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TOOTH WEAR DURING DEVELOPMENTAL AGE OF POLISH CHILDREN IN THE MEDIEVAL PERIOD

ABSTRACT: It is well established that tooth condition is a highly important exponent of overall human health. This study aims to determine the severity, prevalence and distribution of tooth wear during the developmental stages of children, living in medieval Poland based upon skeletal research material sourced from medieval polish cemeteries. The assessment included 237 primary, and 145 permanent human teeth, aged up to 7 years (infans I group) and between 8-15 years of age (infans II group). The degree of tooth wear was determined on the basis of a six-degree scale. In primary dentition, the prevalence of tooth wear ranged from 71.2 to 83.3 % in the infans I group and 83.3 to 92.3 % in the infans II group. The infans I group displayed the most advanced tooth wear of primary incisors, with dentine exposed on significant areas of masticating surfaces and presence of enamel islets, compared with least noticeable tooth wear to the molars. In the infans II group the most pronounced tooth wear with dentine fully exposed was observed in primary molars and canines. The degree of tooth wear found in primary dentition in molar and canine teeth group was more significant in the infans II group than in the infans I group (p = 0.0001 and 0.0012). This study concluded that the examined primary teeth of medieval children showed significantly worn enamel and dentine. It also concluded that the degree of tooth wear of the primary canines and molars into the dentin, increased significantly with progression of the individual's age, thus confirming it to be an inevitable process of normal physiological wear of teeth and evolving relationship within the masticatory system.

KEY WORDS: Primary dentition – Incisal tooth wear – Occlusal tooth wear – Medieval Period

INTRODUCTION

A great degree of emphasis in dental anthropology research is laid on the fact, that the condition of the teeth is an important indicator of the general health and condition of the individual's well being. Previous research data reveals that tooth condition is a significant indicator of an individual's age and reflects the pattern of diet consumed (Steckel *et al*. 2005). This research greatly helps to gain further insight and widen

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understanding regarding dental occlusion. Out of several factors affecting dentition (caries, pulpitis, trauma, periodontitis) tooth wear is one of the most crucial issues.

Contemporary dentistry broadly refers to three main factors affecting the loss of dental hard tissue: abrasion, attrition and erosion. In this context the term abfraction is also more and more frequently used (Fung, Brearley Messer 2013). Abrasion is defined as wear of tooth hard tissue caused by contact with foreign bodies and substances taken into the oral cavity, including food (Addy, Shellis 2004). Attrition is a physiological loss of tooth hard tissues caused by tooth to tooth contact arising on occlusal contacts of the opposing dental arches (Bell *et al*. 1998). Especially when accompanied by malocclusion this process may also affect approximal, buccal and lingual surfaces. On the other hand erosion is a non-bacterial chemical process caused by the presence and action of intrinsic and extrinsic acids (Addy, Shellis 2004, Grippo *et al*. 2004, Grippo *et al.* 2012). A great deal of controversy pervades regarding abfraction as a possible cause of loss of tooth hard tissue, it is assumed that abfraction occurs due to occlusal forces causing microfractures of enamel and dentin at the cement-enamel junction. It also contributes to reduced tooth resistance to abrasion and erosion (Grippo *et al.* 1991, Grippo *et al*. 2004).

All the above mentioned processes are subject to mutual interaction, and many times due to the complexity of various factors involved, it is not possible to determine the fundamental cause responsible for the loss of tooth tissue.

It is believed that in children, over the past two decades, erosion has been the predominant causative factor attributed to lifestyle and dietary changes, although it is extremely difficult to separate erosion from attrition in the late stages of the primary dentition (Al-Majed *et al.* 2002). It has been shown that the loss of tooth hard tissue can range from 0% to 82% (Kreulen *et al*. 2010). Wide ranging values are reported resulting from inherently different study populations, methodologies and recording indices used.

For most archaeological populations' dental wear is seen to be much more severe than for the modern ones, and is correlated with cultural characteristic behaviours' such as, diet and food preparation techniques i.e. mechanical factors (Dawson, Robson Brown 2013, Teaford, Lytle 1996). It is concluded therefore that the function of attrition is to adjust the occlusal surfaces during tooth eruption and occlusal development (Abreu 1995). This process is enhanced with abrasion which is characteristically dependent on the environmental conditions the studied individuals live in.

