

**TO THE ACADEMIC COUNCIL OF THE FACULTY OF MEDICINE,  
UNIVERSITY OF BELGRADE**

At the meeting of the **Academic Council** of the Faculty of Medicine in Belgrade, held on April 3, 2024, under reference number 19/XXIII-4/3-IV, a committee was appointed to evaluate the completed doctoral dissertation titled:

**“Forensic taphonomy of mass graves – importance of quantifying  
skeletal remains fragmentation”**

the candidate Igor Vaduvesković, employed at the Center for Skeletal Biology, Institute of Anatomy, Faculty of Medicine, University of Belgrade. The mentor is Prof. Dr. Marija Đurić.

The committee for the evaluation of the completed doctoral dissertation is composed of:

1. Prof. Dr. Slobodan Nikolić, Professor at the Faculty of Medicine in Belgrade
2. Prof. Dr. Danijela Đonić, Professor at the Faculty of Medicine in Belgrade
3. Prof. Dr. Mirjana Roksandić, Professor at the Department of Anthropology, University of Winnipeg, Canada

Based on the analysis of the submitted doctoral dissertation, the committee unanimously submits the following to the Academic Council of the Faculty of Medicine:

**REPORT**

**A) Overview of the Doctoral Dissertation Content**

Igor Vaduvesković's doctoral dissertation consists of a total of 45 pages and is divided into the following chapters: introduction, research objectives, materials and methods, results, discussion, conclusions, and references. The dissertation contains a total of four tables, 7 graphs, and 15 figures. It includes an abstract in both Serbian and English, the candidate's biography, and information about the committee.

In the **introduction**, fundamental concepts related to the investigation of mass graves and data analysis from a forensic context are defined, including the tissue decomposition process and taphonomic factors influencing body decomposition. Additionally, geological and

anthropogenic taphonomic factors altering human remains in mass graves are elucidated. Towards the end of the introduction, the issue of fragmentation of human remains in mass graves is addressed, along with the principles of quantifying mixed and fragmented osteological material. The latest research findings on the phenomenon of fragmentation in mass graves are presented. The introduction highlights the importance of engaging in bioanthropological research, specifically studying taphonomic processes in mass graves for forensic purposes. Natural processes of body decomposition and skeletonization in different environments are considered, as well as processes induced by human activity. The introduction also outlines the fundamental issues related to skeletal taphonomy research for forensic purposes, suggesting that most modifications of human remains in mass graves occur due to human activity peri or post mortem, and the degree of fragmentation of human remains reflects circumstances surrounding the death or post-mortem treatment of individuals. A review of recent methodological studies on possible causes of varying degrees of body fragmentation in secondary mass graves is provided as an overview of new insights.

The **objectives** of the study are precisely defined. Given the high variability of human remains fragmentation in mass graves, there is a need for its quantification. The quantification of bone fragmentation involves calculating the Fragmentation Index (FI) using a formula developed by the author and mentor, which was employed for the first time in this type of research. FI was calculated for each analyzed mass grave, and the distribution of different levels of fragmentation in the entire group of examined graves was analyzed. The difference in FI between primary and secondary graves was explored. A comparative analysis of FI levels among secondary mass graves with similar chronologies and formation histories was conducted, along with the calculation of the correlation between the Fragmentation Index (FI) and the error in estimating the Minimum Number of Individuals (MNI). Furthermore, a difference in fragmentation between primary and secondary mass graves was observed, as expected. However, the variability of fragmentation among secondary graves formed in the same manner is exceptional. Determining the reasons for this variability is also an objective of this study.

