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The olecranon aperture of the humerus: a meta-analysis with anthropological and clinical discussion

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With 2 figures and 5 tables

Abstract: The olecranon aperture is an anatomical variant of the humerus that communicates the olecranon fossa with the coronoid fossa. It is also known as the supratrochlear foramen. Older anatomical textbooks refer to it as a rare variation caused by the perforation of the thin bony plate which separates both fossae. This anatomical variant may be confused as an osteolytic lesion of the humerus in radiographic images. The present work aims to perform a meta-analysis of the olecranon aperture. Heterogeneity between studies was evaluated using I2 estimation and the Cochran Q statistic test. A random effect model was used for all analyses. A total of sixty-one studies (20,338 humeri) were included in this meta-analysis. The pooled prevalence of the olecranon aperture was 21.9% (95% confidence interval: 18.6% to 25.3%). This variant was more commonly found in female than in male bones (statistically significant difference). The olecranon aperture is a common anatomical variant among the general population, although individuals from Africa possess a higher predisposition to develop it. The name supratrochlear foramen is incorrect, as foramina are conduit to vessels or nerves, as such, we propose the term olecranon aperture.

Keywords: supratrochlear foramen; anatomical variants of humerus

Introduction

The olecranon aperture of the humerus (OAH) (also known as the septal aperture, supratrochlear foramen or *foramen olecrani*) is an anatomic variant. It is located at its distal epiphysis and is characterized as a perforation of the bony wall that separates the olecranon fossa and the coronoid fossa (Fig. 1) (Chagas et al. 2016; Scheuer & Black 2000; Tubbs et al. 2016).

The prevalence of the OAH is highly variable, as it can range from 0.3% (Papaloucas et al. 2011) to 47% (Glanville 1967). This has been subject to debate, as the data so far observed different prevalence rates between numerous ethnic groups (Chagas et al. 2016; Mays 2008; Ming-Tzu 1935; Myszka 2015).

According to the literature the aperture was firstly described by Meckel (Chagas et al. 2016; Meckel 1831; Papaloucas et al. 2011). Its description is present in classic (Cruveilhier 1851; Meckel 1831; Sharpey et al. 1864; Spalteholz 1975; Testut & Latarjet 1958; Wolf-Heidegger 1971) and a few recent anatomical textbooks/atlases (Platzer 2013; Schünke et al. 2011). The olecranon aperture is also mentioned in veterinary orthopedics (DeCamp et al. 2016), veterinary anatomy (Ruberte et al. 2017; Sisson et al. 1975) and osteology books (Scheuer & Black 2000). However, in some recent books it is completely absent (Gilroy et al. 2016; Latarjet & Liard 2011; Moore et al. 2014; Netter 2014; Rouvière & Delmas 2002; Standring 2008).

The olecranon aperture possesses clinical and surgical significances, since it can be misdiagnosed as an osteolytic lesion in radiographs and predispose low-energy fractures. Furthermore, it has been observed that presence of the OAH is somehow related to a narrow medullary canal, which may alter the preoperative planning of intramedullary nailing, a gold standard procedure to treat supracondylar fractures (Akpinar et al. 2003; Chagas et al. 2016; Li et al. 2015; Paraskevas et al. 2010; Sunday et al. 2014).

Moreover, the OAH is known for its anthropological aspect, as it is more commonly found in individuals from ancient times such as the Neolithic period and among non-human primates (Chagas et al. 2016; Lamb 1890; Testut & Latarjet 1958).

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Fig. 1. The olecranon aperture of the humerus.

The study presented herein aimed to perform a meta-analysis of the OAH with the purpose of establishing the prevalence of this variation among the general population and discuss its morphological, clinical and anthropological aspects.

Material and methods

Systematic review and inclusion and exclusion criteria

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al. 2009) and the Evidence-Based Anatomy guidelines (Henry et al. 2016). Institutional review board approval was not required. Inclusion criteria for studies in this meta-analysis were: original research manuscripts, scientific journals and theses; papers that involved human patients or involved cadaveric samples with a sample of 20 bones or more. The literature search was performed in April 1st, 2018. Editorials, commentaries, letters to the editor, conference abstracts, case reports and papers with a sample less than 20 bones were excluded.

Search strategy

The search was performed in three major electronic databases: Public MEDLINE, PubMed, Scopus, the Scientific Electronic Online Library (SciELO), TRIP, Google Scholar, Cochrane. There were no restrictions regarding language or date. The terms used in this search were: “supratrochlear foramen”, “septal aperture”, “olecranon aperture”, “supratrochlear aperture”, and “olecranon foramen”, separately. Furthermore, the reference list of retrieved articles was reviewed in order to identify studies that were not identified from the preliminary literature searches.

Data extraction and quality assessment

Data from the included studies were individually extracted by two reviewers (L.A.S.P., C.A.A.C.). Data to be extracted included: year, country, total sample size (including side and sex), prevalence, shape and morphometric data of the olecranon aperture, whenever possible, thus, any paper which

had only the prevalence, was not excluded from this meta-analysis, but was excluded from the sex or side pooled data, for instance. This was performed with the purpose of including as many works as possible. If possible, the authors of a particular manuscript were contacted for clarification in the event of any discrepancies.

Statistical analysis

The statistical analysis was performed with the aid of MedCalc Statistical Software version 14.8.1 (MedCalc Software bvba, Ostend, Belgium) and the MetaXL version 2.0 by EpiGear Pty Ltd (Wilston, Queensland, Australia).

Heterogeneity between studies was evaluated using I^2 estimation and the Cochran Q statistic test. A random effect model was used for all analyses. The two-tailed z-test was used in order to compare proportions between the sex and sides of the bones ($p < 0.05$ was considered as significant) and the two-tailed Student's t-test was performed to detect any significant difference of the measurements between the left and right sides ($p < 0.05$ was considered as significant). The Chi-squared test was performed to verify differences among the regional prevalence of the OAH ($p < 0.05$ was considered as significant).

Study identification

The keywords "supratrochlear foramen", "septal aperture", "olecranon aperture", "supratrochlear aperture", and "olecranon foramen" when searched separately, yielded 106 articles on the PubMed database, 7 articles on the SciELO database, 58 articles on Scopus, 27 on the TRIP database, 191 in MEDLINE, 131 on the ScienceDirect, 0 on the Cochrane and 975 on the Google Scholar database. Thus, a total of 1495 papers were found.

