



University of Dundee

The post-mortem resilience of facial creases and the possibility for use in identification of the dead

Hadi , Helmi; Wilkinson, Caroline M.

Published in:
Forensic Science International

DOI:
[10.1016/j.forsciint.2013.12.014](https://doi.org/10.1016/j.forsciint.2013.12.014)

Publication date:
2014

Licence:
CC BY-NC-ND

Document Version
Publisher's PDF, also known as Version of record

[Link to publication in Discovery Research Portal](#)

Citation for published version (APA):

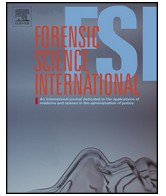
Hadi , H., & Wilkinson, C. M. (2014). The post-mortem resilience of facial creases and the possibility for use in identification of the dead. *Forensic Science International*, 237, 149.e1-149.e7.
<https://doi.org/10.1016/j.forsciint.2013.12.014>

General rights

Copyright and moral rights for the publications made accessible in Discovery Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.



Forensic Anthropology Population Data

The post-mortem resilience of facial creases and the possibility for use in identification of the dead[☆]Helmi Hadi^{a,b}, Caroline M. Wilkinson^{a,*}^a Centre for Anatomy and Human Identification (CAHID), University of Dundee, Dow Street, Dundee DD1 5EH, UK^b School of Health Sciences, University Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia

ARTICLE INFO

Article history:

Received 28 February 2013

Received in revised form 27 June 2013

Accepted 16 December 2013

Available online 18 January 2014

Keywords:

Facial creases

Cadaver

Facial identification

Embalming

Bloating

ABSTRACT

The post-mortem resilience of facial creases was studied using donated bodies in order to establish the efficacy of crease analysis for identification of the dead. Creases were studied on normal (pre-embalmed) and bloated (embalmed) cadavers at the Centre for Anatomy and Human Identification (CAHID) to establish whether facial bloating would affect facial crease visibility. Embalming was chosen to simulate the effects produced by post-mortem bloating. The results suggested that creases are resilient and changes were only detected for creases located on the periphery of the face, particularly at areas where the skin is thick, such as at the cheeks. Two new creases not previously classified were identified; these creases were called the vertical superciliary arch line and the lateral nose crease. This research suggests that facial creases may be resilient enough after death to be utilised for human identification.

© 2014 The Authors. Published by Elsevier Ireland Ltd. All rights reserved.

1. Introduction

1.1. Facial creases

Facial creases have been previously studied in relation to ageing. The terms wrinkles, furrows and folds are used interchangeably and no common accepted classification exists [1]. A crease is described “a line made by pressing, folding or wrinkling” [2]. A wrinkle is “a slight ridge in the smoothness of a surface, such as a crease in the skin as a result of age” [3]. A furrow is “any deep wrinkle in the skin, as on the forehead” [4]. A fold is “a line or mark made by folding” [5]. Wrinkling is usually limited to the dermal layer and can be cosmetically treated [1]. Folds are caused by intrinsic ageing, laxity of the skin, bone loss, gravity and sagging [1] and the skin extends more and declines in elasticity as a person grows older. Thin people and women have a higher skin extensibility compared to fat people and men [6]. Ezure and Amano [7] studied skin elasticity and concluded that the dermal elasticity of the skin is impaired if there is a high amount of subcutaneous adipose tissue and the lack of dermal elasticity increases the likelihood of skin sagging.

The two most common methods utilised for face wrinkle measurement involve the use of skin casts or skin replicas [1,8–10] or the use of images [1,10–17]. Biopsies [11,18,19], direct 3D in-vivo measurements [20] and elasticity measurements using a cutometer [8,10,21] have also been employed and a few studies utilised depth, number or length measurements for wrinkle quantification [12,14,19,22]. Three-dimensional measurements taken from the skin replicas rely on visual assessment by researchers to categorise the wrinkles [1,9]. Recently, there was a trend of measuring skin wrinkles directly on the skin without the use of replicas [20] and unique study into face wrinkle categorisation made use of computer algorithms to identify wrinkles and creases on human faces [22]. While most facial crease research has focused on the cosmetic and ageing perspectives, in this article we describe a novel method of utilising creases for identification on post-mortem faces.

