bear the traces of this process, which consist of remnants of casting materials such as plaster, wax and rubber, all of which adhere to the surface. Damage to the surfaces and joins, as well as significant distortion, is also evident, Figure 6. The deleterious effects of these processes have also been detailed by Monge and Mann [6]. The remnants of moulding materials need to be removed from the Krapina bones with great care otherwise they will pull off more fragments of periosteum, tooth enamel or dentine.

The use of plasticine (a putty composed of petroleum jelly, fatty acids, and calcium carbonate) or ‘Blu-Tack’ (a blue putty composed of hydrocarbon polymers, mineral oil, fillers and pigment) to make temporary joins or to support specimens during measurement or photography has also resulted in damage to the specimens, Figure 7. There is a large amount of Blu-Tack adhering to the surfaces. Blu-Tack and plasticine are difficult to remove from porous surfaces and also cause oily stains.

Other extraneous debris noted on specimens included black fibres from fabrics used as back cloths for displays or photography, and patches of adhesive that would seem to be the result of attaching specimens to black fabric for display, Figure 8.

The surfaces of the specimens are dirty and often show numerous superficial nicks, scratches and indentations that have accrued since excavation as a result of that process and subsequent handling, including the use of metal measuring implements and dental tools, Figure 9. They also show copious pencil marks, which have been made to locate joins, mark measuring points or left as residues when tracing the edges of fragments. In addition, the specimens bear numbers in ink indicating their place in various cataloguing sequences. These numbers are wearing away or have partly disappeared as a consequence of surface loss and are becoming difficult to read. The resin used in conjunction with the red ink is beginning to degrade, resulting in shrinkage and cracking that will eventually cause the loss of the number and damage to the bone.

ASSessment

Examination of the Krapina collection indicates that much of the damage that it has suffered is due to handling, the incorrect application of resins as preservatives and adhesives, as well as the moulding of specimens for casting. There are no records of which materials have been used or of how, when and by whom they have been applied. The pressure to allow the collection to be researched has resulted in the requirements of these uses having priority over conservation considerations, despite the best efforts of the curator to monitor and restrict any unnecessary activity.
DISCUSSION

In 2005 the Ethiopian government offered to loan the remains of a 3.2 million-year old skeleton of *Australopithecus afarensis* (popularly known as Lucy), an early human ancestor, to museums in the United States. In response, the council of the International Association for the Study of Human Palaeontology passed a resolution against the loan of human fossil remains for the purpose of display. This international body of scientists involved in research on human evolution feared that the risks of packing, transporting and displaying human fossils were too great to allow, because of the immense value of the specimens to the history of humanity. Instead, the Association wishes to restrict access to scientists and only move specimens to their laboratories for scientific reasons. As this report on the Krapina collection shows, concern for these fossils is legitimate and this is not an isolated case [6, 7]. However, in this case the cause of deterioration is not the exhibition of the fossils but handling during scientific investigations and lack of professional conservation. The curation and conservation care that such specimens receive in museum exhibitions is protectively benign by comparison with the way in which specimens are sometimes handled during research.

Thanks to the informed concerns of Dr Radovčić, it is not too late to reverse some of the damage and halt further deterioration of the Krapina specimens if immediate action is taken. This is a case which should be a wake-up call to the palaeoanthropological community. Work on the reconstruction of fossils should not take place without the participation of professional conservators. Instead of preventing the display of the common origins of humanity, the Association for the Study of Human Palaeontology should be setting internationally accepted guidelines for the handling, reproduction and sampling of fossil human remains. These should focus on record keeping, storage, handling and conservation, and should monitor research requirements to ensure they can be met without detriment to the specimen. The following suggestions made for the Krapina specimens might form a starting point.

Recording

Curatorial and conservation records whether manual or electronic should be kept for every specimen. These should include curatorial data such as catalogue numbers, as well as information about specimen condition and details of any actions taken with specimens such as conservation treatment or scientific sampling. These details should include by whom, when, how and with what materials or equipment any work was done.

Storage

Specimens should be placed in storage in supportive, inert materials. The storage areas should provide suitable environmental conditions. The past environmental conditions in which the objects have been stored should be taken into account, but for collections that have not previously been kept in very dry conditions, the recommended environmental conditions for archaeological bone are 40–55%
relative humidity with daily fluctuation of ±5% or less and a temperature of 16–20°C with daily fluctuations of less than ±2°C [8]. These conditions should be monitored to provide a constant check on their stability and conditions maintained by appropriate equipment if necessary.

Handling and conservation

Cautious, conservation-conscious handling regulations should be drawn up to which researchers must sign up before they are allowed access to the material. These regulations should prevent any further moulding of the specimens and any activities that involve handling or applying materials to the surfaces or joins. Reconstruction of specimens and new joins should always be made in collaboration with professional conservators experienced in dealing with organic materials. Institutions should have clear policies on the sampling of the specimens for dating, DNA or isotope analyses, and such other techniques as may develop. Where possible, institutions should look to the future and try to adopt techniques such as computerized axial tomography (CAT scanning), magnetic resonance imaging (MRI) or three-dimensional (3D) laser scanning to avoid casting and to reduce the need for direct access to the fossils by making high-resolution 3D images available electronically. If casting is essential then rapid prototyping using scanned data should be considered as an alternative to traditional techniques [9].

These guidelines should not restrict scientific work, but they could raise standards, improve the techniques of enquiry and ensure the preservation of the fossils. Most of these points will already be accepted and implemented as best practice in many museums. The recording, storage and handling requirements can be simply and cheaply achieved almost anywhere, but access to professional conservation skills and suitable laboratories is not so easy. Where internationally important specimens are concerned, the sharing of knowledge and skills between collaborating institutions should ensure the involvement and training of conservators and access to techniques that may not be available in the place of discovery; loan programmes may facilitate this.

CONCLUSIONS

It is important that museums be allowed to display and borrow human fossils for exhibition if they are in a suitable condition [7]. At a time when globalization goes hand in hand with social fragmentation and intolerance, such fossils have the extraordinary power to remind us of our common origins as we search for new identities in a world of complexity and difference. In this role their significance extends beyond science to the diplomatic, provoking questions that may enlighten our attitudes to one another and providing opportunities to raise crucial funding for scientific and museum projects in the country of origin. Human fossils are rare and precious archives of human ancestry that need to be shared. To protect and preserve them we need to build up standards of care and presentation that will enable this, rather than restrict access to the few.

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REFERENCES