A three-dimensional evaluation of Māori and New Zealand European faces

Joseph S. Antoun,* Caleb Lawrence,*† Arthur Leow,*† Roberto Rongo,+ George Dias± and Mauro Farella*

Discipline of Orthodontics, Department of Oral Sciences, University of Otago, Dunedin, New Zealand,* Department of Neurosciences, Section of Orthodontics, University of Naples "Federico II", Italy+ and Department of Anatomy, University of Otago, Dunedin, New Zealand±

Equal contribution from both authors†

Objective: Māori patients are often inappropriately treated using Caucasian norms, despite obvious differences in facial morphology. There is currently very little data concerning the nature and/or magnitude of these differences in facial features. The objective of the present study was therefore to evaluate the facial features of Māori and New Zealand (NZ) Europeans.
Methods: Two convenience samples of 30 Māori and 30 NZ Europeans, evenly matched for age and gender, were recruited from amongst students of the University of Otago, New Zealand. Using a 3D white-light scanner, 12 facial scans were taken of each participant, which were then merged to form a single 3D image of the face. Prior to scanning, round markers were fixed to the skin in order to facilitate the localisation of facial anthropometric points and from which vertical, sagittal, and transverse measurements were assessed from the 3D facial image. Univariate and multivariate analyses of variance were used to test for differences between the two groups before and after adjusting for body mass index (BMI).
Results: Significant differences were found in vertical, sagittal, and transverse facial dimensions, before and after adjusting for BMI. The overall face of Māori was significantly larger than that of NZ Europeans, although the facial proportions were generally similar. However, Māori had a broader face, more anterior position of the chin and reduced facial convexity in comparison with NZ Europeans ($p < 0.01$).
Conclusion: Māori have markedly different sagittal facial features compared with NZ Europeans. These distinctive features may reflect important differences in environmental and genetic influences between the two populations. The findings from the present study may assist the clinician in the treatment planning and assessment of facial dysmorphology in these ethnic groups.
(Aust Orthod J 2014; 30: 169–175)

Introduction

It has long been recognised that Māori have markedly different dentofacial features compared with their Caucasian counterparts. Early Māori dentitions were characterised with wide dental arches, large teeth, and increased intercanine and molar distances in comparison with British colonists born in New Zealand.[1]

Several distinctive skeletal features have also been reported in prehistoric Polynesian skulls found in New Zealand, and include a markedly curved mandible (commonly known as a 'rocker jaw'), an open cranial base angle and an increased upper anterior facial height.[2] By contrast, contemporary Polynesian populations have been associated with a broader face, longer mandible and a larger upper anterior facial height in comparison with Caucasians.[3]

Within the Polynesian population, there is also a degree of variation in craniofacial form. Māori, for example, have relatively larger upper facial heights compared with most other native population groups.[4] It is possible that these unique facial features may be
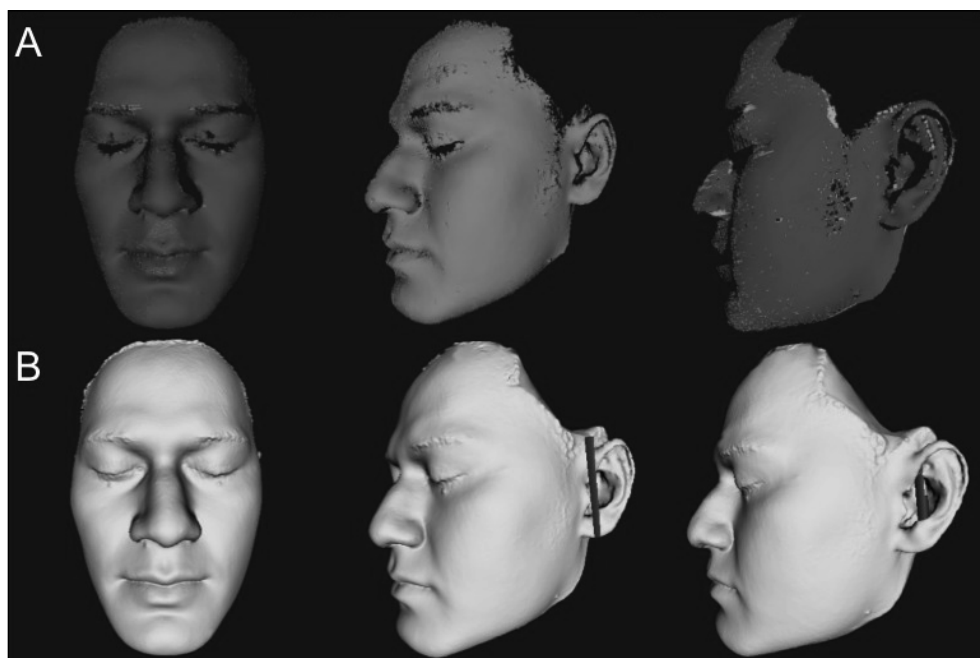
Figure 1. Reconstruction of a participant's face using stereophotogrammetry. A, Images of the facial scans (two superimposed scans per position) in the frontal, oblique and lateral views; B, Reconstructed face that was formed by merging the facial scans (right and left sides of the face).

