J Forensic Sci, Jan. 2003, Vol. 48, No. 1
Paper ID JFS2002204_481
Available online at: www.astm.org

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Age Estimation from Teeth in Children and Adolescents

ABSTRACT: The aim of this cross-sectional study was to evaluate the dental formulas according to age because of possible changes during the last decades. From these dental formulas, the median age of emergence for the permanent teeth was deduced.

The study population corresponded to the 1 to 15 year-old children who had consulted either a pediatric dentist or orthodontist in the city of Nice (France). Data were collected from the 5848 patients' charts that included an orthopantomography. This permitted the observation of emerged teeth and agenesis. Bar charts were used to indicate the dental formula according to age.

There was no significant difference in the emergence pattern of both controlateral maxillary and mandibular teeth. Only the anterior tooth emergence significantly differed according to the maxillary. The lower central incisor was the lone tooth with a median age earlier than others; the remaining teeth had an age equivalent to those of previously estimates.

KEYWORDS: forensic science, forensic dentistry, dental age, dental formulas, cross-sectional study

Forensic dentistry requires the average ages of the emergence of permanent teeth, as well as the dental formula, for estimating the dental age of a subject with an unknown civil age. During the last century, there has been a tendency observed in the developed countries towards an earlier emergence of the permanent teeth. This secular trend has been attributed mainly to the earlier onset of puberty (1) and indirectly to better child health and nutrition (2). On the other hand, in the same developed countries, the number of children with healthy dentition has constantly increased since the seventies. Therefore, poor dental health of deciduous teeth might indirectly affect the emergence ages of some permanent teeth (3). The aim of this study was to evaluate new dental formulas according to age in the beginning of the 21st century. These dental formulas should make it possible to deduce the average ages of emergence of the permanent teeth. Finally, the ages corresponding to counts of permanent teeth in the oral cavity were also assessed, to make results readily available for forensic dentistry.

Materials and Methods

In this cross-sectional study, the studied population corresponded to 10 138 children (1 to 15 years old) who all consulted one of the pediatric dentists or orthodontists in the city of Nice (France), during the period 2000–2001. These specialists were practicing in one of the two hospitals (pediatric dentistry and orthodontic departments) or in one of the 17 private practices, in the city of Nice, with an approximate population of 102 195 children aged 1–15 years (4).

To prevent spurious results, we had to exclude from the analysis, children with particular clinical events corresponding to severe dental caries of the temporary teeth with radicular lesion without treatment, temporary teeth extractions indicated by severe dental caries, extractions indicated by an orthodontist, and narrow arch form incompatible with a normal emergence of the permanent teeth. One of the above clinical events could have modified the emergence of the permanent teeth. Data were collected from the charts of both treated and simply registered patients, in the year 2000–2001. Children corresponding to charts with either unreadable or missing personal data, and/or with bad quality, or dateless orthopantomography, were also excluded. The children were included only if their chart contained complete personal information (first name, date of birth, and orthopantomography date to compute the civil age at the radiography taking) plus a readable orthopantomography (inclusion criteria).

Two investigators were trained to examine individually all radiographs: they reported germs, emerged teeth, agenesis, and the dentition phases with reference to the classification of Bjork et al., modified by Demoge (5). The emergence of a tooth was defined when it had reached the occlusal table. The agenesis of an anterior tooth was acknowledged in children without the corresponding germ after 15 months of age, because mineralization initiates from the third to the fifteenth month (2,6). In the case of the premolars or second molars whose mineralization initiation is usually between one and half and 3 years (2,6), the agenesis was acknowledged in all children above three years of age without corresponding germs. When first observations differed in 455 orthopantomo-

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Received 11 June 2002; and in revised form 23 Aug. 2002; accepted 24 Aug. 2002; published 11 Dec. 2002.

graphies (7.78%), both dentists conducted a second examination to agree on the teeth emergence.

Bar charts were used to indicate the dental formula according to age. Median ages at the emergence of teeth were evaluated in each half maxillary, when children with a corresponding tooth agenesis were excluded. Median age was defined as the age when 50% of children presented a particular tooth in the oral cavity: this was evaluated with a simple graphic method using cumulative frequency curves (age in X-axis and percent of people with a particular tooth in Y-axis). The first (Q1) and third (Q3) quartiles allowed to calculate the standard deviation $\sigma = \frac{(Q_3 - Q_1)}{2 \times 0.6745}$ (7). Using a Chi square test, we compared the age (age categorized in a period of one year) of each emerged tooth type according to the controlateral sides or the two maxillaries. Finally, the counts of permanent teeth were assessed according to age. Statistical analysis was performed with SPSS 11.0 for Windows.

