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Approximating the face of 'Aunty': a question of likeness

Susan Hayes

University of Western Australia, suehayes@uow.edu.au

Hallie Buckley

University of Otago

Richard Bradley

Iwi Rangitane

Nick Milne

University of Western Australia

John Dennison

University of Otago

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Abstract

This paper describes two approaches to the facial approximation of three individuals from the Wairau Bar burial site (New Zealand). Two individuals were approximated working in direct reference to the remains and incorporated manual drafting. The third individual, 'Aunty' (the respectful title given by the iwi Rangitane elders) was approximated from CT scans and using computer graphics. The computer graphic approach enabled a greater level of precision in the application of the research and recommendations that inform a facial approximation, and facilitated collaboration with appropriate expertise. The computer-graphic approach, however, also resulted in a more photographic facial appearance, which can imply a greater level of knowledge about hard/soft tissue relationships than is currently available.

Keywords

aunty, approximating, question, likeness, face, CAS

Disciplines

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4	Journal Name	Journal of Archaeological Method and Theory	
5	Corresponding Author	Family Name	Hayes
6		Particle	
7		Given Name	Susan
8		Suffix	
9		Organization	University of Western Australia
10		Division	School of Anatomy and Human Biology M309, Faculty of Life and Physical Sciences
11		Address	Crawley, Perth 6009, Australia
12		e-mail	susan.hayes@uwa.edu.au
13		Family Name	Buckley
14		Particle	
15	Author	Given Name	Hallie
16		Suffix	
17		Organization	University of Otago
18		Division	Department of Anatomy and Structural Biology, School of Medical Sciences
19		Address	Dunedin , New Zealand
20		e-mail	
21	Author	Family Name	Bradley
22		Particle	
23		Given Name	Richard
24		Suffix	
25		Organization	Rangitane Iwi
26		Division	
27		Address	Masterton , New Zealand
28		e-mail	
29	Author	Family Name	Milne

30		Particle	
31		Given Name	Nick
32		Suffix	
33		Organization	University of Western Australia
34		Division	School of Anatomy and Human Biology M309, Faculty of Life and Physical Sciences
35		Address	Crawley, Perth 6009, Australia
36		e-mail	
37		Family Name	Dennison
38		Particle	
39		Given Name	John
40		Suffix	
41	Author	Organization	University of Otago
42		Division	Department of Anatomy and Structural Biology, School of Medical Sciences
43		Address	Dunedin , New Zealand
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Approximating the Face of ‘Aunty’: A Question of Likeness

Susan Hayes · Hallie Buckley · Richard Bradley ·
Nick Milne · John Dennison

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Abstract This paper describes two approaches to the facial approximation of three individuals from the Wairau Bar burial site (New Zealand). Two individuals were approximated working in direct reference to the remains and incorporated manual drafting. The third individual, ‘Aunty’ (the respectful title given by the *iwi* Rangitane elders) was approximated from CT scans and using computer graphics. The computer graphic approach enabled a greater level of precision in the application of the research and recommendations that inform a facial approximation, and facilitated collaboration with appropriate expertise. The computer-graphic approach, however, also resulted in a more photographic facial appearance, which can imply a greater level of knowledge about hard/soft tissue relationships than is currently available.

Keywords Rangitane · 2D facial approximation · Manual drafting · Computer graphics · Repatriation of remains

Introduction

The Wairau Bar is located between Cloudy Bay and the Wairau Lagoon on the north eastern corner of New Zealand’s South Island. In January 1939, a 13-year-old boy, Jim Eyles, dug a trench on the Wairau Bar and unearthed grave goods and human bones from what was later to become referred to as Burial 1. Since 1939, a total of

S. Hayes (✉) · N. Milne
School of Anatomy and Human Biology M309, Faculty of Life and Physical Sciences,
University of Western Australia, Crawley, Perth 6009, Australia
e-mail: susan.hayes@uwa.edu.au

H. Buckley · J. Dennison
Department of Anatomy and Structural Biology, School of Medical Sciences, University of Otago,
Dunedin, New Zealand

