

EXTERNAL DENTAL CHARACTERS AND DIVERSITY OF **HOMO** **ERECTUS** AMONG THE FOSSIL RECORD OF **JAVA**

ABSTRACT

Hominin variability in Java Island should be impacted by the dynamics of Pleistocene climatic and related biogeographical patterns changes. The aim of this study is to characterize the diversity of Javan hominins by exploring the external dental morphological features. We applied metric measurements and observations of the external characters using the scoring method on a sample of 75 upper and lower second molars (M2) from Sangiran and Wajak sites, including *Pongo* and hominin fossils. Similarities and differences are observed and clustering analysis applied. Preliminary results display four hominin groups, suggesting coexistence and parallel occupation of Java Island around the boundary of Lower to Middle Pleistocene, and further detailed studies may clarify the evolutionary meaning of this variability.

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KEYWORDS :

Homo erectus
Taxonomic diversity
Dental Character

UISPP
Journal

UISPP

The Journal of the
International Union for
Prehistoric and
Protohistoric Sciences

Vol. 2
Special issue 2
September 2019

INTRODUCTION

Java Island is located on the volcanic arc at the southeastern part of Sundaland, and emerged thanks to volcano-tectonic processes during Late Pliocene and Early Pleistocene times. A large part of the area was still below the water level about 1.8 million years ago (Sémah, *et al.*, 2000), and the Pleistocene sea-level drops during glacial periods opened land bridges connecting the emerged area with the mainland.

The first reconstruction of faunal succession scheme of the Pleistocene of Java was proposed by von Koenigswald (1935) and was modified by de Vos, *et al.*, (1982) and de Vos (1983). Based on this scheme, the faunas can be grouped into three main units: the oldest unit is endemic and unbalanced fauna (without hominins), the middle unit is partially endemic (characterized by *Stegodon* and *H. erectus*), the younger Late Pleistocene unit represents a balanced, non-endemic tropical rainforest fauna with presence of the earliest modern humans (*H. sapiens*) (van den Bergh, *et al.*, 2001). Dispersals and endemism that affected the terrestrial vertebrate fauna must have also affected hominins (van den Bergh, 1999).

Fossil hominins found in Java reflect a large spatio-temporal diversity. The taxonomic assignment of the Pleistocene fossils found in this area has been subject of debate for a long time. The first human fossil found in Java (in 1888) is the specimen Wajak 1 from Wajak cave (Tjampurdarat, East Java) which was assigned to '*Homo wajakensis*' (Dubois 1922; Aziz & de Vos 1989). Wajak 1 is a fairly complete skull and Wajak 2 consists of fragments of cranium and mandible (Schwartz & Tattersall 2003).

Later on, and based on the analysis of several mandibles from Sangiran, von Koenigswald mentioned four different taxa : Sangiran 6 as '*Meganthropus palaeojavanicus*', Sangiran 1B as '*Pithecanthropus mojokertensis*' and Sangiran 5 as '*P. dubius*'; from cranial fossils were described Sangiran 3 and 4 as '*P. robustus*' (Weidenreich, 1945; von Koenigswald, 1950). Oppenoorth (1932) proposed the name '*Homo (Javanthropus) soloensis*' for the Ngandong calvaria. This perspective was modified later : Jacob (1967) grouped the Ngandong remains in '*P. soloensis*'; Sartono (1991) suggested two genera of hominins: *Australopithecus* ('*A. (Meganthropus) palaeojavanicus*') and *Homo*, the latter encompassing '*H. robustus*' and *H. erectus*, including '*H.e. erectus (H.e. trinilensis)*' and '*H.e. soloensis (H.e. ngandongensis)*'.

Then it was proposed that all those Lower and Middle Pleistocene hominins belong to *H. erectus* (Mayr, 1950; Rightmire, 1984; Widiyanto, 2001; Antón, 2003), with the exception of the Wajak fossils (see for instance Storm, 1976). Grounding on the cranial morphology, Widiyanto (1993; 2001) described three groups of Indonesian *Homo erectus*, identified as "Robust", "Trinil-Sangiran", and "Ngandong" also claimed a gradual and continuous morphological evolution from Lower to Middle Pleistocene (1.6 Ma - 0.1 Ma or less). According to Kaifu *et al.* (2008), the development of some unique cranial features on the latest group of Javanese *H. erectus* suggests that this lineage went extinct without contributing to modern human descent.