After the exclusion of repeated articles, application of exclusion criteria (editorials, commentaries, letters to the editor, conference abstracts, case reports and papers with a sample less than 20 bones), application of inclusion criteria (original research manuscripts, scientific journals and theses; papers that involved human patients or involved cadaveric samples with a sample of 20 bones or more) and reference searching, 141 papers were fully reviewed and 61 studies were included in this meta-analysis. The search process is depicted in Fig. 2.

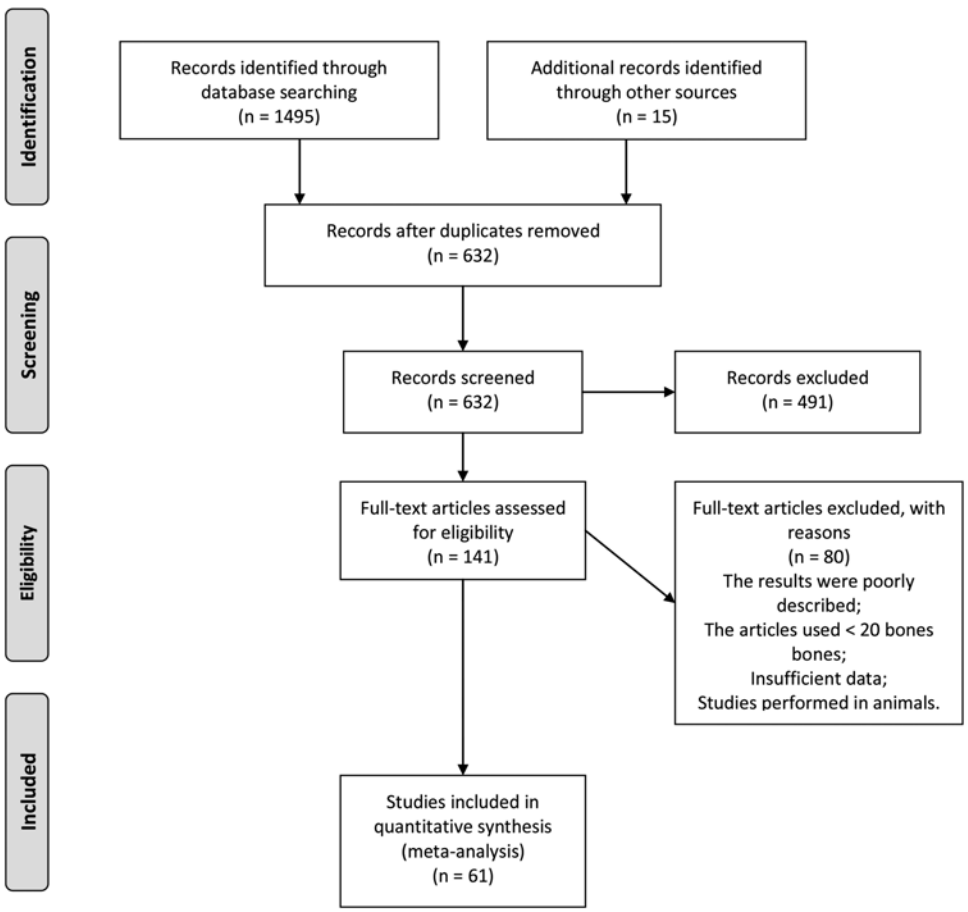

Fig. 2. Flowchart depicting the search process.

Characteristics of included studies

A total of sixty-one studies were included in this meta-analysis (Ajay et al. 2010; Akabori 1934; Akpinar et al. 2003; Ananthi et al. 2011; Arunkumar et al. 2015; Aydin Kabakci et al. 2017; Bhanu & Sankar 2012; Burute et al. 2016; Chagas et al. 2016; Dang et al. 2016; Deshmukh et al. 2018; Diwan et al. 2013; Erdogmus et al. 2014; Ferguson & Stewart 1940; Glanville 1967; Gnes et al. 2018; Jadhav 2015; Joshi et al. 2017; Joshi et al. 2016; Koyun et al. 2011; Krishnamurthy et al. 2011; Kubicka et al. 2015; Li et al. 2015; Mahajan 2011; Mahitha et al. 2016; Manjappa & Premchand 2014; Mathew et al. 2016; Mays 2008; Mayuri et al. 2013; Ming-Tzu 1935; Myszka 2015; Nagar 2011; Nagar et al. 2015; Naqshi et al. 2015; Nayak et al. 2009; Nayak et al. 2007; Ndou et al. 2013; Neiberg 2014; Oláh 1990; Öztürk et al. 2000; Papaloucas et al. 2011; Paraskevas et al. 2010; Patel et al. 2013; Perdikis & Joffe 1962; Pietrusewsky et al. 1991; Raghavendra et al. 2014; Ramamurthi 2016; Riesle & Dastugue 1983; Savitha & Dakshayani 2016; Shivaleela et al. 2016; Singhal & Rao 2007; Smith 1976; Sunday et al. 2014; Taxman 1994; Trotter 1934; Varalakshmi et al. 2014; Veerappan et al. 2013; Veldman 2013; Vladimirovich 2014; Woo 1943; Yutian & Yingyi 1984).

Fifty-five of the studies were conducted using dry bone samples (Ajay et al. 2010; Akabori 1934; Arunkumar et al. 2015; Aydin Kabakci et al. 2017; Bhanu & Sankar 2012; Burute et al. 2016; Dang et al. 2016; Deshmukh et al. 2018; Diwan et al. 2013; Erdogmus et al. 2014; Ferguson & Stewart 1940; Glanville 1967; Gnes et al. 2018; Jadhav 2015; Joshi et al. 2017; Joshi et al. 2016; Krishnamurthy et al. 2011; Li et al. 2015; Mahajan 2011; Mahitha et al. 2016; Manjappa & Premchand 2014; Mathew et al. 2016; Mays 2008; Mayuri et al. 2013; Ming-Tzu 1935; Myszka 2015; Nagar 2011; Nagar et al. 2015; Naqshi et al. 2015; Nayak et al. 2009; Nayak et al. 2007; Ndou et al. 2013; Neiberg 2014; Oláh 1990; Öztürk et al. 2000; Papaloucas et al. 2011; Paraskevas et al. 2010; Patel et al. 2013; Perdikis & Joffe 1962; Pietrusewsky et al. 1991; Raghavendra et al. 2014; Ramamurthi 2016; Riesle & Dastugue 1983; Savitha & Dakshayani 2016; Shivaleela et al. 2016; Singhal & Rao 2007; Smith 1976; Sunday et al. 2014; Taxman 1994; Trotter 1934; Varalakshmi et al. 2014; Veldman 2013; Vladimirovich 2014; Woo 1943; Yutian & Yingyi 1984), and six were imaging studies (Akpinar et al. 2003; Ananthi et al. 2011; Chagas et al. 2016; Koyun et al. 2011; Kubicka et al. 2015; Veerappan et al. 2013); these (55+6=61) were used in further analyses.