R. Bradley
Rangitane Iwi, Masterton, New Zealand

42 individuals have been removed from the site, constituting the largest sample of human remains dating back to early Maori settlement, approximately 600 years ago (Buckley *et al.* 2010). Two studies have been undertaken on the remains, including the field observations of Roger Duff during excavation (1950, 1956) and detailed laboratory analysis by Philip Houghton (1975, 1977). In April 2009, the Wairau Bar *tupuna* (ancestors) were repatriated to the *iwi* Rangitane, the custodians of the site, and ceremonially reburied. As part of the repatriation process to Rangitane, a re-examination of the Wairau Bar *tupuna* was undertaken at the University of Otago, New Zealand. One aspect of this re-examination included the facial approximation of three individuals with complete cranial remains (Burial 1, Burial 2.1 and Burial 6). The aim of the facial approximation was to provide Rangitane with a visual representation of their *tupuna*. From the perspective of Rangitane, it was vitally important for the future protection of the *tupuna* that they were given more human characteristics than that of 'mere scientific curiosities'.

The approximation of the facial appearance of two individuals (Burial 2.1 and Burial 6) was undertaken primarily at the University of Otago in December 2008. The method involved first measuring and photographing each skull before manually drafting the likely facial appearance, and was a technique that had been used previously with the remains of four individuals from the Teouma Lapita burial site (Hayes *et al.* 2009a). The approximation of the third individual (Burial 1) commenced in late 2009 at the University of Western Australia, and was undertaken solely through reference to photographs and computed tomography (CT) scan data. This paper describes the two techniques employed: the manual 2D approximation method working with direct reference to the remains of Burial 2.1 and Burial 6, and the approximation of Burial 1 ('Aunty'), which was fully computer graphic and based predominantly on the information provided by CT scans. The method used to approximate the facial appearance of Burial 1 does not draw on recent developments in automated virtual facial approximation (for a review, see Claes *et al.* 2010) but is a computer-graphic version of the manual 2D approach. To avoid duplication, much of the research that informs all three approximations is covered in the description of the approximation of Burial 1.

Facial Approximation

A facial approximation (also known as a facial reconstruction) estimates the appearance of an individual based on what is known about how the soft tissues may relate to skull morphology, and this appearance can take the form of a 3D sculpture, a 2D illustration, or a virtual 3D image. Across all three media (3D, 2D and virtual), key practitioners who have had considerable influence on contemporary facial approximation methods include Mikhail Gerasimov (1955, 1971), Betty-Pat Gatliff (Snow *et al.* 1970), Richard Neave (Prag and Neave 1997), and Karen Taylor (2001). Not all of the recommendations published by most, if not all, practitioners have been subject to rigorous testing, and Carl Stephan has been justifiably critical of both forensic and archaeological facial approximations techniques (2005, 2003a). There have, however, been a number of studies that very usefully add anthropometric validity to the experience-based recommendations of Mikhail Gerasimov (1955),

such as his techniques for estimating nasal projection, location and tip shape (Rynn *et al.* 2009) and for approximating mouth width and lip height (Wilkinson *et al.* 2003). Stephan himself has added considerably to the field by presenting substantial improvements for soft tissue prediction guidelines, including eyeball projection (Stephan 2002b), nose projection (Stephan *et al.* 2003), mouth width approximation (Stephan 2003b) and positioning of the eyebrow (Stephan 2002a). Stephan's more recent publications include a comprehensive study of the reliability of soft tissue depth data (Stephan and Simpson 2008), cadaveric studies of eyeball location within the orbit and the position of the eyelid corners (canthi), that extend past research undertaken in this area (Stephan and Davidson 2008; Stephan *et al.* 2009), and an elucidation of anatomical patterns useful for predicting the temporalis muscle and the superficial temporal fat pad (Stephan and Devine 2010). Where relevant, the approximations described here refer to these studies. However, there is also reference to recommendations that so far lack appropriately published verification, particularly those of Gerasimov (1955, 1971), Fedosyutkin and Nainys (1993), Prag and Neave (1997), Taylor (2001) and Wilkinson (2004).

Manual 2D Facial Approximation: Burial 2.1 and Burial 6

The individual unearthed from Burial 6 was a young to mid-aged adult male at the time of death, while the individual from Burial 2.1, also male, was slightly younger (Buckley *et al.* 2010). In Houghton's estimation, all of the remains unearthed from the Wairau Bar burial site were of Polynesian origin (1975), which is in agreement with an earlier analysis conducted by Harry Shapiro from the American Museum of Natural History (reported in Duff 1950).

