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APPENDIX I
ETHICAL APPROVAL

NOTE: This letter is included on pages 355-356 of the print copy of the thesis held in the University of Adelaide Library.

Appendix I – Ethical Approval

APPENDIX II

OSSEOUS LANDMARK DEFINITIONS (BY REGION)

This is a list of all the landmarks used in this study produced by the *Persona* program.

MANDIBLE

- cd.l/cd.r** **condylion laterale left/right:** The most lateral point on the condylar head.
- cb.l/cb.r** **coronoid base left/right:** The point of intersection between mandibular alveolar ridge and anterior border of coronoid process (usually located near or at the junction of the ramus with the body of the mandible).
- ct.l/ct.r** **coronoid tip left/right:** The most superior point on the coronoid process.
- gn** **gnathion:** The most inferior point on the mandibular symphysis in the mid-sagittal plane (sometimes referred to as menton).
- go.l/go.r** **gonion left/right:** A point on the angle of the mandible located by the bisection of the angle formed by the mandibular line and the ramus line.
- id** **infradentale:** The most antero-superior point on the mandibular alveolar margin in the mid-sagittal plane.

MAXILLA AND NASAL

- al.l/al.r** **alare left/right:** The most lateral point on the anterior nasal aperture.
- ans** **anterior nasal spine:** The apex of the anterior nasal spine. (Also known as spinal point (sp) or acanthion (ac)).
- gpf.l/gpf.r** **palatine foramen left/right:** The centre of the greater palatine foramen.
- inm.l/inm.r** **inferior naso-maxillare left/right:** The most inferior point on the naso-maxillary suture.
- morfl.l/morfl.r** **medial orbitale left/right:** The most medial point on the orbital margin in the region of the fronto-lacrimal suture.
- ms.l/ms.r** **maxillare superius left/right:** The most postero-superior point on the maxilla determined from CT slice images. (located in sagittal view as the most superior point on the maxillary surface, at the junction of orbital and infra-temporal surfaces.)
- mxt.l/mxt.r** **maxillary tuberosity left/right:** The most postero-inferior point in the midline of the maxillary tuberosity.
-

na	nasale: The tip of the nasal bone.
n	nasion: The most anterior point of the frontonasal suture. (If suture not clearly identified then the deepest point on the nasal notch can be substituted in the midline.)
nli.l/nli.r	naso-lacrimal inferius left/right: The most antero-inferior point on the margin of the naso-lacrimal groove as it exits the orbit (usually this point is located at the small spicule of bone covering the lateral wall of the naso-lacrimal groove and the inferior orbital rim).
or.l/or.r	orbitale left/right: The most inferior point on the infraorbital margin.
pns	posterior nasal spine: The apex of the posterior nasal spine.
pr	prosthion: The most antero-inferior point on the maxillary alveolar margin in the mid-sagittal plane.
snm.l/snm.r	superior naso-maxillare left/right: The most superior point on the naso-maxillary suture.
zmi.l/zmi.r	zygomaxillare inferius left/right: The most inferior point on the zygoma, in the region of the craniometric landmark, zygomaxillare - the lowest point on the external suture between zygomatic and maxillary bones.

NASAL BONES

inm.l/inm.r	inferior naso-maxillare left/right: The most inferior point on the naso-maxillary suture.
na	nasale: The tip of the nasal bone.
n	nasion: The most anterior point of the frontonasal suture. (If suture not clearly identified then the deepest point on the nasal notch can be substituted in the midline.)
snm.l/snm.r	superior naso-maxillare left/right: The most superior point on the naso-maxillary suture.

VOMER

ans	anterior nasal spine: The apex of the anterior nasal spine. (Also known as spinal point (sp) or acanthion (ac)).
h	hormion: The most posterior and medial point on the junction of the vomer and sphenoid bones.
pns	posterior nasal spine: The apex of the posterior nasal spine.