The study performed by Glanville (1967) included two samples from different regions (Netherlands and Africa), while the study conducted by Perdikis and Joffe (1962) provided three samples from different continents (Africa, Europe and Asia).

Twenty-eight studies were from South Asia (India) (Ajay et al. 2010; Ananthi et al. 2011; Arunkumar et al. 2015; Bhanu & Sankar 2012; Burute et al. 2016; Dang et al. 2016; Deshmukh et al. 2018; Diwan et al. 2013; Jadhav 2015; Joshi et al. 2017; Joshi et al. 2016; Krishnamurthy et al. 2011; Mahajan 2011; Mahitha et al. 2016; Manjappa & Premchand 2014; Mathew et al. 2016; Mayuri et al. 2013; Naqshi et al. 2015; Nayak et al. 2009; Nayak et al. 2007; Patel et al. 2013; Raghavendra et al. 2014; Ramamurthi 2016; Savitha & Dakshayani 2016; Shivaleela et al. 2016; Singhal & Rao 2007; Varalakshmi et al. 2014; Veerappan et al. 2013). Twelve studies were from Europe (Poland, England, Greece, Netherlands, Western Russia, Hungary, Yugoslavia and Rome) (Glanville 1967; Gnes et al. 2018; Kubicka et al. 2015; Mays 2008; Myszka 2015; Oláh 1990; Papaloucas et al. 2011; Paraskevas et al. 2010; Perdikis & Joffe 1962; Smith 1976; Veldman 2013; Vladimirovich 2014). Eight studies came from the Middle East (Turkey and Israel) (Akpinar et al. 2003; Aydin Kabakci et al. 2017; Erdogmus et al. 2014; Koyun et al. 2011; Nagar 2011; Nagar et al. 2015; Öztürk et al. 2000; Riesle & Dastugue 1983). Six studies came from East Asia (China, Japan and Korea) (Akabori 1934; Li et al. 2015; Ming-Tzu 1935; Perdikis and Joffe 1962; Woo 1943; Yutian & Yingyi 1984). Six studies were from America (Brazil and United States of America) (Chagas et al. 2016; Ferguson & Stewart 1940; Neiberg 2014; Pietrusewsky et al. 1991; Taxman 1994; Trotter 1934) and four studies represented Africa (South Africa, Nigeria, Congo, Angola, Zambia and Mali) (Glanville 1967; Ndou et al. 2013; Perdikis and Joffe 1962; Sunday et al. 2014). These data are also summarized in Table 1.

Table 1. Number of studies by region.

Region	N
Africa	4
America	6
South Asia	28
Middle East	8
East Asia	6
Europe	12

Pooled prevalence and shape of the OAH

A total of sixty-one studies (n = 20338) were included in the analysis of the OAH. The overall pooled prevalence of the OAH was 21.9% (95% confidence interval [CI]: 18.6% to 25.3%).

The OAH was present in 26.6% (95% CI: 21.5% to 31.9%) of 6866 left humeri and in 19.4% (95% CI: 15.3% to 23.8%) of 6860 right humeri in forty-one studies. This was considered to be a statistically significant difference ($p < 0.05$).

The OAH was present in 21.9% (95% CI: 13.5% to 31.8%) of the female sample and in 12.1% (95% CI: 7.4% to 17.6%) of the male sample. This was considered to be a statistically significant difference ($p < 0.05$).

Table 2. Pooled prevalence of the olecranon aperture and its shape.

Sample	N	Pooled prevalence	95% CI	*p*-value
Overall	20338	21.9%	18.6% to 25.3%	–
Left	6866	26.6%	21.5% to 31.9%	< 0.05
Right	6860	19.4%	15.3% to 23.8%	
Female	3703	21.9%	13.5% to 31.8%	< 0.05
Male	6033	12.1%	7.4% to 17.6%	
Shape	1611	–	–	< 0.05
Oval	–	71.0%	–	
Round	–	22.5%	–	
Triangular	–	3.5%	–	
Irregular	–	3.0%	–	

N = number of humeri; CI = confidence interval; $p < 0.05$ was considered significant.

Twenty-four studies (n = 1611) were included in the analysis of the shape the OAH. In 71.0% (95% CI: 61.6% to 76.0%) the shape of the OAH was oval, in 22.5% (95% CI: 17.1% to 28.4%) the shape of the OAH was round, in 3.5% (95% CI: 1.9% to 5.5%) the shape of the OAH was triangular and in 3.0% (95% CI: 1.2% to 5.6%) the shape of the OAH was irregular. This data can be found in Table 2.

According to this meta-analysis, studies performed in Africa had the highest prevalence of the OAH (31.0%), while the studies performed in Europe had the lowest prevalence of the OAH (11.1%). These data are summarized in Table 3.

Statistically significant difference ($p < 0.05$) was observed between the pooled prevalence of OAH from studies performed in Africa and the prevalence reported in studies from South Asia, Middle East, East Asia and Europe (Table 4).

Results of studies conducted in America showed statistical significance ($p < 0.05$) when compared with results from Middle East and Europe. Results of studies conducted in South Asia showed statistical significance ($p < 0.05$) when compared with those reported in papers from Africa, Middle East and Europe.

The pooled prevalence reported in studies from the Middle East showed statistical significance against all other regions. Likewise, the pooled prevalence from Europe showed statistical significance when compared with the prevalence in all other regions except East Asia. The latter also showed statistical significance when compared with the prevalence in all other regions, except, as previously mentioned, results of European studies.