The soft tissue profile changes throughout life based on the growth and thickening of the soft tissue [23]. Donofrio [24] suggested that the face has its own baseline skin elasticity, and when young people gain or lose fat, the skin remains firm and will follow the new outline of the face [24]. In old faces, however, the skin elasticity is different, and when old people have fluctuating weight, the skin does not contract back to the baseline frame [24] and remains creased with an excess of skin to underlying fat area. Donofrio demonstrated the difference between young and old face skin elasticity by utilising a balloon anthology, showing that skin extends more and declines in elasticity as a person gets older. The effect is seen more dramatically in women nearing 40 years of age

[☆] This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial-No Derivative Works License, which permits non-commercial use, distribution, and reproduction in any medium, provided the original author and source are credited.

* Corresponding author. Tel.: +44 1382 386324.

E-mail address: c.m.wilkinson@dundee.ac.uk (C.M. Wilkinson).

[25]. The lack of dermal elasticity increases the likelihood of skin sagging. However, research utilising a durometer showed no correlation between body mass index (BMI) and skin wrinkles at eleven locations on the face in early postmenopausal women [26].

Some facial creases are utilised for identification of the living [27], but the use of facial creases for identification of the dead has not been previously studied. Since faces may alter significantly due to post-mortem effects, facial creases may be a resilient feature that can aid identification.

1.2. Post-mortem changes to the face

Early post-mortem changes occur within the first two hours of death [28]. As the cardiac system no longer supplies oxygenated blood to the body, skin colour changes are almost immediate. “Pallor” can be seen as early as 15–30 min after death in people with light coloured skin, although this may not be noticeable in dark skinned people [28]. Intrinsic coagulation will activate resulting in blood clots in all the blood vessels and this may create patchy discolouration and pooling. At the same time, rigour mortis (or stiffening of the muscles) starts to occur in the eyelids, neck, jaw and this may spread throughout the body. Rigour mortis will start between 2 and 6 h post-mortem depending on the environment [28]. Environmental factors such as temperature, water, pH and the partial pressure of oxygen [29] may affect the timing of decomposition changes. Late post-mortem changes include, algor mortis, and livor mortis [28]. Homeostatic mechanisms of the body stop functioning with somatic death and this causes the unregulated growth of bacteria and fungi aided by the availability of carbohydrate, protein and fat from autolysis [28]. Bloating is caused by the large quantity of gases released from these microorganisms [28]. The accumulation of gases occur most in the gastrointestinal and respiratory track where there is a high availability of red blood cells [28]. Bloating is the result of the accumulation of gases on the cadaver and this effect is clearly seen on the face [28]. Bloating has an extensive effect on facial appearance, but it is unclear how facial crease patterns would be affected by post mortem bloating. Their resilience during bloating will be a significant factor as to whether or not facial creases can be used for identification of the dead.

In this study embalming was utilised to simulate early post-mortem bloating, as the infusion of embalming fluid has a similar effect on the tissues of the face. Embalming is utilised to preserve tissue from decomposition by coagulating the protein which dehydrates and hardens the tissue, and prevents bacterial growth [30]. In the 19th century, embalming was carried out with heavy metals like arsenic and mercury [30]. After World War II, embalming by arterial injection became less popular due to economic and health reasons [31] and ice was used to replace the heavy metals enabling temporary preservation [30,31]. Current embalming techniques make use of motorised injection such as using a pressure pump to force the embalming fluid into the cadaver [30]. Usually, the right carotid and femoral arteries are chosen as the sites for arterial embalming with the jugular or femoral veins as the sites where the blood is drained. When using the femoral artery, the embalming fluid can be directed upwards towards the abdomen or downwards towards the foot. The fluid can be introduced upwards and downwards at the same time by using separate injectors. The appendages of the body may still need direct fluid injection as the organs furthest from the thoracic region embalm poorly [30]. There were two different methods of embalming utilised in this study:

(1) Thiel method

In order to preserve the plasticity of the soft tissues, an embalming method using 4-chloro-3-methylenphenols with salts and ethylene glycol has been recently developed ([32] in

[33]). This method was first discovered by Walter H. Thiel and this method is now in use at the University of Dundee. Cadavers are first embalmed traditionally by introducing the Thiel embalming fluid through the femoral artery with the aid of a pressure pump. After embalming, the cadavers are then stored in tanks filled with the Thiel embalming fluid so that the embalming fluid properly embalms the cadavers.

(2) Formaldehyde method

The embalming fluid is composed of 1–5% Formaldehyde, 30–60% Methanol and 5–10% Phenol [34] and the embalming procedure is similar to Thiel method except that the body is not placed in a tank but sealed in a plastic bag, transferred to a metal tray and left for a week [35]. An Infutrace mixture of 20% is pumped into the body [35].

