

# Dental Evidence of Exhumed Human Remains From the 1991 War in Croatia

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## ABSTRACT

*The aim of this paper is to present the post mortem dental evidence and dental health of the victims exhumed throughout the territories of Croatia that was temporarily occupied during the war. A total number of 62,432 teeth out of 1,253 human bodies exhumed from 5 different counties were analyzed. The majority of victims inhabited those areas before 1991. Post mortem dental characteristics were analyzed according to the American Board of Forensic Odontology and WHO methodology. The results show the highest level of the dental health before 1991 in the Vukovarsko-Srijemska County. The decayed (D), missing (M), filling (F), teeth (T), DMFT of that County was at the lowest level i.e. at 5.2. In all of the other counties, it was always between 6 and 12. The material most frequently used for the dental fillings was amalgam. Its highest frequency level was recorded in the County 4 (8%) and lowest in the County 1 (1.5%),  $p < 0.001$ . The most frequent prosthodontic appliances were acrylic dentures. Their frequency was lowest in the County 5 (1.3%) and highest in the County 3 (11.6%),  $p < 0.001$ . Determination of sex and dental age showed that victims were mostly men (79%) of middle and elderly age (89%). Teeth were useful also for monitoring of the quality of exhumations – taking into consideration number of empty dental sockets. The highest number of empty dental sockets was recorded in the County 3 (40.4%) and lowest in the County 1 (13.5%),  $p < 0.001$ . Even after many years in the soil, teeth proved to be the most preserved human organs and valuable indicators of identity as well as of the way of life before death.*

**Key words:** dental records, prosthodontic appliances, forensic dentistry, war victims, mass graves, dental health

## Introduction

Teeth and jaws usually abound among paleontological and archeological finds because of their resistance to post mortal influences. In addition, teeth provide valuable information about environmental parameters, diet and identity as well answers to demographic and general health questions.

Traffic accidents and in recent years, terrorist attacks are the most common types of mass disasters after which identification of recovered human remains is necessary. Identification of human remains is performed in different types of situations. Exhumation and identification of individuals killed in armed conflicts is one of the most important<sup>1,2</sup>.

Dead bodies are subject to decomposition, the speed of which varies according to the conditions. When the bodies are recovered after more years, visual identification is impossible. The remaining sources of identification such as clothing, jewelry and other personal effects, forensic anthropology and DNA profiling all have limitations in this type of situation<sup>3</sup>.

Teeth, on the other hand, because of their position and the fact that they are the hardest organs in the human body and thus most likely to remain preserved, are one of the most important factors for the positive identification of recovered human remains<sup>4-9</sup>.

The 1991 War in Croatia caused massive destructions and tragedies for people who lived there. The remains of a large number of victims have been exhumed and most of these individuals have been positively identified<sup>10</sup>.

In this study, we present the results of the dental evidence of victims killed during the war in 1991 and exhumed from the territory in Croatia.

## Subjects and Methods

In this paper, we present dental evidence of 1,253 human remains exhumed from 1995 to 2000. The remains were recovered from 60 mass graves located in five Croatian Counties: Vukovarsko-Srijemska (County 1), Osiječko-Baranjska (County 2), Sisačko-Moslavačka (County 3), and Brodsko-Posavska (County 4) as well as from Ličko-Senjska (County 5) (Figure 1).

The total number of analyzed jaws is 2,422 of which 1,169 maxillae and 1,253 mandibles. Post mortem dental analysis was performed on 62,432 permanent teeth (incisors, canines, premolars and molars).

Mass graves were located with the help of witnesses, individuals who helped bury the remains and in a few cases by individuals who survived executions. The bodies were recovered by the Government Commission for Imprisoned and Missing Persons. Identification was carried out by a multidisciplinary team of forensic experts, which included forensic pathologists, one forensic anthropologist, one forensic odontologist, radiologists and molecular biologists. The identification process and teeth analysis were carried out at the Department of forensic medicine and Criminology at the Zagreb School of Medicine.

