Appendix One: Standard Operating Procedures for DNA Sampling on Site

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edited and approved by Dr Peter Jones

SCOPE

This procedure is to be used for the Fromelles First World War deceased at the Pheasant Wood grave site in France. The procedure is to be carried out by Oxford Archaeology and LGC Forensics only. The method is applicable to the ranking and selection of bone and teeth samples and the protocol of removing identified body parts under forensic conditions to undertake DNA analysis.

AIM

To identify optimum teeth and bone samples for DNA analysis in such a way as to maintain a chain of custody from the grave to LGC Forensics' premises in Middlesex. The currently anonymous remains will be identified by their DNA profile and compared with that from surviving relatives.

RESPONSIBILITIES

Before taking and processing samples, all staff from both Oxford Archaeology and LGC Forensics must have read the appropriate risk assessments as documented in the original Fromelles tender before processing any samples.

Individual archaeologists and a scribe will be responsible for ensuring the sample for DNA analysis correlates with the corresponding bar-code and associated paperwork. It is also the responsibility of the individual archaeologists and the scribe to correctly attribute Oxford Archaeology body numbers to bar codes. SoCO Janet Worthington is responsible for ensuring that the chain of custody is maintained from collection of samples at the grave, to storage, and then ensuring samples are packaged appropriately and collected by the LGC Forensics nominated courier.

LGC Forensics is responsible for transportation of the samples from the site (Fromelles, France) to LGC Forensics (Teddington, UK). LGC Forensics (Teddington, UK) is responsible for confirming to SoCO Janet Worthington receipt of samples within 12 hours of receipt. In conjunction with DNA specialists, Nicholas Márquez-Grant will examine and record the preservation and condition of samples submitted for DNA analysis. This will be carried out in the LGC Forensics DNA forensics laboratory at Teddington with appropriate measures in place to protect against any potential DNA contamination.

LGC Forensics DNA staff will liaise with Oxford Archaeology field staff and provide feedback to ensure that any changes in sampling methodology are communicated.

Others responsible in the project are:

- Caroline Barker: lead anthropologist for Oxford Archaeology and responsible for all anthropology.
- Dr Louise Loe: project manager for Oxford Archaeology and responsible for all aspects of the archaeology, body recovery, anthropology and storage of remains.
- Dr James Walker: project manager with overall responsibilities for all activities undertaken by LGC Forensics.
- Dr Peter Jones: responsible for the DNA aspects of the project design and overseeing the project on behalf of the CWGC.
- Prof. Margaret Cox: responsible for the project design and monitoring of the archaeology and anthropology on behalf of the CWGC.
- David Richardson: overall project manager for CWGC responsible for the overall project management and all activities on site at Pheasant Wood.

GENERAL PRACTICES

General practices to adhere to:

1. Full PPE (face mask, Tyvek suits, hairnets, gloves, over-shoes (if not wearing a pair of designated site boots) should be used to control and minimize contamination as much as possible.

ii. When on site, full PPE must be worn beyond the demarcated zone which is the inside the graves.

iii. Use clean gloves when dealing with a new skeleton.

iv. Always sterilise tools (with MicroSol 3+) before use on a skeleton and between skeletons. Usually 10 minutes sterilization should be enough, unless heavily stained. Always WEAR GLOVES, when dealing with MicroSol 3+.

v. Photograph the skeleton before sampling if practical.

vi. Survey the 3D position of each sample taken.

vii. Minimise the amount of exposure to air of the tooth or bone. As soon as the tooth or bone has been uncovered, act as quickly as is practical and preferably remove the sample within 10 minutes of exposure. However, do not let safety be compromised when taking samples.

viii. Get help from a 'clean' scribe who can provide you with the sample pots and bags and write the information on the bag. SoCO investigator Janet Worthington can help regarding filling in the bag details or any appointed and trained person. These details should include: name of site, skeleton number, label, description of content (for example, lower left second molar, left third metacarpal, mid-shaft section of right radius), location (grave number) date and time and signature.

ix. Remember to label every pot and bag with the bar code labels provided.

x. Samples must be kept either refrigerated at 4°C or frozen at -20°C. The storage of the samples depends upon the sample type. Below lists the storage conditions for various samples and should be used for guidance. If in doubt refer to James Walker (LGC Forensics) for advice.
- Dry tooth 4°C
- Dry small bones 4°C
- Waterlogged bones -20°C
- Soft tissue including brain -20°C

PRIORITY OF SAMPLES

Samples to be taken should be of the best in the best condition possible. A minimum of one tooth and one bone sample should be taken from each body as well as any soft tissue and hair where present.

Determine sample to be taken:

i. One tooth (preference: upper canine, upper second molar, any other, no cracks, cavities, caries, fissures, attrition, and roots must be completely formed – but not in order of preference).

ii. One bone (MC2/3 any MT; 5 x 2 cm long bone fragment – for example, radius, ulna, fibula; intact bone); weathering must be below stage 3 (after McKinley 2004, 16)

iii. Hair sample.

iv. Brain (when accessible).

If only 1 tooth is present, only 2 samples are to be taken per body (1 tooth and 1 bone). If no teeth are present, then 2 bone samples per body are to be taken.

TEETH

Teeth samples have the best opportunity of preserving DNA in good condition due to the enamel that protects the dentin from which the DNA is extracted.

i. In choosing which teeth are best for sampling the following criteria should be followed:
- Molar (preferably an upper – due to longer root)
- Any other tooth: upper canine, pre-molar, incisor (in rank order)

ii. To choose the best molar tooth – examination of degree of preservation should be carried out. Check that there is no major caries that may affect the pulp.

iii. The molar must be fully formed. This can only be verified once extracted.

iv. Do not sample teeth with severe attribtion or where major cracks or fissures are apparent.

v. A second dental sample should be taken; preferably (in rank order):
- upper canine
- a premolar
- lower canine

SKELETAL ELEMENTS

In discussion with the Commonwealth War Graves Commission (CWGC) and Oxford Archaeology (OA) at the site it has been decided that due mainly to practicality that the following whole bones are to be submitted for DNA analysis:

- Metacarpals
- Metatarsals

These have to be as intact as possible and not more than grade 3 erosion., as described by McKinley (2004, 16). If these samples are too damaged (high fragmentation, heavy cortical erosion, exhibit pathological changes – for example, periostitis); the next best alternative is:

- Fibula mid shaft.

Other alternatives are:
- long bones
- radius, ulna rib and if all fails then the femur

TISSUE AND HAIR

If soft tissue or well preserved hair is present, continue taking dental and bone samples as required. Soft tissue can be submitted, especially if the Achilles tendon is present.

RECORD OF BONE WEATHERING

This method is carried out using the grades by McKinley (2004, 16) which range from 0 (excellent preservation) to grade 5 (heavy erosion and modification of the profile), Bone with weathering equal or less than grade 3 is suitable for DNA testing.

The following information needs to be recorded with the sample:

i. Soil type

ii. 3-D co-ordinates of where the body was excavated

iii. Relative degree of water logging i.e.
- Dry
- Damp
- Wet
- Sitting in water

EQUIPMENT/KIT

Full PPE to be worn at all times by staff and all visitors within the graves. This includes masks, double gloves, Tyvek suit, overshoes (or designated site boots), and hairnet. New gloves are to be used for each individual body.

Dental pliers/forceps to be sterilised in MicroSol solution prior to use.

SAMPLE RECORDING FORMS

To record and process the samples three forms are required: a tamper evident bag, a set of bar codes and a sample container (Table A1.1).

Each form records particular information relating to the DNA sampling as well as other information. For the purposes of the SOP it is only that information relevant to the DNA SOP that will be described.

The most important task is the bar code, of a particular sample for DNA analysis must be associated, correctly with the appropriate body or body part.

Two numbering systems operate side by side to record samples for DNA analysis. The OA numbering system and the LGC Forensics numbering system. The system used by OA is a sequential four digit numbering system that records all samples recovered with a unique number. The unique number is generated manually by OA and placed on the evidence log (FA13F (f2.1). The evidence log sheets are allocated by the SoCO (Janet Worthington) and signed for by the grave supervisors (Ambika Flavel and Roland Wessling). Each recoverable item from the graves is given a unique identifier and then assigned a 'type' with the appropriate code such as SA (sample), B (Body), BP (Body Part) etc. Samples are associated with other samples or bodies on the evidence log by writing in the appropriate evidence number in the 'associated evidence' column.

The sample to be taken for DNA analysis takes a unique evidence number from the evidence log and is also given a unique eight digit alpha numeric bar code. The operation of associating the bar code with the evidence number, the Body number, and the physical sample, is the critical step of this process. Further information on the skeletal remains is recorded on the body location, attitudes and properties form, along with the body number and bar code. The process is described below.

