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TOOTH AGENESIS CODE (TAC) VALUES IN A SAMPLE OF ORTHODONTIC PATIENT POPULATION

BİR GRUP ORTODONTİ HASTA POPULASYONUNDA TOOTH AGENESİS CODE (TAC) DEĞERLERİ

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ABSTRACT

Purpose: There are numerous studies about tooth agenesis, but most focus on the absence of teeth not the patterns of absent teeth. The purpose of this study was to document TAC values in a sample of orthodontic patient population.

Material and Methods: Orthopantomograms of 2733 orthodontic patients (1674 females and 1059 males) between the ages of 12 and 25 years were examined for the evidence of hypodontia. The TAC method was used to determine TAC and TACoverall values for combination patterns of absent teeth.

Results: It was found that 710 (26%) patients had 1600 missing teeth, including third molars. There were 79 combination patterns of these missing teeth. A number of 31 patterns were occurred more than one and symmetrical patterns were clearly showed in congenitally missing teeth.

Conclusions: In this study, the symmetry and combinations of tooth agenesis in an orthodontic patient population by using the TAC and TACoverall values were performed.

Key words: TAC, hypodontia, agenesis.

ÖZET

Amaç: Diş eksikliği ile ilgili çok çalışma olmasına rağmen çoğu çalışma eksik diş paterni yerine diş eksikliğine odaklanmıştır. Bu çalışmanın amacı bir grup ortodonti hasta populasyonunda TAC değerlerini belirlemektir.

Gereç ve Yöntem: Yaşları 12 ile 25 arasında değişen 2733 ortodonti hastasının (1674 kız ve 1059 erkek) panoramik grafileri hipodonti varlığı açısından değerlendirildi. Diş eksikliği kombinasyon paterni için TAC and TACoverall değerlerini belirlemek için TAC methodu kullanıldı.

Bulgular: 710 (% 26) hastada 3. Molar dişler dahil 1600 eksik diş bulundu. Eksik dişlerin 79 kombinasyon paterni vardı. 31 patern birden çok kez gözlendi ve konjenital diş eksikliğinde simetrik patern net olarak görüldü.

Sonuç: Bu çalışmada TAC ve TACoverall değeri kulanılarak ortodonti hasta populasyonundaki eksik dişlerin, simetrilerin ve kombinasyonlarının değerlendirilmesi yapılmıştır.

Anahtar kelimler: TAC, hipodonti, eksiklik

INTRODUCTION

Agenesis of one or more permanent teeth, as known hypodontia in general, is fairly common in contemporary populations.[1-17] Hypodontia is one of the most common anomalies in the development of the human dentition.[15-19] Reported hypodontia frequencies from different populations, excluding third molars, have dramatic ranges (from 0.3%[1] to 11.3%[15]). There are various causes for the congenital absence of a tooth. Environmental influences such as trauma, infections (e.g. Rubella), ionizing radiation, drugs and hormonal changes have an affect on tooth formation during the embryologic stages of dental

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development.[20] Several genetic and syndromic conditions are also known to increase the risk of hypodontia.[21] Hypodontia is associated with the MSX1 that tends to affect premolars and the PAX9 that causes primarily molar agenesis.[21-23] Allelic forms of MSX1, MSX2, PAX9, and other factors modulate the threshold for hypodontia.[24]

With respect to the ongoing advancement in genetic research, it has been suggested that it is essential to have a measurement procedure with which unique patterns of tooth agenesis can be identified.[25] Previous studies make use of frequencies to identify which teeth are missing. This has its limitations in that it addresses only one tooth at a time and not combinations of teeth that are absent. In a recent study, van Wijk and Tan[25] designed the Tooth Agenesis Code (TAC) which can be used to describe patterns of missing teeth. They suggested that the TAC is a practical procedure for assigning unique values for all possible combinations of absent teeth and using this methodology, exact information about which teeth are missing simultaneously can be obtained. This information can be used to answer specific research questions (for instance whether dominant patterns of tooth agenesis can be identified) and contribute to selection of patients for future genetic studies.[25]