Debates about ancient human diversity in Java appear to have mostly considered the skull bones morphological point of view. Only few scholars explored the dental perspective, with the exception of Kaifu *et al.*, (2005; 2006) and Zanolli *et al.*, (2014). In fact, teeth are the most abundant fossils among the hominin collections, and therefore deserve a specific study to compare the fossils' variability and their chronological framework.

MATERIAL AND METHODS

Our sample includes 13 permanent lower second molars (LM2) and 21 upper second molars (UM2) of fossil *Pongo* collected by von Koenigswald between 1936 and 1941 (Zanolli 2011), and 24 LM2 and 17 UM2 of Pleistocene hominins. Almost all teeth were found in Sangiran,

their ages ranging from 1.6 to 0.35 Ma (Falguères, 2001). The Wajak specimen was recently claimed to date back between 37.4 to 28.5 ka (Storm et al. 2013). The *Pongo* sample is intended to test the robustness of the method, its efficiency to discriminate human and non-human primates and distinct hominin groups.

The dental comparisons were conducted following the terminologies employed in Weidenreich, (1937), de Castro, (1988), Bailey (2002), and Martín-Torres *et al.* (2008). Some morphological features are scored using the ASUDAS (Turner *et al.*, 1991) and adjusted for the early Atapuerca hominins by Martín-Torres *et al.* (2012) and for the Indonesian specimens for the present study.

14 characters were considered on the lower molars: middle and distal trigonid crests, anterior and posterior foveas (Martín-Torres *et al.*, 2012), defecting wrinkle, size of C5, C6, and C7 size, groove pattern, protostylid from ASUDAS (Turner *et al.*, 1991), number of cusps, crenulation, mesial and distal marginal ridges by the author.

16 characters were considered on the upper molars: crista obliqua, transversal crest, mesial marginal accessory tubercle, anterior and posterior foveas (Martín-Torres *et al.*, 2012), size of metacone, hypocone, and metaconule size, Carrabelli's cusps, parastyle from ASUDAS (Turner *et al.*, 1991), number of cusps, buccal and lingual accessories cusps, crenulation, mesial and distal marginal ridges by the author.

Mesiodistal (MD) and buccolingual (BL) dimensions of the crown following the methods of Wolpoff (1971), were measured with a standard sliding caliper and recorded to the nearest 0.01 mm. The MD diameter is the maximum distance between mesial-distal faces, and the BL diameter is the maximum width between buccal-lingual faces (Martín-Torres et al. 2008). The statistical software used in this study is PAST (Hammer 2017), boxplot presentation with mean and standard error of univariate comparison for metric data, and classical clustering multivariate analyses for non-metric data with Manhattan distance. This method -inspired by Manhattan city block- defined as the distance of two points in Euclidean space with a fixed Cartesian coordinate system (Dalfó et al. 2007; Dahal 2015). So, it sums the projection lengths of the segment between the points of each sample specimens into the coordinate axes.

RESULTS

The cluster analysis of the LM2 split the sample into five main groups: one group of *Pongo* and four groups of hominins (Figure 1.A). Metric characters add to the consistency of such groups (Figure 2.A). Thus, based on metric and non-metric features, they are described as follows:

- Group 0 (*Pongo*) has very large MD and large BL, with a relatively elongated MD, significant crenulation, pronounced mesial marginal ridge, presence of C5, C6 and C7, with large C5 and C6, marked anterior and posterior fovea
- Group 1 has very large size of MD and BL, square shape relatively, six to seven cusps, presence of C5, C6 and/or C7, with moderate C7, and markedly pronounced protostylid.
- Group 2 has medium size and an elongated shape of MD, six to seven cusps, presence of small C5, C6 and/or C7, weak protostylid, and pronounced anterior fovea.
- Group 3 has medium size of small MD and BL, square shape relatively, six to seven cusps, presence of C5, C6 and/or C7, weak protostylid, and pronounced anterior fovea.