Morphometric analysis

Twenty-two studies (1086 bones) had data regarding the vertical diameter (VD) and the horizontal diameter (HD) of the OAH. The pooled VD was 4.09 mm (standard deviation [SD] = 0.86 mm; 95% CI: 3.71 mm to 4.48 mm), and 4.43 mm (SD = 0.83 mm; 95% CI: 4.06 mm to 4.80 mm) for the right and left sides, respectively. The pooled HD was 5.06 (SD = 1.08 mm; 95% CI: 4.59 mm to 5.53 mm) and 5.45 (SD = 1.31 mm; 95% CI: 4.87 mm to 6.03 mm) for the right and left sides, respectively.

Table 3. Regional pooled prevalence of the olecranon aperture.

Region	N	Pooled prevalence (%)	95% CI
Africa	3386	31.0%	20.3% to 42.8%
America	2290	29.6%	17.9% to 42.8%
South Asia	7103	27.5%	25.2% to 29.8%
Middle East	1735	18.3%	11.1% to 26.7%
East Asia	1533	13.5%	9.5% to 18.0%
Europe	3591	11.1%	5.3% to 18.7%

N= number of humeri; CI = confidence interval; $p < 0.05$ was considered significant.

The difference between left and right side means was not statistically significant at $p > 0.05$. The results are summarized in Table 5.

Discussion

The meta-analysis presented herein compiled data regarding the frequency, shape and size of the OAH in a large number of studies and a large sample of bones. The olecranon aperture was present in 21.9% of 20338 humeri.

According to the literature, the OAH has a predilection for the left side and is more common in women (Chagas et al. 2016; Kubicka et al. 2015; Lamb 1890; Mathew et al. 2016). The findings presented in this meta-analysis corroborated that fact and further added that this difference is statistically significant. Some studies, however, had different results, for example, the work performed by Nayak et al. (2009) showed a predilection for the right side, while in the work conducted by Diwan et al. (2013) the OAH was more

Table 4. *p*-values of the Chi-squared test between regions ($p < 0.05$ was considered significant).

Region	Africa	America	South Asia	Middle East	East Asia	Europe
Africa	–	> 0.05	< 0.05	< 0.05	< 0.05	< 0.05
America	> 0.05	–	> 0.05	< 0.05	> 0.05	< 0.05
South Asia	< 0.05	> 0.05	–	< 0.05	< 0.05	< 0.05
Middle East	< 0.05	< 0.05	< 0.05	–	< 0.05	< 0.05
East Asia	< 0.05	< 0.05	< 0.05	< 0.05	–	> 0.05
Europe	< 0.05	< 0.05	< 0.05	< 0.05	> 0.05	–

Table 5. Pooled morphometric data of the olecranon aperture (N = 1086).

Side	Measurement	Mean (mm)	SD (mm)	*p*-value
Right	VD	4.09	0.86	> 0.05
	HD	5.06	1.08	
Left	VD	4.43	0.83	
	HD	5.45	1.31	

N = number of humeri; VD = vertical diameter; HD = horizontal diameter; SD=Standard deviation; $p < 0.05$ is considered significant.

common in males. In contrast, Singhal & Rao (2007) showed a similar frequency for side (27.9% and 27.8% for the right and left sides, respectively).

Despite side predilection, there were no significant differences between the size of the foramen between the right and left sides. This is in accordance with a few isolated studies (Chagas et al. 2016; Li et al. 2015).

Regional differences were also present, as samples from Africa and India showed a statistically significant higher prevalence than the samples from other populations. In addition, older studies proposed that African populations had a higher prevalence of the OAH than populations from other regions (Hirsh 1927; Lamb 1890). The same has been observed in this meta-analysis, although the number of analyzed studies was not satisfactory (4 studies).

The term "olecranon foramen" is present in older anatomical textbooks (Testut & Latarjet 1958) and older articles (Lamb 1890), however, most papers, recent articles and anatomical textbooks preferred the term supratrochlear foramen (Chagas et al. 2016; Dang et al. 2016; Diwan et al. 2013; Erdogmus et al. 2014; Tubbs et al. 2016), intercondyloid foramen (Ananthi et al. 2011), septal aperture (Mays 2008; Ming-Tzu 1935; Myszka 2015) or supratrochlear aperture (Ndou 2016; Ndou & Schepartz 2016), according to our bibliographic search.

As pointed out by Shivaleela et al. (2016), foramina are conduits for the passage of nerves or vessels, and apertures are merely openings in bones, further reiterating a nomenclature review of this anatomical variant. In addition, recent studies have shown that there are many divergences within the Nomina Anatomica, hence, re-evaluation of these ambiguous terms is needed (Strzelec et al. 2017).

In addition, Roaf (1957) reported a case of the median nerve passing through this aperture, although the author could not confirm that hypothesis. It seems that it was only a case of intra-articular/intra-osseous entrapment of the median nerve caused by traumatic injury during callus formation, a rare complication of elbow fractures (Akansel et al. 2003; Erra et al. 2013). As such, we propose herein that this anatomical variant of the humerus should be labeled as "olecranon aperture", as it does not give passage to any nerve or vessel.

It has been known that the OAH is highly prevalent in some higher primates (gorilla, orangutan, and chimpanzee), while in other primates, such as the gibbon, it shows a low prevalence (Hirsch 1928; Schultz 1937). In other animals, such as cattle, dogs, pigs and rabbits the OAH can also be present (Adams & Crabtree 2008; Haziroglu & Ozer 1990; Sisson et al. 1975). In these animals, the OAH can be used as an anatomical landmark to place pins to treat humeral fractures (Ruberte et al. 2017).

The presence of the OAH has been attributed to many causes, and the articles published by Erdogmus et al. (2014), Myszka (2015) and Chagas et al. (2016) give a good summary of these causes. We will discuss only some of the causes in the following paragraphs.

Bone robusticity was thought to be the cause of the OAH (Benfer & McKern 1966). This theory was revisited by Ndou & Schepartz (2016) who concluded that there was a significant correlation between bone measurements (such as epicondylar breadth and humerus length) and the presence of the OAH, as they observed that bones with the OAH had smaller measurements.

Another question arises if we take into account the fact that the thin bony membrane that separates the olecranon and coronoid fossa is always present until the age of seven years (Nayak et al. 2009). Akabori (1934) stated that the olecranon aperture is absent or rare in embryonic and infantile humeri and the youngest humerus examined by him which had the OAH was from a 9 year-old female.