The TAC method is based on binary arithmetic.[25] In the TAC method, binary arithmetic is applied to the presence (0) or absence (1) of teeth in order to determine unique numbers associated with any possible pattern of tooth agenesis. Each quadrant of human dentition normally contains 8 teeth. The teeth are numbered 1-8, according to FDI (Fédération Dentaire Internationale) tooth numbering system.[26] Tooth value can be determinated by calculating 2^{n-1}, in which "n" is the tooth number. Schematic representation of the human dentition and application of binary arithmetic to assign unique values to patterns of tooth agenesis is shown in Table 1. For each quadrants (q1, q2, q3, and q4), a unique TAC value can be obtained. For example; suppose a specific pattern is q2 = (0, 1, 0, 0, 1, 0, 0, 1) implicating that teeth 22, 25 and 28 are absent. For q2, TAC value is obtained by calculating the sum of the values associated with missing teeth using Table 1, which is 2 + 16 + 128 = 146. This pattern of q2 = (0, 1, 0, 0, 1, 0, 0, 1) equals the TAC value q2 = 146. The pattern associated with TAC value 146 is thus (0, 1, 0, 0, 1, 0, 0, 1). In this example, this pattern is valid for q2 and q3. For q1 and q4, this pattern should be mirrored (i.e. 1, 0, 0, 1, 0, 0, 1, 0).

With 32 possible teeth, the number of different patterns equals more than 4 billion combinations (2^{32}). For this reason, Van Wijk and Tan[25] proposed to apply this procedure to each quadrant, separately. Creton at al[27] constructed a new variable called "TACoverall" that was used to identify similar patterns of tooth agenesis throughout the mouth among different patients. This variable is composed of the TAC values of each quadrant.[27] TACoverall value is obtained by calculating the sum of (TACq1 x 10^9) + (TACq2 x 10^6) + (TACq3 x 10^3) + (TACq4). For example; suppose a patient's TAC values of q1, q2, q3, and q4 are 123, 100, 38, and 5. TACoverall value of this patient is 123100038005 for him or her mouth. The returned value, TACoverall, is a unique number in which, when displayed with thousands separators, the 4 underlying TAC scores remain recognizable.[27]

Literature search in January 2009 revealed no previous studies, using the method of TAC, about the patterns of tooth agenesis in the permanent dentition in a sample of orthodontic patient population. The aim of this study was, therefore, to document the TAC values in a sample of orthodontic patient population.

MATERIAL AND METHODS

The files of the randomly selected patients included anamnestic data, dental cast, orthopantomograms and intraoral photographs. The patients younger than 12 years old were excluded from the study. The files of patients with developmental anomalies such as ectodermal dysplasia, cleft lip or plate and Down's syndrome, or who had undergone orthodontic treatment previously were also excluded from the study. So, a total of 2733 patients' records of sufficient quality were obtained for the study. The study sample compromised from orthodontic patients ranging from 12 to 25 years of age, 1674 of which were females with an average of 15.19 ± 2.56 years old, and 1059 of which were males with an average of 14.63 ± 2.15 years old.

Hypodontia was evaluated for all permanent teeth from the orthopantomograms. The diagnosis of hypodontia from orthopantomograms has been verified to be reliable in previous studies.[10,14,19] A tooth was registered as congenitally missing when no trace could be found on radiograph and the treatment records confirmed that the tooth had not been extracted. Longitudinal, taken during orthodontic treatment, and final, taken at the end of orthodontic treatment, orthopantomograms of the selected patients were available. These orthopantomograms were used to determine hypodontia to prevent the registration of late mineralized teeth as congenitally missing teeth. Anamnestic data, dental casts and intraoral photograps were also used to exclude patients with missing teeth because of extraction and to ensure the accurate diagnosis of hypodontia.

To minimize variability in the present study, examinations were carried out jointly by the first and second authors of the article (two academics from the Department of Orthodontics) over approximately 2 months. Ten percent of orthopantomograms of patients with and without hypodontia, selected randomly, were reexamined by the third author of the article from another department (an academic from the Department of Orthodontics) one month after the initial survey, and reproductibility of 100% was obtained in the identification of hypodontia.

