

## ORIGINAL PAPER

### Frequency and Distribution of Enamel Hypoplasia in Ancient Skulls from Different Eras and Areas in Greece

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#### **Abstract:**

This study presents an anthropological analysis of enamel hypoplasias from 309 skulls from archaeological excavations in various geographical areas of the Hellenic landscape belonging to different chronological periods. The sample comprises a total of 1386 permanent teeth of different morphological types were recognized and graded as to the feature of enamel hypoplasia. The examination of the enamel hypoplasia is based on macroscopic observation. The diagram used for the evaluation of this feature was the one proposed by Brothwell in 1971. The frequency of enamel hypoplasia in the dentition of ancient skulls from Greece is relatively restricted. Of the total of 1386 teeth examined, 323 teeth of the upper jaw displayed the characteristic linear hypoplasia which corresponds to 23.2 % of all cases. In particular, in the skull series we examined the greatest disruption of enamel formation was found on the canines of the upper jaw, while it also exists, albeit at a declining frequency, in the first molars, the second molars, followed by the lateral incisors and central incisors as well as the third molars. In the first molars, the frequency of hypoplasia is consistently high in the teeth of these skulls from all three periods examined (antiquity, the middle ages and the new age).

**Key words:** dental anthropology, infection, metabolic stress, nutrition, enamel, enamelblasts, calcium, skeletal material, skulls, archaeological excavation.

#### **Introduction**

Over the past years, a new area of dental anthropology has developed, allowing for the study of the biology of ancient population groups and in particular allowing us to establish the circumstances pertaining to the poor nutrition and physiological stress which had an impact on the physical development and living conditions of the members of these

populations, according to Scott and Turner (1983). Systematic disorders, such as poor nutrition and infectious diseases, in general lead to anomalies in the production of tooth enamel during the development of the human body. The term enamel hypoplasia refers to a reduction in depth of the enamel deposit, which may be due to metabolic stress, genetic factors or injuries, according to Rose et al (1985). Dental tissue displays the best wear

and greatest resistance to external influences, by comparison to all other tissues in the human body (Pitsios 2003, Hillson 1996, Goodman et al. 1988). Hence the study of the various metric and morphological traits of the teeth provides information about the genetic relations of population groups, the biological age of specific individuals, their diet, the ecological circumstances and the environment in which they lived and certain pathological conditions with which they were confronted during their lifetimes (Zafiri 2006,2008).

In particular, due to their immediate relation to the function of chewing and the type of food they chew, a person's teeth are influenced and their morphological characteristics are "shaped" in a way which reflects, to a certain extent, the food that this individual consumed (Kay 1985, Scott & Turner 1988). They can also reflect an individual's nutritional situation, which entails balancing of the energy needs of the body with its nutrition intake. This balance is influenced by a variety of factors, such as illnesses and the environment. These effects often lead to the appearance of dysplasia on the surface of the enamel, the most frequent of which is hypoplasia (Pitsios 2003, Zafiri and Pitsios 2006). This is a condition in which certain areas of enamel are not sufficiently deep, as a result of the interruption of the activity of the enamelblasts (Sarnat and Schour 1941), which provide a biological record of the progressive development of the human body.

Enamel is the most rigid tissue of the teeth and it is also the one richest in calcium, covering each individual tooth crown and acting as a protective sheath, which can be described as a cell-less organic substance. In histological terms, it consists of a multitude of calcium-rich prisms, located across the entire breadth of the enamel and constituting its main body. The prisms are separated from each other by an inter - prism substance, the growth of which constitutes an induced procedure and placement of the enamelblasts at the point where the connection between tooth and enamel ultimately occurs, according to Hillson et al. (1999).

The term enamel hypoplasia refers to a malformation of tooth enamel due to a malfunction of the enamelblasts and a loss of their functional capacity resulting in the formation of enamel with inferior depth. This

disorder is clinically expressed in the form of pits or cavities and recesses in the enamel, which are of anomalous depth and display a partial or entire lack of enamel (Hillson 1992). Enamel hypoplasia is often accompanied by hypo-calcination, an insufficient calcium content, in the organic base layer of the enamel. Both of these anomalies are established throughout the development of a person's teeth for the duration of enamel formation, and they may pertain to one or several teeth or even to a person's entire dentition (Scott 1991a, Brothwell and Sandison 1967). They are usually due to local or general disorders, or they may have genetic reasons, although it is not always possible to pinpoint the cause of the disorder. In general, these disorders can be put down to metabolic stress, poor nutrition, a deficiency in vitamin A, C and D, or they can be linked to weaning in infants. Other causes may be illnesses entailing a high fever, as well as pre- and perinatal anoxia (Lukacs 2001b). They may also sometimes be due to local injuries, root tip inflammation of the deciduous teeth or to a prolonged presence of these deciduous teeth in the oral cavity (Sarnat and Schour 1941, Rose et al. 1985, Alan et al. 1991).