- Group 4 shows reduced and small size of MD and BL, four cusps with plus (+) groove pattern, absent of deflecting wrinkle and distal marginal ridge, weak protostylid and less pronounced anterior fovea.

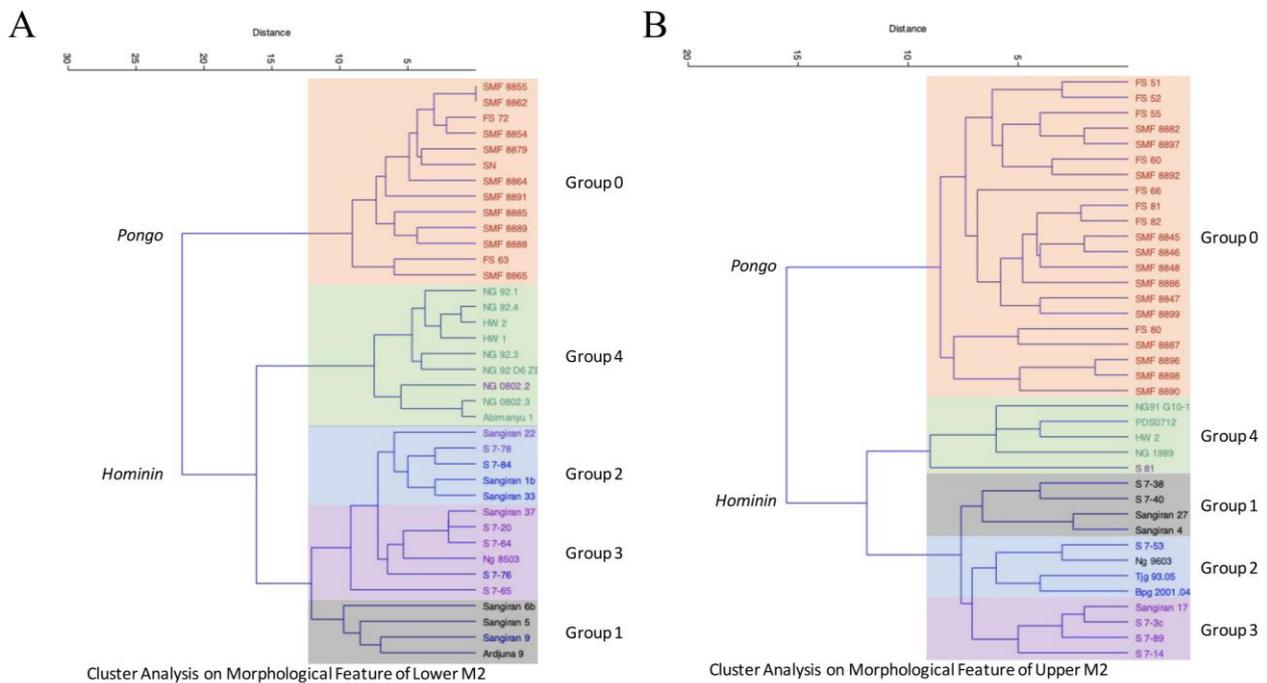


Fig. 1: Cluster Analysis on Morphological Feature: A. Lower M2 specimens, and B. Upper M2 specimens. Abbreviation: Bapang (Bpg), Ngebung (Ng/NG), Frankfurt Senckenberg (FS), Padas (PDS), Sangiran Dome (S), Senckenberg Museum Frankfurt, specimen without number from Sangiran Dome (SN), Tanjung (Tjg), Wajak (HW). All the specimen came from Sangiran site, except Wajak.