In the **materials and methods** chapter, it is stated that the study is based on data from 13 mass graves (two primary and 11 secondary) resulting from armed conflicts in the former Yugoslavia (1995 and 1999): Rudnica, Cerska, Lažete 01, Budak 01, Čančarski put 04, Čančarski put 06, Čančarski put 08, Čančarski put 10, Hodžići put 01, Hodžići put 02, Liplje 02, Liplje 07, and Zeleni Jadar 04. The Rudnica site was investigated by a forensic team from the Faculty of

Medicine in Belgrade, from whose report the data were extracted. Other sites were investigated by the International Commission on Missing Persons (ICMP), and the data were systematized in the databases of the Republic Center for Research of War, War Crimes, and Search for Missing Persons (Banja Luka, Republika Srpska). The candidate participated in excavations at all mentioned sites. The analyzed documentation contains original forensic field reports from which data on the number of bodies and body parts (totaling more than 5000 cases) excavated from each grave were extracted, as well as information on the estimated MNI and results from available DNA analyses (number of different DNA profiles, DNA count). These data are necessary for calculating the Fragmentation Index (FI), which quantifies the relationship between (approximately) complete bodies (trunk with head and limbs), body parts (isolated heads, limbs, hands, feet, and parts of the trunk, or other body parts containing at least two articulated bones), and isolated bones (bones not articulated with other bones, either whole or fragmented). In current forensic archaeology protocols, cases involving human remains are labeled as 'B' (body) if they represent a complete or at least 75% of a body. The label 'BP' (body part) refers to parts of human remains containing at least two articulated bones, while the term 'GBP' (general body part) is assigned to smaller body parts (individual bones or bone fragments) that are not connected in situ to any other remains in their immediate vicinity.

The FI is calculated by dividing the number of complete bodies by the sum of body parts, isolated bones, and complete bodies:  $FI = B / (BP + GBP + B)$ . FI can have values between 0 and 1, where a lower index value indicates more fragmented and more disarticulated bodies in the grave. The error in estimating the MNI was also calculated using the following formula:  $MNI\ error = (MNI - DNA\ count) / DNA\ count (\%)$ . The correlation between the obtained MNI error and FI values for the given sites was examined, showing the relationship between MNI error and the degree of fragmentation of skeletal remains. FI and MNI error were described descriptively as the mean  $\pm$  standard deviation or median (min-max) depending on the normality of the data distribution (Kolmogorov-Smirnov test). The difference in FI between primary and secondary graves was examined using an appropriate statistical test for assessing the significance of two independent samples. The association between MNI error and FI was examined considering normal distribution using Pearson correlation. A p-value less than 0.05 was considered statistically significant. Origin software was used for statistical analysis.

In the **results** chapter, all obtained results are described in detail and clearly presented.

The **discussion** is written clearly and comprehensively, with a presentation of data from other studies and a comparative overview of the results obtained in the doctoral dissertation.

The **conclusions** succinctly summarize the most important findings arising from the work's results.

The used **literature** contains a list of 104 references.

## **B) Verification of the Originality of the Doctoral Dissertation**

Based on the Regulations on the Procedure for Checking the Originality of Doctoral Dissertations Defended at the University of Belgrade and the findings in the iThenticate report used to check the originality of the doctoral dissertation titled 'Forensic Taphonomy of Mass Graves – Importance of Quantifying Skeletal Remains Fragmentation,' authored by Igor Vaduvesković, we note that the determined Similarity Index of the text is 26%. The most significant source of this degree of similarity is the overlap of sentence parts in the dissertation text with the content of scientific publications resulting from work on this doctoral thesis that is listed in the reference list and cited in the dissertation:

Matching of 12% (1535 words) of the dissertation content with a scientific publication:

- Vaduvesković I, Djuric M. Mass grave complexity effects on the minimum number of individuals estimation. *Forensic Sci Med Pathol.* 2020 Mar 1;16(1):57–64. DOI:[10.1007/s12024-019-00186-3](https://doi.org/10.1007/s12024-019-00186-3);

Matching of 7% (917 words) of the dissertation content with a scientific publication:

- Vaduveskovic I, Starovic A, Byard RW, Djuric M. Could a “body fragmentation index” be useful in reconstructing events prior to burial: Case studies of selected primary and secondary mass graves from eastern Bosnia. *Leg Med.* 2020 Nov 1;47:101766. DOI: [10.1016/j.legalmed.2020.101766](https://doi.org/10.1016/j.legalmed.2020.101766);

