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Author(s): Ryder, S., Sales, G. D. & Fischer, E. E.

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Curious specimens in the collection: Comparative dental anatomy, skulls, and historical catalogues

Steven Ryder,[1] Dr Gillian D. Sales,[1*] Erica E. Fischer[2]

[1]*Museum of Life Sciences, King's College London, Guys Campus, London, SE1 1UL*

[2]*Centre for the History of Science, Technology, and Medicine, Department of History, King's College London, Strand, London, WCR2 2LS*

Email for correspondence: steve.ryder@kcl.ac.uk

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Abstract

In the Museum of Life Sciences at King's College London is a series of craniofacial specimens which were originally housed in the Royal Dental Hospital of London and the London School of Dental Surgery. These sagittally-sectioned skulls and mandibles are distinctive in their preparation. One half skull and mandible have been dissected out to show the roots of each tooth. This made these specimens particularly useful for teaching dental students about different dentitions, which was a required part of the curriculum for becoming a dental surgeon. However, the sectioned component parts had become separated over the decades, and we searched the collection with the intention of reuniting these parts into a complete specimen. Using historical documents from the Royal Dental Hospital and the London School of Dental Surgery, we traced specimens through their early histories, matching specimens with their identifications, catalogue entries, and donors. A selection was then mounted and labelled for preservation as part of a trial to develop a system for handling these delicate specimens.

Keywords: Royal Dental Hospital of London, Odontological Society of Great Britain, handling collection, Museum of Life Sciences, KCL, dentistry, education, history of dental surgery

Introduction

Over the last few years, the Museum of Life Sciences at King's College London has been documenting specimens from a comparative odontological collection that originally came from the Royal Dental Hospital and London School of Dental Surgery. Many of these specimens can be dated to the early 1900s. It became apparent that what often appeared to be numerous loose bone fragments kept in several open storage boxes were, in fact, a group of sagittally bisected (cut through the midline) skulls. These skulls represented the various dentition types of the several different functional feeding groups (carnivore, omnivore, insectivore, etc.).

The specimens comprise whole mammalian skulls and mandibles and skulls sectioned for mounting into quadrants, two quadrants of which are dissected to show the roots of teeth on one side. They were used to demonstrate vertebrate tooth morphology to dental students, but over time the skull components became separated. Decades later some were found, rerecorded, and boxed separately. Because the various parts were not seen together, and consequently were not identified as parts of a single specimen nor parts of a collection, the significance of skull/mandible/four quadrants was not recognised. As a consequence, the individual parts were considered to be of little value.

A project funded by the Bill Pettit Memorial Award, awarded through the Natural Sciences Collections Association (NatSCA), was undertaken to document and preserve this group of delicate specimens, establishing that at least some of the specimens in the craniofacial collection are of historical importance in the development of dental education and research into comparative odontology. Many have now been restored, re-mounted, and re-labelled to show the quadrants as they would have been displayed originally. This article features some of the specimens that have been examined and the processes of identifying and restoring them.

History of the craniofacial collection

The Odontological Society of London (est. 1856) was created with a two-fold purpose: to provide a forum for dental practitioners to exchange ideas and techniques and to provide a corporate body to raise professional standards by implementing an examination for dental surgery (Payne, 1925). Legislation, which required a mandatory professional qualification (L.D.S., Licence in Dental Surgery) in order to practise as a dental surgeon, introduced some degree of regulation to the profession (Gelbier, 2017). Consequently, it was necessary to have a suitable institution where training and examination to meet these new requirements could be fulfilled. In 1858, the Odontological Society founded the Dental Hospital of London (later the Royal Dental Hospital, RDH). In the following year, the London School of Dental Surgery (LSDS) was established in the Hospital to instruct dental students on a course meeting the requirements of the L.D.S. (Smith and Cottell, 1997; Gelbier, 2017). This included an element of comparative dental anatomy which involved the work of Charles Sissmore Tomes (1846-1928).

Charles Tomes was a dental surgeon who specialised in craniofacial anatomy, expanding on the work of his father (Tomes and Tomes, 1873). Trained in both Natural Sciences and Medicine, he had an interest in comparative anatomy and was an authority on odontology, tooth morphology, and dental histology. His work, *A Manual of Dental Anatomy, Human and Comparative*, first published in 1876, became an important reference book for understanding differences between the dentitions of a wide variety of animals. During preparation of this book, Tomes accumulated a number of specimens and these, together with some of his father's work and with specimens discussed at evening meetings of the Odontological Society, formed the 'Odontological Society Museum', established in 1859. This museum included whole skeletons, though the craniofacial portion consisted of whole skulls, mandibles, teeth, and sectioned specimens of these parts.