The location of the hypoplasia on the surface of the tooth and its presence on specific teeth of an individual's dentition allow for the calculation of the biological age of the person in question at the time when the hypoplasia was formed (Reid and Dean 2000). Furthermore, the extent of the enamel hypoplasia with respect to dentition in an individual and the number of teeth which are subject to this disorder varies, depending on: 1) the number of teeth already formed prior to the occurrence of the damaging influence, 2) the percentage of tooth crown already formed prior to the occurrence of the disorder, 3) the period of time over which the element responsible for the damage was active fig1.

Enamel hypoplasia is a source of information about the stress level of development in earlier populations (Skinner, 1996). The study of enamel imperfections allows for the calculation of the prevalence of morbidity during childhood in connection with the duration and episodes of pressure hiding behind these imperfections in tooth enamel (Hillson et al. 1999).

The majority of studies published over the past few years were based on macroscopic observation. While the age of the person in question at the time when the enamel hypoplasia was formed is calculated based on its position on top of the crown of a specific tooth, data from the classic diagram by Logan and Kronfeld (1935) with respect to the duration of tooth formation duration is also used (Goodman et al.1980, Reid and Dean 2000). In recent years, enamel hypoplasia has been rated based on the classification system published by the International Dental Federation for Developmental Defects of Enamel (DDE), which determines four types: a) pits or cavities, b) horizontal recesses, c) vertical recesses, and d) areas lacking enamel. This system determines three degrees of severity: mild, medium and intense, based on the breadth and depth of the imperfections (Duray, 1996). A similar three – degree evaluation of enamel hypoplasia was suggested by Brothwell in 1971, (3) intense (2) middle (1) minor. His diagram has been used to evaluate many skeletal remains all over the world.

**The Material**

The material for this study was obtained from the anthropological collections at the Museum of Anthropology of the University of Athens. The skeletal material contained in the

collections at the Museum of Anthropology is very well preserved, classified with archaeological serial codes and hence appropriate for carrying out anthropological analyses and drawing conclusions. In our study, we examined typical enamel hypoplasia in the teeth of eight series of skulls from the Museum of Anthropology. These were a total of 309 skulls from archaeological excavations in various geographical areas of the Hellenic landscape belonging to different chronological periods. In particular, 45 skulls from the Middle Ages from Leonidio in Arcadia were examined, bearing the serial code AKK1, as well as 57 skulls from the Middle Ages from Tripoli in Arcadia bearing the serial code number AKM2, 32 skulls from the Middle Ages from Tripoli in Arcadia bearing the serial code number ATA6 and 27 skulls from the Middle Ages from Avdira near Xanthi bearing the serial code number ΕΑΞ1. In addition, 15 ancient skulls from Markopoulo in Attica were examined, these bearing the serial code number ATA1, 18 ancient skulls from the Ancient Agora with the serial code number ATA4 and 56 ancient skulls from Eretria on the island of Evia, with the serial code number EYX1. Finally, the teeth of a total of 69 new age skulls from excavations in the Athens area in later years were examined, these bearing the serial code ATA7 (Table 1).

**Table 1**

no	Serial code	Origin	Time period	Number	Number of of teeth
1	AKK 1	Leonidio / Arcadia	Middle Ages	45	107
2	AKM 2	Tripoli / Arcadia	Middle Ages	57	89
3	ATA 1	Markopoulo / Attica	Ancient	15	46
4	ATA 4	Ancient Agora	Ancient	18	68
5	ATA 6	Athens	Middle Ages	32	66
6	ATA 7	Athens	New Age	59	111
7	EYX 1	Eretria / Evia island	Ancient	56	293
8	ΕΑΞ1	Avdira / Thrace	Byzantine	27	606
	ΣΥΝΟΛΟ	-	-	309	1386

The teeth from all of these series are in very good condition. However, there are very few of them, since in the majority of skulls from most of the series examined quite a few teeth

are missing from their places in the alveoles, since they were not assembled and hence not recorded during the excavation. Nonetheless, the material was deemed satisfactory and

sufficient for statistical analysis and the gleaning of information from the biological archives in the enamel about these specific ancient Greek populations. A total of 1386 permanent teeth of different morphological types were recognized and graded as to the feature of enamel hypoplasia fig2.