The traditional 2D approximation method used for Burial 2.1 and Burial 6 involved measuring and visually assessing the skull, and then digitally photographing the frontal and lateral views. Firstly, a lateral approximation was drafted, and this was used to estimate feature location and shape in the frontal view (Figs. 1 and 2). Using a layer of tracing paper over a life-size print-out of the photographed skull, a muscle layer was then systematically compiled, following the anatomical recommendations of Neave (Prag and Neave 1997), Taylor (Taylor and Angel 1998), Wilkinson (2004) and Needham (2002), together with cross-references to two established anatomical texts (McMinn *et al.* 1999; Romanes 1986). One deviation from these recommendations is that the muscle layer for all of the approximations does not include the frontalis, nasalis, procerus and corrugator muscles. Because the soft tissue depths of the cranial vault are comparatively minimal, the frontalis has only a limited impact on surface appearance, and neither the nasalis nor procerus have been found to influence nasal shape (Macho 1989). The corrugator is a very small muscle, but it is likely that because of its role in lowering and raising the eyebrow heads, and our perceptual sensitivity to changes in this area of the face (Haig 1986), this muscle can easily suggest aspects of facial expression, such as frowning, even when minimally represented. Another deviation from the anatomical recommendations is that, as can be seen (Figs. 1 and 2) the approximation of the surface anatomy includes some visibility to the underlying bone and approximated musculature. This visibility minimises the inclusion of information that has unknown

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underlying skull and approximated musculature, this may emphasise that the completed images are approximate, anthropologically derived, illustrations.

Computer-Graphic 2D Facial Approximation: Burial 1

The individual first unearthed in 1939 was a young to mid-aged adult female at the time of death (Buckley *et al.* 2010). CT scans (3 mm slice thickness) of the cranium and mandible were sent by the University of Otago to the University of Western Australia and uploaded using the 3D visualisation software, Amira (v.3.1.1). Using the orthographic view, which removes the effects of 2D perspective, anthropometric measures and angles were taken using the functions provided within the software (Table 1). What is implied by these measures in relation to individual features (eyes, nose, mouth *etc.*) is covered in the following sections, but generally they indicate that Burial 1 had a brachycephalic head form (Cranial Index 82.9), with a wide and somewhat low coronoid process and a gonial angle of less than 125° (120.5°) which is understood to be consistent with a rounded or rectangular face shape (Fedosyutkin and Nainys 1993). The zygomatic vertical profile (approximately 58°) is neither acutely angled (less than 50° is associated with Europeans) or relatively flat (greater than 65° is associated with Asian populations) (Gerasimov 1955). Overall, and as can be seen in Table 1, the cranial remains of Burial 1 are very symmetrical, with only small differences between the right/left anthropometric measures.

Table 1 Burial 1: anthropometric measures and angles

Aspect	Measure
Max width of parietal bones	148.9 mm
Max length glabella-occipital bone	179.7 mm
Angle mandible base/ramus	Right, 120.5°
Maximum orbital height	Right, 37.3 mm
	Left, 37.3 mm
Maximum orbital width	Right, 38.6 mm
	Left, 38.9 mm
Angle of glabella/fronto-maxillary suture on FHP	Right, 126.5°
	Left, 125.5°
Angle of zygomaticomaxillary suture profile	Right, 58.0°
	Left, 57.7°
Nasion–acanthion	52.55 mm
Rhinion–subspinale	39.74 mm
Nasion–subspinale	58.4 mm
Maximum nasal aperture width	21.98 mm
Chin triangle height	27 mm
Side of rami height	Right, 15.5 mm