In 1872, impelled by a large consignment of specimens received from Australia and an impending move to new premises in Leicester Square, Charles Tomes catalogued the collection. In his first survey of the contents of the museum, Tomes produced a comprehensive listing of specimens, and this catalogue was published in the *Transactions of the Odontological Society* (The Odontological Society of Great Britain, 1874). The LSDS selected specimens from this catalogue in order to teach the comparative dental anatomy part of the curriculum for the L.D.S. (Smith and Cottell, 1997). The collection continued to expand, and there were two further catalogues assembled in 1885 and 1894. The 165-year-old record is incomplete and confused, so it is not possible to entirely reconstruct the collection completely. The bulk of the Odontological Society Museum passed to the Royal College of Surgeons of England in 1909, leaving the remainder at the LSDS where it continued to be used for the Comparative Dental Anatomy course until the 1970s (Gelbier *et al*., 2021).

Documents at the Museum of Life Sciences relate to the Comparative Dental Anatomy collection which was retained at the LSDS; one is a taxonomic catalogue of osteological specimens produced by Tomes (the 'Special Catalogue'). The second is a series of 90 practical sheets, produced after 1874, which relate to specimens listed in the Special Catalogue. A third document, the 'List of Donors and Donations', indicates that members of the Odontological Society continued to donate specimens to the LSDS collection after 1901, rather later than the published catalogue suggests.

There have been inevitable losses of specimens but also additions by successive generations, each of which has introduced their own particular, cumulative anomalies to the collection and its documentation. Whilst the original record-keeping was adequate, this has not always been the case, particularly in more recent decades when the collection was largely unmanaged. As a consequence, the exact inventory of the original collection is unknown. The collection was also moved twice and has been merged with another partially documented collection of zoology specimens, when United Medical and Dental Schools and King's College, London merged in 1998.

Where the records are more complete and the specimens can be found, the group can be reassembled as a collection. As part of this process, a small group of sectioned and dissected

skulls of mammals has been located and reassembled. Each skull has been sagittally bisected resulting in four parts: two skull/maxillary sections and two mandibles (see Figure 1). The teeth of the left-hand side have been exposed by removal of the alveolar plate, exposing the roots for inspection as described by Charles Tomes (Tomes, 1882). This makes the collection of particular interest in the history of dental surgery, comparative dental anatomy, and education in these fields.

Identifying specimens was contingent on locating each of the component parts which had often been previously catalogued and boxed as separate specimens. Initially, a simple visual match could be made, for size and for other physical attributes, such as colour, texture, staining, etc. It was necessary to identify and reunite mandibular and maxillary quadrants and confirm a match by checking the occlusal fit of the upper and lower tooth arcade which is unique to each pair because of local wear. Sometimes the animal could be identified using old labels (when present), but otherwise they were identified by matching unlabelled specimens against historical records if possible. Where records were missing, more recent reference materials were consulted to aid identification of specimens.

Early days

Early in the project, two large fragments of a sectioned skull comprising a right-hand part-cranium and maxilla complete with a full set of molars, and a second fragment comprising the right -hand premaxilla (Figure 1a), were found in a box of bone fragments. Identification was hampered because they were unlabelled, and a large proportion of the skull had been damaged or removed during preparation.

The general appearance and arrangement of the incisors indicated a large rodent about the size of a beaver (see Table 1 for the naming conventions for teeth used in this paper). However, the incisors were smaller, less robust, and pale in colour rather than the orange, iron-stained enamel front surface of a beaver (Beddard, 1902). Fortunately, all the molars were present and in good condition, so it was possible to identify the reconfigured skull. Tooth morphology of the molars indicated the family Caviidae (Verzi and Quintana, 2005; Berkovitz and Shellis, 2018), and the skull size and shape, which was too large for a guinea pig but too small for Capybara, indicated the genus *Dolichotis* Desmarest, 1820, the mara (Owen, 1845) (Figure 1a). Because it was in quite poor condition and was only a partial skull, the specimen was put aside for further appraisal later.