Results

Of the 10 138 patients charts screened, 5848 were included. They represented 1 to 15 year-old children at eight different dentition stages (Table 1). The median age at the emergence of the permanent teeth, as well as its range, are presented in Table 2. They were not evaluated with a similar number of children according to the observed different agenesis: 53 children up to 1.5 years with agenesis of the tooth 12; and 44, 20, 19 and 4 children for the teeth 22, 32, 42, and 43 respectively. If we were dealing with the premolar mineralization initiation, all children over three years of age without corresponding germs were excluded, to determine the median ages. There were respectively 7, 10, 6, 30, 29, 114, and 104 children for the teeth 14, 44, 34, 15, 25, 35, and 45. Finally, 4, 2, 4, and 6 children older than three years without 17, 27, 37, and 47 germs respectively were excluded.

Since we found no significant difference in the emergence pattern of controlateral maxillary and mandibular teeth, we combined the data from both sides. The emerged teeth on the two maxillaries were indicated by half maxillary according to the age in Figs. 1–15. From this we deduced the most frequent dental formula according to age. When we compared the median ages concerning the emergence of homologous teeth, only anterior teeth significantly differed according to the maxillary (Table 3). Finally, the ages of children with 1 to 28 permanent teeth in their mouth are presented in Table 4.

TABLE 1—*Repartition of the children aged 1–15 years according to the different stages of dentitions.*

Stage	Definition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Primary dentition emerging	Deciduous teeth emerging	2	5														7
Primary dentition complete	Deciduous teeth fully emerged	1	60	255	422	353	66	3									1160
Early mixed dentition	1st molars or incisors emerging			1	21	237	496	526	270	27	18	4	2				1602
Intermediate mixed dentition	1st molars and incisors fully emerged						14	121	281	301	105	24	7		1		854
Late mixed dentition	Canines or premolars emerging						7	66	176	293	412	276	95	25	6	2	1358
Adolescent dentition	Canines or premolars fully emerged									3	15	15	11	3			47
Adult dentition constitution	2nd molars emerging									9	39	66	73	46	12	7	252
Young adult dentition	2nd molars fully emerged									2	15	66	122	135	125	103	568
		3	65	256	443	590	583	716	727	635	604	451	310	209	144	112	5848

TABLE 2—*Age median at the emergence of permanent teeth.*

Teeth	*n*	Min	Median	Max	SD	Teeth	*n*	Min	Median	Max	SD
11	5848	4.50	6.75	9.50	0.86	21	5848	5.00	6.75	9.50	0.86
12	5795	5.50	7.50	11.00	0.99	22	5804	5.50	7.50	11.00	0.99
13	5848	7.00	11.50	15.50	1.60	23	5848	7.00	11.50	15.50	1.60
14	5841	6.00	10.33	14.00	0.92	24	5848	7.00	10.33	14.00	0.92
15	5818	7.00	11.50	15.50	1.48	25	5819	7.00	11.50	15.50	1.48
16	5848	4.50	5.83	7.50	0.70	26	5848	4.50	5.83	7.50	0.70
17	5844	9.00	12.08	15.50	1.31	27	5846	9.00	12.08	15.00	1.31
41	5848	4.00	5.75	8.00	0.74	31	5848	4.00	5.75	8.00	0.74
42	5829	5.00	6.88	10.50	0.93	32	5828	5.00	6.88	9.50	0.93
43	5844	6.50	10.12	13.00	1.27	33	5848	6.50	10.12	13.00	1.27
44	5838	6.50	10.21	14.00	1.35	34	5842	6.50	10.21	14.00	1.35
45	5744	7.00	11.50	15.50	1.61	35	5734	7.00	11.50	15.50	1.61
46	5848	4.00	5.71	7.50	0.68	36	5848	4.00	5.71	7.50	0.68
47	5842	9.00	11.75	15.00	1.39	37	5844	9.00	11.75	15.00	1.39

SD: Standard deviation.