If the OAH appears whenever there is more pressure on the olecranon fossa, why it is not more prevalent in the elderly? This question remains unanswered. In fact, the article by Myszka (2015) found the opposite: younger humeri had a higher percentage of the OAH, although the studied sample was small. It is hard to obtain accurate data regard-

ing the age of a bone, and it is even harder to obtain bones completely free of pathologies, since the elderly people are more prone to develop diseases that affect bones and joints, which may confuse the observer when studying the OAH, as it may be caused by external factors (Geusens & van den Bergh 2016; Myszka 2015).

The clinical significance of this aperture can be appreciated by a radiologist and an orthopedist, as it can be confused for an osteolytic lesion (Arunkumar et al. 2015; Chagas et al. 2016; Erdogmus et al. 2014). *Osteochondritis dissecans* of the thin wall between the olecranon and coronoid fossae have been reported (Chagas et al. 2016; Tubbs et al. 2016). The presence of the olecranon aperture has also been reported to predispose low-energy fractures of the distal humerus (Sahajpal & Pichora 2006).

Moreover, the studies conducted by Akpinar et al. (2003), Veerappan et al. (2013) and Paraskevas et al. (2010) showed that humeri with the OAH had a narrower medullary canal, thus imposing higher obstacles in intramedullary nailing procedures – an operation performed to treat supracondylar fractures. A recent study performed by Ndou et al. (2017), however, found no relation whatsoever with the width of the medullary canal and the presence of the OAH.

In summary, there are still numerous questions regarding the etiology of the OAH despite several morphological, biomechanical and anthropological studies performed over the years.

Furthermore, there should be a revision of the nomenclature regarding this variation, since the names "supratrochlear foramen" and "septal aperture" are not accurate. We propose a name "olecranon aperture" due to its spatial relationship with the olecranon and the fact that it is not conduit for vessels or nerves.

References

Adams, B. J., & Crabtree, P. J. (2008). Comparative Skeletal Anatomy: A Photographic Atlas for Medical Examiners, Coroners, Forensic Anthropologists, and Archaeologists (1st ed.). Humana Press. https://doi.org/10.1007/978-1-59745-132-1

Ajay, K., Anu, S., & Poonam, S. (2010). A Study of Supratrochlear Foramen of Humerus with Its Clinical Implications. *Clinical Research, 2*, 58–60.

Akabori, E. (1934). Septal Apertures in the Humerus in Japanese, Ainu and Koreans. *American Journal of Physical Anthropology, 18*(3), 395–400. https://doi.org/10.1002/ajpa.1330180320

Akansel, G., Dalbayrak, S., Yilmaz, M., Bekler, H., & Arslan, A. (2003). MRI demonstration of intra-articular median nerve entrapment after elbow dislocation. *Skeletal Radiology, 32*(9), 537–541. https://doi.org/10.1007/s00256-003-0667-4 PMID: 12898058

Akpinar, F., Aydinlioğlu, A., Tosun, N., Doğan, A., Tuncay, I., & Unal, O. (2003). A morphometric study on the humerus for intramedullary fixation. *The Tohoku Journal of Experimental Medicine, 199*(1), 35–42. https://doi.org/10.1620/tjem.199.35 PMID:12688558

Ananthi Kumarasamy, S., Subramanian, M., Gnanasundaram, V., Subramanian, A., & Ramalingam (2011). Study of Intercondyloid Foramen of Humerus. *Argentine Journal of Clinical Anatomy, 3*, 32–36.

Arunkumar, K. R., Manoranjitham, R., Raviraj, K., & Dhanalakshmi, V. (2015). Morphological Study of Supratrochlear Foramen of Humerus and Its Clinical Implications. *International Journal Anatomy and Research, 3*(3), 1321–1325. https://doi.org/10.16965/ijar.2015.233

Aydin Kabakci, A. D., Buyukmumcu, M., Yilmaz, M. T., Cicekcibasi, A. E., Akın, D., & Cihan, E. (2017). An Osteometric Study on Humerus. *International Journal of Morphology, 35*(1), 219–226. https://doi.org/10.4067/S0717-95022017000100036

Benfer, R. A., & McKern, T. W. (1966). The correlation of bone robusticity with the perforation of the coronoid-olecranon septum in the humerus of man. *American Journal of Physical Anthropology, 24*(2), 247–252. https://doi.org/10.1002/ajpa.1330240213 PMID:5938202

Bhanu, P. S., & Sankar, K. D. (2012). Anatomical Note of Supratrochlear Foramen of Humerus in South Costal Population of Andhra Pradesh. *NMJ, 1*, 28–34.

Burute, P., Singhal, S., & Priyadarshini, S. (2016). Supratrochlear Foramen; Morphological Correlation and Clinical Significance in Western Maharashtrian Population. *Indian Journal of Anatomy, 5*(3), 275–279. https://doi.org/10.21088/ija.2320.0022.5316.13

Chagas, C. A., Gutfiten-Schlesinger, G., Leite, T. F., Pires, L. A., & Silva, J. G. (2016). Anatomical and Radiological Aspects of the Supratrochlear Foramen in Brazilians. *Journal of Clinical and Diagnostic Research : JCDR, 10*(9), AC10–AC13. https://doi.org/10.7860/JCDR/2016/21846.8503 PMID:27790415

Cruveilhier, J. (1851). *Tratado De Anatomia Descriptiva*. Madrid: Abienzo.

Dang, B., Malik, V. S., & Parmar, P. (2016). Supratrochlear Foramen: Incidence, Importance and Clinical Implications in North-Indian Population. *International Journal of Integrative Medical Sciences, 3*(4), 265–269. https://doi.org/10.16965/ijims.2016.113

DeCamp, C. E., Johnston, S. A., Déjardin, L. M., & Schaefer, S. L. (2016). *Brinker, Piermattei and Flo's Handbook of Small Animal Orthopedics and Fracture Repair* (5th ed.). Missouri: Elsevier.

Deshmukh, V. R., Arathala, R., & Seth, S. (2018). The Supratrochlear Foramen of the Humerus: Formation and Clinical Implications. *International Journal of Scientific Research (Ahmedabad, India), 7*, 763–765.