ZYGOMA

- gwl./gwl.r** **greater wing laterale left/right:** A point located at the junction of the inferior orbital fissure with the suture between the greater wing of the sphenoid and the zygomatic bone. The point can be visualised from within the orbital cavity and at the base of the temporal fossa. The landmark is found at the inferior notch of the spheno-zygomatic suture.
- lor.l/lor.r** **lateral orbitale left/right:** The most lateral point on the orbital rim.
- or.l/or.r** **orbitale left/right:** The most inferior point on the infra-orbital margin.
- slor.l/slор.r** **supero-lateral orbitale left/right:** The intersection of the fronto-zygomatic suture with the lateral orbital rim (almost the intersection of the curve of the supra-orbital rim with the lateral orbital rim).
- zf.l/zf.r** **zygo-frontale left/right:** The point located at the posterior extremity of the fronto-zygomatic suture.
- zmi.l/zmi.r** **zygomaxillare inferius left/right:** The lowest point on the external suture between zygomatic and maxillary bones. (in the region of the craniometric landmark, zygomaxillare).
- zt.l/zt.r** **zygo-temporale left/right:** The mid-point of the bony concavity formed between the frontal and temporal processes of the zygomatic bone.
- zti.l/zti.r** **zygo-temporale inferius left/right:** The point located on the lower border of zygomatic arch at the intersection of zygo-temporal

ETHMOID

- es** **ethmoid spine:** The tip of the ethmoid spine.
- ms.l/ms.r** **maxillare superius left/right:** The most postero-superior point on the maxilla determined from CT slice images (located in sagittal view as the most superior point on the maxillary surface, at the junction of orbital and infra-temporal surfaces).
- morfl.l/morfl.r** **medial orbitale left/right:** The most medial point on the orbital margin in the region of the fronto-lacrimal suture.
- nli.l/nli.r** **naso-lacrimal inferius left/right:** The most antero-inferior point on the margin of the naso-lacrimal groove as it exits the orbit (usually this point is located at the small spicule of bone covering the lateral wall of the naso-lacrimal groove and the inferior orbital rim).
- ofa.l/ofa.r** **optic foramen anterior left/right:** The centre of the anterior opening of the optic canal.

FRONTAL

- br** **bregma:** The intersection of the sagittal and the coronal sutures on the surface of the cranial vault.
- morfl.l/morfl.r** **medial orbitale left/right:** The most medial point on the orbital margin in the region of the fronto-lacrimal suture.
- n** **nasion:** The most anterior point of the frontonasal suture. (If suture not clearly identified then the deepest point on the nasal notch can be substituted in the midline.)
- spc.l/spc.r** **sphenion c left/right:** The junction of the coronal suture and the sphenoid bone.
- spa.l/spa.r** **sphenoidale anterior left/right:** The most anterior point on the posterior margin of the lesser wing of sphenoid at the junction with the frontal bone (see sphenoid).
- snm.l/snm.r** **superior naso-maxillare left/right:** The most superior point on the naso-maxillary suture.
- sor.l/sor.r** **superior orbitale left/right:** The most superior point on the supra-orbital margin.
- zf.l/zf.r** **zygo-frontale left/right:** The point located at the posterior extremity of the zygomatic bone at the fronto-zygomatic suture. (see zygomatic bone)

OCCIPITAL

- as.l/as.r** **asterion left/right:** The intersection between temporal, parietal and occipital sutures on the surface of cranial vault.
- ba** **basion:** The point on the anterior margin of the foramen magnum (determined as posterior inferior point on the clivus of the skull).
- fmlhg.l/fmlhg.r** **foramen magnum lateralis left/right:** The most lateral point on the margin of the foramen magnum at the region of hypoglossal foramen.
- l** **lambda:** The intersection between the lambdoid and sagittal sutures on the surface of the cranial vault.
- o** **opisthion:** The mid-sagittal point on the posterior margin of the foramen magnum.
- petp.l/petp.r** **petrous posterius left/right:** The most posterior point on the crest of the petrous temporal bone at its junction with the lateral wall of the posterior cranial fossa (occipital bone).

pts.l/pts.r **pterygo-superius left/right:** The postero-superior extremity of the medial pterygoid plate, where it approximates the apex of the petrous temporal bone. (see maxilla)

PARIETAL

as.l/as.r **asterion left/right:** The intersection between temporal, parietal and occipital sutures on the surface of the cranial vault (see occipital bone).

br **bregma:** The intersection of the sagittal and the coronal sutures on the surface of the cranial vault (see frontal bone).

l **lambda:** The intersection between the lambdoid and sagittal sutures on the surface of the cranial vault (see occipital bone).

spc.l/spc.r **sphenion c left/right:** The junction of the coronal suture and the sphenoid bone (see sphenoid).

spt.l/spt.r **sphenion t left/right:** The intersection of the temporal, parietal and sphenoid bones (see sphenoid).