PROCEDURE

Samples to be taken should be of the best quality possible. A minimum of one tooth and one bone sample should be taken from each body as well as any soft tissue and hair where present, as described above.

i. Record the time the specimen is uncovered on the sample recording form.

ii. Collect the sample either manually or with dental equipment. Check if the tooth is fully formed, has no dental caries affecting the

Table A1.1: Sample forms and required information for each form

Name of Item	*Version*	*Information Recorded for DNA Analysis*
Evidence Log	OP01L (f2.0)	Evidence No. Type, Association, Bar code
Sample Recording Form	FA13F (f2.1)	Sample type, storage location, Barcode, Body No, Archaeologist ID
Body Location, Attitudes and Properties Form	FA12SH(f2.0)	Evidence No, Bar code, Body Number, Storage location, Soil conditions, Bone Grade, Time and duration of retrieval, Archaeologist ID,
Tamper evident bag	As per bag	Bar code, Body No, SOCO ID, TEB ID,
Set of 20 Bar Codes in a plastic snap lock bag	As per LGC	Bar code
Sample Container	To suit sample	Bar code

pulp (for occlusal pit/fissure caries one can use a dental probe to investigate the depth of the cavity). If dental probe is used make sure it is sterile and minimise damage as much as possible.

iii. If the tooth does not meet the correct criteria, select any possible tooth that is the most `healthy' or well preserved for DNA sampling. If only one tooth is present, be it incisor, canine, etc., then sample that tooth.

iv. Place into appropriate sample container (falcon tube, universal container, 50ml sample pot, knife tube or bag).

v. Place the bar code onto sample container, evidence log, sample recording form, body location form and tamper evident bag (TEB).

vi. Place the sample into cool box and record time on sample recording form.

vii. Complete all paperwork relating to the sample, ensuring sample recording form corresponds with TEB and all information listed in Table A1.1 is recorded on the appropriate forms.

viii. An outer snap lock bag containing surplus bar codes is to be marked with the sample number and placed with sample form inside the cool box.

ix. Survey point to be taken to record the 3D coordinates of the sample.

x. Any used dental equipment to be returned to the MicroSol solution.

xi. Cool box to be handed to SoCO or delivered personally to the DNA lab.

xii. Change outer gloves after sample has been taken.

xiii. SoCO moves cool box to DNA room and checks that the same bar code is on all items – that is, sample container, TEB, sample recording form. Ensure surplus bar codes are in a snap lock bag with the sample.

xiv. Enter details of the sample in the freezer register. Place a bar code into the freezer register in the appropriate space. Assign a freezer location number to each sample and write this on a piece of paper and attach this with tape to the TEB and record in the freezer register.

xv. Photocopy/scan the sample recording form and attach a strip of three bar codes to the front. Place in arch lever file on DNA desk (marked 'copies').

xvi. Attached remaining bar codes in snap lock bag to the front of original sample recording form and place in an arch lever file (marked 'originals').

xvii. Place sample in the appropriate fridge/freezer storage facility. Storage of samples as above.

xviii. Scan the bar code with the bar code reader, into the spreadsheet.

xix. Store original sample recording forms and surplus bar codes together, until the associated body arrives at mortuary. Reunite sample recording form, evidence log and body location form and bar codes and handover to the mortuary.

HANDOVER OF REMAINS

When called to the grave to receive remains, the following procedure applies:

i. Notify the mortuary manager of the imminent arrival of remains.

ii. Liaise with staff at grave for the handover.

iii. Check that sample record, evidence log and body location form correspond with the body number and all finds associated with that body correspond with the with body number.

iv. At the time of handover, record signature, date and time on the continuity evidence form.

v. Carry boxed remains into mortuary and sign the continuity form. Hand to the mortuary manager, who will sign for receipt of the remains.

PROCEDURE FOR THE COLLECTION OF SAMPLES BY COURIER

Courier deliveries are to be pre arranged with LGC Forensics who will inform the courier (Top Speed Couriers) of the exact pick up and delivery time. LGC Forensics will then confirm back by email to the SoCO that a delivery has been arranged stating the date and time. This may be set up on a regular shipment order, but the same process applies.

Samples for delivery to LGC Forensics to be prepared the day(s) before collection. Samples for DNA analysis are to be sent to LGC Forensics based upon the following criteria:

i. The sample is unique to that body.

ii. A sample from a particular body has NOT been sent previously unless specifically requested by LGC Forensics.

iii. The sample to be chosen will be in the following order of priority:
- One tooth
- One small bone
- Any other sample requested

iv. All samples for delivery to LGC Forensics are to be placed in a cool box with a minimum of two cool blocks below the samples at time of courier arrival. The cool box must be marked

on the outside with the words "EXEMPT HUMAN SPECIMENS".

v. Photocopies of the sample recording form (corresponding to samples going to LGC Forensics) is to be placed in a large clear plastic snap lock bag and taped to the top of the cool box with LGC Forensics tape.

vi. Seal the cool box with LGC Forensics tape.

vii. Continuity form for Courier Service to be completed with bar codes attached, Sample number and body umber written in and signed and dated by the SoCO or her designated representative and courier.

viii. Freezer Register to be signed by the courier in the allocated space next to detail of all the individual samples being collected.

ix. Within 12 hours of receipt of samples, LGC Forensics will forward a sample continuity form (see below).

x. Once this has been received an entry in the freezer register can be added and the bar codes scanned to record that they have been received by LGC Forensics.

xi. A green highlighter pen is then used to cross out samples no longer in OA custody.

VOLUNTEER SAMPLES FOR ELIMINATION DATABASE

The SoCO or her OA representative have no involvement in the taking of volunteer samples (these are taken by David Richardson/or representative), but they are being stored within OA's DNA freezer. If handed a sample by David Richardson or his representative, the following procedures apply:

i. Enter the ID number of the sample in the rear page of the freezer register and gain a signature from the person requesting storage of sample.

ii. Place the sample (2 small tubes) into a small evidence bag and seal. Write the ID number on the outside of bag and place the sample into a brown bag in base of freezer.

iii. Write the ID number on the outside of the brown bag.

iv. No paperwork is to be completed or retained except the contents forms kept by David Richardson.

v. All volunteer samples are to be forwarded to LGC Forensics with next available courier pick up.

vi. Complete the volunteer sample continuity form and place the samples in a larger evidence bag separately from the site samples. Place in a cool box for transportation.

vii. Courier to sign continuity form.

viii. For continuity, only Janet Worthington, or her representative, is authorised to go into the DNA freezer and fridge.

ASSISTING MORTUARY STAFF WITH BRAIN TISSUE SAMPLES

When requested to assist mortuary staff with the sampling of brain tissue the following procedures apply:

i. On discovering brain tissue (it is preferable to sample brain tissue prior to x-ray. However, if the remains have gone through X-ray note it on sample form.).

ii. Prepare 10% solution of MicroSol (see Equipment List).

iii. Place instruments into the MicroSol solution for 10 minutes.

iv. Contact the SoCO and ask for DNA Sample Kit for Brain Tissue.

v. Clean an area of the work table with MicroSol.

vi. Place the skull on absorbent mat -preferably on a support.

vii. Remove the instruments from the MicroSol and dry off with paper towel.

viii. Wear Tykek suits, double gloves, face mask and hair net.

ix. Take 2 x ~2.5ml samples of tissue and place in an appropriate container.

x. Dispose of all implements used to recover the brain tissue.

xi. Sign the sample recovery form and hand over the samples to the SoCO.

xii. Remove the remaining brain tissue and place it in a bag labelled with the body number.

xiii. Hand over the sample to the SoCO for freezer storage.

xiv. Record on the Evidence Log, the samples and remaining tissue in storage.

xv. Issue an evidence number, complete the sample recovery form, evidence log and exhibit bag, and ensure that bar codes are placed on all items relating to the sample.

xvi. Sign the relevant paperwork and seal the bag.

xvii. Enter the sample into fridge/freezer storage, as above.

TOOTH CATEGORIES

1 – PERFECT: no fissuring, no damage, no flaking of the enamel, good preservation of the root (not eroded, not damaged, not broken), no caries, root must be

fully formed and closed, no or slight wear (slight dentine exposure, less than *c* 10% of tooth surface).

2 – GOOD: there are one or two fissures but good preservation of the root, no flaking of enamel, fully formed, no caries, slight wear (*c* 10% maximum and certainly less than 1/3 of crown worn),

3 – FAIR: damaged tooth (cracks, enamel flaking), but root well preserved (not broken, not so eroded as to modify its profile), no caries; 3b) some damage to root, some wear (up to 1/3 of tooth crown) but NO CARIES.

4 – POOR: a carious lesion but not affecting pulp cavity.