due to ethnicity-specific environmental and genetic factors. Few studies have investigated the facial features of present-day New Zealand Māori, and compared them with those of other ethnic groups living in the same region.

Therefore, the aim of this study was to investigate the facial features of Māori and New Zealand (NZ) European adults using non-invasive three-dimensional (3D) imaging. It was expected that this knowledge would improve the orthodontic and surgical treatment planning of Māori patients. Moreover, such data may play an important role in the evaluation of orthodontic treatment needs of Māori people.

Methods and materials

Study sample

Two convenience samples of 30 Māori and 30 NZ Europeans, closely matched for gender and age, were recruited from the registers of: (1) the University of Otago Student Services; (2) the New Zealand Dental Students' Association; (3) Te Roopu Māori; and (4) Nga Mokai o Nga Whetu (the latter two are Māori student organisations at the University of Otago). Inclusion criteria included a willingness to participate, at least one occluding molar on each side, and eligible ethnic background. Study participants

were classified as 'Māori' if at least one grandparent was of unmixed Māori ancestry, and as 'NZ European' if both grandparents were of European descent. Participants with inflammatory or degenerative diseases of the temporomandibular joint, cleft lip and/ or palate, craniofacial syndromes, facial asymmetries, and histories of facial fractures or orthognathic surgery, were excluded from the study. Participation incentives were offered in the form of prizes, which were randomly drawn at the end of the study. The study was approved by the Ethics Committee of the University of Otago, New Zealand.