SPHENOID

ac.l/ac.r **anterior clinoid left/right:** The most posterior point on the anterior clinoid of the lesser wing of the sphenoid bone.

es **ethmoid spine:** The tip of the ethmoid spine. (see ethmoid)

gwl.l/gwl.r **greater wing laterale left/right:** A point located at the junction of the inferior orbital fissure with the suture between the greater wing of the sphenoid and the zygomatic bone. The point can be visualised from within the orbital cavity and at the base of the temporal fossa. The landmark is found at the inferior notch of the speno-zygomatic suture (see zygomatic bone).

gwm.l/gwm.r **greater wing mediate left/right:** The most inferior point of the superior orbital fissure, where the greater wing of the sphenoid joins the body of the sphenoid, (just above the floor of the foramen rotundum).

hn.l/hn.r **hamular notch left/right:** The deepest point of the hamular notch located centrally between the maxillary tuberosity and the pterygoid process of the sphenoid.

hp.l/hp.r **hamular process left/right:** The tip of the hamular process of the medial pterygoid plates of the sphenoid.

h **hormion:** The most posterior and medial point on the junction of the vomer and sphenoid bones. (see vomer)

ms.l/ms.r **maxillare superius left/right:** The most postero-superior point on the maxilla determined from CT slice images. (located in sagittal view as the most superior

	point on the maxillary surface, at the junction of orbital and infra-temporal surfaces.) (see maxilla)
pc.l/pc.r	posterior clinoid left/right: The most superior and lateral point on the posterior clinoid.
ptl.l/ptl.r	pterygo-lateralis left/right: The most lateral point on the lateral pterygoid plate located at the posterior/inferior angle.
pts.l/pts.r	pterygo-superius left/right: The postero-superior extremity of the medial pterygoid plate, where it approximates the apex of the petrous temporal bone. (see temporal bone)
s	sella: The centre of the sella turcica.
spa.l/spa.r	sphenoidale anterior left/right: The most anterior point on the posterior margin of the lesser wing of sphenoid (see frontal bone).
spc.l/spc.r	sphenion c left/right: The junction of the coronal suture and the sphenoid bone (see frontal).
spt.l/spt.r	sphenion t left/right: The intersection of the temporal, parietal and sphenoid bones (see temporal and parietal bones).
ss.l/ss.r	spine of sphenoid left/right: A point on the bony projection near the opening of foramen spinosum on external cranial base.
zf.l/zf.r	zygo-frontale left/right: The point located at the posterior extremity of the fronto-zygomatic suture (see zygomatic bone).

TEMPORAL

as.l/as.r	asterion left/right: The intersection between temporal, parietal and occipital sutures on the surface of the cranial vault. (see parietal and occipital)
au.l/au.r	auriculare left/right: The most superior point on the root of the zygomatic arch.
po.l/po.r	external auditory meatus superius (ie porion) left/right: The most superior point on the margin of the external auditory meatus.
ma.l/ma.r	mastoidale left/right: The most inferior point on the mastoid process.
petsa.l/petsa.r	petrous superius anterior left/right: The most anterior point on the crest of the petrous temporal bone at the margin of the foramen lacerum and the base of the posterior clinoid.
petp.l/petp.r	petrous posterius left/right: The most posterior point on the crest of the petrous temporal bone at its junction with the lateral wall of the posterior cranial fossa (occipital bone).

pts.l/pts.r	pterygo-superius left/right: The postero-superior extremity of the medial pterygoid plate, where it approximates the apex of the petrous temporal bone. (see sphenoid)
spt.l/spt.r	sphenion t left/right: The intersection of the temporal, parietal and sphenoid bones. (see parietal and sphenoid)
ss.l/ss.r	spine of sphenoid left/right: A point on the bony projection near the opening of foramen spinosum on external cranial base.
zt.l/zt.r	zygo-temporale left/right: The mid-point of the bony concavity formed between the frontal and temporal processes of the zygomatic bone. (see zygomatic bone)
zti.l/zti.r	zygo-temporale inferius left/right: The point located on the lower border of zygomatic arch at the intersection of zygo-temporal suture.