TABLE 3—*Emerged teeth according to age.*

Controlaterale Teeth	ddl	χ^2	*p*	Homologous Teeth	ddl	χ^2	*p*
11.21	5	2.28	0.810	11.41	5	171.57	0.000
12.22	6	1.09	0.982	12.42	8	147.81	0.000
13.23	7	0.82	0.997	13.43	8	113.14	0.000
14.24	8	2.23	0.973	14.44	6	3.15	0.790
15.25	6	1.35	0.969	15.45	7	2.78	0.904
16.26	3	0.28	0.964	16.46	3	3.17	0.366
17.27	6	1.38	0.967	17.47	6	13.20	0.039
41.31	4	0.15	0.997	21.31	5	155.63	0.000
42.32	6	0.44	0.999	22.32	8	145.07	0.000
43.33	6	0.28	0.999	23.33	8	115.42	0.000
44.34	7	1.64	0.977	24.34	8	10.42	0.233
45.35	6	0.44	0.998	25.35	6	1.86	0.932
46.36	3	0.37	0.946	26.36	3	6.59	0.086
47.37	4	0.33	0.988	27.37	5	14.36	0.013

TABLE 4—*Ages corresponding to counts of permanent teeth.*

Teeth Count	*n*	Mean	SD	IC (95%)	Minimum	Maximum
1	39	5.74	.58	[5.55–5.93]	4.50	7.00
2	119	5.87	.64	[5.76–5.99]	4.50	7.50
3	63	6.02	.75	[5.83–6.21]	4.50	7.50
4	121	6.15	.76	[6.02–6.29]	4.00	8.00
5	48	6.16	.69	[5.96–6.36]	4.50	8.00
6	303	6.58	.81	[6.48–6.67]	4.50	9.50
7	93	6.91	.82	[6.74–7.08]	4.50	9.00
8	193	7.17	.85	[7.05–7.29]	5.00	9.50
9	91	7.54	.90	[7.36–7.73]	5.50	9.50
10	479	7.70	.99	[7.61–7.79]	5.00	11.00
11	120	8.34	1.06	[8.15–8.53]	6.00	11.50
12	937	8.83	1.11	[8.76–8.91]	6.50	12.50
13	188	9.50	1.13	[9.33–9.66]	6.50	12.50
14	170	9.73	1.15	[9.56–9.90]	7.50	12.50
15	128	9.94	1.09	[9.75–10.13]	7.00	14.00
16	110	10.10	1.25	[9.87–10.34]	6.50	12.50
17	104	10.49	1.15	[10.26–10.71]	8.00	14.50
18	119	10.52	1.19	[10.31–10.74]	7.50	14.00
19	77	10.79	1.13	[10.53–11.04]	8.50	14.00
20	106	10.80	1.22	[10.56–11.03]	7.00	14.00
21	61	11.01	1.29	[10.88–11.54]	8.00	15.00
22	66	11.21	1.06	[10.77–11.24]	9.50	13.00
23	66	11.26	1.14	[11.22–11.78]	9.00	15.50
24	87	11.50	1.16	[11.02–11.51]	7.00	14.50
25	49	11.96	1.42	[11.72–12.54]	9.50	15.00
26	101	12.13	1.36	[11.69–12.22]	8.00	15.50
27	58	12.67	1.36	[12.31–13.03]	9.50	15.50
28	549	13.34	1.38	[13.22–13.45]	9.00	15.50

Discussion

In our study, the counting of emerged teeth (8–11) was used to estimate age by dental maturity: one advantage of this method, when compared with radiographic method based on tooth mineralization (12,13), is being more precise (3). Other advantages are that it requires neither special equipment nor specialization to assess the presence or absence of a tooth (11). It is easily used in forensic pathology and anthropology. We selected a cross-sectional design the same as most studies concerning teeth emergence (8,11–24). In the current study, this design was particularly appropriate since the principal objective was to determine the dental formula according to age in Nice. Consequently, it allowed the inclusion of 5848 patients 1 to 15 years of age with specialized dental care in either pediatric dentistry or orthodontic, showing the great external validity of our results. Our number of included children was greater than others similar studies (8,9,15,19,24–26). If we exclude the Hurme's study which summarized 24 articles about 39 000 children from eight European and North American countries, only two studies used a larger sample (18,20,27).