5 – All the above: flaking of enamel, poor preservation of root, roots formed but damage, wear

5+ – Good preservation and no caries but root not formed or caries+? CARIES affecting the pulp (for example, gross caries)

To aim for 1.
5+ should only be taken if no other teeth available.

Appendix Two: Statistical Methods Employed to Analyse the Data from the Anthropological Analysis

by Richard Wright

METHODS EMPLOYED

Contingency tables were analysed using the statistical package XLStat by Addinsoft. This package (as do most other statistical packages published within the last ten or so years) allows Monte Carlo methods for the computation of the probabilities of the deviation from expected frequencies happening by chance (Baglivo 2005, 233; McKillup 2006, 211).

Before computer intensive methods of randomisation became available, the chi-square value of the contingency table was calculated by hand. Two values were then required to look up, in a table, the probability of the deviation from expected frequencies happening by chance. The two values required were chi-square and the degree of freedom. The lookup table for chi-square gave probabilities in terms of brackets, for example, <0.05 and >0.01.

Modern methods have made the older approach outmoded. They use the Monte Carlo approach – specifically what are known as permutation or shuffling methods (Cleophas *et al*. 2009; 478). Essentially, the Monte Carlo method randomises the counts in the rows in a contingency table, but keeps the total of each row constant. The method is computer intensive, because some thousands of randomly constructed contingency tables have to be analysed, to derive the probabilities (with XLStat, 10,000 permutations were used). This new approach to contingency tables has several advantages:

- Expected frequencies of 5 or less, no longer distort the value of chi square (Peat and Barton 2005, 215).
- Probabilities are given as a specific value such as 0.032, and no longer lie within a bracketed range.
- The values for chi square and degrees of freedom are redundant, and need no longer clutter the report on a contingency table.

Our approach in reporting individual analyses has been to present the following information:

- The contingency table of counts, on which the analyses are based.
- The probability of the deviation from expected frequencies happening by chance.
- A conventional level for claiming statistical significance (the so-called alpha level) is where the calculated probability is less than 0.05. Where a result is statistically significant (i.e. the probability is less than 0.05), we then present the following information.
- The Pearson's Phi association coefficient. Unlike chi square, which measures the strength of the deviation in relation to the total numbers in the contingency table, the association coefficient measures the strength of the deviation from expected frequencies regardless of the total number of cases in the contingency table. Its values range between 0 and 1.0. This is an important statistic for keeping the substantive importance of the result in perspective. For example, in very large samples the probability may be very low (that is, the result is highly significant statistically, at $p<0.0001$), but the strength of the effect negligible in terms of the subject matter, for example <.200.
- The phi coefficient is put into words that reflect its magnitude.
- So-called adjusted residuals are used to examine which of the cells in the contingency are statistically significant (Fisher and van Belle 1993).
- The results are put in the language of the subject matter being investigated.

In the few cases where the rows in the table have a natural order (for example. the rows are ordered from individuals that are adolescent to those that are mature adults) we have applied the Cochran-Armitage test for detecting a significant trend (Piegorsch and Bailer 1997, 242).

STATISTICAL ANALYSIS OF PATTERNING IN THE GRAVES

Introduction

It was obvious to those working at Pheasant Wood that the human remains were not uniform in their properties over the five major graves. For example, it was seen, from early on in the excavation, that the remains in Grave Two were in a worse state of preservation than the remains in Grave One.

This section of the report includes two ways of looking at this lack of uniformity over the graves. It tests the various individual properties, to see whether the differences in their frequencies are significantly different, in a statistical sense, between the graves. To do this, the chi-square method is used – with extra statistics.

The whole table of occurrence of properties in the graves is looked at by multivariate analysis. The method used is correspondence analysis. This method considers all the properties simultaneously, and looks for the most important latent pattern of properties, that distinguishes the graves from one another.

Chi-Square

The use of chi-square is common in archaeology (Shennan 1997), so needs no special justification here. Its use is illustrated by the example of the frequencies of adherent fabric in graves one to five. Computations were carried out by XLStat.

Question to be looked at

The question to be looked at is whether there is a statistically significant association between adherent fabric and grave numbers.

Table of observed frequencies

Since the table is a contingency table, statistical testing using chi-square is appropriate. These notes reflect the language associated with that test (Table A2.1).

We must use counts as our frequencies, not percentage frequencies.

Table A2.1: Observed frequencies of adherent fabric in the graves

Grave number	*Presence*	*Absence*
1	2	48
2	16	35
3	11	41
4	4	46
5	3	41

Table of expected frequencies

From the observed frequencies in Table A2.1 can be computed the expected frequencies shown in Table A2.2.

Why are these frequencies expected? The word relates to what we would expect as frequencies if there was no relation between the occurrence of adherent fabric and graves.

In all our cells, there are differences between the observed and expected frequencies. The question to be answered is this. What is the probability of getting differences of this magnitude when the differences are due to sampling variability alone? A similar question would be what the chances are of getting a run of 9 heads, by sampling variability alone, with an unbiased coin.

The null hypothesis

To look at the questions raised, we use a chi-square test of independence between adherent fabric and graves. We set up two hypotheses:

- Null hypothesis: the rows and columns of the table are independent; that is, there is no relation between adherent fabric and the graves.
- Alternative hypothesis: there is a link between the rows and columns of the table; that is, there is a relation between adherent fabric and the graves.

A convention is to accept the null hypothesis if the probability of getting the difference is greater than 0.05.

By contrast, if the probability is equal to, or less than, 0.05 we reject the null hypothesis and accept the alternative hypothesis. This level of probability of 0.05 is a so-called alpha level. It sets a threshold of a probability of the chance of 1 in 20.

Getting chi-square results

In the old days, when computations had to be done by hand, one calculated a value for chi-square, and with a number called the degree of freedom, looked up a table of the probabilities for the calculated value of chi-square.

Table A2.2: Expected (theoretical) frequencies, assuming that there is literally no relation between adherent fabric and grave numbers

Grave number	*Presence*	*Absence*
1	7.3	42.7
2	7.4	43.6
3	7.6	44.4
4	7.3	42.7
5	6.4	37.6

Today, one can use a computer intensive Monte Carlo method of estimating the probabilities of chi-square, which gives more accurate estimates of probability when the counts in or more of the cells is low (Peat and Barton, 2005). The number of iterations used in XLSTAT is 10,000.

In other words, the long-winded method of presenting chi-square results can be abandoned. It can be replaced by a simple value of probability, which is to be compared with the alpha level.

Interpreting the results for adherent fabric and the graves

For adherent fabric, and using the computer-intensive Monte Carlo method, we get the following result for the probability of chi-square:

p-value: 0.00050

This value is much less than the alpha level of 0.05, showing as it does that there is a 1 in 2,000 chance of getting the differences between the observed and expected frequencies by sampling variability alone. Obviously, for adherent fabric we reject the null hypothesis and accept the alternative hypothesis of there being an association between adherent fabric and the graves.

Degree of association

Had the probability been greater than the alpha level of 0.05, leading to the acceptance of the null hypothesis, then that would be the end of our analysis.

Yet, we have seen that the probability for adherent fabric is highly significant. So, the question now is how much are adherent fabric and graves associated. A commonly used measure of association is Pearson's Phi association coefficient. The value of chi-square cannot be used, because it depends on sample size (Osborn 2006).

The value of this coefficient can range between 0 and 1. Zero is the value that would be obtained from Table A2.2 of expected frequencies.

The value obtained for the observed frequencies of Table A2.1 is 0.297. Put into words, this value can be said to show only slight association.

Adjusted residuals

When we have a significant result, and where the number of rows is greater than two (as they obviously are when five graves are looked at), we will want to probe the chi-square results more deeply. For example, for adherent fabric we will want to know whether all five graves contribute to a significant result. This deeper probe is achieved by using the values of the adjusted residuals (Van Belle and Fisher 1993).

The numbers in Table A2.3 can be treated as z-scores. We see that only graves one and two contribute to the statistically significant result. Grave One has a significantly low frequency of adherent fabric and Grave Two a significantly high frequency. Graves three to five are not contributing to the significance, and therefore show no pattern.

Table A2.3: The adjusted residuals for adherent fabric and graves, showing which graves contribute to the statistically significant result

Grave number	*Presence*
1	-2.373
2	3.816
3	1.513
4	-1.475
5	-1.608

Presentation of results

The results for all the properties are shown in Figure A2.1. They can be interpreted by referring to the example of adherent fabric, presented above.

Correspondence analysis (CA)

Chi-square has allowed us to look at the graves and properties, taking the properties one by one. What is now wanted is a method of characterising and distinguishing the graves by taking account of all the properties simultaneously.

The method of correspondence analysis

Caroline Barker supplied the counts shown in Table A2.4, in which the graves can be thought of as being described by variations in the counts of various properties.