More recently, a 150mm cork-lidded glass tube was found amongst other specimens in the collection. The label, 10.19.5, combined with existing documents identified it as *Dolichotis* (Figure 1b, c). Because this tube potentially contained another part of the skull, it was re-assembled. Unfortunately, the tube contained only fragments: an upper and lower left incisor, left mandible (dissected), a condylar process, two fragments of the right mandibular molars, and three left maxillary molars (Figure 1c). There were no other bone fragments, suggesting that the left skull quadrant has been lost.

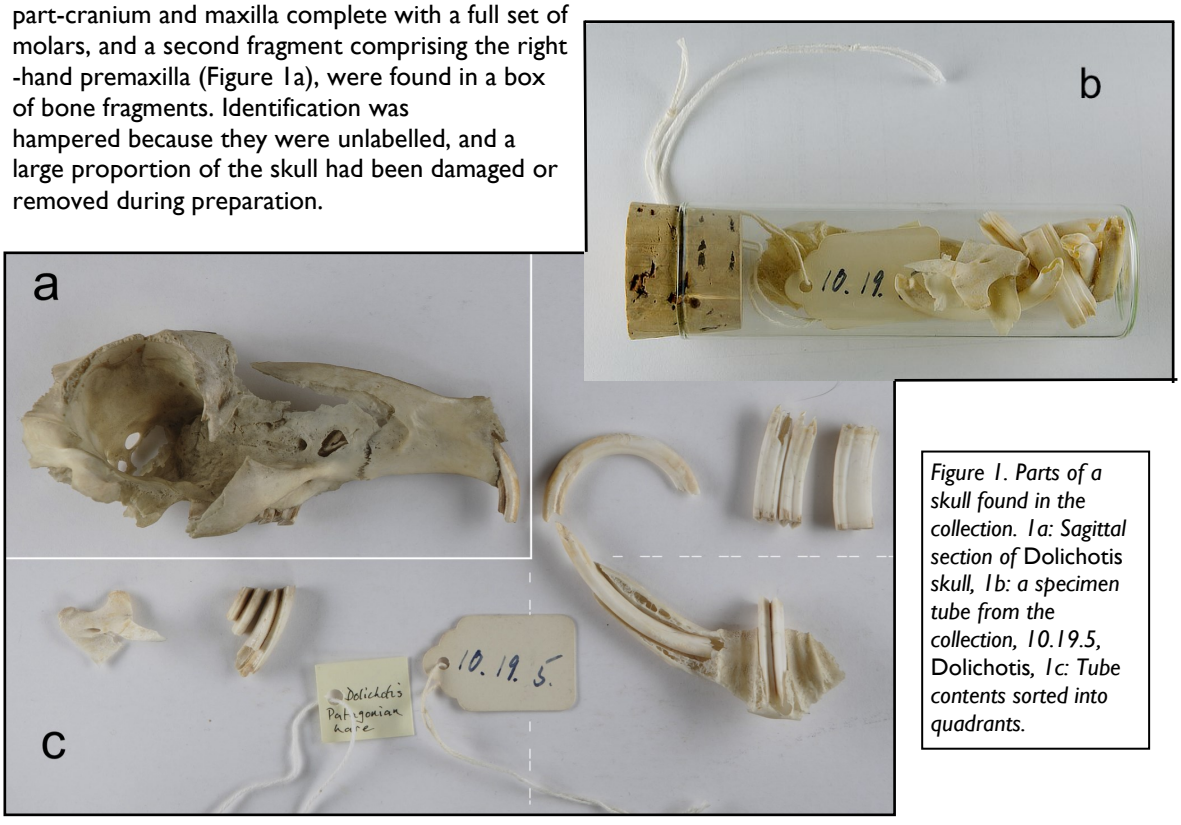

Figure 1. Parts of a skull found in the collection. 1a: Sagittal section of Dolichotis *skull, 1b: a specimen tube from the collection, 10.19.5,* Dolichotis*, 1c: Tube contents sorted into quadrants.*

Table 1. The naming conventions used for teeth in this paper.