Three-dimensional facial imaging

A 3D white light scanner (HDI Advance, 3D3 Solutions, Burnaby, Canada) was used to capture facial scans of the study participants after an initial calibration according to the manufacturer's instructions. The scanner was coupled with a projector which generated a fringe pattern onto the face being scanned. During the scan, the fringe was modified in width and phase as the emitted light deflected onto the face's surface. Two cameras were then used to capture this deformed fringe pattern and calculate the distances between the projected points. Similar to a previous study,[5] this information was used to create a 3D model.
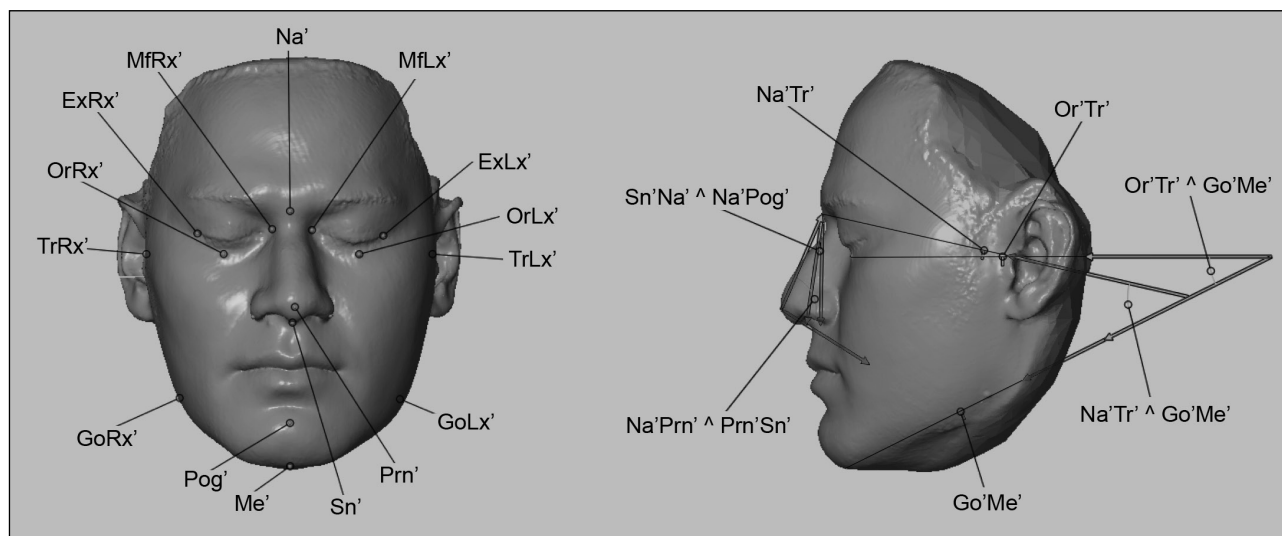
Figure 2. Facial landmarks and measurements used in the study.

To ensure consistency, facial scans were carried out in a standard setting, which included similar light conditions and a fixed scanner position. Prior to scanning, removable round plastic markers were attached to the face in order to localise several anthropometric points that required identification via palpation (Tragion, Gonion and Orbitale). The remaining landmarks were identified by visually inspecting the scans.

Twelve scans were recorded of each participant's face in order to form a complete 3D image (Figure 1). The facial scans consisted of: (1) two frontal scans of the head held in a natural position (teeth in occlusion and eyes closed during the scanning process); (2) two frontal scans with the neck in maximum extension; and (3) four lateral scans obtained at 45 and 90 degrees to the long axis of the light scanner. The third step was repeated for the contralateral side of the face. The scans were used to produce 12 successive 3D meshes, which were registered, integrated and merged to create a single 3D image of each participant's face by means of the FlexScan3D software (HDI Advance, 3D3 Solutions, Burnaby, Canada). Image registration and integration were based on the Iterative Closest Points (ICP) algorithm, in which the distance of two objects was defined as the closest Cartesian distance between the objects.[6] The registration and integration process were carried out in the following sequence: (1) manual superimposition of the scans; (2) initial alignment based on mesh geometry; and (3) fine alignment to improve the accuracy of the final 3D image. Mesh merging was based on the Power Crust algorithm.[7]

The merging process was carried out by averaging the overlapping mesh data. This process of 3D reconstruction from data acquired in 2D is referred to as stereophotogrammetry. Facial measurements were acquired using a 3D inspection and mesh-processing software, specifically developed for the dimensional analysis of 3D point clouds (GOM Inspect, GOM GmbH, Braunschweig, Germany).

Data collection and statistical analysis

The facial measurements consisted of six sagittal, eight vertical and five transverse variables. The variables were chosen to represent a wide range of linear and angular measurements that are commonly used in cephalometric analyses. A diagrammatic illustration of the 19 variables is presented in Figure 2.

Descriptive statistics were applied using the Statistical Package for Social Sciences (SPSS version 15.0, Chicago, IL, USA). Multivariate analysis of variance was used to test for differences between groups after adjusting for covariates such as age, gender, and Body Mass Index (BMI). A second multivariate model unadjusted for BMI was also produced to evaluate the effect of BMI on facial soft-tissue measurements.