Table A2.4: The counts of properties within the graves

	Root activity	*Bone plastic deformation*	*Adherent fabric*	*Metal staining*	*Bone texture wet/green*	*Lime deposits*	*Non-osseous tissue present*	*Complete >95%*	*Fragmentation <25%*	*Erosion <25%*
Grave 1	3	8	2	2	48	49	47	50	44	47
Grave 2	11	5	16	27	0	31	18	27	3	9
Grave 3	8	5	11	7	0	43	42	44	25	23
Grave 4	0	14	4	4	50	50	48	50	47	50
Grave 5	2	10	3	4	44	44	42	40	40	44

Property	Probability by Monte Carlo chi-square	Pearson's Phi association coefficient	Interpretation of Pearson's Phi	Interpretation of adjusted residuals
Graves 1-5				
Bone texture - wet/green & dry/crumbly	< 0.0001	0.984	Very high association	Graves 1,4 & 5 tend to wet/green bone. Graves 2 & 3 tend to dry & crumbly bone
Non-osseous preservation - presence & absence	< 0.0001	0.582	Moderate association	Graves 1,4 & 5 tend to non-osseous preservation. Grave 2 tends not to preserve.
Metal staining - presence & absence	< 0.0001	0.474	Moderate association	Grave 2 tends to metal staining, Grave 1 tends to no metal staining.
Lime deposits - presence & absence	< 0.0001	0.468	Moderate association	Graves 1,4 & 5 tend to lime deposits. Grave 2 tends to absence.
Adherent fabric - presence & absence	0.0005	0.297	Slight association	Grave 2 tends to high adhering fabric, Grave 1 tends to low.
Root Activity - presence & absence	0.0014	0.267	Slight association	Grave 2 tends to high root activity, Grave 4 tends to low
Bone plastic deformation - presence & absence	0.0560	na	na	na
Graves 2, 3 & 6 near edge of wood: Graves 1, 4 & 5 away from edge of wood				
Bone texture - wet/green & dry/crumbly	< 0.0001	0.984	Very high association	Near wood tends to dry & crumbly bone. Away from wood tends to wet/green.
Erosion <25% & >25%	< 0.0001	0.736	Strong association	Near wood tends to >25% erosion. Away from wood tends to <25% erosion.
Fragmentation <25% & >25%	< 0.0001	0.663	Strong association	Near wood tends to >25% fragmentation. Away from tends to <25% fragmentation.
Non-osseous preservation - presence & absence	< 0.0001	0.466	Moderate association	Near wood tends not to preserve non-osseous. Away from wood tends to preserve.
Completeness - >95% & <95%	< 0.0001	0.412	Moderate association	Near wood tends to <95% completeness. Away from wood tends to >95% completeness.
Lime deposits - presence & absence	< 0.0001	0.414	Moderate association	Near wood tends to absence of lime. Away from wood tends to presence.
Metal staining - presence & absence	< 0.0001	0.354	Slight association	Near wood tends to metal staining. Away from wood tends to no metal staining.
Adherent fabric - presence & absence	< 0.0001	0.300	Slight association	Near wood tends to adherent fabric. Away from wood tends to no adherent fabric.
Root Activity - presence & absence	0.0003	0.254	Slight association	Near wood tends to high root activity. Away from wood tends to low.
Bone plastic deformation - presence & absence	0.0083	0.169	Negligible association	Near wood tends to no deformation. Away from wood tends to no deformation.

Fig. A2.1 Summary results of chi-square tests

The appropriate multivariate method of analysis for such a table is correspondence analysis (CA), which is a form of principal components analysis modified for analysis of counts (Greenacre (2007).

As Mike Baxter (1994) writes: 'CA is described in terms of a PCA of appropriately transformed data for both rows and columns.' These appropriate transformations are part of the CA program itself, not something to be done beforehand and externally.

As an aside, Shennan (1997) converts counts into percentage frequencies before using CA. This is incorrect procedure. The method of correspondence analysis has its own conversion to relative frequencies by both rows and columns. Converting to percentage frequencies is not only unnecessary, but is also harmful. By doing correspondence analysis on percentage frequencies we mask some heuristic advantages of CA.

CA scores

CA fits the graves and properties to the same scale, and assigns scores to the CA axes. The CA scores for the first two axes are plotted as a scattergram in Figure A2.2. They account for 99.1% of the variance in the original data, so the remaining scores for CA3 and CA4 are trivial, and should not be interpreted. The correspondence analysis scores for the data shown in Table A2.5.

We must now spell out some principles of interpreting the results of CA:

- The axes are independent of each other, and show distinct characterisations of both graves and properties; so the axes must be considered individually.
- Graves and properties that have scores close to absolute values of zero are not distinguished by that CA axis. They are, as it were, perfectly ordinary and should normally be ignored when it comes to interpretation.
- The further away graves and properties are from zero, whether in a positive or negative direction, then the more distinctive they are on that axis.
- Graves and properties that are far away from

Table A2.5: The correspondence analysis scores for the data shown in Table A2.4

	CA1	*CA2*
Grave 1	-0.257	0.015
Grave 2	1.111	0.184
Grave 3	0.281	-0.334
Grave 4	-0.253	0.062
Grave 5	-0.236	0.067
Root activity	1.222	-0.125
Bone plastic deformation	-0.053	0.137
Adherent fabric	1.148	-0.046
Metal staining	1.486	0.458
Bone texture wet/green	-0.552	0.304
Lime deposits	0.111	-0.055
Non-osseous tissue present	-0.026	-0.137
Complete >95%	0.078	-0.097
Fragmentation <25%	0.311	-0.062
Erosion <25%	-0.239	0.027

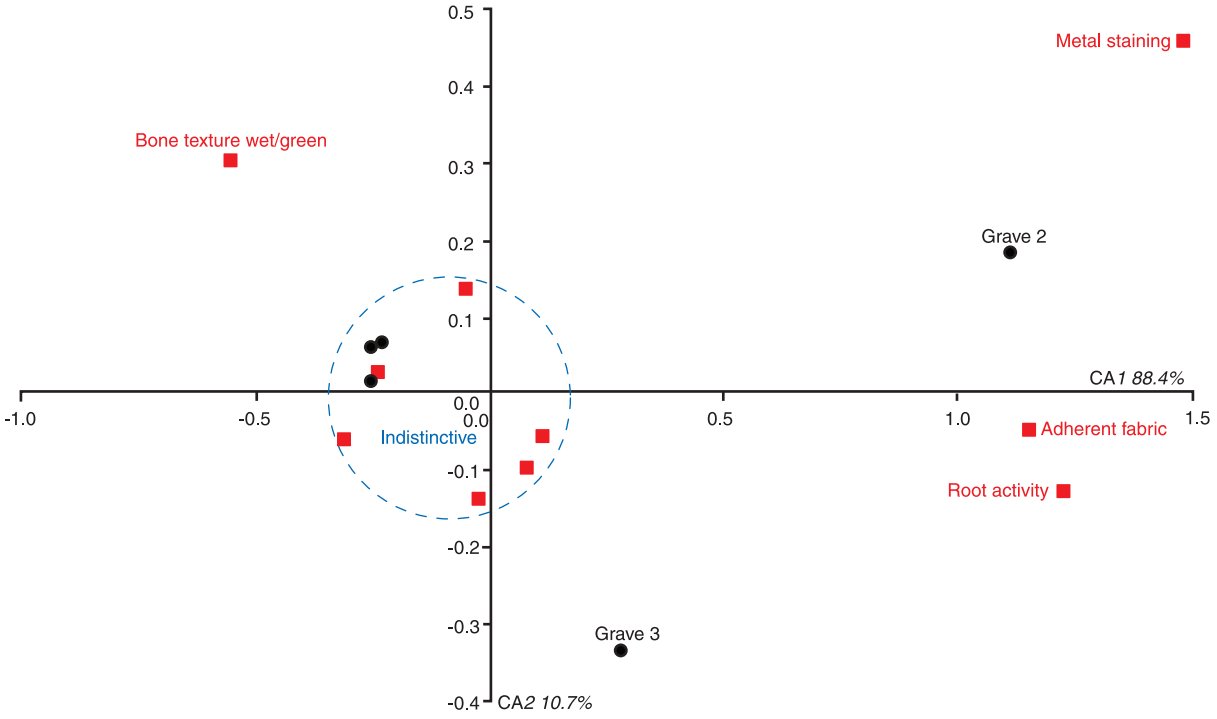

Fig. A2.2 Correspondence analysis scattergram

zero, whether in a positive or negative direction, are mutually characterised.

- A grave with a high positive value is characterised by properties with a high positive value. It will have relatively high counts of those properties. It will also have relatively low counts of properties with low negative values.
- Conversely (and perhaps counterintuitively) a grave with a high negative value is characterised by properties with a high negative value. It will have relatively high counts of those properties. It will also have relatively low counts of properties with high positive values.