**Purpose**

The main aim of the present study is to record the frequency of enamel hypoplasia in the teeth of eight series of ancient skulls from Greece and from different periods (antiquity, the middle ages and the new age) and geographical locations. A further goal of the study is to estimate the variety of the degree of expression of this feature in each morphological tooth type, as well as to define the periods in which developmental stress had

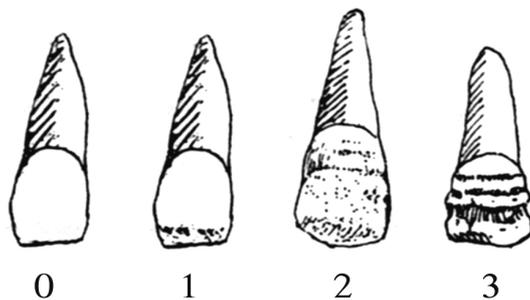
the greatest influence on the formation of the crown, resulting in imperfections in the enamel structure of the tooth.

**Method**

We examined the enamel hypoplasia based on macroscopic observation, since this method is non-destructive and did not damage the teeth from the archaeological collections at the Museum of Anthropology. In order to better recognize the morphological features of the teeth under examination, a magnifying glass was used in a good number of cases. We checked for the morphological feature of enamel hypoplasia with horizontal recesses. The diagram used for the evaluation of this feature was the one proposed by Brothwell in 1971.

**Diagram 1**

Brothwell diagram (1971).



0 corresponds to an absence of hypoplasia, 1 indicates minor hypoplasia, 2 medium and 3 severe hypoplasia.

The system for the study and recording of the teeth and the feature in question is determined in the anthropological document as shown in the following in Table 2:

**TABLE 2**  
**ANTHROPOLOGICAL DOCUMENT**

Skeletal material ..... Skeleton no..... date..... Source..... ..... .....	

maxilla

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

mandible

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17

We studied the enamel hypoplasia separately on the upper and lower jaw of each skull. For practical reasons, in our comparative analysis of hypoplasia in eight series of skulls we used only the teeth of the maxilla. The corresponding data was classified in tables and numbered 1 - 32 for each morphological type of tooth, as shown in the diagram of teeth in the anthropological research document (table 2). The teeth were analyzed with the statistical package SPSS13. For the statistical analysis of our data we used the z-test, while the equality of the percentages was

checked with the t-test.

**Statistical Analysis – Results**

A) The homogeneity of the eight series of skulls was examined with respect to the feature of enamel hypoplasia, the period of time they belong to and the geographical area of Greece where they were found.

The equality of the proportions of the samples was tested by using the z-test. Cluster analysis was used for the grouping of the skulls series. The tests were carried out at  $\alpha=0.05$ .

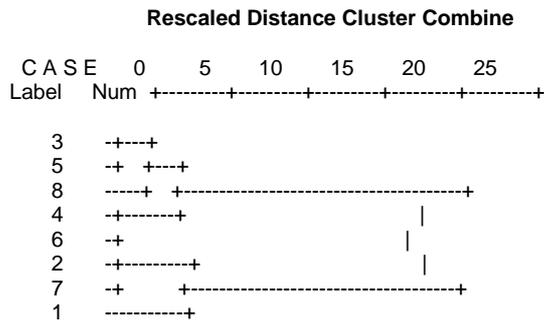
**TABLE 3**  
Percentage of teeth with enamel hypoplasia

Codification	Skull groups	Percentages
1 AKK1	Middle ages, Leonidio, Arcadia	0.51
2 AKM2	Middle ages, Tripoli, Arcadia	0.42
7 ATA 4	Ancient Agora of Athens	0.37
6 ATA1	Ancient skulls, Markopoulo, Athens	0.26
4 ΕΑΕ1	Byzantine skulls, Avdira, Thrace	0.22
5 EYX 1	Ancient skulls, Eretria, Evia	0.17
3 ATA 6	Middle ages, skulls from Athens	0.16
8 ATA 7	New age skulls, Athens	0.09

The following dendrogram shows the classification of the analysis according to the clusters:

The dendrogram shows that the series of skulls form two groups, as recorded in the following in table 4.