Method error

The errors of the method were calculated from 12 randomly selected participants, taken equally from each study group. A set of 10 variables was re-measured by one examiner (RR) after a 'memory-washout'

Table I. Socio-demographic characteristics of the study groups.

	Māori (%)	NZ Europeans (%)	p value[†]
Gender			
Male	15 (50.0)	15 (50.0)	- - -
Female	15 (50.0)	15 (50.0)	
Age group (years)			
Under 21	8 (26.7)	9 (30.0)	0.670
21 to 23	13 (43.3)	15 (50.0)	
23 and over	9 (30.0)	6 (20.0)	
BMI			
Under 22.8	4 (13.3)	16 (53.3)	**0.001**
22.8 to 28.3	10 (33.3)	10 (33.3)	
28.3 and over	16 (53.3)	4 (13.3)	

[†] Chi-Square test
Significant value in bold

period of at least eight weeks. The method error for the 10 measurements was calculated using Dahlberg's formula.[8] Systematic differences between duplicated measurements were tested using a paired Student's t-test ($p < 0.1$).[9] The method errors (%) were very low for the linear and angular measurements, ranging from 0.2 to 4.4%. There was no systematic error for any of the 10 measurements (Student's t-test; $p > 0.1$).

Results

The mean ages of the Māori and NZ European samples were 22.7 ± 3.3 and 22.2 ± 1.8 years, respectively. Descriptive statistics for the two study groups are presented in Table I. The Māori group had a significantly higher BMI, with nearly 70% of the sample in the upper and middle tertiles ($p < 0.001$). By contrast, some 70% of NZ Europeans had a BMI score within the lower and middle tertiles (Table I).

Overall, all participating males tended to have larger soft-tissue dimensions than females (Table II). Māori participants possessed larger sagittal, vertical and transverse soft-tissue dimensions than NZ Europeans. Several of these distinctive facial features were evident in the 'average' Māori and NZ European faces that were reconstructed by merging the entire pool of 3D faces in each group (Figure 3).

After adjusting for age and gender, Māori participants had a significantly increased mandibular length and nasal angle, decreased facial convexity, and a greater posterior, mid-facial and total anterior facial height
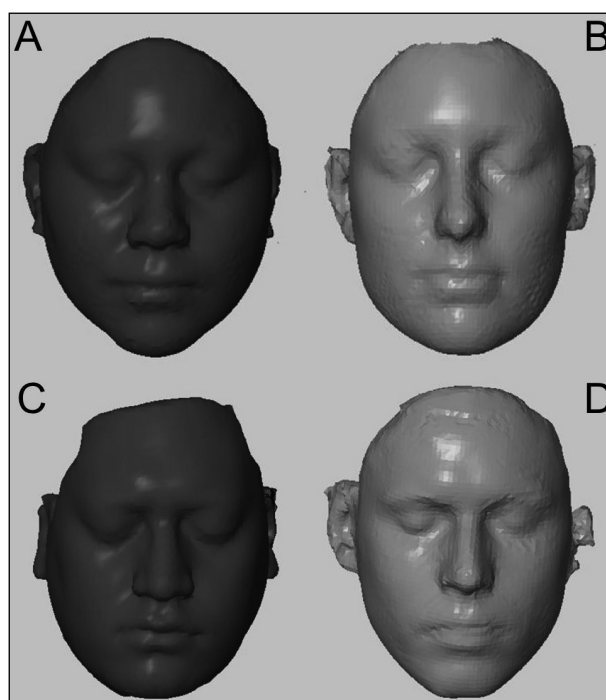

Figure 3. Average reconstructed face of A, 15 Māori females; B, 15 NZ European Females; C, 15 Māori males; D, 15 NZ European Males.

compared with NZ Europeans ($p < 0.05$). Māori also had a significantly broader face, eye width and nose (at the base and bridge).

Following the addition of BMI as a covariate in the model, statistical significance disappeared for mid-facial height, width of the face, eyes and nasal bridge ($p > 0.05$). Māori, however, continued to display a significantly longer mandible, increased nasal angle,

Table II. Soft tissue dimensions in the sagittal, vertical and transversal planes by study group (Mean ± Standard Deviation).