Table 1 is used to change a missing tooth into a unique TAC value. The TAC values of each quadrant of selected patients were calculated using the procedure described by van Wijk and Tan.[25] TACoverall values, described by Creton[27], were also calculated. All descriptive analyses were performed using the SPSS software package.

A total of 710 patients (441 females and 269 males) were found to have congenitally missing teeth, including third molars, in our 2733 subjects. A number of 1600 tooth (1048 in females and 552 in males) was absent, indicating an average of 2.25 missing teeth per individual with tooth agenesis. Descriptive results are shown in Table 2.

The various combinations of missing teeth were calculated as the TACoverall values. There were 79 combination patterns of these 1600 missing teeth. These combination patterns, given with TACoverall values, were showed in Table 3. A number of 31 TACoverall values occurred more than one and most of the TACoverall values showed symmetrical combination patterns. Symmetrical patterns were given with thick punto in Table 3.

The TAC values of each quadrant of the jaw are shown in Table 4. In the maxilla, the TACs 128, 2, and 130 were the most common patterns (24.9%, 2.7%, and 1.3%, respectively). In the mandibula they were 128, 16, 129, and 1 (19.3%, 1.3%, 0.7%, and 0.4%, respectively). A symmetrical hypodontia pattern has clearly been showed in this table. But there was no symmetry for some TAC values. These values were 1, 26, 132, 138, 154, 210 and 145, 146, 148, 130 in maxilla and mandibula, respectively.

Predictibaly, the third molars were the most commonly absent teeth in the most of the combination patterns. After the third molars, the maxillary lateral incisors were the most at risk for hypodontia.

Table 1: Schematic representation of the human dentition. A is the numbers of teeth according to the FDI tooth numbering system. B is the TAC values associated with missing teeth.

Right Upper Jaw (quadrant 1)									Left Upper Jaw (quadrant 2)							
A	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
B	**128**	**64**	**32**	**16**	**8**	**4**	**2**	**1**	**1**	**2**	**4**	**8**	**16**	**32**	**64**	**128**
A	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38
Right Lower Jaw (quadrant 4)									Left Lower Jaw (quadrant 3)							

Table 2: Descriptive analysis of the study (SD in parenthesis).

Descriptive & Frequencies	*Females*			*Males*			*Total*		
	n	%	Mean-age	n	%	Mean-age	n	%	Mean-age
Study Sample	1674	*61.3*	15.19(2.56)	1059	*38.7*	14.63(2.15)	2733	*100*	14.97(2.43)
Patients With Tooth Agenesis	441	*62.1*	15.35(2.50)	269	*37.9*	14.82(2.43)	710	*100*	15.15(2.48)
Number of Missing Teeth	1048	*65.5*	-	552	*34.5*	-	1600	*100*	-

Table 3: TACoverall values (combinations of missing teeth) of Turkish orthodontic patients (Symmetric patterns with thick punto).