In a cross-sectional study, the estimation of the exact age of emergence is not possible because the follow up of the children is non-existent for the complete dentition period (28). Only a longitudinal study could assess this. This last design was not selected because of the increased risk of bias (losses to follow-up) and ethical problems with yearly orthopantomography. To account for the previous study limitation, we substituted the average age at the emergence by the median age. It has been demonstrated that median age at the emergence of specific teeth may be the best method to estimate dental age on the basis of tooth emergence accounting for the irregularities in the clinical eruption (3). This was based on two results. First, the median and average ages were not significantly dif-

ferent; this even if the median is a bit lower than the mean (15,24). Second, the median had the advantage of not being influenced by the not well represented lowest age categories. Clinical practice can explain the different sizes for the age categories. Children under three rarely consult a dentist. Moreover, the usual age of orthopantomography indication is after two to three years of age. For these reasons, few patients aged one to two years were included.

Our study had some limitations because the gender unfortunately, was not registered on file. To prevent the risk of information bias related to gender classification, we did not use the first name as a proxy of this variable. In fact, some first names can be used for both genders. Besides, some foreign names did not allow us to assign gender and thus the variable was excluded. This limitation did not appear to cause an impact in the internal validity of our results. Even if some authors indicated that girls teeth erupt around three to five months earlier than boys (20); most studies showed no difference between gender and particular class of teeth (7,29): upper (23), incisors (17,30), premolars (1,17,31), first (11,17,23,30) and second molars (30). It appears that the greatest difference should affect the mandibular canines (31,32) although no gender difference was found in the emergence of the canines by others (1,23). Finally, differences in the general sequence of development were not apparent between males and females (29).

In the present study based on radiography examination, teeth were considered erupted if they had reached the occlusal table (8). Thus, the age of emergence could be greater than other ones estimated when only the entire occlusal surface was visible (1,26) or as soon as the tooth pierced the gingiva (11,15,31,33). It was not the case even though the time taken for a tooth to erupt from the piercing of the gum to occlusion usually varied from 3 to 12 months (34).