The relevance of these measures is discussed in the text

The overall cranial shape in the frontal view is pentagonoid, which is a common feature of New Zealand prehistoric remains (Houghton 1975). Rotating the cranium along a defined axis within Amira (v3.1.1) shows that this individual's Frankfurt Horizontal Plane (FHP) varies slightly between the left and right lateral views, with the right orbit being very slightly lower than the left. The left lateral orientation is in smoother agreement with both the posterior and frontal views, and therefore this was used to orient the cranium in preparation for the approximation. Images of the cranium and mandible (frontal and lateral) were extracted and entered into Adobe Photoshop CS2 as separate layers within one file set to 300 dpi. The cranium was scaled according to the maximum nasal aperture width in the frontal view, and the inter-landmark distance nasion-subspinale was used to check that this scale agreed with the left lateral view. The frontal and left lateral images of the mandible were scaled according to the height of the right ramus and positioned with a 2-mm space between the condylar process and the mandibular fossa simulating the articular disc, as recommended by Neave (Prag and Neave 1997) and Taylor (2001). Because of significant post-mortem tooth loss, inter-molar occlusion was estimated on the basis that the lower left molars were likely to be of similar to slightly greater height than the corresponding upper molars (John McGeachie, personal communication). Overall, the articulation resulted in the body of the mandible being orientated at an angle of 26.5° relative to the FHP. Frontal and lateral articulations of the mandible, together with the metric and morphological analyses undertaken (and described in the succeeding sections) can be seen in Fig. 3.

Soft Tissue Depths

Soft tissue depths, and their direction relative to the surface of the bone, were taken from the global averages calculated by Stephan and Simpson (2008), which are soft tissue data sets of weighted means calculated from a synthesis of a large number of previously published studies. In a previous analysis Stephan and colleagues have

Fig. 3 Frontal and lateral articulation of the mandible

shown that there are greater differences within the sexes than between them in most areas of soft tissue data collection (Stephan *et al.* 2005), and Stephan and Simpson's (2008) overall findings are that soft tissue depth measurement errors are as large (or larger than) the differences observed between population groups. From this, they conclude that the practical meaning of differences between population groups, despite findings of statistical significance, is very small and effectively negated.

Taylor (2001) recommends that practitioners apply soft tissue depth markers directly onto the skull, or skull cast, prior to a 2D reconstruction so that changes due to perspective are included in 2D photographs. Amira (v3.1.1), however, does not permit its measure indicators to go beyond the outer surface of the bone, and therefore these were applied within Adobe Photoshop CS2. It should be noted, however, that the extracted images are orthographic and that only the midline soft tissue depths were used in both views (left lateral and frontal). Although such a reduction in the number of soft tissue depth guides would likely be problematic in a clay or virtual 3D facial approximation, a 2D facial approximation is achieved using single perspective images and is, therefore, predominantly informed by those depths occurring along the sagittal midline in the frontal view, and coronal outline for the frontal view. As can be seen in Fig. 3, the left ramus is largely absent, and both zygomatic arches have been broken. The soft tissue points on the left ramus were estimated through reference to the right ramus, and the approximate location of the zygomatic landmarks were estimated from the direction of the zygomatic roots when the cranium is viewed from above. The soft tissue landmarks and their corresponding depths are shown in Table 2.

Eyes

Application of Gerasimov's (1955) orbital measures and recommendations suggest Burial 1 had a rounded eye form where the width of the orbits are slightly greater than the height, which is a characteristic observed in Asian populations. Burial 1 also displays a middle-type orbital profile, which, according to Gerasimov, is associated with an eyeball that sits comparatively centrally within the orbit, and has been observed in both Asian and European populations. The shape of the interior of the orbital cavity (referring to the sagittal slice of the mid orbit) is what Gerasimov refers to as an 'open eye form'. This eye form gradually and consistently widens from the back of the eye socket to the front, which Gerasimov associates with eyeball protrusion. Further, the sharpish appearance of the upper orbital border and dullish lower orbital border suggests, according to Gerasimov, that Burial 1 may have had thin eyelids that followed the shape of the protrusion of the eyeball and perhaps there was a presence of epicanthic folds.