Dimension	Māori		NZ Europeans		p value[†] (Unadjusted for BMI)	p value[‡]
	Male	Female	Male	Female		
Sagittal						
Go′ − Me′ (mm)	100.9 ± 6.2	96.9 ± 6.7	96.5 ± 6.2	91.8 ± 3.8	**0.003**	0.347
Tr′ − Sn′ (mm)	136.5 ± 4.7	127.3 ± 5.9	134.2 ± 4.0	125.2 ± 5.0	0.111	0.999
Tr′ − Me′ (mm)	158.1 ± 6.7	146.1 ± 7.9	149.6 ± 5.9	138.2 ± 5.0	**< 0.001**	0.013
Tr′ − Pog′ (mm)	151.7 ± 5.5	139.2 ± 7.1	142.5 ± 6.0	132.9 ± 4.6	**< 0.001**	**0.007**
Sn′ ^ Na′ ^ Pog′ (degrees)	7.0 ± 2.5	6.8 ± 2.2	10.7 ± 2.0	9.3 ± 3.3	**< 0.001**	**0.005**
Na′Prn′ ^ Prn′Sn′ (degrees)	102.8 ± 8.3	110.2 ± 11.2	98.7 ± 5.4	99.1 ± 5.1	< 0.001	< 0.001
Vertical						
Na′ − Me′ (mm)	131.3 ± 6.1	119.7 ± 6.9	126.1 ± 7.6	113.5 ± 6.8	**0.003**	**0.041**
Na′ − Sn′ (mm)	57.1 ± 3.8	55.7 ± 2.8	56.4 ± 4.9	51.9 ± 3.2	**0.034**	0.125
Sn′ − Me′ (mm)	75.4 ± 5.7	67.7 ± 10.1	72.9 ± 4.5	64.0 ± 6.7	0.114	0.241
Tr′ − Go′ (mm)	75.9 ± 6.3	66.9 ± 5.2	69.6 ± 4.4	60.7 ± 5.0	**< 0.001**	**0.006**
Sn′ − Me′ / Na′ − Me′	0.57 ± 0.04	0.56 ± 0.07	0.58 ± 0.02	0.56 ± 0.03	0.934	0.956
Tr′ − Go / Na′ − Me′	0.57 ± 0.06	0.56 ± 0.04	0.55 ± 0.06	0.54 ± 0.05	0.098	0.344
Or′Tr′ ^ Go′Me′ (degrees)	25.4 ± 6.0	24.5 ± 4.3	27.4 ± 6.6	27.7 ± 6.1	0.098	0.364
Na′Tr′ ^ Go′Me′ (degrees)	37.8 ± 6.3	37.4 ± 4.0	39.9 ± 6.9	39.2 ± 5.7	0.234	0.733
Transversal						
Mf′ - Mf′ (mm)	24.0 ± 2.2	23.1 ± 2.2	23.5 ± 3.6	21.6 ± 2.4	0.135	0.923
Al′ - Al′ (mm)	37.2 ± 2.9	30.8 ± 3.0	31.5 ± 1.6	28.1 ± 1.4	**< 0.001**	**< 0.001**
Ex′-Ex′ (mm)	101.0 ± 5.5	94.7 ± 5.9	93.8 ± 4.9	91.1 ± 4.1	**< 0.001**	0.166
Tr′ - Tr′ (mm)	152.5 ± 5.2	140.9 ± 7.4	146.1 ± 4.5	135.7 ± 5.3	**< 0.001**	0.135
Go′ - Go′ (mm)	127.0 ± 20.6	109.2 ± 15.0	115.4 ± 5.5	106.7 ± 5.9	0.068	0.712

[†] Adjusted for gender, age
[‡] Adjusted for gender, age and BMI
Significant values in bold

decreased facial convexity, greater posterior and total anterior facial height, and a broader nasal base in comparison with NZ Europeans ($p < 0.05$).