Our results of equal emergence of controlateral teeth agreed with earlier studies (7,17,28,31–33). This invalidated a tendency for the right permanent teeth to erupt somewhat later than the corresponding teeth on the left (34,35). The median ages at the emergence of the different tooth types obtained in our study showed general agreement with other results, except for the lower central incisor. We obtained a median age, 5.75 years, earlier than the 6–7 years usually found (1,7,14,15,19–21,23–26,30,31,33,35). Only four studies found similar results in girls (3,8,17,36). However, the earliest emergence age of this tooth has already been reported in recent studies (3,17). The range from 4 to 8 years was comparable with age limits described in literature (3,8). They were outside the usual limits of age (median age $\pm$ 2 standard deviation). The other teeth to emerge at the same time were the first molars at 5.71 and 5.83 years for the lower ones and upper ones respectively. Our results confirmed the simultaneous first molars and lower central incisors' emergence, followed by upper central incisors (10,11,24,25,28). They confirmed again the lower first molar (7) or central incisor (17,37) as the first permanent tooth to erupt. In our results, the median age of the emergence of first molars was just earlier than others, and ranged from 6.1 to 6.9 years (1,3,7,14,15,17,19,20,23–26,30,31,33,35,38). Only three studies found an age below six years (8,21,36). The upper central incisor emerged one year later than its antagonist with a median emergence age of 6.75 years. This confirmed the other authors results, which ranged from 6.33 (22) to 8.16 years (19,35). Most studies indicated an average age of about seven years (7,16,18,20,21,23–25,30). Some more recent surveys showed a younger age of 6–7 years (3,14,15,17,22,26,31–33,36). The minimum age limit, 4.5 years, was comparable with other ones (3,16,18). On the other hand, maximum age limit of 9.5 years was inferior to 10–11 years, found by different authors (16,18,22). Whatever the studies, the standard deviations were lowest for first molars and central incisors. Thus our results were in agreement with the lowest variation for the first teeth to erupt (2,28). The next teeth to emerge were lower lateral incisors at 6.88 years according to other studies (3,17,22,25,32,36). However, most authors estimated a median emergence age of seven years (1,7,8,14–16,18,20–24,30,31,33,38) and sometimes of eight years (19,35). The range from 5 to 10.5 years was equivalent to other ranges given in different studies (3,8,16,38). Only Godeny showed a larger range of 4 to 11 years (18). We explained this difference by his greater sample size: it should cause a more important variability. The difference between our results concerning upper lateral incisors and others was not as important as it was for its antagonist. Many of them agree for an emergence at 7.5 years (3,8,14,15,17,22,24–26,31–33,36) even if some indicated eight years (1,7,16,18,20,21,23,35). As other anterior teeth, the canines were at the occlusal level earlier in the lower arch than in the upper one (24,33,34,39). However our results showed a mean difference greater than six months for these corresponding teeth (7,28). All agreed to 10 years of age for the emergence of the lower canines (7,15,18,19,21,23,26,30,35,38) with a slight tendency for earlier emergence in girls at nine (1,3,8,14,16,17,20,24,31–33,36). Contrary to the inferior age limit, the superior age limit was smaller than 14 years, which was found in previously published cross-sectional studies with a greater sample size (16,18). Except for some girls at 10 (1,3,8,14,15,17,22,24, 32,36) and some boys at 12 (19,35), the emergence of upper canines at 11 years was confirmed (7,16,20,21,23,26,30,31,33,38). As reflected by the standard deviations, this age of emergence was the most variable (2). Next, the variability was significant for premolars and second molars. So the highest standard deviations were in the last teeth to emerge (2,37). First premolars were the next teeth to emerge at 10 years, in agreement with various studies (1,3,15,17–20,23,24,26,33,36,38). Taking into account the standard deviations, the normal variation of age emergence was in agreement with the formerly found nine (31) or 11 year-olds (35,40). However, our results differed for lower premolars that emerge later than the corresponding upper ones (33). Our results confirmed the greatest intermaxillary variations in the eruption timing, only between incisors and canines (17,32,39). Both second premolars emerged one year later, at 11 years (1,14,15,17,18,26, 30,31,33,36,38), without disagreement with emergence ages at 10 (22,41) or 12 (35,40). Finally, it was the same pattern for the last teeth to emerge, even though we found an emergence age of the lower second molar a little earlier than the corresponding upper ones. The standard deviations for the emergence of the second molars, and consequently the normal variation, authorized a difference of about three to four months. No referenced studies report an age at the emergence for the second molars other than 11–12 years. On the other hand, our range from 9 to 15.5 years was smaller than the others, found in cross-sectional studies previously mentioned, with a greater sample size (16,18). Generally the median ages at the emergence of the permanent teeth in our study were earlier than average ages shown by various authors. Since this small difference has been evaluated by other authors and proved to be non-significant (15,24), secular effect on the timing of tooth eruption can not be agreed (1,17,31,36). If some factors such as economic conditions, nutrition, sanitation, and medical care, have advanced the dental maturity (8,9,31,36), the decrease in number of caries in primary teeth for the last three decades resulted in an opposite effect. Therefore, no difference was observed.

Our results agreed with earlier studies that showed the variability in the emergence order, yet they indicated some typical dentition or dental formula according to the age. At one year, most of the

children were in the primary dentition emerging stage: all of them had their temporary teeth except the second molars (Fig. 1). One year later, this primary dentition emerging stage was not the most common. Thus, the complete primary dentition stage was the most frequently observed in 2 to 5 year-olds, although the first permanent teeth erupted as early as four years (Figs. 2–5). At six and seven, early mixed dentition was the predominant one. Nevertheless, the fifth and the sixth years of life represented the first period of intensive tooth eruption (23). The most frequent dental formula varied according to maxillary, with central incisors at six years, and lateral ones at seven. There were a permanent lower one, and a temporary upper corresponding. Next, intermediate mixed dentition and late mixed dentition were most often observed from 8 to 11 years. These dentition stages were characterized by an important variability of the eruption sequence. The bar charts according to age were easier to use than numeric dental formula corresponding to different order of emergence (Figs. 6–11). Our results confirmed the most observed order of eruption in lower (IC, M1, II, C, PM1, PM2, M2) and upper (M1, IC, II, PM1, C, PM2, M2) maxillaries (7,8,9,24,30,33,42). Young adult dentition stage was the most frequent from 12 years (Figs. 12–15). In the same way, we preferred an alternative method with ages corresponding to counts of permanent teeth (Table 3). Our results closely resembled those by Nystrom et al. in Finland (3). The standard deviation increasing with the number of teeth was interesting to note. This corresponded to the biggest variations in the last teeth to erupt. The simultaneous use of both, tooth count and median ages of emergence of different teeth, permit a better assessment of the dental age.