Currently very little research appears to have been carried out on the tooth wear of the primary teeth, with only a few studies of European collections so far undertaken (Arnold *et al*. 2007, Dawson, Robson Brown 2013, Mays, Pett 2014, Torlińska *et al.* 2015). Thus, the aim of this work was to determine the prevalence, distribution and severity of wear of mineralised tissue, occurring in primary and permanent teeth of individuals living in the Middle Ages, on the basis of skeletal material collected in Poland.

MATERIAL AND METHODS

Skeletal material tested for this study was sourced from five medieval Polish cemeteries: Kołobrzeg, Słaboszewo, Chełmska Góra near Koszalin, Poznan, and Ląd near Słupca. The material belongs to the Institute of Anthropology of the Faculty of Biology at Adam Mickiewicz University in Poznan and the Archaeological Museum in Poznan. A general evaluation was carried out for 103 skulls in total.

Age of the individuals' was determined on the basis of the Howorka's criteria, with age groups specified as follows: children with primary teeth from the first year of life until eruption of the first permanent molars (ca. 6–7 years), called Infans I group, and children with mixed dentition from eruption of the first permanent molars to eruption of the second permanent molars (ca. 12–14 years), called Infans II group (Howorka 1936).

Of the total 103 skull specimens examined, 45 skulls belonged to the Infans I group, i.e. up to 7 years of age, and the rest 58 skulls examined belonged to the Infans II group i.e. 8 to 15 years of age (*Table 1*). Skulls were obtained from the Kołobrzeg cemetery dating back to the 14th – 18th century, the cemetery in Słaboszewo dated from the 14th – 17th century, the cemetery in Chełmska Góra near Koszalin, dating from the 12th – 16th century, the Garbary Street cemetery in Poznań Old Town, which

TABLE 1. Number of individuals from each cemetery classified into age groups.

Age group	Kołobrzeg	Słaboszewo	Chełmska Góra	Garbary Poznań	Ląd Słupca
Younger	2	14	-	15	14
Older	7	19	12	7	13
Total	9	33	12	22	27

was used in the early and late medieval times i.e. 12th – 13th and 14th – 16th centuries, respectively. Finally, some skulls were sourced from the early 11th – 13th century medieval cemetery in Ląd near Słupca.

Due to a small number of skulls coming from particular cemeteries the analysis of tooth wear was carried out without the location criteria, thus representing more general trend in the past Polish populations. Likewise, because of a small number of teeth and skulls available, tooth wear analysis was not related to a particular year of life, but to the whole dentition in two dental stages (full primary dentition and mixed dentition). Therefore, the study was conducted according to the traditional criterion used in anthropology (Infans I and II group), making the comparison with other researches easier.

The dental examination of all teeth present in alveoli was performed by the researcher with the use of a dental mirror in an artificial light. Teeth loss was classified as postmortem if there was an evidence of an alveolar socket for permanent teeth, and antemortem around the time of permanent teeth eruption (Caglar *et al.* 2007). It was barely possible to state if the loss of primary teeth took place during an individual's lifetime or postmortem due to resorption processes occurring during permanent teeth eruption.

Tooth wear was considered as two processes: attrition, caused by direct tooth on tooth contact with formation of flat facets, and abrasion which results from friction with a foreign agent in the oral cavity such as a coarse medieval diet (Ayers *et al.* 2002, Dawson *et al*. 2013).

Tooth wear was assessed on the basis of a six-degree scale used during the research carried out by Malinowski and Wypych (1966), according to the following criteria:

0° – No signs of wear.
1° – Worn enamel on dental cusps, without exposure of dentine.
2° – Dentine exposed on significant areas of masticating surfaces and enamel islets present.
3° – Dentine fully exposed.
4° – Worn dentine with chamber exposed.
5° – Wear reaching the level of the dental neck.

The scale was used for this study to allow quickly and efficiently categorize the tooth wear.