1.3. Facial comparison

Photogrammetry is one of the techniques used to compare the proportional relationships of one photograph to another photograph to determine the visual similarities. The problems of photogrammetry include, and are not limited to, inconsistent lighting conditions, distance/lens distortion, photographic retouching, age and weight changes and facial expression differences [36].

In craniofacial comparison, photograph-to-photograph superimposition may not yield results of high accuracy [36] and repeat measurements are recommended in order to avoid errors [36]. One problem with relying on 2D images for comparison is the variation which exists due to different views between photographs. If a person tilts the head forward, the forehead will appear larger compared to the chin which will appear smaller. Similarly, if the head is tilted backwards, the chin will appear larger than the forehead [37]. However, some research suggests that it is possible to do facial mapping between similar face angles even though the exact angle is unobtainable [38] and the acceptable threshold of face angle variation is expert dependent [37,38]. This study utilised photogrammetry in order to compare the normal and bloated faces.

The overall aim of this study was to assess and explore the resilience of facial creases by comparing the crease patterns on the same face with and without bloating. Identification of different faces from facial crease morphology was not taken into account in this research.

2. Materials and methods

All research was conducted in the Centre for Anatomy and Human Identification (CAHID) University of Dundee. Ethical approval has been obtained prior conducting the research from the University of Dundee ethics board and all donors consented to the use of their bodies for forensic research.

A Canon D30 Camera and a 2 GB compact flash card with an Intervalometer Timer Remote Controller TC-80N3 was mounted to a fixed tripod on the beam of the mortuary roof for image recording. Prior to embalming, the face was covered by the mortuary technician with a cloth to enable the researcher to setup the camera without viewing the face. Test images were taken of the covered face area to ensure that the camera was focused correctly. Prior to embalming, the Intervalometer was switched on to record images at 15-s intervals. The cloth was removed by the technician prior to the introduction of the embalming fluid. The researcher was present in the embalming room, but did not view the head during the embalming procedure.

Two of the seven cadavers were embalmed utilising the Thiel method, whilst the rest were embalmed with the conventional Formaldehyde method. The researcher was notified when the embalming procedure was complete and the Intervalometer was

then switched off. The camera was dismantled and the Flash Card was stored in a secure location to ensure that could not view the images. This process was repeated for a total of seven cadavers.

2.1. Image analysis

After a two-month period, images of the bloated (embalmed) faces were selected by an independent collaborator and returned to the researcher. Crease analysis was then performed on each image using Adobe Photoshop CS3 software installed on a Viglen desktop computer. Crease markings in Photoshop were carried out utilising a Wacom Intuos3 Stylus tablet. The modified images were analysed to record the visible facial creases. Normal (pre-embalmed) cadaver facial images were selected by the researcher a month after analysis of the bloated faces and crease pattern analysis performed following the same method. The time gap before the analyses ensured no bias through memory.

In this way crease tracings were produced for bloated and normal faces using Photoshop. Images of the faces used for the tracings were then removed so that only the crease tracings were present. Crease tracings of the bloated and normal faces were aligned with each other using superimposition to find the best match. The superimposition was aligned when the majority of the creases overlapped. Superimposition was carried out qualitatively by visual analysis without the aid of quantitative analysis.

No morphing or aspect ratio distortion of the crease tracings was performed, and only rotation and movement of the creases vertically and horizontally were utilised in Photoshop when superimposition was carried out. The modality of the creases was also analysed to compare the normal and bloated faces. Face creases were categorised and selected based on the findings in previous literature [39]. Visual representations of the crease legends [39] used in the study are shown in Fig. 1.

Example analysis is shown in Table 1. Table 2 shows the creases visible during bloating and also shows the crease resilience,

availability and strength. Visual analysis was carried out to find the best superimposed crease for each cadaver.

3. Results

In total, twenty facial creases were identified on the seven cadavers. The most commonly recorded creases were horizontal forehead creases, vertical glabellar lines, nasolabial folds and transverse nasal lines. The least recorded creases were periauricular lines, cheek folds, marionette lines and upper eyelid creases (refer to Fig. 1 for visual description of crease morphology and the location of the creases).

During bloating, the most common response for most (50%) of the creases was to remain stable. The NLF showed the most variable response to bloating, staying the same for three subjects, becoming less defined for three and disappearing for one subject.

The lower lip and chelion lines most frequently disappeared during bloating. Only five other creases (around the lips and orbits) disappeared for any subjects during bloating, but this was not the most common response for these creases. These and all other creases were more often recorded as becoming less defined or staying the same during bloating. Four creases appeared during bloating for some subjects and these included the bifid nose crease, mental crease, lower eyelid and chin crease.