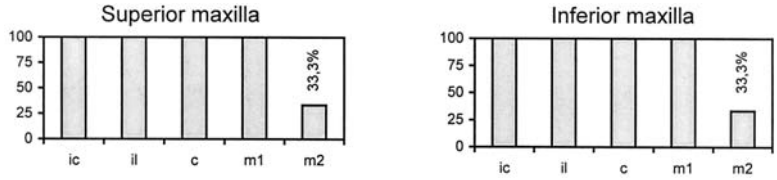

FIG. 1—*Temporary teeth (%) in three children of one year old.*

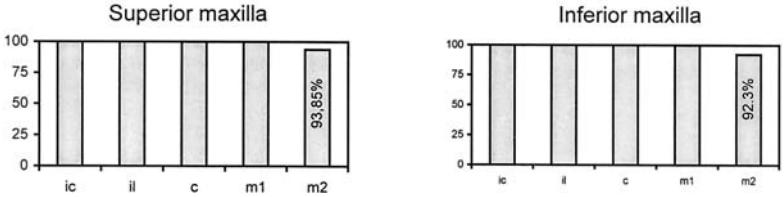

FIG. 2—*Temporary teeth (%) in 65 children of two year old.*

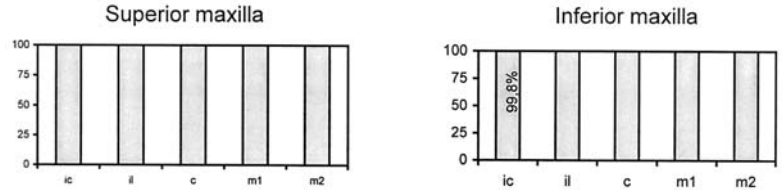

FIG. 3—*Temporary teeth (%) in 256 children of three year old.*

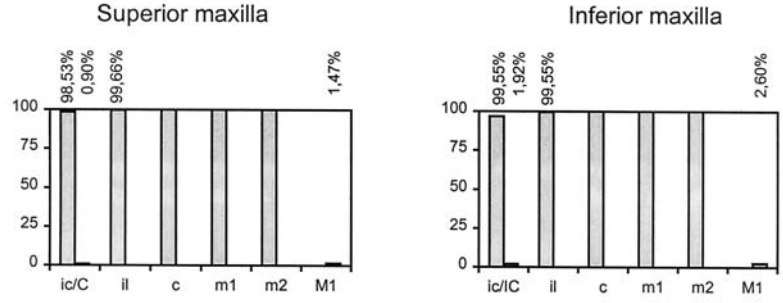

FIG. 4—*Temporary and permanent teeth (%) in 443 children four year old.*

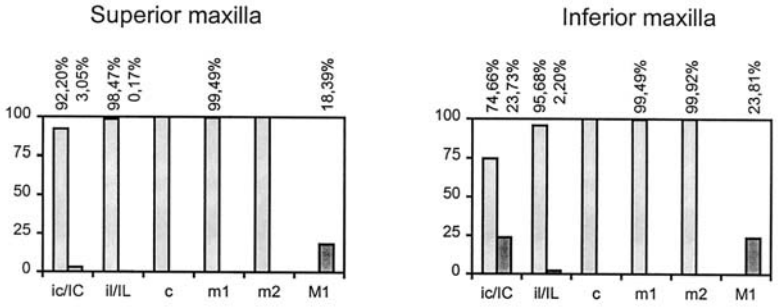

FIG. 5—*Temporary and permanent teeth (%) in 590 children five year old.*

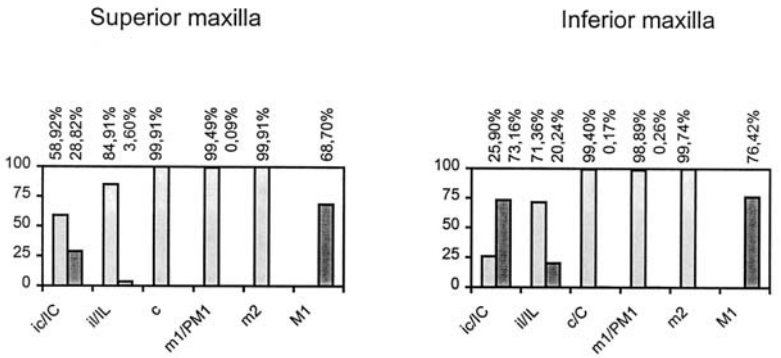

FIG. 6—*Temporary and permanent teeth (%) in 583 children six year old.*