The analyzed upper and lower jaws, after being separated from the other parts of the body, were cleaned from adhering soft tissue and disinfected in 3% H<sub>2</sub>O<sub>2</sub>. Post mortem dental characteristics were analyzed according to the American Board of Forensic Odontology (ABFO) methodology<sup>10</sup>. The jaws were left to dry for several days after which they were photographed. Additionally, X-rays were taken of selected teeth using the intraoral method with long cone. All oro-dental characteristics such as occlusion, abrasion, dental restorations, root canal fillings, missing teeth (ante mortem missing or

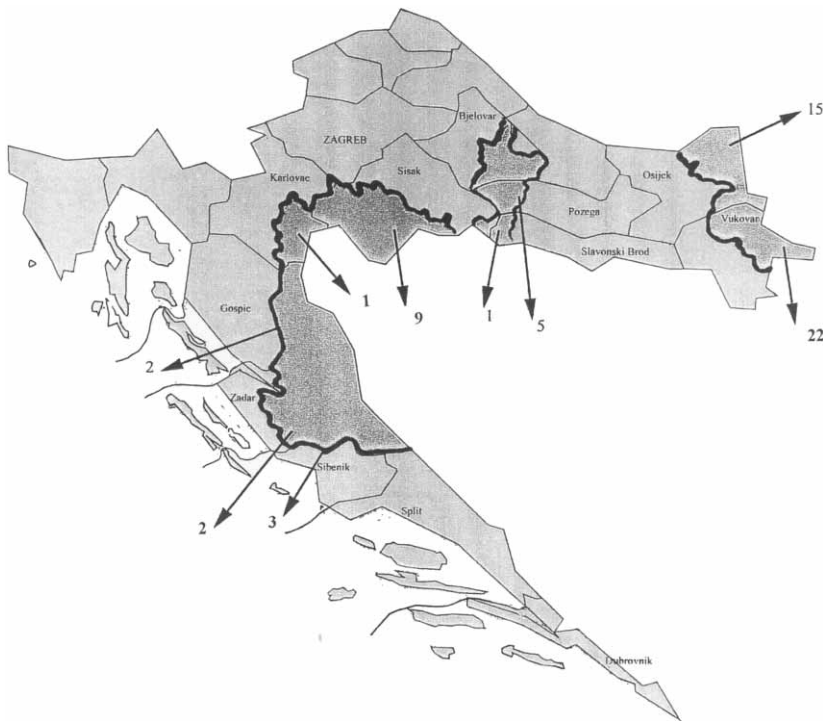


Fig. 1. The number of mass graves in formerly occupied territory of Croatia.

extraction and post mortem missing teeth), crown morphology, tooth position, metallic crowns (non-full coverage and full coverage e.g. inlays/onlays, full cast, veneers, porcelain fused to metal), removable partial and complete dentures, and evidence of smoking were carefully recorded in the Postmortem Interpol Disaster Victim Identification Forms.

The frequency of the Decayed (D), Missing (M), Filling (F) Teeth (T), (DMFT) was monitored and measured according to the WHO<sup>5,11</sup>.

Dentitions were also used for assessment of age-at-death. Several methods were used for the estimation of the dental age according to Haviko method for childhood and adolescence group and Johanson and Solheim methods for middle age and older groups.<sup>12</sup> The recovered remains

were classified into 3 age groups: childhood and adolescence (from 6 to 25 years), middle-age (from 26–40) and after 41 years<sup>12–14</sup>. In skeletonized remains, sex was determined by forensic anthropologists based on pelvic and cranial criteria according Phenice and Krogman<sup>15,16</sup>.

Forensic odontologist independently estimated sex in skeletonized remains based on the characteristics of the craniofacial skeleton according Briggs<sup>17</sup>. The results were concordant in the majority of cases.

Data are presented with absolute and relative frequencies with 95% confidence interval limits (CIL). Proportions related to counties were compared with the Vukovarsko-Srijemska County using the proportion test where only p-values lower than 0.05 were considered significant.

## Results

The majority of recovered individuals were male (79.2% or 990/1,253). Females comprised 20.8% (263/1,253) of the sample.