Discussion

To assist in orthodontic evaluation and treatment planning, the purpose of this study was to investigate the facial features of Māori and NZ European adults using a non-invasive 3D imaging technique. Facial scans of tertiary students were assessed in the three orthogonal planes to evaluate important differences in facial form between the two groups.

Māori participants generally had larger facial measurements compared with NZ Europeans, which is consistent with the findings of a previous study investigating Polynesian samples presenting with obstructive sleep apnoea.[3] The increased dimensions of the measured facial features were not surprising since Māori and Pacific Island populations are known to have greater bone mineral density and markedly larger skeletal bones than Caucasians.[10,11] Increased body size in Polynesians has been attributed to a number of environmental factors such as colder climates and dietary habits.[2] Genetic factors are also likely to play a role, with Māori exhibiting several unique genetic variants and markers.[12,13] Indeed, several authors have

attributed the relatively large craniofacial dimensions of pre-contact Māori skulls to unique neotenic features such as the prolonged patency of the premaxillary suture, which reportedly persists into adulthood in order to allow for a greater period of growth.[14]

There were several similarities between the facial features of Māori found in the current study and those reported in present-day Polynesians; namely, a longer mandible, and increased transverse breadth.[3] Moreover, an increased upper anterior facial height similar to that reported in present-day and early Polynesians was noted,[3,15,16] but without a concurrent increase in either the mandibular plane angle or in lower anterior facial height. It has been postulated that the open cranial base angle and increased mid-facial height found in these early Polynesian skulls led to a downward and backward displacement of the mandible.[2] In order to maintain a functional occlusion, the mandible also underwent an upward body remodelling rotation that resulted in a reduced gonial angle.[2] No valid conclusions could be drawn regarding the morphological features or growth patterns of craniofacial bones in present-day Māori populations, although distinctive differences seem to exist between them and NZ Europeans.

Most of the differences between Māori and NZ European faces in the present study occurred in the sagittal plane. Examined NZ Europeans displayed a more convex profile than Māori. In support of this observation, significant differences in malocclusion indices have also been reported between Māori and NZ Europeans, although the aetiological factors underlying these differences were not investigated.[17] Dental features were not assessed in the present study, and therefore no comments can be made regarding the type or severity of malocclusions between the two groups.

It is noteworthy that several variables, such as upper facial height and several transverse measurements, became statistically insignificant after adjusting for BMI. While excessive adipose tissue may affect the magnitude of some transverse soft tissue measurements, the use of BMI as a sole indicator of obesity in multi-ethnic populations remains questionable. Ethnicity appears to play an important role in the relationship between body fat and BMI, with Māori and Pacific Island people exhibiting higher BMI scores than European and Indian-Asian populations due to greater bone mineral mass.[18,19] The use of body fat percentage may therefore be a more valid measure which can be used to adjust for body size in future studies.

The study's limitations included the use of a non-random, small sample, which may have limited the general nature of the findings. Despite the study's focus on the facial features of adults, it is likely that considerable difference in growth patterns and facial characteristics also exist between Māori and NZ European children. It is also possible that the use of mixed-descent Māori participants may have diluted the observed differences in facial features between the two study groups. Although every attempt was made to recruit unmixed-descent Māori participants, the sampling frame and geographic distribution of the target population limited access to an ideal sample. The vast majority of Māori in New Zealand are located in the northern regions, with only 6% residing around the study's research centre (2006 Census, Statistics New Zealand). Replicating this study in areas that are heavily populated with Māori may therefore offer greater insight into the differences between the two ethnic groups.

Nevertheless, the relatively simple and non-invasive 3D imaging technique utilised in the present study has identified a number of clinically useful findings, which support its use for investigating facial form in larger samples. The use of stereophotogrammetric techniques does not provide direct information regarding an underlying skeletal morphology, although it does offer advantages over traditional cephalometric techniques, such as a lack of exposure to unnecessary radiation, simultaneous assessment of multiple planes, and longitudinal sample evaluation using superimposition methods.