Eyeball projection was estimated following Stephan's (2002b) technique, where a line is drawn connecting the superior and inferior rims of the orbit, and the eyeball is positioned allowing a further 3–4 mm for the bulge of the cornea. The malar tubercle is often cited as corresponding to the location of the lateral canthal tendon (*e.g.* Fedosyutkin and Nainys 1993; Gerasimov 1955), which Stephan and Davidson

Table 2 Soft tissue depths applied in the approximations

Median points	Total weighted mean (mm)	SD+1	SD-1
Lateral view			
Opisthocranion	6.5	9	4
Vertex	5	6	4
Glabella	5.5	6.5	4.5
Nasion	6.5	7.5	4.5
Midnasal	4	5	3
Rhinion	3	4	2
Subnasale	13	15.5	9.5
Midphiltrum	11.5	13.5	8.5
Prosthion	11.5	14.5	8.5
Lower lip	13	15.5	10.5
Labiomental	11	13	9
Pogonion	11.5	13.5	8.5
Gnathion	8.5	11.5	5.5
Menton	7	9.5	4.5
Frontal view			
Zygomatic	6	7	5
Mid-ramus	17.5	21.5	13.5
Gonion	10	16	4

Data from Stephan and Simpson (2008)

(2008), drawing on the work of TD Stewart and others, verify as a consistent finding. In the case of Burial 1, the location of the malar tubercle suggests that the eyelids would have met relatively low in the orbit. The eyeball was taken to be the average female diameter of 23.9 mm (Wolff 1997, cited in Wilkinson 2004), the iris diameter of 10–12 mm and eyeball location was checked against the reported average distances of orbital rim to exocanthion (5 mm) and length of the medial canthus (5 mm) (Larrabee and Makielski 1993).

Nose

Lateral nasal projection was estimated according to Rynn *et al.*'s algorithms for all populations (2009), with these regression analyses both verifying Gerasimov's method of approximating nasal tip location and incorporating Gerasimov's recommendations for estimating nasal shape (1955, 1971). The estimation of nasal projection (24.7 mm from the nasion, at a right angle to the nasion-prosthion plane) is shown in Fig. 3, as is the probable location of the nasal wings and approximate shape of the nasal tip. Gerasimov's (1955) method for locating the nasal tip is typically understood to comprise the intersection of a line continuous with the direction indicated by the lower third of the nasal bones, with a line continuous with the direction indicated by the nasal spine, though this

interpretation has recently come into question (Ullrich and Stephan 2011). As there was not sufficient information in either the CT scans or the photographs to show whether the nasal spine was fully intact, nasal spine direction was achieved using the nasal spine line (posterior to anterior), as recommended by Wilkinson (2004) and as indicated by the CT scan mid-sagittal slice. According to Rynn *et al.* (2009), their algorithm is generally indicative of the commencement of the nasal tip, while Gerasimov's 'two-tangent' method is more informative concerning overall nasal tip dimensions, and therefore both need to be included in an approximation of the nose. Also according to Gerasimov (1955) and verified by Rynn *et al.* (2009), the nose wing starts where the crista conchalis meets the anterior rim of the nasal aperture, finishes 4 mm below the nasal base and is at its deepest 6 mm from the lateral edge of the aperture. However, while Gerasimov (1955) suggests that the shape of the wing is roughly similar to the shape of the lateral lower border of the aperture, Rynn *et al.* (2009) found that the profile of the nasal tip is also significantly related to the angularity of the profile of the aperture. In addition, this study also confirms Gerasimov's (1955) recommendation that any deviation of the vomer in the frontal view will indicate asymmetry, and in this case the vomer veers slightly to the left, indicating the right side of the nose was slightly larger. The nasal aperture base indicates a slight upwards tilt to the left (a common feature and what Woo (1931) calls 'nasal wryness'), which, according to Fedosyutkin and Nainys (1993) will be visible in the frontal view. The depth of the canine fossa was unable to be measured using Amira (v3.1.1), due to this being a measure of bone surface concavity, and as mentioned, the software does not allow measures that go beyond the outer surface of the skull. However, according to Gerasimov (1955), a rounded eye form is often associated with a shallow canine fossa, and if the canine fossae are shallow then it is less likely that the naso-labial folds were marked (Fedosyutkin and Nainys 1993).