In the statistical analysis, the Chi-square test was used to test the significance of difference between the Infans I and the Infans II group, calculated for all teeth. The Mann-Whitney U test was used to test the significance of difference of tooth wear in molars, canines and incisors between the Infans I and the Infans II group, and between the upper and lower jaw calculated for all teeth in the Infans I and the Infans II group. The statistical significant difference in molars, canines and incisors between the upper and lower jaw, in the Infans I and the Infans II group, was tested with the Fisher Freeman Halton test, the Fisher exact test, and the Chi-square test. The statistical significant difference between molars, canines and incisors in the Infans I and the Infans II group was tested with the Fisher Freeman Halton test and the Chi-square test. A p-value less than 0.05 was considered as statistically significant.

RESULTS

The number of teeth examined comprised of 237 primary and 145 permanent teeth specimens. The number of teeth in each particular group varied depending on their loss occurring during an individual's life and after death and results are shown in the tables concerning degree of tooth wear for each age group.

The Infans I group included the most numerous molars i.e. 66, whereas incisors and canines were much less frequent in the material examined i.e. 36 and 30 respectively. For the Infans II group the number of teeth examined involving primary dentition included 61 molars, 18 incisors and 26 canines. Permanent teeth in Infans II group comprised of 81 molars, 28 incisors, 17 canines and 19 premolars. In each age group mandibular teeth were best preserved.

Tables 2, 3 and *4* show tooth wear of primary and permanent dentition divided into age categories. The most advanced stage of tooth wear observed in the examined skeletal material was fully exposed dentine, found in primary teeth in the Infans II group, i.e. in the late stages of the primary dentition.

In the Infans I group the majority of incisors were found with dentine exposed on significant areas of masticating surfaces with enamel islets present, compared to canines and molars with worn enamel on dental cusps, without exposure of dentine. In the Infans II group the majority of primary teeth in all teeth groups were found with dentine exposed on significant areas of masticating surfaces with enamel islets present. Whereas the majority of permanent teeth in the Infans II group were found with worn enamel on dental cusps, without exposure of dentine.

There was no statistically significant difference between the degree of tooth wear on a tooth type level between the upper and lower jaw in all age groups (*Tables 2–4*).

TABLE 2. Prevalence of tooth wear and significant differences between the upper and lower jaw in primary dentition in the Infans I group. No. (%). a, Fisher Freeman Halton test; b, Chi-square test.

	Incisor			Canine			Molar		
	maxilla	mandible	p-value	maxilla	mandible	p-value	maxilla	mandible	p-value
No. of teeth present	17	19		14	16		29	37	
0º Degree of wear	4 (23.5)	2 (10.5)		4 (28.6)	3 (18.7)		6 (20.7)	13 (35.1)	
1º Degree of wear	6 (35.3)	7 (36.9)	0.607 [a]	7 (50.0)	11 (68.8)	0.672 [a]	15 (51.7)	15 (40.5)	0.450 [b]
2º Degree of wear	7 (41.2)	10 (52.6)		3 (21.4)	2 (12.5)		8 (27.6)	9 (24.4)	

TABLE 3. Prevalence of tooth wear and significant differences between the upper and lower jaw in primary dentition in the Infans II group. No. (%). a, Fisher Freeman Halton test.

	Incisor			Canine			Molar		
	maxilla	mandible	p-value	maxilla	mandible	p-value	maxilla	mandible	p-value
No. of teeth present	7	11		14	12		31	30	
0º Degree of wear	1 (14.3)	2 (18.2)		1 (7.1)	1 (8.3)		-	-	
1º Degree of wear	2 (28.6)	1 (9.1)	0.810 [a]	5 (35.7)	2 (16.7)	0.770 [a]	11 (35.8)	9 (30.0)	0.440 [a]
2º Degree of wear	3 (42.9)	7 (63.6)		6 (42.9)	7 (58.3)		14 (44.9)	18 (60.0)	
3º Degree of wear	1 (14.2)	1 (9.1)		2 (14.3)	2 (16.7)		6 (19.3)	3 (10.0)	

TABLE 4. Prevalence of tooth wear and significant differences between the upper and lower jaw in permanent dentition in the Infans II group. No. (%). a, Fisher Freeman Halton test; b, Fisher exact test.