Maxillary tooth	I: incisor, C: canine, P: premolar, M: molar + superscript *e.g.,* M^1
Mandibular tooth	i: incisor, c: canine, p: premolar, m: molar + subscript *e.g.,* m_1

According to Owen (1845), the tooth formula for a *Dolichotis* is:

$$\frac{1.0.1.3}{1.0.1.3}$$

This formula appears consistent with what remains of the specimen. Because only the tube contents were labelled, it will never be possible to confirm with absolute certainty that this was a single prepared specimen, although only one skull was listed in our records. The form of the dissection is consistent with others in the collection, and all the parts match in size. It does not seem unreasonable to suggest that these two specimens could belong together, so the parts have been catalogued together.

A Mystery specimen revealed

There was no label present in another glass tube which contained a mix of loose teeth and fragile bone fragments. Obscured amongst the tightly packed teeth, a bone appeared to be part of a skull. Carefully pouring the contents into a petri dish revealed four quadrants - two half-mandibles and what looked like two paper-thin skull sections. No teeth were in position in the dissected side, hampering recognition. However, the presence of a whole skull, or rather all four quadrants, was indicated by the appearance of two of the bone fragments, each of which had a section cut away to show the roots of the teeth. It seemed to be a whole upper and lower right and a dissected upper and lower left skull pair (Figure 2). This quadrant convention for comparative dental specimens is an emerging theme in the collection. Unfortunately, because many specimens have become dispersed or lost, it is not always apparent if all the quadrants can be located.

The whole right-hand mandible, (left in Figure 2) was complete, but the right-hand skull section was missing two incisors, the rear-most molar and one other intermediate tooth in the maxilla. The left-hand skull section (right in Figure 2) was unrecognisable given the lack of order and context in the dish, the absence of teeth, and the fact that the sections are only part skulls. They were difficult to comprehend as complementary elements of a single skull until they were each oriented correctly, as shown below in Figure 2. This difficulty is illustrated in the previous *Dolichotis* specimen (Figure 1b).

The mandible was typically diprotodont with a large procumbent incisor, and the 1-premolar + 4-molar arrangement of the posterior teeth was typical of marsupial dentitions such as those of opossum, cuscus, kangaroo, and wallaby (Tomes, 1923). The upper anterior dental arcade, with three strongly curved incisors followed by two widely spaced unicuspid teeth (C and P^1; see Table 1), is typical for the koala and for the Phalangeridae group of opossums and cuscuses.

Figure 2. The skull of Trichosurus vulpecula *(Kerr, 1792) arranged into quadrants before restoration.*

The general tooth formula for the Phalangeridae (Berkovitz and Shellis, 2018), is:

$$\frac{3.1.2.4}{2.0.1.4}$$

which matches our specimen. Comparison between this skull section and other skulls in our collection resulted in a close match to *Trichosurus vulpecula* (Kerr, 1792), the common brushtail opossum. After comparing the tooth formula and some skull reference images, sorting the teeth in a petri dish showed that most, if not all, of the teeth were present and so they were divided into approximate upper and lower sets (Figure 3a, 3b). The maxillary incisors (I^{1-3}) formed a simple anterior triplet and were identified first. Their unique curved form and respective sizes made selection straightforward. These teeth, particularly I^2 and I^3, were worn into an arc at the cutting surface at the point at which they occlude with the lower incisor i_1 (Figure 4). Starting with the right-hand whole maxilla, each tooth was secured in position with buffered PVA glue, but drying time gave plenty of opportunity to make small final adjustments to achieve perfect alignment. The finished quadrants were then set aside to cure.

The intermaxillary suture on the skull was clearly defined, which facilitated placement of the canine as the first tooth in the maxillary arcade. This was followed by the slightly confusing caniniform first premolar which has almost identical morphology to the canine and can only be distinguished by size (Figure 3b, 1st and 2nd from left in petri dish). Premolar P^2 (Figure 3b, 3rd from left in petri dish) is relatively large in both the upper and lower jaws and had a strongly developed anterior cusp giving