Mouth

There has been considerable post-mortem tooth loss, and therefore a photograph of the cranium taken shortly after it was unearthed (Eyles 1939 reproduced in Buckley *et al.* 2009) together with the appearance of the alveolar ridges in the CT scans, were used to estimate aspects of mouth shape. Both the photograph of the cranium and the direction of the maxillary alveolar ridges show a slight degree of maxillary prognathism, which is associated with a degree of upper lip eversion and fullness (Gerasimov 1955). The mouth corners were taken to be in the region of the canine-premolar junction and in line with the medial edge of the iris (Stephan 2003b; Wilkinson *et al.* 2003). The mouth slit was approximated on the basis that this would be roughly consistent with the occlusal line indicated by the upper molars (Fedosyutkin and Nainys 1993), and also approximated with reference to the Facial X pattern documented by George (1993, 2007). Wilkinson *et al.* (2003) have used regression analyses to approximate upper and lower lip height (which have also been observed to more or less correspond to the height of the enamel of the central incisors (Gerasimov 1955)), but this was not possible to determine in this instance. Instead, the upper vermilion border was taken to be approximately in

the region of a point just below the prosthion, and lower lip height was estimated 275
using the Facial Triangle pattern, also observed and documented by George (1993, 276
2007). The shape of the upper and lower lips are related to the relative prominence 277
of the upper and lower central incisors and canines (Wilkinson *et al.* 2003). There 278
was no suggestion that these teeth were particularly prominent in either the 279
photograph taken shortly after the cranium was unearthed (which shows the upper 280
teeth to be square and evenly shaped) or the CT scans of the alveolar ridges, so the 281
upper and lower vermillion borders were taken to be fairly flat. 282

Jaw 283

The mandible does not overtly display a 'rocker jaw' morphology—the lower 284
border has an indication of convexity from front to back, but the gonial angle 285
(120.5°) is larger than that associated with the 'rocker' morphology displayed in 286
pre-historical New Zealand remains measured by Houghton (1977): mean gonial 287
angle of female rocker jaws ($n=63$): 97.85°, SD 4.05; mean gonial angle of 288
females lacking rocker jaws ($n=18$): 102.20°, SD 4.05). That the gonial angle is 289
also considerably larger than Houghton's non-rocker jaw values is curious, but it 290
should be noted that Houghton's sample of pre-historical female remains lacking 291
rocker jaws is fairly small ($n=18$). There is a slight groove on the mental 292
eminence, but the muscle attachments do not appear to be sufficiently marked to 293
indicate a possible cleft in the chin, and the softly rounded mandibular border 294
suggests that the soft tissues of the jaw were likely to be relatively even in 295
thickness and follow a soft, rounded contour (Gerasimov 1955). As the chin height 296
(menton to the alveolar border) is greater than the height of the body of the ramus 297
as measured from the M3 alveolar border to a line continuous with the gonial 298
angle (a difference of 11.5 mm), this may suggest a high chin (Fedosyutkin and 299
Nainys 1993). 300

Ears 301

Houghton (1975) comments that the mastoid processes of Burial 1 are small 302
compared with other prehistoric New Zealand female cranial remains. As the 303
mastoids are also downward (relative to the Frankfurt Horizontal Plane) and 304
inwardly pointing, this may indicate attached lobes (Fedosyutkin and Nainys 305
1993) and small, non-protrusive ears (Gerasimov 1955). The angle of the ear could 306
be similar to the angle of the ramus (Fedosyutkin and Nainys 1993) while ear 307
height was taken to be similar to the distance between the subnasale and menton 308
(Farkas 1987). Ear height in a facial approximation is more typically taken to be 309
similar to the height of the nose (*e.g.* Wilkinson 2004). However, a preliminary, 310
unpublished study by Helen McIntosh at the University of Western Australia found 311
that neither measures of the nose (nasion-subnasale or glabella-subnasale) 312
significantly correspond to ear height, but that the relationship identified by 313
Farkas (1987) (ear height corresponding to the distance subnasale-menton) held for 314
a group of mid-age adults ($n=21$). 315

Muscle Layer

316

The muscles were built up and checked against the descriptions provided by the 35th (Warwick and Williams 1973) and 40th editions of Gray's Anatomy (Standring 2008). Each muscle was shaped within a separate file using Adobe Photoshop CS2, warped onto the appropriate bony attachments and critically evaluated. This evaluation found some discrepancies within the recommendations used for the two previous approximations (Burial 2.1 and Burial 6), with these discrepancies being in agreement with suggestions that anatomical illustrations will tend to include aspects of pedagogical emphasis (Roberts and Tomlinson 1992), such as exaggeration (Gombrich 1977).