	Incisor			Canine			Premolar			Molar		
	maxilla	mandible	p-value	maxilla	mandible	p-value	maxilla	mandible	p-value	maxilla	mandible	p-value
No. of teeth present	15	13		8	9		10	9		39	42	
0º Degree of wear	6 (40.0)	5 (38.5)		1 (12.5)	4 (44.4)		5 (50.0)	6 (66.7)		18 (46.1	18 (42.9)	
1º Degree of wear	7 (46.7)	6 (46.1)	1.000 [a]	7 (87.5)	5 (55.6)	0.183 [b]	5 (50.0)	3 (33.3)	0.650 [b]	17 (43.6)	16 (38.1)	0.571 [a]
2º Degree of wear	2 (13.3)	2 (15.4)		-	-		-	-		4 (10.3)	8 (19.0)	

Research showed there was no statistically significant difference between a degree of tooth wear in the Infans I group (p = 0.849), in the Infans II for primary dentition (p = 0.727), and the Infans II for permanent dentition (p = 0.396) between the upper and lower jaw calculated for all teeth (not included in the table).

Finally there were no statistical differences in tooth wear between tooth types in age groups on tooth type level (p = 0.054, 0.107, 0.052), refer *Table* 5.

There was a statistically significant difference in degree of tooth wear between the Infans I and the Infans II group regarding all teeth (p<0.0001, Chi-square test, not included in the table). The difference in degree of tooth wear was significant in molar and canine teeth group (p=0.0001 and 0.0012, respectively). The degree of tooth wear was more severe in the Infans II group than in the Infans I (*Table* 6).

TABLE 5. Differences in tooth wear between tooth types in age groups. No. (%).a, Chi-square test; b, Fisher Freeman Halton test.

Age group	Degree of wear	Incisor No.(%)	Canine No.(%)	Molar No.(%)	p- value
Infans I	0 º	6(16.7)	7(23.3)	19(28.8)	0.054 [a]
	1-3 º				
		30(83.3)	23(76.7)	47(71.2)	
	Total	36(100)	30(100)	66(100)	
Infans II-Primary teeth	0 º	3(16.7)	3(12)	2(7.7)	0.107[b]
	1-3 º	15(83.3)	22(88)	24(92.3)	
	Total	18(100)	25(100)	26(100)	
Infans II-Permanent teeth	0 º	11(39.3)	5(29.4)	36(44.4)	0.052 [b]
	1-3 º	17(60.7)	12(70.6)	45(55.6)	
	Total	28(100)	17(100)	81(100)	

TABLE 6. Statistically significant differences in degree of tooth wear of primary dentition between Infans I and Infans II group on tooth type level. a, Mann-Whitney U test.

		Tooth wear		p-value
Teeth group	Age group	Total	Degree 1 º -3 º	
Incisor	Infans I	36(100)	30(83.3)	p=0.168 [a]
	Infans II	18(100)	15(83.3)	
Canine	Infans I	30(100)	23(76.7)	p=0.0012 [a]
	Infans II	25(100)	22(88.0)	
Molar	Infans I	66(100)	47(71.2)	p=0.0001 [a]
	Infans II	26(100)	24(92.3)	

DISCUSSION

Tooth wear on incisal and occlusal surfaces is to some extent, considered a physiological process taking place during an individual's whole life. The incisal edges of maxillary and mandibular anterior teeth and occlusal surfaces of posterior teeth are often regarded clinically as surfaces affected by mechanical wear due to the potentially high levels of attrition and abrasion (Al-Dlaigan *et al.* 2002).Therefore, in this study the

above mentioned dental surfaces were taken into account.

According to the present results, tooth wear is a common issue in an individuals' dentition during the developmental age and in this research the wear of teeth ranged from 71.2 % to 92.3% in primary dentition, and up to 70.6% in permanent dentition. In every population a different percent of teeth with signs of tooth wear is noticed. Still, it is never the case that all the teeth are affected with tissue loss. A recent examination of 1282 primary teeth and 2225 permanent teeth of the contemporary 6–12-year-olds, on buccal, lingual and occlusal surfaces, displayed that 78% of primary teeth and 22 % of permanent had tooth wear, so tooth wear was particularly affecting primary teeth (Fung *et al.* 2013). Therefore, the process may be considered wide spread. Teeth, taking part in occlusion, show signs of mechanical wear depending on the period of use in the oral cavity. What is more, the differences in tooth structure and composition between primary and permanent teeth, make primary dentition more susceptible to wear.