There were two types of unclassified creases discovered in this research not documented in literature. The first crease was present at the medial corner of the eye and terminated at the root of the alae and followed meniscus shape (see Fig. 2) and was recorded on two subjects. This crease was named the lateral nose crease. The second of unclassified crease was recorded at the forehead as a semi-vertical line starting at the eyebrows and terminating on brow. These creases were present on two subjects and remained stable throughout bloating and could be useful for identification. As no ante-mortem photographs were available, it is unknown if these creases manifested after death. These creases were named the vertical superciliary arch lines (see Fig. 2).

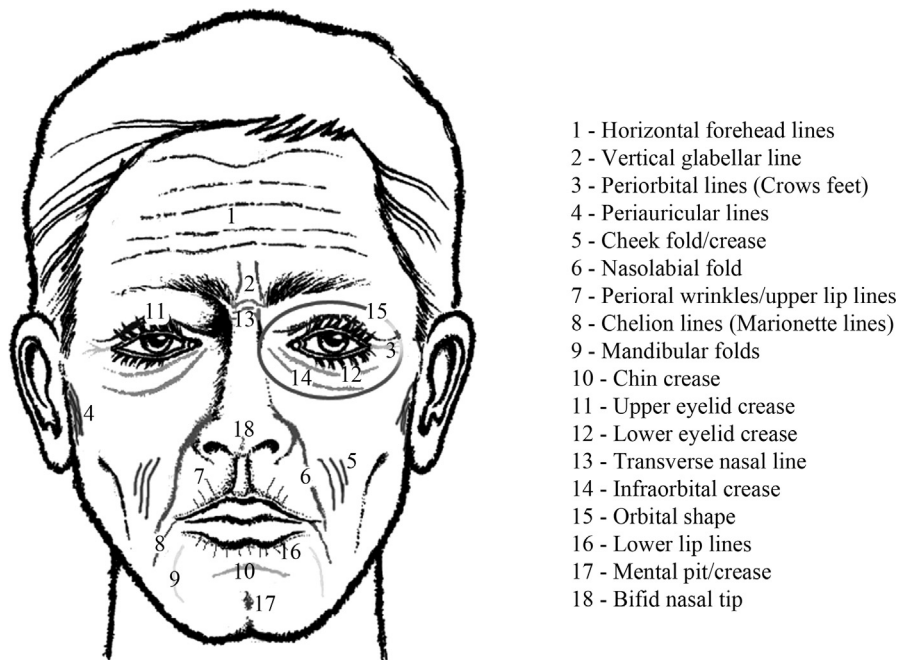


Fig. 1. Location of folds and wrinkles on the human face. Figure modified from Dunn and Harrison [39].

Table 1
Example analysis of crease resilience with bloating. This is not a real cadaveric face.








	Original image	Edited image with crease tracings	Face crease tracings without face
Normal			
Bloated			
Crease comparison	Superimposition of crease tracings of normal (green) and bloated (purple) faces		
			

Table 2
Comparison of modality of creases from normal and bloated faces.

Number (refer Fig. 1)	Wrinkle/folds/creases present on face	Face/subject						
		1	2	3	4	5	6	7
1	Horizontal forehead lines	+	>	>	+		+	<
2	Vertical glabellar line	+	>	+	+			<
3	Periorbital lines (crows feet)		+	<	+	>		+
4	Periauricular lines				+			
5	Cheek fold/wrinkle	+			+			
6	Nasolabial fold	/	+	>	+	>	>	+
7	Perioral wrinkles/upper lip lines	<	>		/	+	+	>
8	Chelion lines (marionette lines)	+	>		/	+	/	
9	Mandibular folds (marionette lines)	>	>		+	+	/	
10	Chin crease		>		>	\	<	
11	Upper eyelid		+					+
12	Lower eyelid		+				\	\
13	Transverse nasal line	+	>	+	+	+	+	+
14	Infra orbital crease	+		>	+	/	<	+
15 (Ellipse shape)	Orbital shape	+			+	/		
16	Lower lip lines	/	>	/	/	+	>	
17	Mental pit/crease					\	\	
18	Bifid nose				\			
Others	Unclassified crease			+	+	\		
	Unclassified crease			++				

Graphical depiction available in Table 6.