TACoverall Values	***Females***		***Males***		***Total***		***Occurred More than one***
	n	%	n	%	n	%	
0	1233	*73.7*	790	*74.6*	2023	*74.0*	
1	2	*.1*	1	*.1*	3	*.1*	*
16	1	*.1*	1	*.1*	2	*.1*	*
128	31	*1.9*	14	*1.3*	45	*1.6*	*
16000	2	*.1*	1	*.1*	3	*.1*	*
16016	3	*.2*	4	*.4*	7	*.3*	*
16128	1	*.1*	0	*.0*	1	*.0*	
128000	34	*2.0*	20	*1.9*	54	*2.0*	*
128016	2	*.1*	0	*.0*	2	*.1*	*
128128	48	*2.9*	18	*1.7*	66	*2.4*	*
2000000	6	*.4*	2	*.2*	8	*.3*	*
2**128128**	0	*.0*	1	*.1*	1	*.0*	
2**129129**	1	*.1*	0	*.0*	1	*.0*	
16016000	0	*.0*	1	*.1*	1	*.0*	
128000000	22	*1.3*	27	*2.5*	49	*1.8*	*
128000128	2	*.1*	3	*.3*	5	*.2*	*
128016000	1	*.1*	0	*.0*	1	*.0*	
128016**128**	1	*.1*	0	*.0*	1	*.0*	
128128000	0	*.0*	5	*.5*	5	*.2*	*
128128128	9	*.5*	5	*.5*	14	*.5*	*
128144128	1	*.1*	0	*.01*	1	*.0*	
2000000000	12	*.7*	2	*.2*	14	*.5*	*
2001001001	0	*.0*	1	*.1*	1	*.0*	
2002000000	8	*.5*	10	*.9*	18	*.7*	*
2002000016	0	*.0*	1	*.1*	1	*.0*	
2002001001	1	*.1*	0	*.0*	1	*.0*	
2002016144	1	*.1*	0	*.0*	1	*.0*	
2018000000	1	*.1*	0	*.0*	1	*.0*	
2128000000	1	*.1*	0	*.0*	1	*.0*	
2130000000	2	*.1*	0	*.0*	2	*.1*	*
2138148144	1	*.1*	0	*.0*	1	*.0*	
160000000000	0	*.0*	1	*.1*	1	*.0*	
16016000**016**	1	*.1*	0	*.0*	1	*.0*	
18002**016016**	1	*.1*	0	*.0*	1	*.0*	
24024016000	1	*.1*	0	*.0*	1	*.0*	
128000000000	49	*2.9*	43	*4.1*	92	*3.4*	*
128000000016	1	*.1*	0	*.0*	1	*.0*	
128000000**128**	4	*.2*	3	*.3*	7	*.3*	*
128000**128**000	7	*.4*	4	*.4*	11	*.4*	*
128000**128128**	9	*.5*	5	*.5*	14	*.5*	*
128128000000	68	*4.1*	50	*4.7*	118	*4.3*	*
128128000**128**	11	*.7*	5	*.5*	16	*.6*	*
128128000144	1	*.1*	0	*.0*	1	*.0*	
128128001001	1	*.1*	0	*.0*	1	*.0*	
128128001129	1	*.1*	0	*.0*	1	*.0*	
128128016016	1	*.1*	0	*.0*	1	*.0*	
128128016128	1	*.1*	0	*.0*	1	*.0*	
128128128000	6	*.4*	7	*.7*	13	*.5*	*
128128128128	54	*3.2*	20	*1.9*	74	*2.7*	*
128128129129	3	*.2*	0	*.0*	3	*.1*	*
128128144000	1	*.1*	0	*.0*	1	*.0*	
128128144144	1	*.1*	1	*.1*	2	*.1*	*
128130000000	0	*.0*	1	*.1*	1	*.0*	
128130128128	1	*.1*	0	*.0*	1	*.0*	
128144144144	1	*.1*	0	*.0*	1	*.0*	

130002**144144**	0	*.0*	1	*.1*	1	*.0*	
130128000000	0	*.0*	2	*.2*	2	*.1*	*
130**128**000**128**	0	*.0*	1	*.1*	1	*.0*	
130**128128**000	1	*.1*	0	*.0*	1	*.0*	
130**128128128**	4	*.2*	1	*.1*	5	*.1*	*
130128**193193**	1	*.1*	0	*.0*	1	*.0*	
130130000000	2	*.1*	0	*.0*	2	*.1*	*
130130128128	4	*.2*	0	*.0*	4	*.1*	*
130130129128	0	*.0*	1	*.1*	1	*.0*	
130130129129	1	*.1*	1	*.1*	2	*.1*	*
130130192192	0	*.0*	1	*.1*	1	*.0*	
130144000000	1	*.1*	0	*.0*	1	*.0*	
130146000128	0	*.0*	1	*.1*	1	*.0*	