Dental assessment of age was possible in 794 remains (Figure 2). Individuals younger than 25 years comprise 11% (90/794) of the sample, individuals aged between 26–40 years comprise 48% (382/794) of the sample, and individuals older than 40 years comprise 41% (322/794) of the sample.

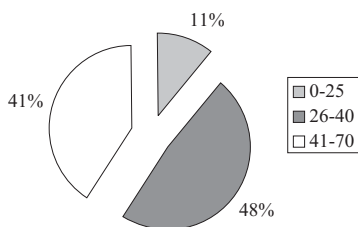


Fig. 2. The distribution of dental age assessment of exhumed human remains.

The dental evidence of the exhumed victims varied between different counties. The results obtained in County 1 were the lowest recorded DMFT and were therefore used as referential results. Ante mortem tooth loss in the analyzed counties was around 10.0% with a range of between 4% recorded in County 4 to 17% in County 5 (Table 1).

Post mortem tooth loss in the analyzed counties was, on average, approximately 20% with the lowest result recorded in County 1 (14%), and the highest in County 3 (40%).

Dental caries frequencies varied from 14% recorded in County 1, to 40% recorded in County 3. The average for all analyzed counties is 23%.

Amalgam fillings were the most frequently found restorative material. Their frequency varied between 2% recorded in

Counties 1 and 2, and 8% recorded in County 4. Composite fillings were very rare. Their frequency was below 3% in all analyzed Counties (Table 1).

Removable partial and complete dentures were the most common type of prosthodontic appliances prescribed for oral rehabilitation (7%). The highest frequency was recorded in County 3 (12%), the lowest in County 5 (1%). Dental bridges in the posterior dentition were found only in the first 3 Counties – in all cases with a frequency less than 1%. Dental bridges were considerably more common in the anterior dentition. This type of dental bridge was recovered from all counties with a frequency of between 1.9–5% (Table 1).

Values for DMFT and correlation with dental age assessment for the analyzed counties were presented. The lowest value of DMFT was recorded in County 1 (5%), the highest in County 3 (14%).

## Discussion

Teeth are the hardest substance in the human body. Teeth represent an important biological document of the conditions in which an individual lived, and a precise way of determining his or her identity. The health, age-at-death, type of food consumed, and in some cases habitual activities can be deduced from the analysis of dental material. The high recovery rate makes teeth a unique factor in archaeological and forensic analyses<sup>18</sup>.

According to historical sources, the analysis of dental cases in forensic contexts in Croatia began in the 1930s<sup>19</sup>. Dental material has been extensively used to identify victims of mass disasters resulting from train crashes or airplane collision<sup>7,20</sup>. The dissolution of the former Yugoslavia and the aggression on the Republic of Croatia resulted in mass destructions and losses of lives<sup>21–23</sup>.

The recovery of missing individuals (1991–1995), and in the period following the reintegration of previously occupied territories, became an important goal.

More than 16,000 people were considered displaced or missing as a result of the aggression on Croatia. Some relocated and settled in other counties or in neighbor-

**TABLE 1**  
DISTRIBUTION OF POST MORTEM DENTAL FINDINGS ON EXHUMED HUMAN REMAINS FROM MASS GRAVES IN DIFFERENT COUNTIES