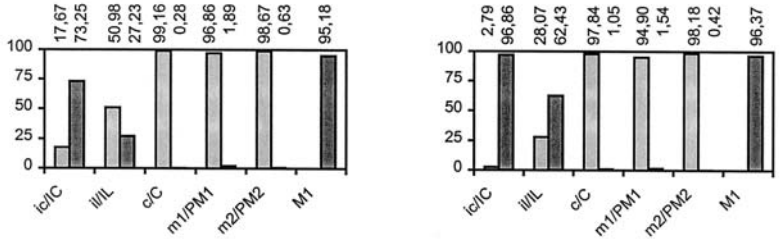

FIG. 7—*Temporary and permanent teeth (%) in 716 children of seven year old.*

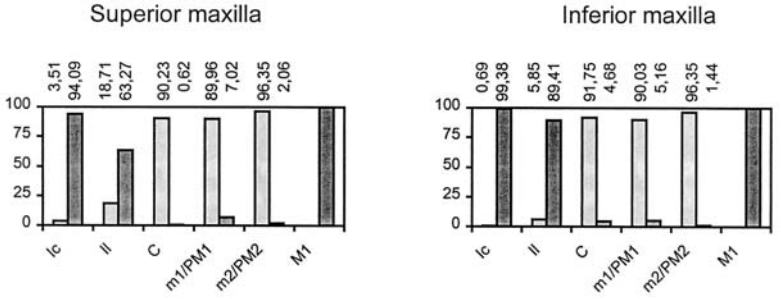

FIG. 8—*Temporary and permanent teeth (%) in 727 children of eight year old.*

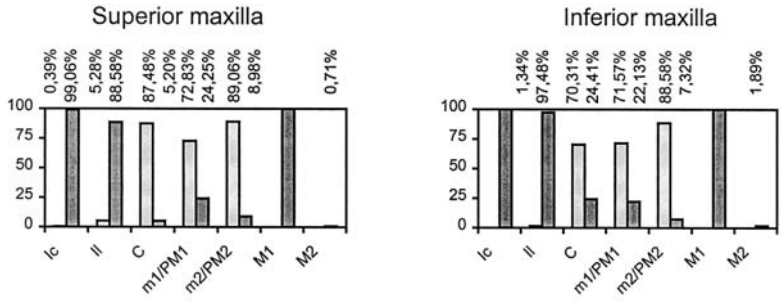

FIG. 9—*Temporary and permanent teeth (%) in 635 children of nine year old.*

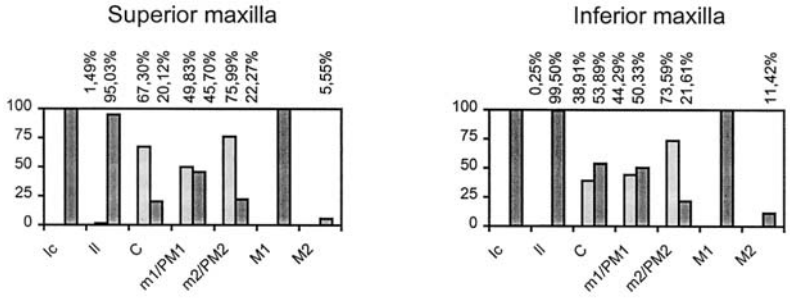

FIG. 10—*Temporary and permanent teeth (%) in 604 children of 10 year old.*

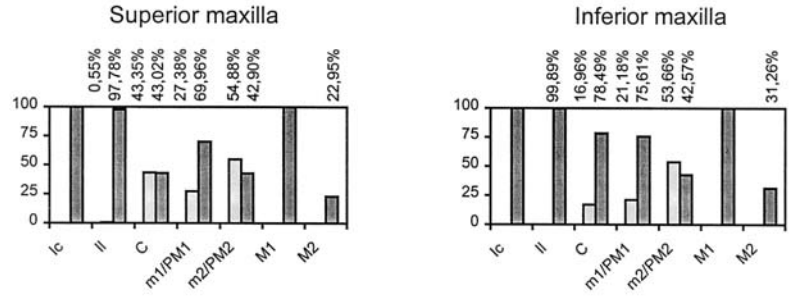

FIG. 11—*Temporary and permanent teeth (%) in 451 children of 11 year old.*

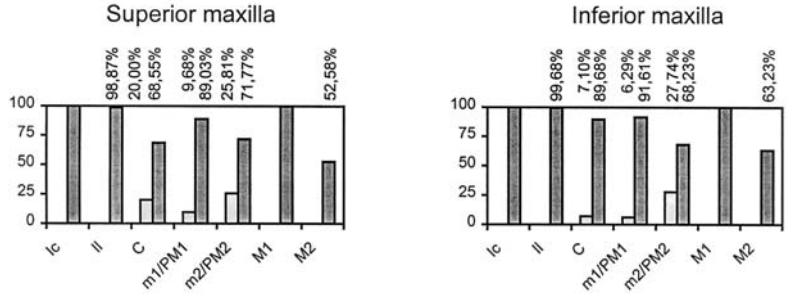