It must be remembered that though tooth wear may be normally contributed to a combination of abrasion, attrition and erosion, however some habits are difficult to document in archaeological samples. It has been documented that the degree of mechanical wear depends on many factors, including not only abrasive properties of food determined by quantity and type of particles contained within, but also the degree of mineralisation of tooth hard tissues, efficiency of tooth suspension, adaptive abilities of temporomandibular joint, activity and strength of muscles of mastication (Grippo *et al*. 2012, Hinton 1982, Pechenkina *et al*. 2002, Wierzbicka-Ferszt *et al*. 2007).

Therefore, the composition, texture, and hardness of food, the distribution of pressure as well as the individuals' direction of chewing has a considerable influence on the wear pattern (Kullmer *et al.* 2007).

Tooth wear starts as soon as the opposing teeth have erupted and are in occlusion in the oral cavity. Initially, small facets appear on the enamel as the cusps are being worn (Bell *et al.* 1998). This leads to morphological changes and a reduction in the tooth crown height, allowing the teeth to slide without interference in all directions during mandibular movement and growth taking place during the development stage of an individual. The facets vary in number, size, and shape depending on the stage of wear and morphology. Their number increases until an advanced wear stage is reached with the facets starting to fuse (Kullmer *et al.* 2007). Whilst the occlusal enamel wears during mastication and the enamel rim maintains occlusion, it exposes the less mineralised dentine, causing a progressive reduction in occlusal force. Furthermore, as the thickness of the enamel decreases over time, the area of exposed dentine increases. The scooped dentin is located lingually in maxillary teeth and buccally in mandibular teeth, which reflects the direction of forces applied on food during masticatory movement (Bell *et al.* 1998). The above signs were well observed in the studied material, as well.

It is assumed that previous generations experienced significant loss of mineralised tissues of the whole dentition because of predominantly abrasive aetiology (Dawson, Robson Brown 2013). When tooth tissue loss is analysed in medieval period, changes in diet over the centuries must be considered. It ought to be remembered that dry food, raw fresh fruit and vegetables, commonly consumed in the past, required more chewing and muscle strength than cooked food. Moreover, higher fibre content enforces longer chewing with relatively small strength masseter muscles (Hinton 1982). It is also known that less thorough preparation of meals made medieval food more fibrous and harder. Grains were the most commonly consumed products at that time and considerable contamination of flour must have had an impact on tooth wear (Ganss *et al.* 2002). As tooth cusp disappears from an early age mainly due to chewing, the crucial information is to know at what age infants began receiving solid dietary supplementation. For the Polish children of medieval times it seemed to happen around the 2nd–3rd year of life (Krenz-Niedbała 2006).

The increased wear of primary teeth observed in our research in the Infans II group in relation to the Infans I group can be explained mainly by the masticatory organ adaptation during the dentition development and the presence of teeth in the mouth until the time of their natural loss, which produced longer exposure to risk factors (Hugoson *et al*. 1996). Changes in tooth wear would also be a result of function of teeth groups, especially if diet is considered and the unprocessed food is consumed. Occlusal surfaces might be the only location where a relationship between lesion severity, its prevalence and age is visible, thus indicating a significant contribution of abrasion produced by mastication (Ganss 2008).

The dentition of young individuals aged 1–14 years living in Scotland in the late Middle Ages (12th – 16th century) analysed by Lunt (1972) showed that cutting edges of front primary teeth of 5–6 year old children displayed more significant loss of enamel with exposure