		Counties				
		Vukovarsko-Srijemska	Osječko-Baranjska	Sisačko-Moslavačka	Brodsko-Posavska	Others
Exhumed bodies	N	907	78	202	23	43
Insufficient jaws	N	21	2	8	0	6
	% (95%GP) <sup>a</sup>	2.3 (1.3–3.3)	2.6 (0.0–6.1)	40 (1.3–6.7)	–	13.9 (3.6–24.3)
	p	–	0.889	0.185	–	< 0.001
Expect teeth number	N	28688	2464	6336	736	1280
Expepected jaws number	N	1793	154	396	46	80
Postmortem lost teeth	N	3874	762	2568	202	245
Antemortem lost teeth	N	1325	173	586	33	216
	% "96% CIL "	4.6 (4.3–4.9)	7.0 (6.0–8.0)	8.9 (8.2–9.7)	4.4 (3.3–6.0)	16.9
	p	–	< 0.001	< 0.001	0.863	(14.8–18.9) < 0.001
Dental caries	N	3874	762	2568	202	245
	% "96% CIL"	13.5	30.9	40.5	27.4	19.1
	p	(13.1–13.9)	(29.1–32.7)	(39.3–41.7)	(24.2–30.7)	(17.0–21.3)
Amalgam fillings	N	345	27	95	40	41
	% "96% CIL"	1.5 (1.3–1.6)	1.7 (1.1–2.4)	2.9 (2.4–3.5)	8.0 (5.6–10.4)	5.0 (3.5–6.5)
	p	–	0.312	< 0.001	< 0.001	< 0.001
Composite fillings	N	108	14	34	12	1
	% "95% CIL"	0.5 (0.4–0.6)	0.9 (0.4–1.3)	1.1 (0.7–1.4)	2.4 (1.1–3.7)	0.1 (0.0–0.4)
	p	–	0.013	0.002	< 0.001	0.367
Malocclusions	N	149	19	78	6	28
	% "95% CIL"	16.4	24.4	38.6	26.1 (8.1–44.0)	65.1
	p	(14.0–18.8)	(14.8–33.9)	(31.9–45.3)	0.219	(50.9–79.4) < 0.001
Removable dentures	N	95	10	46	3	1
	% "95% CIL"	5.3 (4.3–6.3)	6.5 (2.6–10.4)	11.6 (8.5–14.8)	6.5 (0.1–13.7)	1.3 (0.0–3.7)
	p	–	0.528	< 0.001	0.715	0.269
Anterior bridges	N	56	3	10	1	4
	% "95% CIL"	3.1 (2.3–3.9)	1.9 (0.1–4.1)	2.5 (0.9–4.1)	2.2 (0.0–6.4)	5.0 (0.2–9.8)
	p	–	0.068	0.019	0.776	–
Posterior bridges	N	6	2	1	0	0
	% "95% CIL"	0.3 (0.1–0.6)	1.3 (0.1–3.1)	0.3 (0.1–3.1)	–	–
	p	–	0.029	< 0.001	–	–

ing countries. More than 4,000 individuals are presumed dead. Of these, 3,388 have been recovered from mass or individual graves. Positive identification was achieved in 2,805 cases (83%)<sup>24–28</sup>.

Analysis of the recovered remains shows that the most frequent victims were middle aged or older males. Analysis of the dentition and other factors related to oral health shows that dental health was best in County 1. This county has the lowest frequency of dental caries (14%), teeth extractions (5%), and malocclusions (16%). The frequencies of amalgam and composite fillings are the same as in the other Counties. The lowest mean DMFT value is record in County 1 (5.2).

The high number of tooth extractions recorded in County 3 (9%) was accompanied with a high frequency of prosthodontic appliances, particularly removable dentures, recorded at 12% which is the highest frequency of removable dentures recorded in the analyzed Counties. Prosthodontic appliances were mostly complete and made of acrilates. A feature of County 3 is the frequent recovery of several older individuals, of the same sex, from a mass grave with no teeth in either the upper or lower jaw but with complete dentures. Because the dentures were not marked, as is the case in some countries, from an odontological point of view, such cases complicate identification<sup>29,30</sup>. Previous analyses have shown that prosthodontic appliances are, together with other dental restorations, an important element for achieving positive identification<sup>26,28,31</sup>.

The study of alloys used in dental restorations and prosthodontic appliances may be helpful in determining the country of origin and the social standing of the victims<sup>31</sup>.