The mentioned publications are original scientific works by the candidate, where the candidate is the first author of the referenced papers, thus this type of content matching in the doctoral thesis is in accordance with Article 9 of the Regulations on the Procedure for Checking the Originality of Doctoral Dissertations Defended at the University of Belgrade. Furthermore, the content of this doctoral thesis has shown a low degree of similarity (<1%) with numerous sources due to the consistency in referencing and authors, the use of the same methodological approach, and the utilization of recommended definitions and abbreviations of analyzed bone parameters, as well as the consistency in citing institution names, abbreviations of certain

terms, phrase repetitions, and the like. Examples of such terms include: „*Doctoral dissertation, figure, mass grave, primary mass grave, secondary mass grave, taphonomy, bodies (B), body parts (BP), general body parts (GBP), minimum number of individuals (MNI), most likely number of individuals (MLNI), number of identified specimens (NISP), peri mortem, post mortem, ante mortem, United Nations, time of death, ligaments, tendons, Centre for Research of War, War Crimes, and tracing of missing persons in Banja Luka, Republic of Srpska, archaeology, forensic archaeology, stratigrafic method, methods, corelation, DNA, repeat loci, HLA typing, Pearsons corelation, P value, peptides, amino acids, quantity, quality, sex, age, individuals...*“

Based on all the aforementioned, and in accordance with Article 8, Paragraph 2, of the Regulations on the Procedure for Checking the Originality of Doctoral Dissertations Defended at the University of Belgrade, we consider that the report indicates the originality of the doctoral dissertation. Therefore, the prescribed procedure for its defense preparation may proceed.

### **C) Brief Description of Achieved Results**

The significance of this research lies primarily in its multidisciplinary approach, which combines methodological knowledge from the fields of forensic archaeology, forensic anthropology, and taphonomy. By employing a newly developed method, this research has, for the first time, achieved precise, numerical quantification of the fragmentation of human osteological material in mass graves. This method has defined the Fragmentation Index (FI), applicable to human osteological material in a forensic context. For the first time, the research has determined whether the Minimum Number of Individuals (MNI) technique is applicable in mass graves and to what extent it introduces errors in estimation across different graves concerning the degree of fragmentation of human remains. It has also investigated whether mass graves with similar chronologies and formation processes exhibit the same degree of fragmentation of human remains. FI analyses have revealed differences in fragmentation that, due to the same geological/chronological context of the graves, may be solely attributable to human activities (peri-mortem and/or post-mortem) on the buried individuals.

Three groups of sites emerged from the analysis. The first group consists of secondary mass graves showing the highest level of fragmentation (FI below 0.15). In contrast, the primary mass graves represent the opposite extreme in terms of Fragmentation Index (FI) values (0.90 and 0.92 for Lazete and Cerska). The third group falls between the previous two, comprising secondary mass graves with significantly higher FI values compared to the first group of

secondary sites. These sites include Rudnica, Cancari Road 04, Hodzici Road 01, and Hodzici Road 02 (FI between 0.29 and 0.59). These findings, in synergy with forensic reports on causes of death, suggest that not all victims of the events leading to the creation of these mass graves were shot and subsequently buried, but that some individuals may have been victims of combat-related injuries involving the use of explosive weapons.

Furthermore, the newly established Fragmentation Index has shown that the MNI method is completely ineffective in secondary graves due to high fragmentation and carries no weight in identifying victim groups or estimating the number of represented individuals. This study represents pioneering research that encompasses the analysis of a large sample of skeletal material and focuses on anthropogenically induced taphonomic changes observed through the completeness of skeletal remains.