**Dendrogram Using Average Linkage (between groups)**



**TABLE 4**

Group A	Group B
1.AKK1-Middle ages, Leonidio, Arcadia	6. ATA1-Markopoulo, Athens
2.AKM2- Middle ages, Tripoli, Arcadia	3 .ATA 6- Middle ages, Athens
7. ATA 4- Ancient Agora, Athens	8.ATA7- Athens, later years
	5.EYX1- Ancient Eretria, island of Evia
	4. ΕΑΕ1- Byzantine period, Avdira

We used the t-test to check the equality of the percentages within group A confirmed the percentages. The equality check of the equality of these percentages.

pairs	t-statistic value	hypothesis
1-2	1.26	not rejected
2-7	0.63	not rejected

For the verification of the equality of percentages between 7 and 6 (according to the numbering of table 1),  $z = 1.72$ . This equality was not rejected at the level of  $\alpha = 0.05$ . However, it was rejected at  $\alpha = 0.10$ . In order to examine all potential configurations within group B, we performed a series of z-tests.

**TABLE 5**

pairs	z-value
6-4	1.02
4-5	1.14
5-3	0.43
3-8	0.77

Thus the z-test did not eliminate our hypothesis of the equality of the proportions, allowing us to conclude that the proportion of teeth with enamel hypoplasia divided the skulls into two groups. The new age skulls had the smallest proportion of enamel hypoplasia, but the difference over the middle age skulls of Athens is not statistically significant. The problem of missing values becomes clearer in the above matrix. Most of the missing values relate to Δ7 (lateral right incisor), Δ8 (center right incisor), Δ9 (center left incisor), and Δ10 (lateral left incisor) teeth.

We observed that with respect to the ancient skulls, the largest percentages of enamel

hypoplasia were to be found on the following teeth: Δ5 (first right premolars), Δ6 (right canines), Δ10 (left lateral incisors) and Δ11 (left canines). In the teeth from the middle ages, the greatest percentage of enamel hypoplasia was found in the following teeth: Δ5 (right first premolars) and Δ6 (right canines). Especially in the teeth from the Arcadian skulls from Tripoli of the middle ages (AKM2), the percentages of hypoplasia were far higher by comparison to the teeth from the Arcadian skulls from Leonidio in the middle ages (AKK1) and the Athenian skulls from the middle ages (ATA6). The lowest percentages of hypoplasia were observed in the teeth from series ATA7 (Athens, new age).

**B) Applying the analysis of all teeth from the eight skull series:**

**TABLE 6**  
**Percentage of morphological tooth types with enamel hypoplasia according to area of origin**

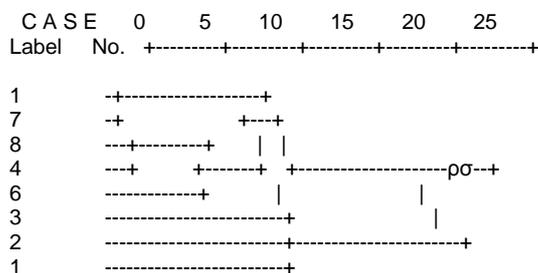
	AKM2	AKK1	EYX1	ATA1	ATA4	ATA6	ATA7	ΞΑΞ1
Δ1	0.00	0.43	0.20	0.20	0.20	0.00	0.00	0.00
Δ2	0.38	0.17	0.17	0.17	0.17	0.30	0.00	0.13
Δ3	0.57	0.73	0.50	0.17	0.50	0.22	0.11	0.19
Δ4	0.33	0.55	0.40	0.25	0.40	0.50	0.17	0.09
Δ5	0.75	0.75	0.67	0.33	0.67	0.33	0.20	0.17
Δ6	1.00	1.00	0.50	1.00	0.50	0.00	0.40	0.57
Δ7	-	1.00	0.00	-	0.00	-	0.00	0.24
Δ8	-	1.00	0.50	-	0.50	-	-	0.33
Δ9	-		0.50	0.00	0.50	-	-	0.20
Δ10	-	0.00	1.00	0.50	1.00	-	-	0.10
Δ11	-	1.00	0.50	1.00	0.50	-	0.50	0.45
Δ12	0.67	0.00	0.38	0.00	0.38	0.00	0.13	0.14
Δ13	0.75	0.67	0.20	0.00	0.20	0.00	0.13	0.14
Δ14	0.50	0.75	0.40	0.20	0.40	0.00	0.07	0.11
Δ15	0.50	0.31	0.20	0.00	0.20	0.33	0.00	0.13
Δ16	0.00	0.22	0.00	-	0.00	0.00	0.00	0.00