Diwan, R. K., Rani, A., Rani, A., Chopra, J., Srivastava, A. K., Sharma, P. K., … Pankaj, A. K. (2013). Incidence of Supratrochlear Foramen of Humerus in North Indian Population. *Biomedical Research, 24*, 142–145.

Erdogmus, S., Guler, M., Eroglu, S., & Duran, N. (2014). The importance of the supratrochlear foramen of the humerus in humans: An anatomical study. *Medical Science Monitor, 20*, 2643–2650. https://doi.org/10.12659/MSM.892074 PMID: 25515544

Erra, C., Granata, G., Liotta, G., Podnar, S., Giannini, M., Kushlaf, H., … Padua, L. (2013). Ultrasound diagnosis of bony nerve entrapment: Case series and literature review. *Muscle & Nerve, 48*(3), 445–450. https://doi.org/10.1002/mus.23845 PMID: 23512616

Ferguson, A. L. L., & Stewart, T. D. (1940). An Ossuary near Piscataway Creek, a Report on the Skeletal Remains. *American Antiquity, 6*(01), 4–18. https://doi.org/10.2307/275942

Geusens, P. P., & van den Bergh, J. P. (2016). Osteoporosis and osteoarthritis: Shared mechanisms and epidemiology. *Current Opinion in Rheumatology, 28*(2), 97–103. https://doi.org/10.1097/BOR.0000000000000256 PMID:26780427

Gilroy, A. M., MacPherson, B. R., & Schuenke, M. (2016). *Atlas of Anatomy* (3rd ed.). New York: Thieme.

Glanville, E. V. (1967). Perforation of the coronoid-olecranon septum. Humero-ulnar relationships in Netherlands and African populations. *American Journal of Physical Anthropology, 26*(1), 85–92. https://doi.org/10.1002/ajpa.1330260111 PMID:5633731

Gnes, M., Baldoni, M., Marchetti, L., Basoli, F., Leonardi, D., Canini, A., … Martínez-Labarga, C. (2018). Bioarchaeological Approach to the Study of the Medieval Population of Santa Severa (Rome, 7th–15th Centuries). *Journal of Archaeological Science, 18*, 11–25.

Haziroglu, R. M., & Ozer, M. (1990). A supratrochlear foramen in the humerus of cattle. *Anatomia, Histologia, Embryologia, 19*(2), 106–108. https://doi.org/10.1111/j.1439-0264.1990.tb00893.x PMID:2240581

Henry, B. M., Tomaszewski, K. A., &Walocha, J. A. (2016). Methods of Evidence-Based Anatomy: A guide to conducting systematic reviews and meta-analysis of anatomical studies. *Annals of Anatomy, 205*, 16–21. https://doi.org/10.1016/j.aanat.2015.12.002 PMID:26844627

Hirsch, I. S. (1928). On a Foramen in the Lower Extremity of the Humerus. *Radiology, 10*(3), 199–208. https://doi.org/10.1148/10.3.199

Hirsh, I. S. (1927). The supratrochlear foramen: Clinical and anthropological considerations. *American Journal of Surgery, 2*(5), 500–505. https://doi.org/10.1016/S0002-9610(27)90533-9

Jadhav, S. (2015). Supratrochlear Foramen and Its Clinical Significance. *Asian Journal of Biomedical and Pharmaceutical Sciences, 5*(46), 13–15. https://doi.org/10.15272/ajbps.v5i46.712

Joshi, M., Chavda, D., Vaniya, V. H., & Sutterwala, I. (2017). Anatomical Study of Supratrochlear Foramen of Humerus and Its Clinical Significance. *Journal of the Anatomical Society of India, 66*, S5–S6. https://doi.org/10.1016/j.jasi.2017.08.022

Joshi, M. M., Kishve, P. S., & Wabale, R. N. (2016). A Morphometric Study of Supratrochlear Foramen of the Humerus in Western Indian Dry Bone Sample. *International Journal of Anatomy and Research, 4*(3.1), 2609–2613. https://doi.org/10.16965/ijar.2016.291

Koyun, N., Aydinlioğlu, A., & Gümrukcüoğlu, F. N. (2011). Aperture in coronoid-olecranon septum: A radiological evaluation. *Indian Journal of Orthopaedics, 45*(5), 392–395. https://doi.org/10.4103/0019-5413.83945 PMID:21886918

Krishnamurthy, A., Yelicharla, A. R., Takkalapalli, A., Munishamappa, V., Bovinndala, B., & Chandramohan, M. (2011). Supratrochlear Foramen of Humerus – a Morphometric Study. *International Journal of Biological and Medical Research, 2*, 829–831.

Kubicka, A. M., Myszka, A., & Piontek, J. (2015). Geometric morphometrics: Does the appearance of the septal aperture depend on the shape of ulnar processes? *Anatomical Record (Hoboken, N.J.), 298*(12), 2030–2038. https://doi.org/10.1002/ar.23272 PMID:26402574

Lamb, D. S. (1890). The Olecranon Perforation. *American Anthropologist, 3*(2), 159–174. https://doi.org/10.1525/aa.1890.3.2.02a00050

Latarjet, M., & Liard, A. R. (2011). *Anatomía Humana* (4th ed.). Madrid: Editorial Medica Pan-Americana.

Li, J., Mao, Q., Li, W., & Li, X. (2015). An anatomical study of the supratrochlear foramen of the Jining population. *Turkish Journal of Medical Sciences, 45*(6), 1369–1373. https://doi.org/10.3906/sag-1407-44 PMID:26775396

Mahajan, A. (2011). Supratrochlear Foramen; Study of Humerus in North Indians. *The Professional Medical Journal, 18*, 128–132.

Mahitha, B., Jitendra, R., Janaki, V., & Navakalyani, T. (2016). Supratrochlear Foramen of Humerus in Telangana State: A Morphometric Study. *International Journal of Anatomy and Research, 4*(2), 2450–2453. https://doi.org/10.16965/ijar.2016.234

Manjappa, T., & Premchand, S. A. (2014). Incidence and Morphometric Study of Humeral Septal Aperture in South Indian Population of Karnataka Region. *International Journal of Pharma and Bio Sciences, 5*, B788–B792.