Interpretation of the scattergram of Figure A2.2

The major CA axis (horizontal) of Figure A2.2 accounts for 88.4% of the variance. It shows Grave Two, and to a much lesser extent Grave Three, characterised by relatively high frequencies of metal staining, adherent fabric, and root activity. These graves are also characterised by a relatively low frequency of Bone texture wet/green, meaning that the bones tend to be crumbly.

The minor CA axis (vertical) of Figure A2.2 accounts for merely 10.7% of the variance. It picks up the fact that Grave Three also combines a relatively low frequency of both bone texture wet/green and metal staining. Grave Two, though to a somewhat smaller extent, combines a relatively high frequency of both these properties. This axis shows what is an essentially slight contrast found between only two graves, both of which (in the broader scope of things shown by CA1's 88.4% in Figure A2.2) are not similar to each other, and stand in contrast to graves one, four and five in the blue hashed circle.

The scattergram of Figure A2.2 accounts for virtually all the variance in the data (99.1%). Any factor not revealed by this scattergram is therefore trivial.

Figure A2.2 usefully shows that most of the graves and properties lie within the blue dashed circle. Their position means that CA finds them indistinctive, and so need no discussion. They are perfectly ordinary, in whatever way one looks at the simultaneous relationship between graves and properties.

Position of graves in site

The scattergram is essentially distinguishing the graves that lie near the wood (graves two and three) and spelling out the particular properties that characterise and distinguish them.

Appendix Three: Anthropology
Contingency Tables and Chi-square Results

RESOLUTION OF COMMINGLING

Table A3.1: Body parts, graves one to five (goodness of fit chi square)

	Number of body parts	*Expected*
Grave One	38	27.8
Grave Two	34	27.8
Grave Three	24	27.8
Grave Four	20	27.8
Grave Five	23	27.8
Total	139	139

COMPLETENESS, CONDITION AND TAPHONOMIC CHANGES

Table A3.2: Fragmentation and timing by body regions (limbs)

Body region	*Post-mortem*	*Peri-mortem*	*Both*	*Total*
Left arm	56	18	4	78
Left forearm	34	17	3	54
Right arm	52	15	3	70
Right forearm	32	21	0	53
Left thigh	66	19	4	89
Left leg	88	22	2	112
Right thigh	56	18	6	80
Right leg	70	18	5	93
Total	454	148	27	629

Table A3.4: Fragmentation and timing by body regions (hands and feet)

Body region	*Post-mortem*	*Peri-mortem*	*Total*
Left hand	5	12	17
Right hand	3	14	17
Left foot	26	9	35
Right foot	27	11	38
Total	61	46	107

Table A3.3: Frequency of body regions and fragmentation

Body region	*Present*	*Absent*	*Total*
Cranium	163	87	250
Mandible	110	140	250
Neck	86	164	250
Thorax	204	46	250
Abdomen	132	118	250
Left Arm	91	159	250
Left forearm	67	182	250
Left hand	18	232	250
Right arm	83	167	250
Right forearm	61	188	250
Right hand	18	225	250
Left thigh	90	160	250
Left leg	115	135	250
Left foot	36	212	250
Right thigh	81	169	250
Right leg	100	150	250
Right foot	39	207	250
Total	1494	2741	250

Table A3.5: Fragmentation and timing by body regions (all regions)

Body region	*Post-mortem fragmentation*	*Peri-mortem fragmentation*	*Total*
Cranium	25	115	140
Mandible	17	83	100
Neck	8	62	70
Thorax	37	96	133
Abdomen	44	49	93
Left Arm	56	18	74
Left forearm	34	17	51
Left hand	5	12	17
Right arm	52	15	67
Right froearm	32	21	53
Right hand	3	14	17
Left thigh	66	19	85
Left leg	88	22	110
Left foot	26	9	35
Right thigh	56	18	74
Right leg	70	18	88
Right foot	27	11	38
Total	646	599	1245

Table A3.6: Lime deposits, layer 1 and layer 2

	Layer 1	*Layer 2*	*Totals*
Grave One	24	25	49
Grave Two	15	16	31
Grave Three	21	22	43
Grave Four	25	25	50
Grave Five	16	28	44
Total	101	116	217

Table A3.7: Lime deposits focal and diffuse

	Diffuse	*Focal*	*Totals*
Grave One	47	2	49
Grave Two	9	22	31
Grave Three	20	23	43
Grave Four	50	0	50
Grave Five	44	0	44
Total	170	47	217

Table A3.8: Bone texture – wet/green and dry/crumbly

	Presence	*Absence*	*Totals*
Grave One	48	2	50
Grave Two	0	51	51
Grave Three	0	52	52
Grave Four	50	0	50
Grave Five	44	0	44
Total	142	105	247

Table A3.9: Non-osseous preservation

	Presence	*Absence*	*Totals*
Grave One	47	3	50
Grave Two	18	33	51
Grave Three	42	10	52
Grave Four	48	2	50
Grave Five	42	2	44
Total	197	50	247

Table A3.10: Metal staining

	Presence	*Absence*	*Totals*
Grave One	47	3	50
Grave Two	18	33	51
Grave Three	42	10	52
Grave Four	48	2	50
Grave Five	42	2	44
Total	197	50	247

Table A3.11: Lime deposits

	Presence	*Absence*	*Totals*
Grave One	49	1	50
Grave Two	31	20	51
Grave Three	43	9	52
Grave Four	50	0	50
Grave Five	44	0	44
Total	217	30	247

Table A3.12: Adherent fabric

	Presence	*Absence*	*Totals*
Grave One	2	48	50
Grave Two	16	35	51
Grave Three	11	41	52
Grave Four	4	46	50
Grave Five	3	41	44
Total	36	211	247

Table A3.13: Root activity

	Presence	*Absence*	*Totals*
Grave One	3	47	50
Grave Two	11	40	51
Grave Three	8	44	52
Grave Four	0	50	50
Grave Five	2	42	44
Total	24	223	247

Table A3.14: Bone plastic deformation

	Presence	*Absence*	*Totals*
Grave One	8	42	50
Grave Two	5	46	51
Grave Three	5	47	52
Grave Four	14	36	50
Grave Five	10	34	44
Total	42	205	247

Table A3.15: Correspondence analysis – presence of all properties, graves one to five

Grave	*Root activity*	*Bone Plastic deformation*	*Adherent fabric*	*Metal staining*	*Bone texture wet/green*	*Lime deposits*	*Non-osseous tissue present*	*Completeness > 95%*	*Fragmentation <25%*	*Erosion <25%*
1	3	8	2	2	48	49	47	50	44	47
2	11	5	16	27	0	31	18	27	3	9
3	8	5	11	7	0	43	42	44	25	23
4	0	14	4	4	50	50	48	50	47	50
5	2	10	3	4	44	44	42	40	40	44
Total	24	42	36	44	142	217	197	211	159	173

Table A3.16: Grave One: erosion, layer 1 and layer 2

	Presence	*Absence*	*Totals*
Layer 1	9	16	25
Layer 2	1	24	25
Total	10	40	50

Table A3.17: Grave Three erosion, layer 1 and layer 2

	Presence	*Absence*	*Totals*
Layer 1	24	4	28
Layer 2	16	8	24
Total	40	12	52

Table A3.18: Grave Four erosion, layer 1 and layer 2

	Presence	*Absence*	*Totals*
Layer 1	1	24	25
Layer 2	0	25	25
Total	1	49	50

Table A3.19: Grave Five erosion, layer 1 and layer 2

	Presence	*Absence*	*Totals*
Layer 1	10	6	16
Layer 2	2	26	28
Total	12	32	44

BIOLOGICAL AGE AT DEATH

Table A3.20: Younger versus older individuals, graves one to five

	Younger	*Older*	*Totals*
Grave One	23	27	50
Grave Two	38	13	51
Grave Three	24	28	52
Grave Four	30	20	50
Grave Five	26	18	44
Total	*141*	*106*	*247*

DENTAL AND ORAL HEALTH

Table A3.21: AMTL timing status

Category	*Observed*	*Expected*
Long term AMTL	124	82
Progressive AMTL	91	82
Recent AMTL	31	82
Total	246	246

Table A3.22: AMTL – maxilla versus mandible (calculations based on number of alveoli)

Category	AMTL	No AMTL	Total
Maxilla	976	2761	3737
Mandible	733	3157	3890
Total	1709	5918	7627

Table A3.23: AMTL – anterior versus posterior (calculations based on number of alveoli)

Category	AMTL	No AMTL	Total
Anterior	259	2655	2914
Posterior	1450	3263	4713
Total	1709	5918	7627