Subsequently, a cluster analysis was attempted, using all types of teeth for which there were no missing values. The results are displayed in the following dendrogram.

HIERARCHICAL CLUSTER ANALYSIS

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine



The dendrogram shows the configuration in two groups of the teeth we studied according to enamel hypoplasia percentage. We found that: three out of four series from the middle ages in our study belong in group A. In group B, we have a configuration of teeth from the

skull series from the ancient Athens Agora, from Ancient Eretria, from the ancient skulls from Markopoulo, Attica, from the Byzantine skulls from Avdira and from the new age skulls from Athens.

TABLE 7

Group A	Group B
Middle ages, Leonidio, Arcadia	Antiquity, Markopoulo, Attica
Middle ages, Tripoli, Arcadia	Ancient Athens Agora
Middle ages, Athens	New Age, Athens
	Antiquity, Eretria, Evia island
	Middle Ages, Avdira, Thrace

For nearly every morphological type of tooth, the percentage of teeth with enamel hypoplasia is higher for the those from the middle ages, followed by the teeth from antiquity. Only for the T14 teeth (first molar of the upper jaw) is the percentage equally high in all three groups, the skulls from the periods of antiquity, the middle ages and the new age.

Based on the enamel hypoplasia of the tooth crown and with the help of the Logan and Kronfeld diagram (1935), we can calculate the age of the individual at the time when the detrimental factor appeared, resulting in a decline in enamel formation during the post-embryonic months in the life of a child. In the case of no 14 (first permanent molar of the maxilla), the decline in enamel formation

began between the fourth and fifth post-embryonic month and can be related to weaning or childhood illnesses.

Discussion – Conclusions

The present study shows that the frequency of enamel hypoplasia in the dentition of ancient skulls from Greece is relatively restricted. Specifically, the occurrence of hypoplasia in a total of 1386 teeth from the 309 skulls examined was as follows: the highest percentages of hypoplasia occurred in the skulls from the middle ages from Leonidio in Arcadia (0.51%), the skulls from the middle ages from Tripoli in Arcadia (0.42%) and the skulls from the ancient Athens Agora (0.37%). We observed that smaller

percentages of enamel hypoplasia occurred in the following series of skulls examined: in the ancient skulls from Markopoulo in Attica, where the presence of enamel hypoplasia was 0.26%, in the skulls from the middle ages from Avdira, Thrace, at 0.22%, in the ancient skulls from Eretria, Evia, at 0.17%, in the skulls from Athens of the middle ages at 0.16% and in the skulls from new age Athens at 0.09%.

Of the total of 1386 teeth examined, 323 teeth of the upper jaw displayed the characteristic linear hypoplasia which corresponds to 23.2 % of all cases. In particular, in the skull series we examined the greatest disruption of enamel formation was found on the canines of the upper jaw, while it also exists, albeit at a declining frequency, in the first molars, the second molars, followed by the lateral incisors and central incisors as well as the third molars. In the first molars, the frequency of hypoplasia is consistently high in the teeth of these skulls from all three periods examined (antiquity, the middle ages and the new age).

If we assume that the greater occurrence of hypoplasia in the canines is representative of the sample under observation and that the expected commencement of enamel formation

in the canines occurs the fourth or fifth post-embryonic month (Logan and Kronfeld 1935), then this period of time could be linked to poor living conditions and malnutrition, or to factors such as weaning, childhood illnesses and infectious diseases.