Mathew, A. J., Gopidas, G. S., & Sukumaran, T. T. (2016). A Study of the Supratrochlear Foramen of the Humerus: Anatomical and Clinical Perspective. *Journal of Clinical and Diagnostic Research : JCDR, 10*(2), AC05–AC08. https://doi.org/10.7860/JCDR/2016/17893.7237 PMID:27042437

Mays, S. (2008). Septal aperture of the humerus in a mediaeval human skeletal population. *American Journal of Physical Anthropology, 136*(4), 432–440. https://doi.org/10.1002/ajpa.20826 PMID:18350584

Mayuri, J., Aparna, T., Pradeep, P., & Smita, M. (2013). Anatomical Study of Supratrochlear Foramen of Humerus. *Journal of Research in Medical and Dental Science, 1*, 33–35.

Meckel, G.-F. (1831). Manual of General, Descriptive and Pathological Anatomy. Philadelphia: Carey & Lea.

Ming-Tzu, P. A. (1935). Septal Apertures in the Humerus in the Chinese. *American Journal of Physical Anthropology, 20*(2), 165–170. https://doi.org/10.1002/ajpa.1330200204

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G., & the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine, 151*(4), 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135 PMID:19622511

Moore, K. L., Dalley, A. F., II, & Agur, A. M. R. (2014). *Clinically Oriented Anatomy* (7th ed.). Philadelphia: Lippincott Williams & Wilkins.

Myszka, A. (2015). Septal aperture aetiology: Still more questions than answers. *Folia Morphologica, 74*(2), 219–224. https://doi.org/10.5603/FM.2015.0034 PMID:26050810

Nagar, Y. (2011). Human Osteological Database at the Israel Antiquities Authority. *Bioarchaeology of the Near East, 5*, 1–18.

Nagar, Y., Abramov, J., & Varga, D. (2015). Human Remains from Amaziya/Duweimeh, Israel (2012. *Bioarchaeology of the Near East, 9*, 69–78.

Naqshi, B. F., Shah, A. B., Gupta, S., Raina, S., Khan, H. A., Gupta, N., & Hassan, N. (2015). Supratrochlear Foramen: An Anatomic and Clinico-Radiological Assessment. *International Journal of Health Sciences and Research, 5*, 146–150.

Nayak, S. R., Das, S., Krishnamurthy, A., Prabhu, L. V., & Potu, B. K. (2009). Supratrochlear foramen of the humerus: An anatomico-radiological study with clinical implications. *Upsala*

Journal of Medical Sciences, 114(2), 90–94. https://doi.org/10.1080/03009730802688819 PMID:19396695

Nayak, S. R., Kumar, M., Krishnamurthy, A., Prabhu, L. V., D'Costa, S., Ramanathan, L. A., … Gorantla, V. R. (2007). Population distance between Dakshina Kannada (South India) and Gujarati (North India) population using infracranial non-metric traits. *Romanian Journal of Morphology and Embryology, 48*(4), 369–372. PMID:18060180

Ndou, R. (2016). The significance of the supratrochlear aperture (STA) in elbow range of motion: An anatomical study. *Anatomical Science International, 93*(1), 88–97. https://doi.org/10.1007/s12565-016-0376-4 PMID:27730491

Ndou, R., Maharaj, S., &Schepartz, L. A. (2017). A radiographic investigation of the relationships between humeral cortical bone thickness, medullary canal width and the supratrochlear aperture (STA). *Surgical and Radiologic Anatomy, 39*(1), 57–68. https://doi.org/10.1007/s00276-016-1701-2 PMID:27241519

Ndou, R., & Schepartz, L. A. (2016). Morphometric Characteristics of the Humerus and Ulna in Limbs Bearing the Supratrochlear Aperture (STA). *Anatomical Record (Hoboken, N.J.), 299*(2), 220–233. https://doi.org/10.1002/ar.23294 PMID:26579992

Ndou, R., Smith, P., Gemell, R., & Mohatla, O. (2013). The supratrochlear foramen of the humerus in a South African dry bone sample. *Clinical Anatomy (New York, N.Y.), 26*(7), 870–874. PMID:22855439

Neiberg, M. L. (2014). *A Non-Metric Trait Variation Analysis of 15th Century Prehistoric Skeletal Remains* (p. 86). Indiana: Ball State University.

Netter, F. H. (2014). *Atlas of Human Anatomy* (6th ed.). Philadelphia: Saunders.

Oláh, S. (1990). Investigation of Bilateral Non-Metric Traits in a Sample from the 10th Century. *Acta Biologica Szegediensis, 36*, 75–79.

Öztürk, A., Kutlu, C., Bayraktar, B., Zafer, A., & Sahinoglu, K. (2000). [The Supratrochlear Foramen in the Humerus (Anatomical Study)]. *Istanbul Tip Fakultesi Mecmuasi, 63*, 55–58.

Papaloucas, C., Papaloucas, M., & Stergioulas, A. (2011). Rare Cases of Humerus Septal Apertures in Greeks. *Trends in Medical Research, 6*(3), 178–183. https://doi.org/10.3923/tmr.2011.178.183

Paraskevas, G. K., Papaziogas, B., Tzaveas, A., Giaglis, G., Kitsoulis, P., & Natsis, K. (2010). The supratrochlear foramen of the humerus and its relation to the medullary canal: A potential surgical application. *Medical Science Monitor, 16*(4), BR119–BR123. PMID:20357712

Patel, S. V. K., Sutaria, L., Nayak, T. V., Kanjiya, D. P., Patel, B. M. H., & Aterkar, S. (2013). Morphometric Study of Supratrochlear Foramen of Humerus. *International Journal of Biomedical and Advance Research, 4*(2), 89–92. https://doi.org/10.7439/ijbar.v4i2.892

Perdikis, P. A., & Joffe, H. B. (1962). The Incidence of the Supracondyloid Process and Supratrochlear Foramen in Humeri of Bantu-Speaking Negroids. *South African Journal of Science, 58*, 23–31.

Pietrusewsky, M., Douglas, M. T., Kalima, P. A., & Ikehara, R. M. (1991). *Human Skeletal and Dental Remains from the Honokahua Burial Site Land of Honokahua*. Hawai'i: Lahaina District Island of Maui.