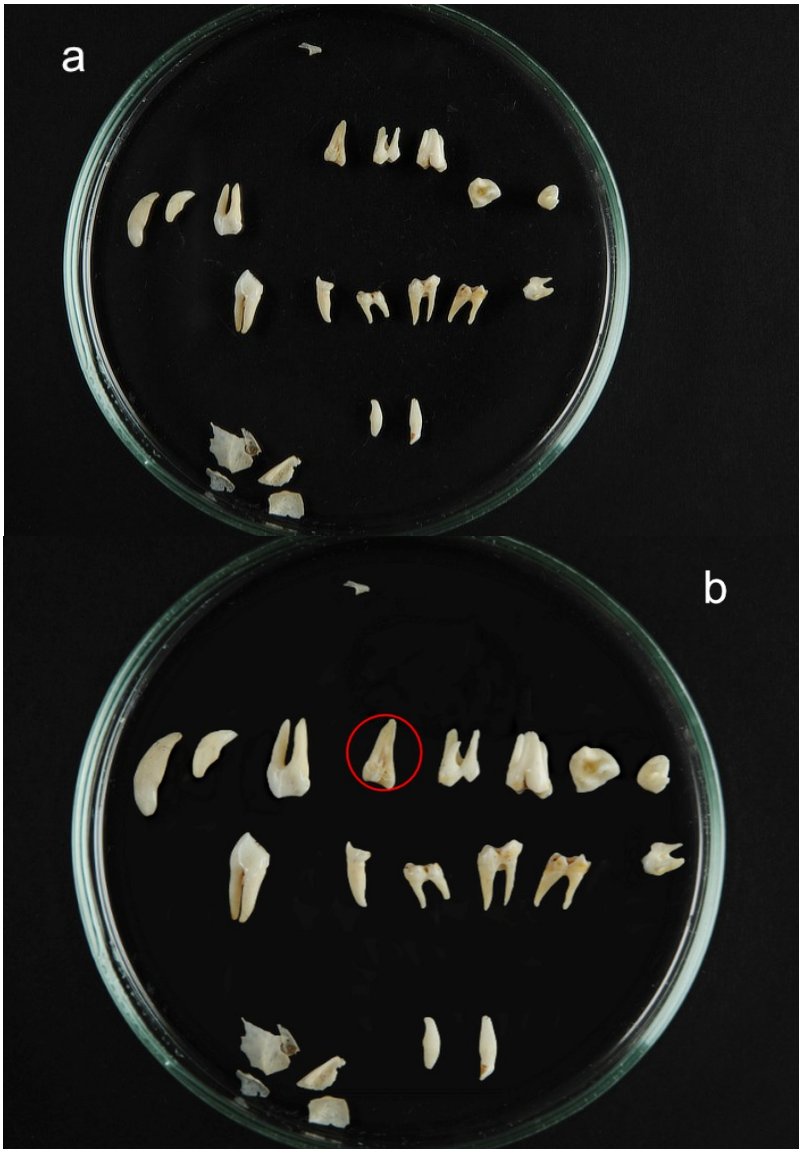

Figure 3. Teeth of Trichosurus vulpecula *a) left, initial sort after incisors have been placed, b) right, the most likely tooth sequence. The circle indicates a broken tooth, only half of which is present.*

it a very distinctive, pointed appearance. This is particularly noticeable on the lower tooth, which is also orientated obliquely in the mandible. It served as the next reference point in the tooth arcade.

In the petri dish, the remaining posterior teeth were more alike; therefore, three-rooted teeth were provisionally assigned to the rear upper quadrant because maxillary molars are often tri-radiate compared to the bi-radiate premolars and mandibular molars. Arrangement by size indicated the likely position of the remaining teeth, and a dry fit helped to confirm positioning before reattachment. It was immediately apparent if there was a slight misalignment or a poor fit, as the roots of the teeth fit closely to the bone. If there was any doubt, substituting a similar tooth from the dish invariably produced either a better result or confirmed the original choice. The positions of the four upper and four lower molars were established in this manner, as well as the upper M^4 missing from the right-hand maxilla (left, Figure 2 and Figure 4).

The finished quadrants were all complete except for the very small mandibular i_2, a tooth so small that it is unlikely to be found, but which should be located immediately behind the large lower incisor (the empty alveolus can be seen on the dissected side, Figure 4). A half tooth (Figure 3b, circled in petri dish) was found to be lower m_2 in the dissected mandible (there is a gap after the 3rd tooth). This tooth was broken into two (the other half is still missing), and consequently it was difficult to identify. Its position only became apparent when the other teeth were matched to their respective sockets. The tooth below it in the dish was not part of the set and neither were the two caniniform teeth shown at the bottom of the dish in Figure 3b.