The same groups were obtained on the UM2 on non-metric features (Figure 1.B) and metric measurements (Figure 2.B) as follows:

- Group 0 (*Pongo*) has very large size of MD and BL, square shape relatively, buccal accessory cusps between paracone-metacone, and lingual accessory cusp between protocone-hypocone, significant crenulation, pronounced mesial marginal ridge and mesial marginal accessory tubercle; it shows a large size for C5.
- Group 1 has very large size of MD and BL with elongated BL, four cusps, presence of transversal crest and crista obliqua, mesial and distal marginal ridge, anterior and posterior fovea, without Carabelli or parastyle.
- Group 2 has large size of MD and BL, five cusps, presence of transversal crest and crista obliqua, mesial and distal marginal ridge, anterior and posterior fovea, also a significant Carabelli or parastyle.
- Group 3 has medium size of MD and reduced BL, five cusps, presence of transversal crest and crista obliqua, mesial and distal marginal ridge, anterior and posterior fovea, without Carabelli or parastyle.
- Group 4 shows reduced and small size of MD with elongated BL, four to five cusps, absent of mesial and distal marginal ridge, no anterior and posterior fovea, and no Carabelli or parastyle.

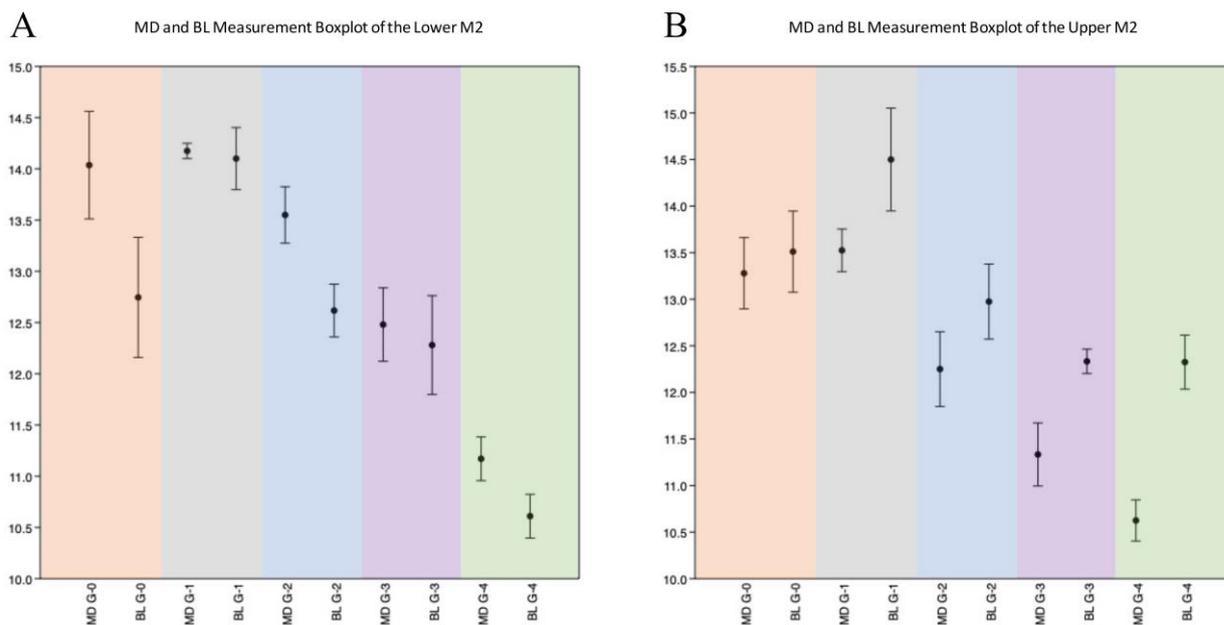


Fig. 2: Boxplot graphic of MD and BL measurements: A. Lower M2 groups, B. Upper M2 groups. Color: Brown (Group 0/Pongo), Grey (Group 1), Blue (Group 2), Purple (Group 3), and Green (Group 4)