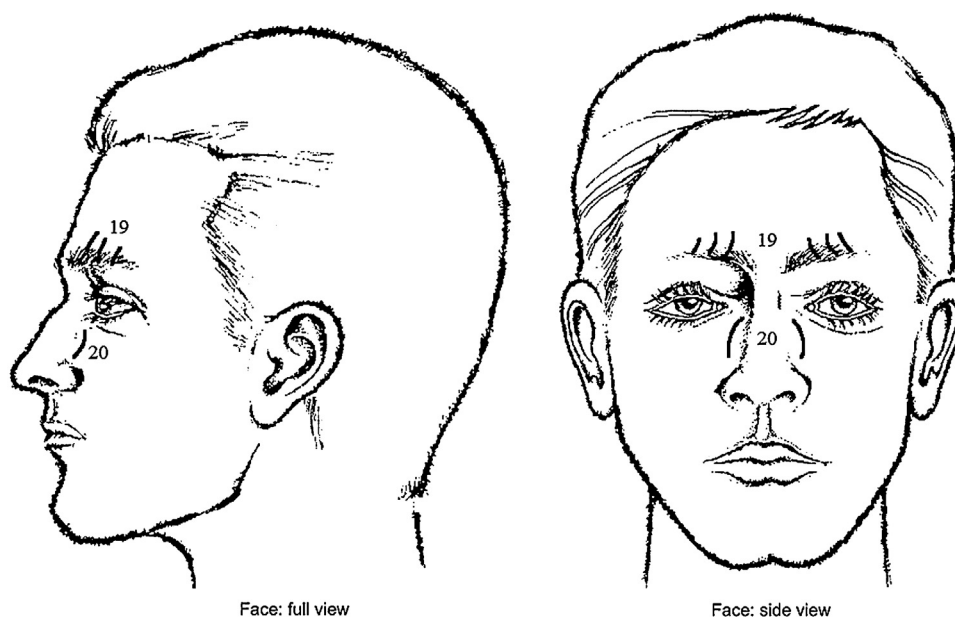
/: Creases only present on normal faces.

\: Creases only present on bloated faces.

+: Creases appeared similar normal and bloated faces.

>: Creases less marked bloated faces.

<: Creases less marked normal faces.



- 19 Vertical superciliary arch lines: Crease starts horizontal and terminate vertical below the forehead
- 20 Lateral nose crease: Convex crease to the nose. Crease starts below the eye lateral side of the nose and terminates before the nose alae

Fig. 2. Location of new creases.

4. Discussion

Embalming was chosen to simulate bloating as one part of the post-mortem changes on the face. The general changes which occur on a face after death in a normal environment are putrefaction, bloating, destruction and finally skeletisation [40]. Bloating is also one of two most dominant factors which affect changes to the face. The other is insect activity [40]. Embalming was also chosen as the effects of bloating can be so severe that bloated faces no longer appear recognisable [41]. However, as this is a dynamic process, it is impossible to simulate all post-mortem conditions and the study of decomposition was not possible.

There were a number of problems associated with crease assessment from embalmed cadavers. Accumulation of the embalming fluid on the face made analysis of some creases difficult and as the cadavers were embalmed, some crease morphology changed due to the difference in direction of the gravitational force when the face is in a supine position. External forces on the face prior to embalming may also induce the formation of artificial creases and some creases were misinterpreted as embalming artefacts (such as blood discolouration). Colour changes also restricted some visual identification.

The embalming fluids filled all the tissue making the face rounder and stretching the skin. When the NLF decreased in strength, it tended to disappear at the mouth portion [42] rather than at the alar region. Since skin sags as a person ages due to the loss of elasticity of collagen fibres and the fold moves medially towards the lips and appears more vertical [36,43], but the process is reversed in the embalming process. The creases move laterally, following the expansion of the mouth and cheek region. Even the three subjects where the fold length remained constant showed a lateral movement at the cheek region with bloating.

The upper eyelid crease was relatively stable throughout bloating due to the low skin thickness in this area. Some creases were only recorded during bloating and this could be due to the swelling of

tissue increasing crease visibility. For example, the bifid nose crease is dictated by the morphology of the paired alar cartilages and the medial crus of the alar cartilage consist of a footplate and columellar segments. The amount of soft tissue between the medial crus and the columellar segments dictates the shape and a lack of adequate soft tissue in this area creates the bifid appearance [44]. This crease may be created artificially or exacerbated with swelling of the soft tissue either side of the cartilage junction.