of dentine than molars and canines. Also, Hugoson *et al*. (1996) analysed the condition of teeth in children living in Sweden, who in 1983 turned 3, 5, 10 and 15 years respectively. The tooth wear referred to primary teeth in the group of 3–5 year olds, and to mixed dentition for the remaining age groups. Again, the observations revealed incisors to be the most worn teeth in 3-year-olds, followed by canines and molars. However, for the 5-year-olds the biggest wear occurred in canines (Hugoson *et al*. 1996). Similarly, Warren *et al*. (2002) who described wear of primary teeth in contemporary 4–5 year-olds born in hospitals in Iowa, claimed it was not dependent on individual's diet and is universal in the primary dentition. For this age range this research noted significant degree of wear in front teeth in the upper tooth arch, subsequently decreasing on canines and molars. Marinelli *et al*. (2005) evaluated condition of teeth in children born in the late 1950s and 1990s. Comparison of tooth wear in canines, first and second molars showed that canines were most worn. These results are convergent with Hugoson's observations in children aged 5. Thus higher degree of wear of incisors (although not statistically significant), followed by canines and molars was observed in our material for this age range before the exchange of dentition, was confirmed by our observations made for historical and contemporary populations, despite differences in diet. In the Infans I group the period of use of incisors (approximately 5–6 years), before they are shed, is longer than for canines or molars (approximately 3–4 years) and this will be a factor here.

On the contrary, according to other data collected for primary dentition of medieval times, more significant loss of hard tissue in this age (before the exchange of dentition) may affect molars, although these differences may result from varying age structure of the studied individuals within the given age categories (Torlińska-Walkowiak *et al.* 2015). The choice of individuals in archaeological samples was beyond control of the researchers. All the above results reveal that groups of teeth in a particular life period are affected with tissue loss, to a varying degree. Still, this process is always markedly visible, and though seemingly modified by many factors, is necessary for the proper development of occlusion.

In a study of a group of contemporary children at 3–6 years of age and re-examination 5 years later, the researchers noticed tooth wear of front teeth in 41% cases and wear of masticating surfaces in ca. 1/5 of molars. As years passed, the researchers reported increased wear in molar area and decreased wear in front section of tooth arches in mixed dentition (Hugoson *et al*. 1996). The above results are convergent with the ones obtained in this study, also for Torlińska *et al*. study, where the most pronounced tooth wear in Infans II group was observed in primary molars (Torlińska-Walkowiak *et al*. 2015). It is known that the lifetime of the primary molars is longer than of the incisors (ca. 8 vs 5 years), so it seems to be a factor here.

Examination of the excavated medieval material from Ostrow Lednicki (Howorka 1936), Cedynia (Torlińska-Walkowiak *et al*. 2015) allowed the conclusion that the same degree of wear affected primary teeth in both jaws, which was also confirmed in this research. On the contrary, some studies of contemporary living children indicate more severe tooth wear of primary teeth in the maxilla (Gatou, Homata 2012, Warren *et al*. 2002).

When interpreting the results of examination of the excavated material, it is important to take into consideration the quantity of teeth available for evaluation. For the Infans I group in the primary dentition, molars were the teeth group most available for evaluation. For the Infans II group within primary dentition, the number of teeth present in alveoli for each particular group increased as follows: incisors, canines, molars. Corbett and Moore (1976), who carried out some observations of the 19th century British population, obtained similar results regarding most numerous teeth group. It is known that because of the structure of primary teeth many single-rooted teeth are lost post-mortem. Moreover, in older children the loss of teeth occurs mainly due to exfoliation but poor preservation of children's skeletons will be also a factor here.

Examination of the excavated material attracts attention of both dentists and anthropologists. The aim of this research is to provide data for retrospective analysis of human health from Medieval times, focusing on the pattern of wear in relation to the whole dentition. The evaluation of tooth wear let the researchers acquaint with process of physiological wear of teeth within the masticatory system. It emphasises the significance the research undertaken, despite difficulties resulting from incomplete materials.

CONCLUSION

In this study tooth wear affected up to 92% of the primary teeth and was registered in all tooth groups, both in primary and permanent dentition, although to varying extents. The examined primary teeth of medieval children had significantly worn enamel and dentine,

enamel islets were present or dentine was fully exposed. It was assumed that the main causative factor was mechanical. It may be concluded that attrition and abrasion of enamel are important contributing factors of an inevitable process, which modifies chewing surfaces to adapt them to changing occlusion. Conclusively the prevalence of tooth wear into the dentin of primary teeth increased alongside with individual's age, especially in the canine and molar tooth groups after eruption of the first permanent molars.

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