132134**129129**	1	*.1*	0	*.0*	1	*.0*	
134134145129	0	*.0*	1	*.1*	1	*.0*	
144**128128**001	1	*.1*	0	*.0*	1	*.0*	
144128144128	0	*.0*	1	*.1*	1	*.0*	
144144128128	1	*.1*	0	*.0*	1	*.0*	
144144129129	1	*.1*	0	*.0*	1	*.0*	
146146016016	1	*.1*	0	*.0*	1	*.0*	
146146146130	1	*.1*	0	*.0*	1	*.0*	
148148144144	1	*.1*	0	*.0*	1	*.0*	
154026**209209**	1	*.1*	0	*.0*	1	*.0*	
162162163163	1	*.1*	0	*.0*	1	*.0*	
210146**144144**	0	*.0*	1	*.1*	1	*.0*	

Table 4: Distribution of TAC values in each quadrant amoung Turkish orthodontic patients.

TACs of q1	*Females*		*Males*		*Total*		*TACs of q2*	*Females*		*Males*		*Total*	
	n	*%*	**n**	*%*	**n**	*%*		**n**	*%*	**n**	*%*	**n**	*%*
0	1400	*83.6*	893	*84.3*	2293	*83.9*	**0**	1439	*86.0*	907	*85.6*	2346	*85.8*
1	0	*.0*	0	*.0*	0	*.0*	**1**	0	*.0*	1	*.1*	1	*.0*
2	27	*1.6*	14	*1.3*	41	*1.5*	**2**	18	*1.1*	15	*1.4*	33	*1.2*
16	1	*.1*	1	*.1*	2	*.1*	**16**	1	*.1*	1	*.1*	2	*.1*
18	1	*.1*	0	*.1*	1	*.0*	**18**	1	*.1*	0	*.0*	1	*.0*
24	1	*.1*	0	*.0*	1	*.0*	**24**	1	*.1*	0	*.0*	1	*.0*
26	0	*.0*	0	*.0*	0	*.0*	**26**	1	*.1*	0	*.0*	1	*.0*
128	221	*13.2*	139	*13.1*	360	*13.2*	**128**	193	*11.5*	128	*12.1*	321	*11.7*
130	14	*.8*	9	*.8*	23	*.8*	**130**	10	*.6*	4	*.4*	14	*.5*
132	1	*.1*	0	*.0*	1	*.0*	**132**	0	*.0*	0	*.0*	0	*.0*
134	0	*.0*	1	*.1*	1	*.0*	**134**	1	*.1*	1	*.1*	2	*.1*
138	0	*.0*	0	*.0*	0	*.0*	**138**	1	*.1*	0	*.0*	1	*.0*
144	3	*.2*	1	*.1*	4	*.1*	**144**	4	*.2*	0	*.0*	4	*.1*
146	2	*.1*	0	*.0*	2	*.1*	**146**	2	*.1*	2	*.2*	4	*.1*
148	1	*.1*	0	*.0*	1	*.0*	**148**	1	*.1*	0	*.0*	1	*.0*
154	1	*.1*	0	*.0*	1	*.0*	**154**	0	*.0*	0	*.0*	0	*.0*
162	1	*.1*	0	*.0*	1	*.0*	**162**	1	*.1*	0	*.0*	1	*.0*
210	0	*.0*	1	*.1*	1	*.0*	**210**	0	*.0*	0	*.0*	0	*.0*
TACs of q4	*Females*		*Males*		*Total*		*TACs of q3*	*Females*		*Males*		*Total*	
	n	*%*	**n**	*%*	**n**	*%*		**n**	*%*	**n**	*%*	**n**	*%*
0	1458	*87.1*	966	*91.2*	2424	*88.7*	**0**	1459	*87.2*	958	*90.5*	2417	*88.4*
1	5	*.3*	2	*.2*	7	*.3*	**1**	3	*.2*	1	*.1*	4	*.1*
16	11	*.7*	6	*.6*	17	*.6*	**16**	14	*.8*	6	*.6*	20	*.7*
128	182	*10.9*	79	*7.5*	261	*9.5*	**128**	181	*10.8*	86	*8.1*	267	*9.8*
129	8	*.5*	2	*.2*	10	*.4*	**129**	7	*.4*	2	*.2*	9	*.3*
130	1	*.1*	0	*.0*	1	*.0*	**130**	0	*.0*	0	*.0*	0	*.0*
144	6	*.4*	3	*.3*	9	*.3*	**144**	5	*.3*	4	*.4*	9	*.3*
145	0	*.0*	0	*.0*	0	*.0*	**145**	0	*.0*	1	*.1*	1	*.0*
146	0	*.0*	0	*.0*	0	*.0*	**146**	1	*.1*	0	*.0*	1	*.0*
148	0	*.0*	0	*.0*	0	*.0*	**148**	1	*.1*	0	*.0*	1	*.0*
163	1	*.1*	0	*.0*	1	*.0*	**163**	1	*.1*	0	*.0*	1	*.0*
192	0	*.0*	1	*.1*	1	*.0*	**192**	0	*.0*	1	*.1*	1	*.0*
193	1	*.1*	0	*.0*	1	*.0*	**193**	1	*.1*	0	*.0*	1	*.0*
209	1	*.1*	0	*.0*	1	*.0*	**209**	1	*.1*	0	*.0*	1	*.0*