In one of the most significant similar studies of ancient skeletal material, albeit from different periods, in which the variety of features of enamel hypoplasia in ancient Greek populations was shown, Angel (1971) makes the following remark: 61% of a total of 60 adults from the skeletal population of Middle Helladic Lerna on the Peloponnese which he studied displayed a high frequency of enamel hypoplasia. Specifically, 18% of the subjects from Lerna displayed severe enamel hypoplasia, whereas the hypoplasia was minor in 43% of the subjects. Furthermore, Angel cites data resulting from the examination of skeletal material from the Mycenaean period, in which severe enamel hypoplasia was found in 4% of his subjects, while he also refers to results from similar studies of skeletal material from the Roman period, in which the frequency of enamel hypoplasia was found to be 11% (Angel 1971).

**Comparison of skulls from the Antiquity the middle ages and the new age**

The following table shows the proportion of teeth with enamel hypoplasia with respect to the three time periods examined.

**TABLE 8**

	<b>Antiquity</b>	<b>Middle Ages</b>	<b>New Age</b>
<b>Δ1</b>	<b>0.14</b>	<b>0.10</b>	<b>0.00</b>
<b>Δ2</b>	<b>0.13</b>	<b>0.24</b>	<b>0.00</b>
<b>Δ3</b>	<b>0.43</b>	<b>0.44</b>	<b>0.11</b>
<b>Δ4</b>	<b>0.13</b>	<b>0.34</b>	<b>0.17</b>
<b>Δ5</b>	<b>0.35</b>	<b>0.39</b>	<b>0.20</b>
<b>Δ6</b>	<b>0.50</b>	<b>0.63</b>	<b>0.40</b>
<b>Δ7</b>	<b>0.17</b>	<b>0.29</b>	<b>0.00</b>
<b>Δ8</b>	<b>0.08</b>	<b>0.33</b>	<b>-</b>
<b>Δ9</b>	<b>0.00</b>	<b>0.12</b>	<b>0.00</b>
<b>Δ10</b>	<b>0.06</b>	<b>0.27</b>	<b>0.00</b>
<b>Δ11</b>	<b>0.38</b>	<b>0.55</b>	<b>0.35</b>
<b>Δ12</b>	<b>0.05</b>	<b>0.21</b>	<b>0.13</b>
<b>Δ13</b>	<b>0.14</b>	<b>0.17</b>	<b>0.13</b>
<b>Δ14</b>	<b>0.50</b>	<b>0.49</b>	<b>0.50</b>
<b>Δ15</b>	<b>0.24</b>	<b>0.15</b>	<b>-</b>
<b>Δ16</b>	<b>0.08</b>	<b>0.17</b>	<b>-</b>

DIAGRAM 2

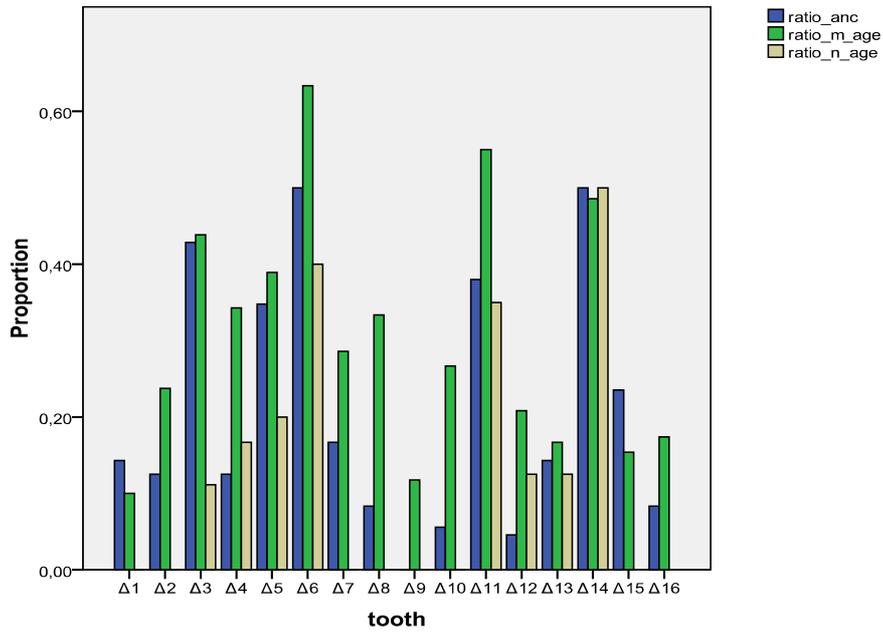


Fig1



Fig2



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