Analysis of the recovered dentition also allows assessment of the quality of the re-

covery process. This can be determined by the number of empty teeth sockets (post mortem missing teeth). A high number of teeth lost post mortem indicate poor excavation technique in which not enough attention was given to the recovery of all available evidence. Our results show that, according to these criteria, the quality of exhumations was best in Counties 1 and 4. The mean post mortem missing teeth in these Counties was between 5 and 6. In other Counties mean values were between 10 and 20 in both jaws. It is obvious that on some locations and mass graves sites little attention was paid to finding of teeth that had been falling out of the teeth sockets due to simple morphology of the roots of the incisors and canines. The results confirm that there was no presence of a dental expert during exhumations in Counties 2, 3 and 5 for which reason no attention was paid to teeth. We would therefore like to suggest the mandatory presence of forensic odontologists on the exhumation sites that would improve and increase the collecting of samples and consequently enable the identification.

The identification processes in Croatia continue because there are still 1,300 persons missing from the 1991 war.

Even after many years in the soil teeth proved to be the most preserved human organs and valuable indicators of identity as well as of the way of life before death. Except for determining the identity their post mortem analysis could be used for monitoring of the dental health.

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## REFERENCES

1. GRIFFITH, C. J., T. H. OETTLE, J. Forensic Odontostomatol., 11 (1993) 63. — 2. DAILEY, J., J. Forensic Sci., 36 (1991) 264. — 3. DEFINIS-GOJANOVIĆ, M., Identifikacija ljudskih ostataka. In: PRIMORAC, D. (Ed.): Primjena analize DNA u sudskoj medicini i pravosuđu. (NZMH, Zagreb, 1991). — 4. CLARK, D. H., Int. Dent. J., 44 (1994) 241. — 5. BOWERS, C. M., G. L. BELL: Manual of forensic odontology. (American Society of Forensic Odontology, Montpellier, 1995). — 6. SOOMER, H., H. RANTA, A. PENTTILIA, Int. J. Legal Med., 114 (2001) 259. — 7. DUMANČIĆ, J., Z. KAIĆ, V. NJEMIROVSKIJ, H. BRKIĆ, D. ZEČEVIĆ, Croat. Med. J., 42 (2001) 657. — 8. ANDERSEN, L., M. JUHL, T. SOLHEIM, H. BORRMAN, Int. J. Legal Med., 107 (1995) 229. — 9. WHITTAKER, D. K., D. G. MACDONALD: A colour atlas of forensic dentistry. (Wolfe Medical Publications, London, 1995). — 10. BRKIĆ, H., D. STRINOVIĆ, M. KUBAT, V. PETROVEČKI, Int. J. Legal Med., 114 (2000) 19. — 11. INTERNATIONAL CRIMINAL POLICE ORGANIZATION: Disaster victim identification guide. (Interpol, 1998). — 12. JOHANSON, G., Odontologisk. Revy., 22 (1971) 1. — 13. SOLHEIM, T., Forensic Sci. Int., 59 (1993) 137. — 14. BANG, G., E. RAMM, Acta Odontol. Scand., 28 (1979) 3. — 15. PHENICE, T. W., Am. J. Phys. Anthropol., 30 (1969) 297. — 16. KROGMAN, W. M., M. Y. ISCAN: The human skeleton in forensic medicine. (C.C. Thomas, Springfield, 1986). — 17. BRIGGS, C. A., Anthropological assessment. In: CLEMENT, J. G., D. L. RANSON (Eds.): Craniofacial identification in forensic medicine. (Arnold, London, 1998). — 18. ALT, W. K., F. W. OSING, M. TESCHLER-NICOLA: Dental anthropology. (Springer, Wien, 1998). — 19. KALLAY, J., Stomatol. Glas., 5 (1934) 157. — 20. HAINES, D. H., Forensic Sci., 1 (1972) 313. — 21. MARCIKIĆ, M., Z. KRAUS, B. DMITROVIĆ, M. MOŠUNJAC, A. MARUŠIĆ, Croat. Med. J., 31 (1991) 7. — 22. ŠKAVIĆ, J., D. ZEČEVIĆ, D. STRINOVIĆ, Croat. Med. J., 33 (1992) 216. — 23. KOSTOVIĆ, I., M. JUDAŠ: Mass killing and genocide in Croatia 1991/1992. A book of evidence. (Croatian University Press, Zagreb, 1992). — 24. STRINOVIĆ, D., J. ŠKAVIĆ, D. ZEČEVIĆ, Experience-based identification model for mass disasters. In: Proceedings. (10th International Meeting on Forensic Medicine Alpe-Adria-Pannonia, Opatija, 2001). — 25. BRKIĆ, H., J. KEROS, Z. KAIĆ, D. STRINOVIĆ, V. PETROVEČKI, Identification of human remains by dental findings. In: Proceedings. (10th International Meeting on Forensic Medicine Alpe-Adria-Pannonia, Opatija, 2001). — 26. STRINOVIĆ, D., J. ŠKAVIĆ, I. KOSTOVIĆ, N. HENISGBERG, M. JUDAŠ, D. CLARK, Med. Sci. Law, 34 (1994) 207. — 27. PRIMORAC, D., S. ANDELINOVIĆ, M. DEFINIS-GOJANOVIĆ, J. Forensic Sci., 41 (1996) 891. — 28. BRKIĆ, H., D. STRINOVIĆ, M. ŠLAUS, J. ŠKAVIĆ, D. ZEČEVIĆ, M. MILIČEVIĆ, Int. J. Legal Med., 110 (1997) 47. — 29. THOMAS, C. J., J. Forensic Odontostomatology, 2 (1994) 13. — 30. BORRMAN, H. I. M., J. A. DIZINNO, J. WASEN, N. RENE, J. Forensic Odontostomatol., 17 (1999) 20. — 31. BRKIĆ, H., J. KEROS, Z. KAIĆ, J. ČADEŽ, Coll. Antropol., 24 (2000) 79.