Table A3.24: AMTL and age at death

Category	AMTL	No AMTL	Total
Adolescent	2	4	6
Young adult	127	11	138
Prime adult	76	5	81
Mature adult	23	2	25
Total	228	22	250

Table A3.25: Caries – maxilla versus mandible (calculations based on number of teeth)

Category	Caries present	Caries absent	Total
Maxilla	504	2229	2733
Mandible	381	2652	3033
Total	885	4881	5766

Table A3.26: Caries – anterior versus posterior (calculations based on number of teeth)

Category	Present	Absent	Total
Anterior	227	2367	2594
Posterior	658	2515	3172
Total	885	4881	5766

Table A3.27: Peri–apical cavities maxilla versus mandible (calculations based on number of alveoli)

Category	Present	Absent	Total
Maxilla	70	3667	3737
Mandible	51	3839	3890
Total	121	7506	7627

Table A3.28: Peri-apical cavities anterior versus posterior (calculations based on number of alveoli)

Category	Present	Absent	Total
Anterior	43	2871	2914
Posterior	78	4635	4713
Total	121	7506	7627

DENTAL WORK

Table A3.29: Fillings maxilla versus mandible (calculations based on number of teeth)

Category	Present	Absent	Total
Maxilla	150	2583	2733
Mandible	385	2648	3033
Total	535	5231	5766

Table A3.30: Fillings anterior versus posterior (calculations based on number of teeth)

Category	Present	Absent	Total
Anterior	151	2582	2733
Posterior	384	2649	3033
Total	535	5231	5766

Table A3.31: AMTL denture replacement maxilla versus mandible (calculations based on number of alveoli)

Category	Tooth replaced	Tooth not replaced	Total
Maxilla	371	3366	3737
Mandible	51	8839	3890
Total	422	7205	7627

Table A3.32: AMTL denture replacement anterior versus posterior (calculations based on number of alveoli)

Category	Tooth replaced	Tooth not replaced	Total
Anterior	161	2753	2914
Posterior	261	4452	4713
Total	422	7205	7627

Table A3.33: AMTL denture replacement – anterior maxilla and mandible (calculations based on number of AMTL available for replacement with denture)

Category	Tooth replaced	Tooth not replaced	Total
Anterior maxilla	156	86	242
Anterior mandible	5	7	12
Total	161	93	254

Table A3.34: AMTL denture replacement – posterior maxilla and mandible (calculations based on number of AMTL available for replacement denture)

Category	Tooth replaced	Tooth not replaced	Total
Posterior maxilla	215	519	734
Posterior mandible	46	673	719
Total	261	1192	1453

Table A3.35: Crowns – maxilla versus mandible (calculations based on number of teeth)

Category	Present	Absent	Total
Maxilla	48	2685	2733
Mandible	15	3018	3033
Total	63	5703	5766

Table A3.36: Crowns – anterior versus posterior (calculations based on number of teeth)

Category	Present	Absent	Total
Anterior	23	2571	2594
Posterior	40	3132	3172
Total	63	5703	5766

Table A3.37: Crowns – anterior maxilla versus anterior mandible (calculations based on number of teeth)

Category	Present	Absent	Total
Anterior maxilla	21	1154	1175
Anterior mandible	2	1417	1419
Total	23	2571	2594

Table A3.38: Crowns posterior maxilla versus posterior mandible (calculations based on number of teeth)

Category	Present	Absent	Total
Posterior maxilla	30	1528	1558
Posterior mandible	12	1602	1614
Total	42	3130	3172

Table A3.39: Dental work and age at death

Category	Present	Absent	Total
Adolescent	2	4	6
Young adult	77	61	138
Prime adult	47	34	81
Mature adult	11	14	25
Total	137	113	250

Table A3.40: Denture and age at death

Category	Present	Absent	Total
Adolescent	0	6	6
Young adult	20	118	138
Prime adult	21	60	81
Mature adult	5	20	25
Total	46	204	250

Table A3.41: Crowns and age at death

Category	Present	Absent	Total
Adolescent	0	6	6
Young adult	19	119	138
Prime adult	11	70	81
Mature adult	2	23	25
Total	32	218	250

Table A3.42: Fillings and age at death

Category	*Present*	*Absent*	*Total*
Adolescent	2	4	6
Young adult	63	75	138
Prime adult	32	49	81
Mature adult	8	17	25
Total	105	145	250

Table A3.43: Presence/absence of dentures (denture Grave One, 0666B not included)

	Present	*Absent*	*Totals*
Grave One	7	43	50
Grave Two	11	40	51
Grave Three	6	46	52
Grave Four	11	39	50
Grave Five	10	34	44
Total	45	202	247

Table A3.44: Presence/absence of amalgam and mixed fillings

	Present	*Absent*	*Totals*
Grave One	16	34	50
Grave Two	15	36	51
Grave Three	20	30	50
Grave Four	21	31	52
Grave Five	15	29	44
Total	87	160	247

Table A3.45: Presence/absence of crowns

	Present	*Absent*	*Totals*
Grave One	3	47	50
Grave Two	4	47	51
Grave Three	6	44	50
Grave Four	9	43	52
Grave Five	9	35	44
Total	31	216	247

Table A3.46: Presence/absence of fillings

	Present	*Absent*	*Totals*
Grave One	20	30	50
Grave Two	19	32	51
Grave Three	24	26	50
Grave Four	25	27	52
Grave Five	18	26	44
Total	106	141	247

Table A3.47: Presence/absence of root canal

	Present	*Absent*	*Totals*
Grave One	2	48	50
Grave Two	4	47	51
Grave Three	3	47	50
Grave Four	4	48	52
Grave Five	3	41	44
Total	16	231	247

GRAVES ONE TO FIVE – ONLY THOSE WITH DENTAL WORK (N=134)

Table A3.48: Presence/absence of denture and other dental work

	Present	*Absent*	*Totals*
Grave One	5	18	23
Grave Two	6	18	24
Grave Three	1	29	30
Grave Four	7	23	30
Grave Five	3	24	27
Total	22	112	134

Table A3.49: Presence/absence of dentures only

	Present	*Absent*	*Totals*
Grave One	3	20	23
Grave Two	5	19	24
Grave Three	5	25	30
Grave Four	4	26	30
Grave Five	7	20	27
Total	24	110	134

Table A3.50: Presence/absence of other dental work (no dentures)

	Present	*Absent*	*Totals*
Grave One	15	8	23
Grave Two	11	13	24
Grave Three	25	5	30
Grave Four	19	11	30
Grave Five	17	10	27
Total	87	47	134

Table A3.51: Presence/absence of amalgam and metal fillings

	Present	*Absent*	*Totals*
Grave One	9	14	23
Grave Two	10	14	24
Grave Three	13	17	30
Grave Four	11	19	30
Grave Five	7	20	27
Total	50	84	134

Table A3.52: Presence/absence of fillings (all types)

	Present	*Absent*	*Totals*
Grave One	11	12	23
Grave Two	19	5	24
Grave Three	24	6	30
Grave Four	25	5	30
Grave Five	18	9	27
Total	97	37	134

Table A3.53: Presence/absence of gold crowns

	Present	*Absent*	*Totals*
Grave One	2	21	23
Grave Two	3	21	24
Grave Three	3	27	30
Grave Four	7	23	30
Grave Five	5	22	27
Total	20	114	134

Table A3.54: Presence/absence of mixed type crowns

	Present	*Absent*	*Totals*
Grave One	1	23	24
Grave Two	0	23	23
Grave Three	2	28	30
Grave Four	1	29	30
Grave Five	1	26	27
Total	5	129	134

Table A3.55: All ante-mortem trauma and pathology

Category	*Present*	*Absent*	*Total*
Adolescent	4	2	6
Young adult	125	13	138
Prime adult	76	5	81
Mature adult	24	1	25
Total	229	21	250

Table A3.56: Infection

Category	*Present*	*Absent*	*Total*
Adolescent	1	5	6
Young adult	21	117	138
Prime adult	3	78	81
Mature adult	2	23	25
Total	27	223	250

Table A3.57: Metabolic disease

Category	*Present*	*Absent*	*Total*
Adolescent	0	6	6
Young adult	21	117	138
Prime adult	10	71	81
Mature adult	3	22	25
Total	34	216	250

Table A3.58: Congenital and developmental

Category	*Present*	*Absent*	*Total*
Adolescent	2	4	6
Young adult	54	84	138
Prime adult	35	46	81
Mature adult	9	16	25
Total	100	150	250

Table A3.59: Joint disease

Category	*Present*	*Absent*	*Total*
Adolescent	0	6	6
Young adult	104	34	138
Prime adult	58	23	81
Mature adult	23	2	25
Total	185	65	250