Platzer, W. (ed.) (2013). *Taschenatlas Anatomie 1, Bewegungsapparat* (11th ed.). France: Georg Thieme Verlag. https://doi.org/10.1055/b-002-33693

Raghavendra, K., Reddy, Y. A. K., Shirol, V. S., Dixit, D., & Desai, S. P. (2014). Morphometric Analysis of Septal Aperture of Humerus. *International Journal of Medical Research & Health Sciences, 3*, 269–272. https://doi.org/10.5958/j.2319-5886.3.2.058

Ramamurthi, K. S. (2016). Morphometric Analysis of Supratrochlear Foramen of Humerus in South Indian Population. *Scholars Academic Journal of Biosciences, 4*, 908–910.

Riesle, P. S., & Dastugue, J. (1983). The Population of the Konamazan Region of Luristan in the Late Bronze Age and in Theiron Period. *East and West, 33*, 177–216.

Roaf, R. (1957). Foramen in the humerus caused by the median nerve. *J. Bone Joint Surg., 39-B*(4), 748–749. https://doi.org/10.1302/0301-620X.39B4.748 PMID:13491642

Rouvière, H., & Delmas, A. (2002). *Anatomie Humaine: Descriptive, Topographique Et Fonctionelle* (15th ed.). Paris: Masson.

Ruberte, J., Carretero, A., & Navarro, M. (2017). *Morphological Mouse Phenotyping: Anatomy, Histology and Imaging* (1st ed.). New York: Elsevier.

Sahajpal, D. T., & Pichora, D. (2006). Septal aperture: An anatomic variant predisposing to bilateral low-energy fractures of the distal humerus. *Canadian Journal of Surgery, 49*(5), 363–364. PMID:17152577

Savitha, V., & Dakshayani, K. R. (2016). Study of Supratrochlear Foramen of Humerus. *International Journal of Anatomy and Research, 4*, 2979–2983. https://doi.org/10.16965/ijar.2016.387

Scheuer, L., & Black, S. (2000). *Developmental Juvenile Osteology* (1st ed.). New York: Academic Press.

Schultz, A. H. (1937). Proportions, Variability and Asymmetries of the Long Bones of the Limbs and Clavicles in Man and Apes. *Human Biology, 9*, 281–328.

Schünke, M., Schulte, E., & Schumacher, U. (2011). *Prometheus Lernatlas der Anatomie* (3rd ed.). Germany: George Thieme Verlag.

Sharpey, W., Thomson, A., & Cleland, J. (1864). *Quain's Anatomy*. London: Walton and Marberly.

Shivaleela, C., Afroze, K. H., & Lakshmiprabha, S. (2016). An osteological study of supratrochlear foramen of humerus of south Indian population with reference to anatomical and clinical implications. *Anatomy & Cell Biology, 49*(4), 249–253. https://doi.org/10.5115/acb.2016.49.4.249 PMID:28127499

Singhal, S., & Rao, V. (2007). Supratrochlear foramen of the humerus. *Anatomical Science International, 82*(2), 105–107. https://doi.org/10.1111/j.1447-073X.2007.00172.x PMID:17585566

Sisson, S., Grossman, J. D., & Getty, R. (1975). *Sisson and Grossman's the Anatomy of the Domestic Animals* (5th ed.). Philadelphia: W B Saunders.

Smith, F. H. (1976). The Neandertal remains from Krapina, northern Yugoslavia: An inventory of the upper limb remains. *Zeitschrift fur Morphologie und Anthropologie, 67*(3), 275–290. PMID:1007392

Spalteholz, W. (1975). *Atlas De Anatomía Humana* (9th ed.). Barcelona: Editorial Labor, S. A.

Standring, S. (2008). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (40th ed.). Edinburgh: Churchill Livingstone.

Strzelec, B., Chmielewski, P. P., & Gworys, B. (2017). The Terminologia Anatomica matters: Examples from didactic, scientific, and clinical practice. *Folia Morphologica, 76*(3), 340–347. https://doi.org/10.5603/FM.a2016.0078 PMID:28026851

Sunday, O. O., Olusegun, O. S., & Oluwabunmi, B. M. (2014). The Supratrochlear Foramen of the Humerus: Implications for

Intramedullary Nailing in Distal Humerus. *Journal of Biology, Agriculture and Healthcare, 4*, 136–139.

Taxman, S. M. (1994). Nonmetric Trait Variation in the Adena Peoples of the Ohio River Drainage. *Midcontinental Journal of Archaeology, MCJA, 19*, 71–98.

Testut, L., & Latarjet, A. (1958). *Tratado De Anatomía Humana* (8th ed.). Barcelona: Salvat.

Trotter, M. (1934). Septal Apertures in the Humerus of American Whites and Negroes. *American Journal of Physical Anthropology, 19*(2), 213–227. https://doi.org/10.1002/ajpa.1330190221

Tubbs, R. S., Shoja, M. M., & Loukas, M. (2016). *Bergman's Comprehensive Encyclopedia of Human Anatomic Variation* (1st ed.). New Jersey: Wiley-Blackwell.

Varalakshmi, K. L., Shetty, S., & Sulthana, Q. (2014). Study of Supratrochlear Foramen of Humerus and Its Clinical Importance. *IOSR J. Dent. Med. Sci., 13*, 68–70. https://doi.org/10.9790/0853-13726870

Veerappan, V., Ananthi, S., Gopal, N., Kannan, G., Prabhu, S., & Karthikeyan (2013). Anatomical and Radiological Study of Supratrochlear Foramen of Humerus. *WJPPS, 2*, 313–320.

Veldman, J. K. (2013). *Non-Metric Traits. An Assessment of Cranial and Post-Cranial Non-Metric Traits in the Skeletal Assemblage from the 17th–19th Century Churchyard of Middenbeemster, the Netherlands*. Department of Archaelogy. Leiden University.

Vladimirovich, P. E. (2014). Traits of Non-Metric Variation on Postcranial Skeleton Bones: The Case of Anthropological Material from the Necropolis Site of Ancient Settlement Vodyanskoe. *Vestn. Volgograd., 4*, 51–70.

Wolf-Heidegger, G. (1971). *Atlas der Systematischen Anatomie des Menschen* (2nd ed.). Basel: Karger.

Woo, T. L. (1943). A Study of the Chinese Humerus. *Biometrika, 33*(1), 36–47. https://doi.org/10.1093/biomet/33.1.36

Yutian, Y., & Yingyi, L. (1984). Investigation on the Supratrochlear Foramen in the Chinese Humerus. *Acta Anthropologica Sinica, 3*, 334–340.

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