FIG. 12—*Temporary and permanent teeth (%) in 310 children of 12 year old.*

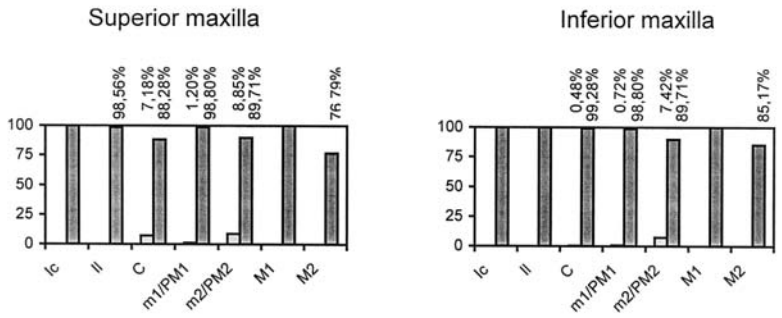

FIG. 13—*Temporary and permanent teeth (%) in 209 children of 13 year old.*

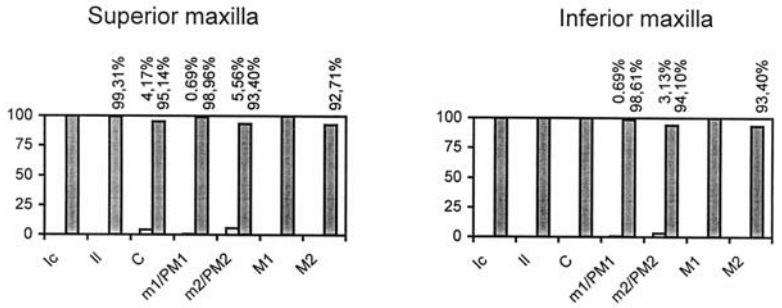

FIG. 14—*Temporary and permanent teeth (%) in 144 children of 14 year old.*

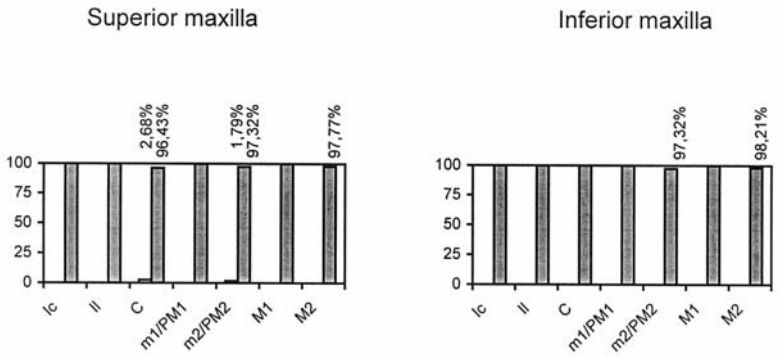

FIG. 15—*Temporary and permanent teeth (%) in 112 children of 15 year old.*

Acknowledgments

The authors thank Rebecca Place-Quintane and Ann Robinson from The Centre for Clinical Epidemiology and Community Studies (Montreal, Canada) for their contribution in the English translation.

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