In most cases, the transverse nasal creases, horizontal forehead creases and the vertical glabellar lines remained relatively stable throughout bloating. This may be due to very thin tissue in these regions and that the introduction of embalming fluid did not affect the tissues significantly. As these creases were the most stable on the face, they were selected as the reference points to superimpose the normal and bloated crease tracings. Creases more lateral such as the NLF and marionette lines exhibited higher amounts of movement compared to creases at the midline region, such as the vertical glabellar line and the transverse nasal line as the skin is more mobile at the cheek and mouth area.

The ability to match crease tracings from normal and bloated faces was difficult based on the crease tracings alone and no perfect match was obtained. Superimposition was achieved by visually assessing the creases of the pre-embalmed and the post-embalmed face of the same cadaver. As the aim of the study was to see the modality of the facial creases, identification of cadavers based on facial creases alone was not carried out. Superimposition was obtained when the horizontal forehead creases, vertical glabellar line and transverse nasal line were utilised as reference points. Identification was possible for three subjects using crease tracings only. These subjects had an abundance of crease marks on the face and this aided comparison. Matching of the NLF creases was impossible due to crease movement.

Post-mortem changes to faces in 3D have been studied in previous research [45]. Tillotson [45] found that dehydration and swelling occurred at different parts of the face. Dehydration was

seen at orifices of the face (central orbital region, upper lip and nostril ends) in 60% cadavers while swelling at the periphery of the face was detected in 30% of the cadavers. In this research, bloating of the face was most noticeable at the periphery region of the face, further from the midline and this affected the position of the NLF fold.

4.1. Limitations

As 3D surface scans were not available, photography was the only method utilised. It is however not an ideal method for analysis as shadows may affect the appearance of crease morphology. Crease analysis was also dependent on the angle of the face which could not be wholly controlled during embalming.

The head of the cadaver was placed on a PVC or wooden block during embalming for support and to reduce movement. As different bodies have different statures, the head did not always fit well on the block. As identification of different cadavers based on facial creases was not carried out, this could mitigate the effect of head angle variation for different cadavers.

Embalming fluid draining from the mouth and nose during the embalming procedure and affected the analysis of creases at the mouth region, particularly at the corners of the mouth. The problem was noted for both Formaldehyde and Thiel methods with the latter being more affected. There were also slight differences in the bloating of faces for both the Thiel and Formaldehyde method. The faces were bloated in both procedures but faces in the Thiel method were more flexible compared to the Formaldehyde method which was more rigid. Visually, there are slight differences between Thiel and Formaldehyde method where faces embalmed with the Formaldehyde method appeared more bloated compared to the Thiel embalmed cadavers. As Thiel embalming was in its infancy, only two cadavers were embalmed with Thiel which may not represent the total effects of Thiel embalming.

It also should be noted that due to the small numbers of cadavers included in this research (seven cadavers in total), the conclusions obtained may not represent the bloating process for all types of bodies found at a crime scene.

5. Conclusion

Most creases were stable during bloating and even those that became less clear were still visible. The most variable crease during bloating was the NLF, which moved laterally and become less visible in some subjects. Some creases not visible during life, such as the bifid nose crease, became visible with bloating. Creases located medially on the face changed less during bloating than those positioned more laterally. Creases located on the face where the skin was thin were the most resilient, as the morphology changed little with bloating. These creases included vertical glabellar lines, forehead creases and transverse nasal creases. Two previously unclassified creases were recorded: vertical superciliary arch lines and lateral nose creases. This research suggests that facial creases may be utilised for human identification due to post-mortem resilience even during bloating.

Acknowledgements

This research was possible with the funding provided by Academic Staff Training Scheme research grant from Universiti Sains Malaysia. The authors would like to thank Roos Eisma, Netta Gallazzi, Greg Mahoney and Marc Moghbel for facilitating the embalming procedure. In addition the authors would like to thank all those who donated their bodies after death to anatomical teaching and research; we are indebted to these generous and selfless people.