Once the shape and attachment patterns of each muscle had been refined, they were entered as separate layers within the Burial 1 Adobe Photoshop CS2 file. An outline of the skull was produced using a Wacom Tablet, and this layer was retained in view at all times to assist in avoiding placement errors caused by the muscles obscuring the underlying bone (see Fig. 4). The order of layering was from the deep to superficial muscles, and also included the parotid gland (Needham 2002; Prag and Neave 1997; Taylor and Angel 1998; Wilkinson 2004), but as with the approximations of Burial 2.1 and Burial 6, the frontalis, procerus, nasalis and corrugators were not included. The flesh of the lips was also not included as this is an aspect of surface anatomy, and unlike most anatomical illustrations of the

Fig. 4 An outline of the skull produced by using a Wacom Tablet

depressor anguli oris and depressor labii inferioris, the fibres that blend with the platysma are not depicted, nor is the platysma itself.

Surface Appearance

The surface appearance of the skin and features was accomplished in reference to over one hundred archival photographs depicting Maori women of young to mid-age and sourced from the National Library of New Zealand digital archives (<http://www.natlib.govt.nz/atli>) and the New Zealand Electronic Text Centre (<http://www.nzetc.org>), both of which were accessed during March 2010. Constructing the surface appearance in reference to digital images involves searching for a particular facial feature that is most similar to the parameters indicated by the anthropological and morphological analyses of the skull. This serves two purposes. Firstly, identifying the presence of a pre-defined feature shape in a large number of archival photographs indicates the plausibility of such a feature occurring within individuals of similar population affinity. For example, while many of the images reviewed depicted women with round, prominent eyes, none of these eye forms included an epicanthic fold, and therefore this aspect of individual variation was not included, even though this is contrary to the recommendation in the literature (Gerasimov 1955). Although most of the women depicted in the archival images had fairly dark irises, there was some variation, and therefore an indeterminate shade (neither dark nor light) was selected, as suggested by Taylor (2001). With regards to the mouth, the corners of the lips were approximated mostly in reference to the Facial X pattern (George 1993, 2007), and this resulted in the mouth corners being located quite low in the face, and with the right being set slightly lower than the left. Low-set mouth corners, and asymmetrical low-set mouth corners, were observed to occur within the archival images of both young and older women and, therefore, this aspect was retained in approximating the mouth shape. The second purpose for using reference images is that there is a tendency to be 'generic' in the rendering of the features if they are produced from an internal, mental construct. This tendency occurs not just in facial approximation, but also in artistic depiction of imagined individuals (Edwards 1999; Gombrich 1977) and in police witness composite images (Taylor 2001). Once the overall face and neck had been blocked in, the image was further rendered using the Adobe Photoshop CS2 'grain' filter tool (see Fig. 5).

Discussion

Three individuals from the same burial site were approximated using two slightly different methods, primarily due to Burial 1 being located in a different museum collection and, therefore, not available for physical examination in 2008. There was some doubt that an approximation could be undertaken without direct reference to the skull, as many of the morphological features of a skull that inform an approximation can be obscured by photographic lighting conditions, and while the skull was represented as CT scan data, perceptual research using scans of facial surfaces have shown that a lack of shading and surface texture information can

Fig. 5 View of the blocked-in face and neck using the Adobe Photoshop CS2 'grain' filter tool

significantly, and deleteriously, impact on recognisability (Bruce *et al.* 1991). There is also the issue, as noted by Claes *et al.* (2010), that even very high resolution CT scans constitute a reduction in shape information. However, the advantages of using CT scan data may possibly outweigh this reduction in information, as a virtual skull does overcome some of the problems that can occur when an approximation is built up from a photograph.