Table A3.60: Circulatory disorders

Category	*Present*	*Absent*	*Total*
Adolescent	0	6	6
Young adult	13	125	138
Prime adult	7	74	81
Mature adult	3	22	25
Total	23	227	250

Table A3.61: Neoplastic disease

Category	*Present*	*Absent*	*Total*
Adolescent	0	6	6
Young adult	4	134	138
Prime adult	1	80	81
Mature adult	1	24	25
Total	6	244	250

Table A3.62: Ante-mortem trauma

Category	*Present*	*Absent*	*Total*
Adolescent	0	6	6
Young adult	38	100	138
Prime adult	27	54	81
Mature adult	10	15	25
Total	75	175	250

Table A3.63: Miscellaneous conditions

Category	*Present*	*Absent*	*Total*
Adolescent	2	4	6
Young adult	48	90	138
Prime adult	32	49	81
Mature adult	6	19	25
Total	88	162	250

PERI-MORTEM TRAUMA

The assemblage (N=250)

Table A3.64: Peri-mortem trauma by body region

Body Region	*Trauma present*	*Trauma absent*	*Totals*
Head	139	111	250
Neck	74	176	250
Thorax	155	95	250
Abdomen	65	185	250
Left upper limb	33	217	250
Right upper limb	34	216	250
Left lower limb	44	206	250
Right lower limb	39	211	250
Total	583	1417	2000

Graves one to five (N=247)

Table A3.65: Presence/absence of peri-mortem trauma

	Trauma present	*Trauma absent*	*Totals*
Grave One	48	2	50
Grave Two	51	0	51
Grave Three	48	4	52
Grave Four	44	6	50
Grave Five	40	4	44
Total	231	16	247

Table A3.66: Presence/absence of multi-trauma

	Trauma present	*Trauma absent*	*Totals*
Grave One	22	28	50
Grave Two	48	3	51
Grave Three	33	19	52
Grave Four	24	26	50
Grave Five	19	25	44
Total	146	101	24

Table A3.67: Presence/absence of peri-mortem trauma to the head

	Trauma present	*Trauma absent*	*Totals*
Grave One	24	26	50
Grave Two	47	4	51
Grave Three	33	19	52
Grave Four	19	31	50
Grave Five	16	28	44
Total	139	108	247

Table A3.68: Presence/absence of peri-mortem trauma to the neck

	Trauma present	*Trauma absent*	*Totals*
Grave One	5	45	50
Grave Two	43	8	51
Grave Three	11	41	52
Grave Four	7	43	50
Grave Five	8	36	44
Total	74	173	247

Table A3.69: Presence/absence of peri-mortem trauma to the thorax

	Trauma present	*Trauma absent*	*Totals*
Grave One	30	20	50
Grave Two	47	4	51
Grave Three	31	21	52
Grave Four	24	26	50
Grave Five	23	21	44
Total	155	92	247

Table A3.70: Presence/absence of peri-mortem trauma to the abdomen

	Trauma present	*Trauma absent*	*Totals*
Grave One	10	40	50
Grave Two	25	26	51
Grave Three	12	40	52
Grave Four	11	39	50
Grave Five	7	37	44
Total	65	182	247

Table A3.71: Presence/absence of peri-mortem trauma to the left upper limb

	Trauma present	*Trauma absent*	*Totals*
Grave One	3	47	50
Grave Two	8	43	51
Grave Three	9	43	52
Grave Four	5	45	50
Grave Five	8	36	44
Total	33	214	247

Table A3.72: Presence/absence of peri-mortem trauma to the right upper limb

	Trauma present	*Trauma absent*	*Totals*
Grave One	4	46	50
Grave Two	6	45	51
Grave Three	9	43	52
Grave Four	6	44	50
Grave Five	9	35	44
Total	34	213	247

Table A3.73: Presence/absence of peri-mortem trauma to the left lower limb

	Trauma present	*Trauma absent*	*Totals*
Grave One	9	41	50
Grave Two	7	44	51
Grave Three	10	42	52
Grave Four	7	43	50
Grave Five	10	34	44
Total	43	204	247

Table A3.74: Presence/absence of peri-mortem trauma to the right lower limb

	Trauma present	*Trauma absent*	*Totals*
Grave One	9	41	50
Grave Two	12	39	51
Grave Three	9	43	52
Grave Four	5	45	50
Grave Five	4	40	44
Total	39	208	247

Table A3.75: Ballistics associated with individuals

	Ballistics present	*Ballistics absent*	*Totals*
Grave One	5	45	50
Grave Two	20	31	51
Grave Three	18	34	52
Grave Four	25	25	50
Grave Five	19	25	44
Total	87	160	247

Ballistics graves one to five (N=247)

Table A3.76: Total ballistics associated with individuals and grave (goodness of fit chi square)

	Ballistics present	*Ballisitcs expected*
Grave One	7	21.8
Grave Two	35	21.8
Grave Three	20	21.8
Grave Four	26	21.8
Grave Five	21	21.8
Total	109	109

Table A3.77: Chi-square results

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Inter-pretation of Pearson's Phi*	*Interpretation, using adjusted residuals where appropriate*	*Cochran-Armitage trend test Monte Carlo p*	*Trend*
Resolution of Commingling, Graves 1-5						
Body parts (goodness of fit chi square)	0.0666	na	na	[not significant]		
Completeness, Condition and Taphonomic Change Graves 1-5						
Lime deposits layer 1 and layer 2	0.6794	na	na			
Lime deposits focal and diffuse	< 0.0001	0.696	Strong effect	Graves 1, 4 & 5 tend to diffuse lime; Graves 2 & 3 focal lime.		
Bone texture - wet/green & dry/crumbly	< 0.0001	0.984	Very high effect	Graves 1,4 & 5 tend to wet/green bone; Graves 2 & 3 tend to dry & crumbly bone		
Non-osseous preservation - presence & absence	< 0.0001	0.582	Moderate effect	Graves 1,4 & 5 tend to non-osseous preservation; Grave Two tends not to preserve.		
Metal staining - presence & absence	< 0.0001	0.474	Moderate effect	Grave Two tends to metal staining; Grave One tends to no metal staining.		
Lime deposits - presence & absence	< 0.0001	0.468	Moderate effect	Graves 1,4 & 5 tend to lime deposits; Grave Two tends to absence.		
Adherent fabric - presence & absence	0.0005	0.297	Slight effect	Grave Two tends to high adhering fabric; Grave One tends to low.		
Root Activity - presence & absence	0.0014	0.267	Slight effect	Grave Two tends to high root activity; Grave Four tends to low		
Bone plastic deformation - presence & absence	0.0560	na	na	na		
Completenes, Condition and Taphonomic Change Graves 2, 3 & 6 near edge of wood ; Graves 1, 4 & 5 away from edge of wood						
Bone texture - wet/green & dry/crumbly	< 0.0001	0.984	Very high effect	Near wood tends to dry & crumbly bone; away from wood tends to wet/green.		
Erosion <25% & >25%	< 0.0001	0.736	Strong effect	Near wood tends to >25% erosion; away from wood tends to <25% erosion.		
Fragmentation by limbs – post-mortem and peri-mortem	0.2035	na	na			
Fragmentation by hands and feet – post-mortem and peri-mortem	< 0.0001	0.423	Moderate effect	Hands low post-mortem high peri-mortem, feet low peri-mortem, high post-mortem		
Fragmentation by body region – post-mortem and peri-mortem	*No test, because of highly variable size of regions*					
Fragmentation <25% & >25%	< 0.0001	0.663	Strong effect	Near wood tends to >25% fragmentation; away from tends to <25% fragmentation.		
Non-osseous preservation - presence & absence	< 0.0001	0.466	Moderate effect	Near wood tends not to preserve non-osseous; away from wood tends to preserve.		