#### **D) Comparative Analysis of the Doctoral Dissertation with Literature Results**

The world-renowned archaeologist Lewis Binford, followed by Lyman, was the first to investigate the complex taphonomic factors that alter grave contents (the collection of all bones within a grave) (Binford 1981, Lyman 1994). They observed that humans play a crucial role in the process of bone mixing and scattering, especially in cases involving the concealment of criminal activities, which may include burning, fragmentation, or relocation of post-mortem remains. In the context of forensic anthropology, many scientists have considered taphonomic processes on bones, among whom the most prominent are Haglund, W.D., and Sorg M.H. (Behrensmeyer 1978, Haglund and Sorg 1997, Blau 2017, Pokines and Symes 2013).

However, literature dealing with taphonomy in terms of bone fragmentation originally comes from zooarchaeological research. In order to describe the degree of fragmentation, archaeologist Curtis Marean introduced the Completeness Index (CI), which is calculated based on the number of carpal and tarsal bones (Marean 1991). Marean's completeness index is a significant improvement over earlier fragmentation indices by Klippel and Cruz-Uribe, based on the ratios of NISP:MNI or NISP:MNE (Klein RG, Cruz-Uribe K, 1984). NISP stands for the number of identified specimens, MNI represents the minimum number of individuals, and MNE is the minimum number of skeletal elements needed for a sample. Lyman describes the NISP:MNI ratio as a measure of "fragmentation intensity" (Lyman 1994). The limitation of this method is that both MNI and MNE are derived values that never truly represent the actual state of the sample."

Quantification of human remains fragmentation in a forensic context, such as mass graves, can be achieved using the so-called Fragmentation Index (FI) (Vaduveskovic et al. 2020). In this regard, this doctoral thesis represents a shift in discourse from zooarchaeology, focusing precisely on elements of taphonomic analysis on fragmented human skeletal remains. In this context, this research brings a detailed analysis of fragmentation phenomena and a precise methodological approach, drawing on knowledge from related disciplines to provide new insights into the problem of skeletal fragmentation in secondary mass graves, as well as all factors influencing the fragmentation and incompleteness of the material.

### **E) Published Works Included in the Doctoral Dissertation**

#### **M23, IF 1.8**

1. Vaduvesković I, Djuric M. Mass grave complexity effects on the minimum number of individuals estimation. *Forensic Sci Med Pathol.* 2020 Mar 1;16(1):57–64. DOI: [10.1007/s12024-019-00186-3](https://doi.org/10.1007/s12024-019-00186-3)

#### **M22, IF 2.0**

2. Vaduveskovic I, Starovic A, Byard RW, Djuric M. Could a “body fragmentation index” be useful in reconstructing events prior to burial: Case studies of selected primary and secondary mass graves from eastern Bosnia. *Leg Med.* 2020 Nov 1;47:101766. DOI: [10.1016/j.legalmed.2020.101766](https://doi.org/10.1016/j.legalmed.2020.101766)

#### **C1, IF 0.29**

3. Vaduvesković I, Djuric M. Forenzička tafonomija masovnih grobnica. *Medicinski Podmladak* 2024. DOI: 10.5937/mp76-41657

### **F) Conclusion (Justification of Scientific Contribution)**

The doctoral dissertation 'Forensic Taphonomy of Mass Graves – Significance of Quantifying Skeletal Fragmentation' by Igor Vaduveskovic represents an original scientific contribution to the understanding of forensic taphonomy.

This doctoral dissertation has been conducted according to all principles of scientific research. The objectives were precisely defined, the scientific approach was original and carefully chosen, and the methodology was contemporary. The results were presented and discussed in a clear and systematic manner, and appropriate conclusions were drawn from them.

Based on all the aforementioned and considering the candidate's previous scientific work, the committee proposes to the Academic Council of the Faculty of Medicine, University of Belgrade, to accept the doctoral dissertation of Igor Vaduvesković and approve its public defense for the acquisition of the academic title of Doctor of Medical Sciences.

In Belgrade, 16.04.2024.

The members of the Committee:

Prof. dr Slobodan Nikolić

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Prof. dr Danijela Đonić

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Prof. dr Mirjana Roksandić

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Mentor:

Prof. dr Marija Đurić

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