

UNIVERSITI TEKNOLOGI MARA

**MORPHOLOGICAL ANALYSIS OF
FRONTAL SINUS FOR HUMAN
IDENTIFICATION AMONGST
MALAYSIAN: A SKULL
RADIOGRAPH AND COMPUTED
TOMOGRAPHY STUDY**

NUR DAMIA IWANI BINTI ZULKIFLEE

Thesis submitted in fulfilment
of the requirements for the degree of
**Doctor of Philosophy
(Medicine)**

Faculty of Medicine

March 2025

ABSTRACT

Biological profiling is necessary for unknown skeletonised remains. In cases of fragmented skeletons, the resiliency of the frontal sinus (FS) suggests its potential in establishing biological identity. Osteometry method is limited to external skeletal evaluation, whereas imaging allows for internal structural analysis. Given the population-specific nature of forensic identification, studies on FS morphology for biological profiling is least being studied and yet to be explored among Malaysian population. Thus, determining suitable identification methods via imaging, to analyse the morphology of FS in Malaysians is necessary. This study aimed to evaluate FS pattern distribution and determine morphological variations by sex, race and age profiles among Malaysians using descriptive analysis, two-dimensional (2D) geometric morphometric, three-dimensional (3D) volumetric, linear measurements and anterior wall thickness analyses respectively. Samples of 504 skull radiographs and 398 head computed tomography (CT) scans of adult Malaysians comprising males and females of Malay, Chinese and Indian races aged of ≥ 20 years old, were retrieved. The FS patterns in posteroanterior skull radiographs were descriptively classified according to the presence or absence of FS. Eight 2D landmarks were applied to the lateral skull radiographs and 2D geometric morphometric analysis was performed using MorphoJ. Three-dimensional models of the FS and its anterior wall were reconstructed from CT scans. Volumetric and linear parameters were determined for the 3D FS. Five types of grids with 12 regions of interest (ROIs) were developed and applied onto the 3D FS anterior wall area. The thickness of the anterior wall within the 12 ROIs were recorded. Results showed that bilateral presence of FS is common (95.4%) and bilateral absence is rare (2.7%). Procrustes ANOVA revealed significant differences in FS shape by sex ($p < 0.0001$) and race ($p = 0.0205$), with 80.6% and 57.4% classification rates, respectively. However, no significant shape differences were observed within age groups. FS volumes differed significantly by sex ($p = 0.000$), race ($p = 0.035$), and age group ($p = 0.039$), with classification rates of 68.0%, 33.1%, and 37.4%, respectively. Linear measurements also showed significant output by sex ($p = 0.000$) and race group ($p = 0.001$) with accuracies of 80.2% and 41.5%, while no significant differences were noted for age. Anterior wall thickness exhibited significant variations by sex ($p = 0.001$), race ($p = 0.036$), and age group ($p = 0.011$), with classification rates of 62.5%, 44.8%, and 40.2%, respectively. Overall, the rarity of FS absence suggests its applicability in forensic identification. Both 2D geometric morphometric on lateral FS, and linear measurement on 3D reconstructed FS model are reliable for sex identification among Malaysians. This population-specific study could assist in enhancing the FS database within the Malaysian context and provides a valuable reference for forensic identification based on FS morphology.

ACKNOWLEDGEMENT

Firstly, I wish to thank Allah S.W.T. for giving me the opportunity to embark on my PhD and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisors Dr Choy Ker Woon, Assoc Prof Datin Dr Mansharan Kaur, Assoc Prof Dr Aspalilah Alias and Dr Helmi Mohd Hadi Pritam.

My appreciation goes to _____ radiologist from University Malaya Medical Centre who provided the facilities and assistance during data collection. Special thanks to my friends and siblings for helping me throughout this journey.

Finally, this thesis is dedicated to my very dear mother and loving late father for their vision and determination to educate me. This piece of victory is dedicated to both. Alhamdulillah.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR’S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xvii
LIST OF SYMBOLS	xxii
LIST OF ABBREVIATIONS	xxiii
CHAPTER ONE INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	4
1.2.1 Disadvantages of Conventional Method	4
1.2.2 Limitations of 2D Models	4
1.2.3 Pitfalls of 3D Geometric Morphometric on Frontal Sinus	5
1.2.4 Lack of Frontal Sinus Database	6
1.2.5 Lack of Malaysian Population-Specific Database on Frontal Sinus	6
1.3 Research Objectives	7
1.3.1 General Objective	7
1.3.2 Specific Objectives	7
1.4 Research Question	8
1.5 Significance of Study	8
1.6 Scope and limitation of the Study	9

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Forensic anthropology involves the analysis of human skeletal remains for the purpose of identification (Hackman et al., 2023). This is achieved by examine the human bones to extract the biological profile which includes sex, ancestry, age and stature, forming the basis of primary identity of an unknown individual (Hackman et al., 2023). Research has been conducted using various skeletal parts to facilitate forensic investigation, such as the pelvic bone and cranium, which demonstrated strong sexual evidence for forensic identification (Spradley, 2016). However, incidents such as mass disaster can result in the fragmentation or absence of skeletal parts, complicating the identification process (Verma et al., 2014; Zulkiflee et al., 2022a). Therefore, the evaluation of other skeletal parts such as frontal sinus may serve as an alternative and conformation for identification. The frontal sinus is often preserved in traumas (Akhlaghi et al., 2016). However, no study has been elucidated on the frontal sinus among the Malaysian population due to the unavailability of Malaysian human skeletal repositories (Hisham, 2019a). This is because of the Malaysian culture that does not practice skeletal donation due to religious and cultural restrictions (Hisham et al., 2019). Therefore, this study will utilise imaging to study frontal sinus for human identification.

Various methods have been introduced to analyse skeletal elements for biological profiling. Conventionally, the osteometry method, which relies primarily on linear distance measurements, was taken directly on skeletal remains using callipers (Bytheway et al., 2010). However, it has a high standard of error and often overlooks the important morphological variance on complex bony features, hence, affecting the reliability of the method used (Gillick, 2012; Sun et al., 2018). Furthermore, the osteometry method leaves out the skeletal shape information and requires to be done on intact bone, which is difficult to achieve in forensic investigations (Austin et al., 2016; Gillick, 2012). The unavailability of skeletal collection in Malaysia has limited direct bone assessment in this population resulting in limited biological profiling studies