DISCUSSION

Calcification of the crowns of the permanent teeth, except third molars, starts at the age of 3 years and is generally completed at 6 years old.[28] In some individuals, there may be delayed development of premolars, hence nobody can be absolutely certain that these teeth are missing below the age of about 9 years, especially among males.[14] The late-forming third molar starts crown mineralization about 9 years of age, and the 95% confidence limits for crown completion include 12 years, even in slower-maturing whites.[21] The changes of a 12-year-old with no radiographic evidence of a third molar, but late-

forming one, are remote. For these reasons, twelve years of age was chosen as the lower limit of this study.

Specific terms are used to describe the nature of tooth agenesis. Hypodontia is most frequently used when describing the phenomenon of congenitally missing teeth in general.[15] Hypodontia is the most common human malformation, and it usually occurs without any other sign or symptom of maldevelopment.[18,29] However, attention currently focuses on transcription factors, notably MSX1 and PAX9.[22,23] These genes is due to their expression against the rest of the person's genotype combined with vagaries of the environment.[24] Hypodontia is typically excessive in the MSX1 and PAX9 pedigrees scrutinized to date, so it is reasonable that other allelic variants with milder effects on the extent of agenesis remain to be characterized.[22]

There are various ways to categorize numeric anomalies of teeth.[27] A trimodal classification would be to group cases into anadontia, hypodontia, and hyperdontia, with syndromic or nonsyndromic as subclasses.[30] Kirkham et al[31] was used a cluster analysis and principal component analysis to identify clusters of absent teeth in hypodontia patients. This is a better approach than numeric classification but cannot be used to classify individual cases.[27] In the literature, patients, who suffer from tooth agenesis, are usually described in terms of the number of absent teeth, not the patterns of absent teeth. However, this is not always a practical method.[27] Because of heredity factors play a role in tooth agenesis, a useful classification of tooth agenesis must be taken into account. Therefore, we chose the TAC method, described by van Wijk and Tan,[25] and the TACoverall value, described by Creton et al,[27] to characterize this population of orthodontic patients for tooth agenesis.

Absence of teeth has been found more often unilaterally than bilaterally.[19] But the symmetry in previous studies was showed only in missing teeth not in combinations of missing teeth. TACoverall values, used to explain the combination patterns of absent teeth in this study, showed the symmetrical combination patterns. TACoverall values were also showed the type of the symmetries (right and left symmetry, upper and lower symmetry and cross quadrant symmetry). A number of 31 TACoverall values occurred both females and males. Most TACoverall values occurred more than one combination. Similarly, the TAC values of each quadrant also showed the symmetric patterns of the jaw. However, some TAC values showed no symmetry.

Finally, the TAC method is a practical way to determine an individual's missing teeth. Using the TAC, the question of whether some patterns of tooth agenesis are more dominant than others can be answered. TAC may provide a tool that can give direction for research aimed at genotype-phenotype relationships. Further studies with TAC method will provide the information about most of the patterns of tooth agenesis and this information will be useful for future genetic researches.

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