References

- [1] G. Lemperle, R.E. Holmes, S.R. Cohen, S.M. Lemperle, A classification of facial wrinkles, *Plastic and Reconstructive Surgery* 108 (2001) 1735–1750.
- [2] Language TAHDotE, Crease. The American Heritage[®] Dictionary of the English Language, 4th ed., Houghton Mifflin Company, 2009, <http://www.thefreedictionary.com/crease> (accessed 17.05.13).
- [3] Language TAHDotE, Wrinkle. The American Heritage[®] Dictionary of the English Language, 4th ed., Houghton Mifflin Company, 2009, <http://www.thefreedictionary.com/wrinkle> (accessed 17.05.13).
- [4] Language TAHDotE, Furrow. The American Heritage[®] Dictionary of the English Language, 4th ed., Houghton Mifflin Company, 2009, <http://www.thefreedictionary.com/furrow> (accessed 17.05.13).
- [5] Language TAHDotE, Fold. The American Heritage[®] Dictionary of the English Language, 4th ed., Houghton Mifflin Company, 2009, <http://www.thefreedictionary.com/fold> (accessed 17.05.13).
- [6] G.E. Pierard, C.M. Lapiere, Physiopathological variations in the mechanical properties of skin, *Archives of Dermatological Research* 260 (1977) 231–239.
- [7] T. Ezure, S. Amano, Influence of subcutaneous adipose tissue mass on dermal elasticity and sagging severity in lower cheek, *Skin Research and Technology* 16 (2010) 332–338.
- [8] T. Fujimura, K. Haketa, M. Hotta, T. Kitahara, Loss of skin elasticity precedes to rapid increase of wrinkle levels, *Journal of Dermatological Science* 47 (2007) 233–239.
- [9] Y. Takema, K. Tsukahara, T. Fujimura, M. Hattori, Age-related changes in the three-dimensional morphological structure of human facial skin, *Skin Research and Technology* 3 (1997) 95–100.
- [10] K. Tsukahara, K. Sugata, O. Osanai, A. Ohuchi, Y. Miyauchi, M. Takizawa, et al., Comparison of age-related changes in facial wrinkles and sagging in the skin of Japanese, Chinese and Thai women, *Journal of Dermatological Science* 47 (2007) 19–28.
- [11] J.H. Chung, Photoaging in Asians, *Photodermatol Photoimmunol Photomed* 19 (2003) 109–121.
- [12] V.L. Ernster, D. Grady, R. Miike, D. Black, J. Selby, K. Kerlikowske, Facial wrinkling in men and women, by smoking status, *American Journal of Public Health* 85 (1995) 78–82.
- [13] S. Nouveau-Richard, Z. Yang, S. Mac-Mary, L. Li, P. Bastien, I. Tardy, et al., Skin ageing: a comparison between Chinese and European populations. A pilot study, *Journal of Dermatological Science* 40 (2005) 187–193.
- [14] K. Tsukahara, Y. Takema, T. Fujimura, S. Moriwaki, M. Hattori, Quantitative two-dimensional analysis of facial wrinkles of Japanese women at various ages, *International Journal of Cosmetic Science* 24 (2002) 71–80.
- [15] K. Tsukahara, Y. Takema, T. Fujimura, S. Moriwaki, T. Kitahara, G. Imokawa, Determination of age-related changes in the morphological structure (sagging) of the human cheek using a photometric scale and three-dimensional surface parameters, *International Journal of Cosmetic Science* 22 (2000) 247–258.
- [16] K. Tsukahara, Y. Takema, H. Kazama, Y. Yorimoto, T. Fujimura, S. Moriwaki, et al., A photographic scale for the assessment of human facial wrinkles, *Journal of Cosmetic Science* 51 (2000) 127–139.
- [17] Y.N. Wang, H. Fang, W.F. Zhu, Survey on skin aging status and related influential factors in Southeast China, *Journal of Zhejiang University Science* 10 (2009) 57–66.
- [18] J.L. Contet-Audonnet, C. Jeanmaire, G. Pauly, A histological study of human wrinkle structures: comparison between sun-exposed areas of the face, with or without wrinkles, and sun-protected areas, *British Journal of Dermatology* 140 (1999) 1038–1047.
- [19] E.C. Paes, H.J. Teepeen, W.A. Koop, M. Kon, Perioral wrinkles: histologic differences between men and women, *Aesthetic Surgery Journal* 29 (2009) 467–472.
- [20] T. Fujimura, K. Haketa, M. Hotta, T. Kitahara, Global and systematic demonstration for the practical usage of a direct in vivo measurement system to evaluate wrinkles, *International Journal of Cosmetic Science* 29 (2007) 423–436.
- [21] Y. Takema, Y. Yorimoto, M. Kawai, G. Imokawa, Age-related changes in the elastic properties and thickness of human facial skin, *The British Journal of Dermatology* 131 (1994) 641–648.
- [22] Y.H. Kwon, N. Da Vitoria Lobo, Age classification from facial images, *Computer Vision and Image Understanding* 74 (1999) 1–21.
- [23] T.F. Foley, P.G. Duncan, Soft tissue profile changes in late adolescent males, *Angle Orthodontist* 67 (1997) 373–380.
- [24] L.M. Donofrio, Fat distribution: a morphologic study of the aging face, *Dermatologic Surgery* 26 (2000) 1107–1112.
- [25] G.E. Pierard, F. Henry, D. Castelli, G. Ries, Ageing and rheological properties of facial skin in women, *Gerontology* 44 (1998) 159–161.
- [26] E. Wolff, L. Pal, T. Altun, R. Madankumar, R. Freeman, H. Amin, et al., Skin wrinkles and rigidity in early postmenopausal women vary by race/ethnicity: baseline characteristics of the skin ancillary study of the KEEPS trial, *Fertility and Sterility* 95 (2011), 658–662e1-3.
- [27] H. Mohd Hadi Pritam, Facial Creases in Human Identification, Dundee, University of Dundee, 2012.
- [28] M.A. Clark, M.B. Worrell, J.E. Pless, Postmortem changes in soft tissues, in: W.D. Haglund, M.H. Sorg (Eds.), *Forensic Taphonomy: The Postmortem Fate of Human Remains*, CRC Press, 1997, pp. 151–164.
- [29] A. Galloway, The process of decomposition: a model from the Arizona-Sonoran desert, in: W.D. Haglund, M.H. Sorg (Eds.), *Forensic Taphonomy: The Postmortem Fate of Human Remains*, CRC Press, 1996, pp. 139–150.
- [30] H.E. Berryman, W.M. Bass, S.A. Symes, O.C. Smith, Recognition of cemetery remains in the forensic setting, in: W.D. Haglund, M.H. Sorg (Eds.), *Forensic*