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## DENTALNI DOKAZ EKSHUMIRANIH LJUDSKIH OSTATAKA U HRVATSKOJ UBIJENIH U RATU 1991. GODINE

### SAŽETAK

Svrha ovoga rada je prikazati poslije smrtni status zubala i dentalno zdravlje žrtava ekshumiranih na privremeno okupiranom teritoriju Hrvatske kroz vrijeme rata. Ukupno je analizirano 62,432 zuba od 1,253 ekshumirana tijela iz 5 hrvatskih županija, a većina žrtava bili su stanovnici tih županija do početka rata 1991. godine. Poslije smrtna analiza zubala načinjena je prema propozicijama Američke komisije foren-

zičnih stomatologa (ABFO) i Svjetske zdravstvene Organizacije (WHO). Postignuti rezultati pokazuju veću razinu dentalnog zdravlja u Vukovarsko-Srijemskoj županiji do 1991. godine. Učestalost karijesa (K), ekstrakcija (E) i ispuna (P), odnosno KEP indeks bio je najniži u promatranj županiji i iznosio je 5.2, dok je u ostalim županijama iznosio od 6 do 12. Najčešći materijal za ispunu na zubima bio je amalgam. Njegova velika učestalost (8%) zabilježena je u Brodsko-Posavskoj županiji, a najniža (1.5%) u Vukovarsko-Srijemskoj županiji,  $p < 0.001$ . Najučestaliji protetski nadomjesci bile su pomične proteze načinjene od akrilata, a njihova učestalost bila je najniža (1.3%) u Ličko-Senjskoj županiji. Najviša učestalost pomičnih zubnih proteza (11.6%) zabilježena je u Sisačko-Moslavačkoj županiji,  $p < 0.001$ . Određivanjem spola i dobi na temelju analize zubala i kostiju kraniofacijesa pokazala je da su žrtve najčešće pripadale muškom spolu (79%), srednje i starije životne dobi (89%). Analizom zubala također je promatran i način ekshumacije, a na temelju učestalosti praznih zubnih alveola. Visoka učestalost praznih zubnih alveola zabilježena je u Sisačko-Moslavačkoj županiji (40.4%), dok je najniža (13.5%) bila u Vukovarsko-Srijemskoj županiji,  $p < 0.001$ . Čak i nakon mnogo godina provedenih u zemlji, zubi kao najpostojaniji ljudski organi služe za određivanje identiteta i pokazuju način života prije smrti, a mogu poslužiti i za promatranje dentalnog zdravlja kao što je to prikazano u ovom radu.