The Museum of Life Sciences has many skulls which have teeth that are loose and sometimes fall out completely, so that it is easy to assume that sockets of the skulls and the teeth which fit into them are not particularly close-fitting. However, the developmental processes that direct the alveolus of the tooth to develop and to bind around the developing root are precise and most exacting (Tomes, 1923). Once the periodontal ligament, which binds the tooth into the alveolus is destroyed during preparation, the tapering, conical form of the roots can cause the teeth to fall from the upper set under the influence of gravity alone, even with the most perfect fit. By ensuring the correct combination of tooth morphology and unique physical fit between tooth and socket, we can be certain that the specimen has been reconfigured correctly, and that the few teeth which remained in the dish upon completion are from other specimens in the collection.

One species or two? Historical taxonomy

All four quadrants of the third specimen were found over time: first a skull and mandible pair, then a skull quadrant, and finally a loose mandible; each matched successively with the rest. Most teeth were present, and there was no conservation required beyond finding all four quadrants (Figure 5). The few missing teeth have not yet been located. Without doubt, these are the most ornate set of teeth in the collection but also the strangest. The specimen was donated in 1904 and is listed in our records as *Galeopithecus volans,* a species name that is no longer in use.

Figure 4. The completed quadrants of Trichosurus vulpecula. *(Quarters numbered using ISO3950/FDI nomenclature, ISO 2016).*

Figure 5. Two half skulls of Cynocephalus volans *(Linn., 1758) (left) and Galeopterus variegatus (Audeb., 1799) (right).*

The dental formula for the extant Dermopterans is (Berkovitz and Shellis, 2018; Stafford and Szalay, 2000):

$$\frac{2.1.2.3}{3.1.2.3}$$

George G. Simpson reorganised the classification of the order Dermoptera in 1945. He deprecated the family *Galeopithecidae* and replaced it with the *Cynocephalidae,* a name which had priority. Within it he re-established the use of two extant generic names, *Galeopterus* and *Cynocephalus*. The generic name *Galeopithecus* was synonymised, which caused a problem of identification; was our specimen now *Galeopterus* or did it follow the specific epithet, *Cynocephalus volans*? However, in his book he provides the answer: '*Galeopithecus volans =Cynocephalus volans'* (Simpson, 1945). Both species are known as colugo or 'flying lemurs', though they neither fly nor are they lemurs.

All the teeth, including the incisors and canines, are multi-cusped (Owen, 1845; Peyer, 1968). The first incisor, I^1, is always absent, causing an edentulous gap on the mesial palate (Stafford and Szalay, 2000; Berkovitz and Shellis, 2018). Consequently, the first two upper anterior teeth are I^2 and I^3. In the image above (Figure 5), the upper first tooth in each row (I^2) is different in both the left skull quadrant and the right skull quadrant, suggesting that we have a half specimen of each genus: *Cynocephalus* (left) with two tines (Stafford and Szalay, 2000) and *Galeopterus* (right) with three vertical tines (Owen, 1845; Stafford and Szalay, 2000).

In the Dermoptera, the third anterior tooth is the upper canine (Fig. 5). This tooth is unusual in that it has a biradiate root (as does the preceding I^3), which is not common amongst mammals. However, in *A Manual of Dental Anatomy,* C.S. Tomes states, by way of explanation, that such forms of teeth are more frequently seen in the paleontological record, which indicates that the Dermoptera are an ancient lineage (Tomes, 1923).

Mounting and labelling

In some cases, the historical documentation can be matched to the specimens under review, and this aspect of the project is ongoing. The 9000 numbers which appear in Table 2 (P no.) are the original specimen numbers allocated in the 'List of Donors and Donations'. The range 9000-9999 was allocated to the Comparative Anatomy section of the LSDS collection ('Special Catalogue'), which also included many other dental materials, human teeth, pathological tissues, etc. Each section of the collection was issued with its own 7xxx, 5xxx, etc. numbering system, so that each class of teaching specimen (e.g., dental pathology, etc.) had its own range of catalogue number. There are many discrepancies in the records, but at least some of the specimens can be positively identified (Table 2).