- Taphonomy: The Postmortem Fate of Human Remains, CRC Press, 1996, pp. 165–170.
- [31] P.S. Sledzik, M.S. Micozzi, Autopsied, embalmed, and preserved human remains: distinguishing features in forensic and historic context, in: W.D. Haglund, M.H. Sorg (Eds.), *Forensic Taphonomy: The Postmortem Fate of Human Remains*, CRC Press, 1996, pp. 483–496.
- [32] H.W. Thiel, Gross morphology and pathoanatomy of the vertebral arteries, *Journal Manipulative Physiological Therapeutics* 14 (1991) 133–141.
- [33] R. Eisma, Thiel Method, Centre for Anatomy and Human Identification, University of Dundee, Dundee, 2009.
- [34] L. Grayson, Embalming Fluid. Chemical Hazard Assessment, University of Dundee, Dundee, 2005p. 2.
- [35] N. Gallazzi, L. Grayson, Human Cadavers, Embalming of CLS Risk Assessment, University of Dundee, Dundee, 2009p. 3.
- [36] M.Y. Işcan, Introduction of techniques for photographic comparison: potential and problems, in: M.Y. Işcan, R.P. Helmer (Eds.), *Forensic Analysis of the Skull*, John Wiley & Sons, 1993, pp. 57–70.
- [37] L.G. Farkas, *Anthropometry of the head and face*, Raven Press, 1994.
- [38] P. Vanezis, C. Brierley, Facial image comparison of crime suspects using video superimposition, *Science & Justice* 36 (1996) 27–33.
- [39] K.W. Dunn, R.K. Harrison, Naming of parts: a presentation of facial surface anatomical terms, *British Journal of Plastic Surgery* 50 (1997) 584–589.
- [40] C. Wilkinson, A. Tillotson, Post-mortem prediction of facial appearance, in: C. Wilkinson, C. Rynn (Eds.), *Craniofacial Identification*, Cambridge University Press, 2012, pp. 166–183.
- [41] K.T. Taylor, *Forensic art and illustration*, CRC Press, 2001.
- [42] J.Q. Owsley, Lifting the malar fat pad for correction of prominent nasolabial folds, *Plastic and Reconstructive Surgery* 91 (1993) 463–474, discussion 75–76.
- [43] S.A. Feik, J.E. Glover, Growth of children's faces, in: J.G. Clement, D.L. Ranson (Eds.), *Craniofacial Identification in Forensic Medicine*, Hodder Arnold, 1998, pp. 203–224.
- [44] R.M. Oneal, R.J. Beil, P.H. Izenberg, J. Schlesinger, Surgical anatomy of the nose, *Operative Techniques in Plastic and Reconstructive Surgery* 7 (2000) 158–167.
- [45] A.C. Tillotson, *Disaster Victim Identification using Craniofacial Analysis*, University of Dundee, Dundee, 2011.