Identification of the Frankfurt Horizontal Plane was greatly facilitated using Amira (v3.1.1), as overlaying the isometric surface with a grid and using the fixed axis rotation tools enabled a very precise orientation across all views. This was the case not just for the cranium, but also for the manipulation required to articulate the mandible. The ability to precisely align the skull also enabled the frontal and lateral views of the skull to be referenced simultaneously, as recommended by Taylor (2001 and see Fig. 3), with the knowledge that both views were fully orthogonal. A further, and more self-evident, advantage of CT scan data is that the internal morphology of the skull could be easily accessed, and in particular the sagittal slices used for determining eye form and nasal spine direction. Ascertaining nasal spine direction,

is, as described, part of the process for approximating nasal tip location, but the anterior nasal spine can be problematic as the spine will often change direction at its extremity, and the direction indicated by the anterior nasal spine in the lateral views can be different to that indicated by the mid-sagittal section of the spine. Instructions in the literature as to how to identify the direction indicated by the anterior nasal spine are fairly vague, such as the 'continuation of the main direction of the point of the bony nose' (Gerasimov 1971:54), 'the general direction of the central part of the nasal spine' (Fedosyutkin and Nainys 1993), 'the main direction of the point of the bony spine' (Wilkinson 2004), 'a line following the direction of the ANS [anterior nasal spine]' (Rynn *et al.* 2009), and as mentioned, common interpretations of Gerasimov's 'two-tangent method' have, recently, been questioned (Ullrich and Stephan 2011). Using the nasal spine line is advantageous as it reduces subjectivity in assessing the main, or general, direction of the anterior nasal spine, and while Wilkinson's (2004) recommendation does not include any verification, the relationship is clearly illustrated within a study of cranial reference planes by Jacobson (1976).

The approximation of the underlying musculature and surface appearance of Burial 1 could have been achieved using the manual 2D approximation method which was used for Burial 6 and Burial 2.1. That is, by printing the scaled images of the isometric surfaces and manually drafting the musculature and facial appearance. However, the decision was made to fully approximate the appearance of Burial 1 within the available software, namely Amira (v.3.1.1) and Adobe Photoshop CS2, so as to explore the differences arising from using computer-graphic techniques. Again, working within a digital environment provided a number of advantages. Most importantly, producing each muscle as a separate layer removes the ephemera of manually drafting. Rather than working with a single layer of hand drawn musculature that cannot be modified easily, each individual muscle was constantly available for critical evaluation and refinement throughout the process, and this greatly facilitated an ease of collaboration with appropriate expertise. In this particular instance, the anatomical build-up took somewhat longer than manual drafting, but a library of muscle layers now constitutes a resource that may be able to be reworked for other individuals.

It is at the level of the surface appearance (the skin layer) that the use of computer graphics becomes somewhat problematic. In two previous papers, we have argued that sketching can produce a 'more accurate' facial approximation because it is less accurate. That is, a sketch is literally a fuzzy rendering of surface details, and therefore can accommodate both the mean and variation of most measures and surface shapes of the face (Hayes *et al.* 2005, 2009a). An attempt was made to mimic the graininess of manual drafting using the grain filter in Adobe Photoshop CS2, but compared with the approximate, sketchy appearance of Burial 6 and Burial 2.1, the surface layer of Burial 1 still has an overall photographic appearance.

Prag and Neave (1997) comment that a lack of manual dexterity and anatomical knowledge can have a negative impact on a facial approximation, and conversely that too close an adherence to a method can produce 'results that are often wooden or lumpish'. In a similar vein, Wilkinson (2004) suggests it is important to produce a 'realistic and believable face' as well as an 'accurate' one. Given many, if not most,

of the existing published recommendations lack appropriate verification, we have some concerns over the use of the term 'accurate' in reference to a facial approximation. Although Gerasimov is translated as calling his approximations, particularly those of historical personages, 'documentary portraits' (Gerasimov 1971), Prag and Neave are insistent that Neave's approximations should not be seen as sharing the accuracy of portraiture (1997), and this view is by far the predominant one within the field. Further, because the practice is understood to be inherently inaccurate, a growing number of practitioners reject the more popular terminology 'facial reconstruction' and instead prefer 'facial approximation' (e.g. George 1993; Haglund 1998; Hayes *et al.* 2009b; Stephan 2002b; Taylor and Angel 1998). Related to these concerns, we suggest another issue is a logical extension of the importance given to the production of a 'realistic and believable face'—which is that using computer graphics to simulate the surface anatomy of an individual can produce a face that is too realistic in appearance, and this may imply the results are far more accurate than they actually can be, or indeed are.

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