Developing Minimally Destructive Protocols for DNA Analysis of Museum Collection Bone Artifacts

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Archaeological Context

Faunal material such as animal bone, ivory, shell and antler were valued by ancient peoples as raw materials for tools, ritual items, jewellery, and musical instruments.

Many of these artifacts have been collected and exhibited in museums around the world.

Analysis of these artifacts is crucial in fully understanding the cultures and contexts from which they came.

Ancient DNA (aDNA) analysis is a powerful analytical tool which can be successfully applied to an array of archaeological questions.

However, due to the destructive nature of current aDNA analysis techniques some museum curators have been hesitant to subject their collections to this kind of analysis.

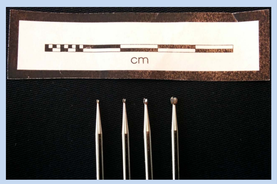
This research aims to develop and apply a minimally destructive (MD) protocol for extracting aDNA from bone artifacts for the purpose of rendering previously inaccessible museum collections available for research.

Methods

Assessing for Damage

- X-ray imaging was used to assess the internal structure of each sample and establish the optimal drilling location and depth,
- This limits damage.

Above: X-rays of Fort D'Epinette test samples. Below: Drill bits. 0.8mm, 1 mm, 1.4mm, 1.8mm



Drilling Technique

- Precision drilling offers control in the drilling process and reduces the likelihood of damage to the artifact's external appearance.
- Drilling was done at 1000 rpm.

Bone Test Samples

All DNA extractions resulting from this technique were processed in the SFU DNA Laboratories using established protocols and contamination controls after undergoing several rounds of testing with the goal of attaining accurate species identifications for each sample with only 2-20mg of bone powder:

Modern Bone

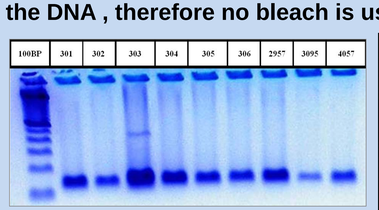
- Ten modern animal bone samples were drilled 38 times. None were extracted.
- This round of testing was done to get accustomed to the drill (ie. kickback) and to make initial observations (ie. drill speed, pressure, powder collection method).

Modern Degraded Bone

- 31 modern degraded samples approximately 30-50 years old were drilled 40 times. Of these drilled test samples 78% were extracted with an 82% success rate.
- This round of testing was done to further test the drilling protocol, as well as test the sample preparation protocols in the lab. Directly bleaching the bone powder in the lab destroyed the DNA , therefore no bleach is used on the bone powder once it is drilled.

Archaeological Faunal Material

- 16 archaeological samples from Fort D'Epinette , BC (~200 years BP) were drilled and extracted, with an 88% success rate.
- This round of testing was done to test the technique on ancient remains, optimize the decontamination protocols during drilling, as well as to test the technique on a spectrum of classified morphological preservation conditions.



PCR amplification gel results from Fort D'Epinette. Universal primers, processed at 52˚C for 60 cycles.

Fort E'Epinette sample 6352 drilled with 1.0mm and 1.8mm drill bits.

Museum Artifact Samples

SFU Museum of Archaeology and Ethnology – Artifacts

- Six artifacts were loaned for this study from four archaeological sites across British Columbia (ElTb-10, FaSu-2, DgRr-1, DhRq-1)
- After the previous three rounds of testing and optimization the drilling technique was applied to these artifacts.
- 100% of the artifacts yielded a species identification.

Sample Name	DNA Species Identification
100	White-tailed deer (Odocoileus virginianus)
117	White-tailed deer (Odocoileus virginianus)
314	Red deer (Cervus elaphus)
323	Red deer (Cervus elaphus)
459	White-tailed deer (Odocoileus virginianus)
948	Sea otter (Enhydra lutris)

SFU Museum artifact species ID.

Sample 948 drilled with 0.8mm and 1.4mm drill bits.

Royal Ontario Museum – Anyang, Henan Province, China

- Nine bone artifacts have been loaned for this study, including five oracle bone fragments.
- The oracle bones were heated until they cracked, and so they may pose a challenge for DNA extraction.
- Due to the fragmentary state of these artifacts, this case study is perfect for assessing the ultimate strengths and weaknesses of this technique.

Above: Late Shang Dynasty (~3,3000 years BP) bone artifacts.

Discussion

The results of this research indicates that this MD DNA sampling technique can be successfully applied to a wide range of materials (date ranges, morphological conditions), and therefore has tremendous research potential.

Currently, MD and "non-destructive" aDNA extraction protocols involve submerging the artifacts in digestive chemicals, or physically breaking the artifact and then repairing the appearance of damage on the external surface.

Although these methods may not be visually apparent, they may cause permanent physical and/or chemical damage to the artifacts.

This MD DNA sampling technique offers a middle range solution that may specifically appeal to museum professionals as it balances the issues of destruction and long term sustainability, while still providing valuable research information.

Significance

Although this current project is aimed at museum collections, this technique would also be applicable to a wide variety of materials and contexts.

This MD technique could help facilitate access to collections previously inaccessible to aDNA research due to concerns over destruction or long term stability.

Accessing these museum collections would mean the opportunity to meaningfully contribute to the archaeological dialogue by producing unique, more precise stories about the histories of these artifacts, which would otherwise remain unattainable.

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