Suitably sized acrylic boxes from a variety of sources were used so that the quadrants could be protected, and each specimen was mounted onto Plastazote foam according to the arrangement shown in the figures above (Figures 2-5) and inserted into the base of the box. We intended to mount some smaller specimens onto a Perspex sheet, which was to be cut and polished to form a

Table 2. List of quadrant specimens identified to date (P no. = original specimen number)

Genus	specific epithet	Authority, date	P no	Donor	Quadrant
Melanosuchus	*niger*	(Spix, 1825)	9114	Austin, H., 1907	Q1,Q2,Q3,Q4
Didelphis	*virginiana*	(Kerr, 1792)			Q1
Sarcophilous	*harrisii*	(Boitard, 1841)			Q3
Trichosurus	*vulpecula*	(Kerr, 1792)	9033		Q1,Q2,Q3,Q4
Phascolarctos	*cinereus*	(Goldfuss, 1817)	9004	Tomes. c1900	Q1,Q2,Q4
Erinaceus	*europaeus*	Linn., 1758	3.5.6/5		Q3
Galeopterus (Galeopithecus)	*variegatus*	(Audeb., 1799)	9140	Hopewell Smith, A., 1904	Q1,Q2,Q3,Q4
Indri	*indri*	(Gmelin, 1788)	9005	Tomes. c1900	Q1,Q2,Q3,Q4
Presbytis		Eschsch, 1821			Q1, Q2
Herpestes	*ichneumon*	(Linn., 1758)			Q2,Q3
Lutra	*lutra*	(Linn., 1758)			Q1,Q4
Enhydra	*lutris*	(Linn., 1758)	9182	Students Society, 1907 [248]	Q1,Q2,Q3,Q4
Hyaena		Brisson, 1762			Q1,Q4
Felis	*catus*	Linn., 1758			Q2,Q3
Dasypus (Tatusia)	*novemcinctus*	Linn., 1758	9000	Tomes. c1880-1900	Q1
Dolichotis		Desmarest, 1820		Unknown, pre-1958	Q1,Q/2,Q3
Hydrochoerus		Brisson, 1762			Q1, Q2,Q3
Procavia	*capensis*	(Pallas, 1766)	9100	Pritchett c1907	Q1,Q4
Tapirus		Brisson, 1762			Q4
Equus	*ferus*	Boddaert, 1785			Q2
Babyrousa	*babyrussa*	(Linn., 1758)			Q1,Q4
Sus	*scrofa*	Linn., 1758			Q1,Q4
Ovis	*aries*	Linn., 1758			Q1,Q4
Quadrants:		Q1: Upper right		Q2: Upper left	
		Q4: Lower right		Q3: Lower left	

mounting plate of suitable size to fit into the box. However, we were unable to commission the work because of the Covid-19 pandemic. This part of the project has been postponed until it can be investigated in more detail, and Plastazote was used as an immediate solution.

The cranio-facial collection was catalogued at least three times previously. Unfortunately, none of these systems is comprehensive; each covers a narrower sub-section of the collection, so that there is some information in each of the three systems. Currently, some specimens have old labels which are faded or are missing completely, so they must be re-identified using the paper record or other reference materials. A small label has been prepared for this project as a pilot for the rest of the collection to assess the feasibility of adding additional collection information. Labels needed to be small enough in size not to

overwhelm the specimen itself. However, the inclusion of as much information as possible from previous, historical labelling systems will make the Museum of Life Sciences historical documentation more accessible.

Conclusion and Further Work

This project has successfully reassembled, as far as possible, three specimens from the original teaching collection of the RDS and prepared them for display so that they can be viewed safely. Other specimens are in the process of being similarly prepared. A long-term goal now is to combine all the data into one comprehensive database. In the short-term, however, we are trialling a labelling system which will enable access to the data from the various historical catalogues. This is still at a provisional stage of development, but identification of the specimens and the correlation between original documents and specimens has been established and should become more apparent as work continues. While these specimens are too delicate to be used regularly for teaching today, they are valuable demonstration material and of interest to historical researchers looking to better understand early methods of teaching dental surgeons.

The paper records which relate to many of the specimens contain valuable data which link the specimen to the well-documented historical record of the Odontological Society and thereby form a unique set which will be preserved, collated, and re-assembled as part of the Museum of Life Sciences collection. For example, there is a specimen of a hippopotamus skull which has been dated to 1859, and we have been able to match paper records to some specimens donated by Charles Tomes, Morton Smale, and Arthur Hopewell Smith, who were all members of the Odontological Society and therefore associated with the RDH from 1880 until 1930. We will attempt to link other donors to particular specimens to give a unique record of this special collection.

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