DISCUSSION

Group 0 represents the *Pongo* fossils, including three main divisions (not discussed in this work). Group 1 includes Lower Pleistocene fossil mandibles from Sangiran, (Sangiran 6b or *Meganthropus* A (von Koenigswald, 1950) and Arjuna 9 (see Widiyanto, 1993). Those fossils come from the so-called Pucangan and Grenzbank series in Sangiran stratigraphy. Widiyanto (1993) groups Arjuna 9 with robust *H. erectus*, but Zanolli *et al.*, (2014) in the *Ponginae*. In our study, it appears closer to teeth from the group 1 than the group 0. Indeed, the very marked presence of protostylid is absent in the *Pongo* fossils of von Koenigswald's collection. Group 2 includes the Sangiran 1b fossil (called '*Pithecanthropus modjokertensis*' (von Koenigswald, 1940) from the same series, but also Sangiran 33 from the early Middle Pleistocene Grenzbank/Kabuh layers. Group 3 includes Sangiran 37 (called '*Pithecanthropus G*' by Aziz, 1981) and Ng 8503 from the lower Kabuh series. Group 4 includes NG 92 D6 from lower Kabuh, Abimanyu 1 from mid-Kabuh, but also the Late Pleistocene Wajak specimen.

Considering the chronological distribution of each group, we note that Group 1 and Group 2 from the Lower Pleistocene correspond to the first hominin groups who settled in Java. During this period, the evolution of the landscape was mainly driven by the development of volcanic activity and by the major climatic cycles (Sémah, *et al.*, 2010). The low-sea level drops during the Lower Pleistocene glacial periods opened land bridges connecting the islands with the mainland Southeast Asia and causing not only faunal but also human migration into this area. The recessions affected to paleogeography of the region creating wide corridors across the Sunda Shelf, and bringing open woodland on Java which was preferred by big mammals and humans (van den Bergh, *et al.*, 2001). The hominin groups were migrated in this period are present at the early Middle Pleistocene (c. 0.8 Ma ago), and only Group 4 lasted until the Late Pleistocene.

The faunal turnovers and human occupation in the Pleistocene time seem to be correlated with extreme global cooling event and sea level decline during the hardest glacial period such

as MIS 22 (Hantoro, 1997; Sémah, *et al.*, 2010). On the other hand, global warming in the interglacial maximum, when the climate is warmer and humid, caused a sea level rise. This condition created an insular environment, causing isolation from continental Asia. Grounding on the proximity of the dental characters, we suggest that Group 3 evolved from the previous Group 2 lineage. Some dental characters similarities with size reduction in Group 3 compared to Group 2 could be the result of isolation and adaptation to an insular environment.

Group 4 might be identified as a newcomer, because it seems that there is no possibility of gradual evolution from previous Group 1 or Group 2. The discoveries of specimen member of the group with the Acheulian artifacts in Ngebung 2 occupation layer in the Sangiran dome suggest that the Group 4 migrated to Java on the boundary of Lower to Middle Pleistocene around 0.8 Ma (Sémah, *et al.*, 1992; Simanjuntak, *et al.*, 2010). This event could be the reflection of the 'mid Pleistocene revolution' as proposed by Sémah *et al.*, (2010), which could be described as the formation of a new geographical territories of the archipelago, with a new genetic flow from the mainland which represented by the Group 4. Finally, this group including '*H. wajakensis*', were survived from the dramatic climatic change through the Middle Pleistocene until the Late Pleistocene.

Our study therefore suggests a complex diversity among hominins of Java that can be identified on dental grounds with at least four groups that coexistence around the Lower to Middle Pleistocene boundary. This result does not contradict those published by von Koenigswald (1950) and Sartono (Sartono 1991). The result also could be compatible with the hypothesis of gradual evolution from Early Pleistocene to Middle Pleistocene as proposed by Widiyanto (1993) and Kaifu *et al.*, (2005), especially presented by Group 2 and 3 in this study. However, we have to consider the possibilities scenario with happen on Group 1 which was extinct in the Middle Pleistocene and Group 4 which is survive until the Late Pleistocene.

CONCLUSION

Focusing on dental features, our study highlights four groups of fossil hominins and their coexistence in Java during the lower Middle Pleistocene. Extinction and local evolution which presented by Group 1, 2 and 3 were could be the result of extreme climatic changes, isolation and adaptation in the islands environment. Further studies could be clarified this hypothesis. Finally, human evolution in Island Southeast Asia appears much more complex history than only one gradual line hypothesis, but linking with the events of isolation, adaptation, repeated migration and coexistence. Further analyses should be compared the dental patterns diversity between island and mainland Asia, also contextualizing with chronology, biogeography, paleo environment, and archaeological proxies.

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