ORBITAL CAVITY

lor.l/or.r	lateral orbitale left/right: The most lateral point on the orbital rim.
ms.l/ms.r	maxillare superius left/right: The most postero-superior point on the maxilla determined from CT slice images. (located in sagittal view as the most superior point on the maxillary surface, at the junction of orbital and infra-temporal surfaces)
morfl.l/morfl.r	medial orbitale left/right: The most medial point on the orbital margin in the region of the fronto-lacrimal suture.
nli.l/nli.r	naso-lacrimal inferius left/right: The most antero-inferior point on the margin of the naso-lacrimal groove as it exits the orbit (usually this point is located at the small spicule of bone covering the lateral wall of the naso-lacrimal groove and the inferior orbital rim).
ofa.l/ofa.r	optic foramen left/right: The centre of the anterior opening of the optic canal.
or.l/or.r	orbitale left/right: The most inferior point on the infraorbital margin.
sor.l/sor.r	superior orbitale left/right: The most superior point on the supra-orbital margin.
slor.l/slор.r	supero-lateral orbitale left/right: The intersection of the fronto-zygomatic suture with the lateral orbital rim (almost the intersection of the curve of the supra-orbital rim with the lateral orbital rim).

NASAL CAVITY

ans	anterior nasal spine: The apex of the anterior nasal spine. (Also known as spinal point (sp) or acanthion (ac)).
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es	ethmoid spine: The tip of the ethmoid spine.
h	hormion: The most posterior and medial point on the junction of the vomer and sphenoid bones.
inm.l/inm.r	inferior naso-maxillare left/right: The most inferior point on the naso-maxillary suture.
ms.l/ms.r	maxillare superius left/right: The most postero-superior point on the maxilla determined from CT slice images. (located in sagittal view as the most superior point on the maxillary surface, at the junction of orbital and infra-temporal surfaces).
morfl.l/morfl.r	medial orbitale left/right: The most medial point on the orbital margin in the region of the fronto-lacrimal suture.
na	nasale: The tip of the nasal bone.
n	nasion: The most anterior point of the frontonasal suture. (If suture not clearly identified then the deepest point on the nasal notch can be substituted in the midline.)
nli.l/nli.r	naso-lacrimal inferius left/right: The most antero-inferior point on the margin of the naso-lacrimal groove as it exits the orbit (usually this point is located at the small spicule of bone covering the lateral wall of the naso-lacrimal groove and the inferior orbital rim).
ofa.l/ofa.r	optic foramen left/right: The centre of the anterior opening of the optic canal.
pns	posterior nasal spine: The apex of the posterior nasal spine.
snm.l/snm.r	superior naso-maxillare left/right: The most superior point on the naso-maxillary suture.

OTHER MEASUREMENTS

cindx.l/cindx.r	cranial index left/right: The bilateral points of maximum convexity on the cranial vault between which maximum cranial breadth is recorded.
cindxa/cindxp	cranial index anterior/posterior: The maximum length of the cranial vault.

APPENDIX III
ABSTRACT FOR PRELIMINARY MANDIBULAR
MORPHOMETRIC ANALYSIS PRESENTED AT THE
ANNUAL CONFERENCE OF INTERNATIONAL
ASSOCIATION FOR DENTAL RESEARCH
2003

3D-CT Analysis of Craniofacial Growth Changes In Malaysians

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Text for poster

In order to define the abnormality of structures of patients with craniofacial anomalies, normative data are needed. Normal data in different population are available and differences have been reported in different populations. Currently there are no detailed data for craniofacial variables for Malaysians.