Table A3.77: Chi-square results (continued)

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Inter-pretation of Pearson's Phi*	*Interpretation, using adjusted residuals where appropriate*	*Cochran-Armitage trend test Monte Carlo p*	*Trend*
Completeness - >95% & <95%	< 0.0001	0.412	Moderate effect	Near wood tends to <95% completeness; away from wood tends to >95% completeness.		
Lime deposits - presence & absence	< 0.0001	0.414	Moderate effect	Near wood tends to absence of lime; away from wood tends to presence.		
Metal staining - presence & absence	< 0.0001	0.354	Slight effect	Near wood tends to metal staining; away from wood tends to no metal staining.		
Adherent fabric - presence & absence	< 0.0001	0.3	Slight effect	Near wood tends to adherent fabric; away from wood tends to no adherent fabric.		
Root Activity - presence & absence	0.0003	0.254	Slight effect	Near wood tends to high root activity; away from wood tends to low.		
Bone plastic deformation - presence & absence	0.0083	0.169	Negligible effect	Near wood tends to no deformation; away from wood tends to no deformation.		
Completenes, Condition and Taphonomic Change						
Grave One erosion layer 1 & layer 2	0.0108	0.400	Moderate effect	Layer 1 tends high; layer 2 low.		
Grave Two erosion layer 1 & layer 2	No test	na	na	All individuals have erosion		
Grave Three erosion layer 1 & layer 2	0.1869	na	na			
Grave Four erosion layer 1 & layer 2	1.0000	na	na			
Grave Five erosion layer 1 & layer 2	0.0002	0.598	Moderate effect	Layer 1 tends high; layer 2 low.		
Age at Death						
Graves 1-5 (N=247)						
Younger versus older individuals	0.0190	0.220	Slight effect	Grave Two tends to higher numbers of younger individuals		
Dental Health - Assemblage						
AMTL timing status (goodness of fit chi square)	< 0.0001			Result highly significant statistically		
Caries - maxilla versus mandible	< 0.0001	0.081	Negligible effect	Maxillary caries higher; mandibular caries lower		
Caries – anterior versus posterior	< 0.0001	0.165	Negligible effect	Anterior caries lower; posterior caries higher		
AMTL maxilla versus mandible	< 0.0001	0.087	Negligible effect	Maxilla has higher AMTL; Mandible lower		
AMTL anterior versus posterior	< 0.0001	0.255	Slight effect	Anterior has lower AMTL; Posterior higher.		
AMTL and age at death	0.0005	0.322	Slight effect	Adolescent has low AMTL	0.034	Adolescent low, compared with remainder; i.e. a bipartite trend.

Table A3.77: Chi-square results (continued)

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Inter-pretation of Pearson's Phi*	*Interpretation, using adjusted residuals where appropriate*	*Cochran-Armitage trend test Monte Carlo p*	*Trend*
Peri-apical cavities maxilla versus mandible	0.0536	na	na			
Peri-apical cavities anterior versus posterior	0.5741	na	na			
Dental Work - Assemblage						
Fillings maxilla versus mandible	< 0.0001	0.124	Negligible effect	Maxilla tends to fewer fillings; mandible to more		
Fillings anterior versus posterior	< 0.0001	0.123	Negligible effect	Anterior tend to fewer fillings; posterior to more.		
AMTL denture replacement maxilla versus mandible	< 0.0001	0.238	Slight effect	Maxilla tends to more replacements; mandible to fewer		
AMTL denture replacement anterior versus posterior	1.0000	na	na			
AMTL denture replacement anterior maxilla versus anterior mandible	0.1303	na	na			
AMTL denture replacement posterior maxilla versus posterior mandible	< 0.0001	0.298	Slight	Posterior maxilla tends to more; anterior mandible to fewer.		
Crowns maxilla versus mandible	< 0.0001	0.061	Negligible effect	Maxilla has more crowns; mandible fewer.		
Crowns anterior maxilla versus anterior mandible	< 0.0001	0.087	Negligible effect	Anterior maxilla has more crowns; anterior mandible fewer.		
Crowns posterior maxilla versus posterior mandible	0.0048	0.052	Negligible effect	Posterior maxilla tends to more crowns; posterior mandible to fewer.		
Crowns anterior versus posterior	0.2022	na	na			
Dental work and age	0.4515	na	na	na	0.855	no trend
Denture and age	0.1094	na	na	na	0.053	no trend
Crowns and age	0.6840	na	na	na	0.908	no trend
Fillings and age	0.5433	na	na	na	0.275	no trend
Graves 1-5 - all individuals (N=247)						
Dentures	0.4485	na	na	na		
Amalgam and mixed fillings	0.7208	na	na	na		
Crowns	0.1575	na	na	na		
Fillings	0.7379	na	na	na		
Root canal work	0.9475	na	na	na		
Graves 1-5 - only those with dental work (N=134)						
Denture and other dental work	0.1344	na	na	na		
Dentures only	0.6639	na	na	na		
Other dental work - no dentures	0.0788	na	na	na		
Amalgam fillings and metal fillings	0.7009	na	na	na		
Filings of all types	0.0303	0.281	Slight effect	Grave One has low presence		
Gold crowns	0.5168	na	na	na		
Mixed type crowns	0.9608	na	na	na		

Table A3.77: Chi-square results (continued)

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Inter-pretation of Pearson's Phi*	*Interpretation, using adjusted residuals where appropriate*	*Cochran-Armitage trend test Monte Carlo p*	*Trend*
Ante-mortem Trauma and Pathology Assemblage (N=250)						
Association with Age at Death						
All ante-mortem trauma & pathology	0.0981	na	na	na	0.964	
Infection	0.0589	na	na	na		
Metabolic disease	0.6159	na	na	na	0.036	Younger more; older fewer
Congenital and developmental	0.8651	na	na	na	0.718	
Joint disease	0.0002	0.294	Slight effect	Adolescents low; mature adults high	0.786	
Circulatory disorders	0.8900	na	na	na	0.013	Younger fewer; older more
Neoplastic disease	0.6525	na	na	na	0.744	
Ante-mortem trauma	0.2030	na	na	na	0.052	Younger fewer; older more
Miscellaneous conditions	0.5640	na	na	na	0.046	Younger fewer; older more
Peri-mortem Trauma and Ballistics Assemblage (N=250)						
Peri-mortem trauma body regions	<0.0001	0.397	Slight effect	Head & thorax high. Remainder low, except neck & abdomen not significant.		
Graves 1-5 (N=247)						
Presence/absence of peri-mortem trauma	0.1143	na	na	na		
Presence/absence of multi-trauma	<0.0001	0.393	Slight effect	Grave Two tends to multi-trauma. Graves 1 & 5 tend to low		
Peri-mortem trauma head	<0.0001	0.417	Moderate effect	Grave Two exceptionally high. Graves 4 & 5 low		
Peri-mortem trauma neck	<0.0001	0.611	Strong effect	Grave Two exceptionally high. Graves 1 & 4 low		
Peri-mortem trauma thorax	<0.0001	0.324	Slight effect	Grave Two high trauma to thorax; Grave Four low		
Peri-mortem trauma abdomen	0.0010	0.268	Slight effect	Grave Two tends to trauma of the abdomen		
Peri-mortem trauma left upper limb	0.3520	na	na	na		
Peri-mortem trauma right upper limb	0.4101	na	na	na		
Peri-mortem trauma left lower limb	0.7572	na	na	na		
Peri-mortem trauma right lower limb	0.2563	na	na	na		
Ballistics associated with individual	0.0002	0.287	Slight effect	Individuals in Grave One tend to low ballistics; in Grave Four to high		
Ballistics associated with grave (goodness of fit chi square)	0.0008		/	[highly significant]		

CHI-SQUARE SIGNIFICANCE TEST: FREQUENCY OF DENTAL WORK

by Richard Wright

Introduction

Caroline Barker supplied me with the observed frequencies of dental work in graves one to five at Pheasant Wood, Fromelles (Table A3.78). The question to be asked is whether there is a statistically significant association between dental work and grave numbers. Since the table is a contingency table, statistical testing using chi-square is appropriate. These notes reflect the language associated with that test.

From this table of observed frequencies can be computed the expected frequencies shown in Table A3.79.

Chi-square – Test of independence between dental work and grave numbers

The core results are:

- Chi-square 4.245
- p-value 0.374

Test interpretation

Null hypothesis: the rows and columns of the table are independent, that is, there is no relation between dental work and grave numbers.

Alternative hypothesis: there is a link between the rows and columns of the table, that is, there is a relation between dental work and grave numbers.

A conventional significance level, used in such testing, is p=0.05 (the alpha level). With the data for dental work and grave numbers, because the computed p-value is greater than the significance level (0.374 compared with 0.05), we should accept the null hypothesis. The chi-square test shows that our deviation between expected and observed frequencies will occur on average 37.4% of the time by chance alone.

Conclusion

We conclude that there is no relation between dental work and grave numbers.

Table A3.78: Observed frequencies of dental work in the graves (Grave Six contained only three individuals, all of whom had dental work. A total of three individuals is too small to be included in Chi-square significance testing, so Grave Six is omitted from consideration.)

	Dental work	*No dental work*	*Total*
Grave One	23	27	50
Grave Two	24	27	51
Grave Three	30	20	50
Grave Four	30	22	52
Grave Five	27	17	44
Total	134	113	247

Table A3.79: Expected (theoretical) frequencies, assuming that there is literally no relation between dental work and grave numbers.

Dental work	*No dental work*	*Total*	
Grave One	27.1	22.9	50
Grave Two	27.7	23.3	51
Grave Three	27.1	22.9	50
Grave Four	28.2	23.8	52
Grave Five	23.9	20.1	44
Total	134	113	247