Conclusions

Despite the increased influence of Western culture in New Zealand, Māori have unique facial features that show resemblance to historical Polynesian skulls. Future investigations of the facial and skeletal features of Māori may therefore enhance our understanding of craniofacial devolvement, especially with regard to the role of genetic and environmental factors. From a clinical perspective, the present study indicates that the use of Caucasian norms in Māori individuals may lead to inaccurate interpretations of the underlying skeletal relationship in this group. Moreover, non-invasive 3D imaging can assist clinicians in assessing facial dysmorphology of different ethnic groups.

Acknowledgments

Corresponding author

Professor Mauro Farella

Discipline of Orthodontics, Department of Oral Sciences, Faculty of Dentistry, University of Otago

PO Box 647, Dunedin 9054
New Zealand

Email: mauro.farella@otago.ac.nz

References

1. George VH. A comparative study op [sic] the jaws and occlusion of Maori and of British born in New Zealand. International Journal of Orthodontia, Oral Surgery and Radiography 1926;12:20-7.
2. Houghton P. Polynesian mandibles. J Anat 1978;127:251-60.
3. Coltman R, Taylor DR, Whyte K, Harkness M. Craniofacial form and obstructive sleep apnea in Polynesian and Caucasian men. Sleep 2000;23:943-50.
4. Kean MR, Houghton P. Polynesian face and dentition: functional perspective. Am J Phys Anthropol 1990;82:361-9.
5. Rongo R, Antoun JS, Lim YX, Dias G, Valletta R, Farella M. Three-dimensional evaluation of the relationship between jaw divergence and facial soft tissue dimensions. Angle Orthod 2014;84:788-94.
6. Besl PJ, McKay ND. A method for registration of 3-D shapes. IEEE Trans Pattern Anal Mach Intell 1992;14:239-56.
7. Amenta N, Choi S, Kolluri RK. The power crust, unions of balls, and the medial axis transform. Computational Geometry 2001;19:127-53.
8. Dahlberg G. Statistical methods for medical and biological students. London: George Allen & Unwin, 1940.
9. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
10. Reid IR, Mackie M, Ibbertson HK. Bone mineral content in Polynesian and white New Zealand women. Br Med J (Clin Red Ed) 1986;292:1547-8.
11. Cundy T, Cornish J, Evans MC, Gamble G, Stapleton J, Reid IR. Sources of interracial variation in bone mineral density. J Bone Miner Res 1995;10:368-73.
12. Woodfield DG, Simpson LA, Seber GA, McInerney PJ. Blood groups and other genetic markers in New Zealand Europeans and Maoris. Ann Hum Biol 1987;14:29-37.
13. Benton M, Macartney-Coxson D, Eccles D, Griffiths L, Chambers G, Lea R. Complete mitochondrial genome sequencing reveals novel haplotypes in a Polynesian population. PLoS One 2012;7:e35026.
14. Kieser JA, Dennison KJ, Dias GR. Premaxillary suture in early polynesians. Int J Osteoarchaeol 1999;9:244-7.
15. Kean MR, Houghton P. The Polynesian head: growth and form. J Anat 1982;135:423-35.
16. Houghton P, Kean MR. The Polynesian head: a biological model for *Homo sapiens*. J Polyn Soc 1987:223-42.
17. Foster Page LA, Thomson WM. Malocclusion and uptake of orthodontic treatment in Taranaki 12-13-year-olds. N Z Den J 2005;101:98-105.
18. Rush E, Plank L, Chandu V, Laulu M, Simmons D, Swinburn B et al. Body size, body composition, and fat distribution: a comparison of young New Zealand men of European, Pacific Island, and Asian Indian ethnicities. N Z Med J 2004;117:U1203.
19. Rush EC, Goedecke JH, Jennings C, Micklesfield L, Dugas L, Lambert EV et al. BMI, fat and muscle differences in urban women of five ethnicities from two countries. Int J Obes (Lond) 2007;31:1232-9.