In this study we performed detailed analysis of growth changes of craniofacial bones and develop standards for craniofacial variables for Malaysians Malays using 3D-CT. The scans were obtained from 200 Malay children and adolescents and were reconstructed into 3D.

The PERSONA software was used to locate landmarks on the 3D-CT. We have located up to 115 landmarks per patients. However, for this presentation results for mandibular analysis is highlighted.

2 approaches are presented here. The first, we follow the method of plotting various variables against age. The results are presented here and they are quite easy to follow.

A second approach combining Generalised Procrustes and Principal Component Analyses were applied to the data for shape analysis.

Using the second method, multiple variables were reduced and summarised. The result of this analyses were plotted.

Distance = Procrustes distance from the mean.

Root mean square residuals after least square registration.

Size = centroid size (distance of each landmark to the mean)

We produce the mean mandibular shape by warping/deform the mandibular surface of the subject with the smallest Procrustes distance from the mean.

Then the PCA scores were derived by warping to mean surface at +2 and -2 standard deviations for each mode.

PCA score 1 account for 51% of population shape variations and correlated with age and size. ± 2 standard deviations for each PCA scores are presented.

Colour codes indicate distances from the mean. White means zero distance and red means maximum distance from the mean.

For PCA score 1 most variations occur at the chin and condyle. +2 std deviation resembling adult mandible and -2 std deviation resembling those of infant/child.

PCA score 2 accounts for 9% of population shape variations, scattered more or less about zero and no significant correlation can be offered. Visualisation shows more variation occur for the incisor teeth.

PCA score 3 accounts for 8% of population shape variations and follows the same pattern as score 2. Visualisation also shows more variations at the anterior aspect of the mandible.

Conclusion – we have quantified craniofacial growth and development in a large Malaysian sample. 3D morphometric analysis shows that mandibular growth pattern vary between variables and sexes. We hope that the new standard will provide important resources for surgeons to treat patients with craniofacial abnormalities.

APPENDIX 1V

ACADEMIC ACTIVITIES

PRESENTATIONS WITH ABSTRACTS

- Australasian Society for Human Biology 16th Annual Scientific Meeting, Perth, 9-11th December 2002
 - Craniofacial asymmetry in Malaysian Malays based on 3-D CT analysis
- Australasian Society for Medical Research, Adelaide, Australia, 30th May 2003
 - Craniofacial morphology of Malaysian Malay children and young adults: a 3D-CT analysis and potential clinical applications
- Australasian Cleft Lip and Palate Association Conference, Sydney, 8 – 9th August 2003
 - Craniofacial morphology of Malaysian Malay children and young adults: a 3D-CT analysis and potential clinical applications
- International Association for Dental Research, Australian and New Zealand Division, Melbourne, 28th September – 1st October 2003
 - 3D-CT analysis of craniofacial growth changes in Malaysians
- Australasian Society for Medical Research, Adelaide, Australia, 23rd-25th November, 2003
 - 3D-CT analysis of craniofacial growth changes in Malaysians
- 14th Biennial Congress - Asian Surgical Association, Kota Kinabalu, Sabah, Malaysia, 4th – 6th December 2003
 - 3D-CT Analysis of Craniofacial Growth Changes in Malaysians and potential clinical applications

ADDITIONAL PRESENTATIONS

- The Universiti Sains Malaysia Craniofacial Surgery Course, Kota Bharu, Malaysia, 13th-15th July 2002

-
- 3D-CT analysis of craniofacial growth changes in Malaysians
 - Colgate Australian Clinical Dental Research Centre Research Day, 22 August 2003
 - 3D-CT analysis of craniofacial growth changes in Malaysian Malay children and young adults
 - Australian Craniofacial Symposium. Australian Craniofacial Unit, Women's and Children's Hospital, Adelaide, 16 May 2003
 - 3D-CT analysis of craniofacial growth changes in Malaysians

PAPERS PUBLISHED

Rajion ZA, Townsend GC, Netherway DJ, Anderson PJ, Yusof A, Hughes T, et al. (2006). A three-dimensional computed tomographic analysis of the cervical spine in unoperated infants with cleft lip and palate. *Cleft Palate Craniofac J* 43:513-18.

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