https://doi.org/10.54589/aol.39/1/93

Chronology and sequence of permanent tooth eruption in children in Buenos Aires City

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ABSTRACT

Knowledge of the timing and sequence of permanent tooth eruption is essential for assessing occlusal development and providing population-specific reference standards to support diagnosis, prevention, and treatment planning. ***Aim:*** *To estimate mean age for eruption of permanent teeth, except third molars, in children in Buenos Aires City (CABA), compare means according to sex, jaw and laterality, and identify the eruption sequence per arch.* ***Materials and Method:*** *An observational, prospective, cross-sectional study was conducted (March–July 2024) on 4- to 15-year-old children who received care at Buenos Aires University's School of Dentistry and at four private offices in Buenos Aires City. A tooth was considered erupted when at least one cusp or incisal edge pierced the gingival epithelium. Mean ages were estimated using the Kärber method with 95 % confidence intervals (CI), and the sequence was established by placing those means in order.* ***Results:*** *We evaluated 1,063 children (532 female), mean age 9.9 ± 2.6 years. The first teeth to erupt were lower central incisors, and the last were upper second molars. No difference was observed between hemiarches. Teeth belonging to the lower incisor-canine group erupted significantly earlier than their homologous upper teeth. Girls presented earlier eruption than boys, with significant differences for all teeth except upper central incisors, and upper and lower first molars. Sequence for the upper jaw was 6–1–2–4–3–5–7 in girls, and 6–1–2–4–5–3–7 in boys. Sequence in the mandible was 1–6–2–3–4–5–7 in girls, and 1–6–2–4–3–5–7 in boys, with chronological proximity between canine and premolars in some comparisons.* ***Conclusion:*** *In this sample, eruption began with lower central incisors, was symmetrical, earlier in girls, and earlier in the lower incisor-canine group, with sequential stability in both sexes during the first transitional period, and variations in the second.*

Keywords: *tooth eruption - permanent dentition - child - cross-sectional studies*

Cronología y secuencia de erupción de la dentición permanente en niños de la Ciudad de Buenos Aires

RESUMEN

El conocimiento de la cronología y la secuencia de erupción de la dentición permanente es fundamental para evaluar el desarrollo oclusal y disponer de parámetros poblacionales de referencia que orienten el diagnóstico, la prevención y la planificación terapéutica. ***Objetivo:*** *Estimar la edad media de erupción de las piezas dentarias permanentes, excluyendo terceros molares, en niños de la Ciudad Autónoma de Buenos Aires (CABA), comparar las medias según sexo, maxilar y lateralidad, e identificar la secuencia eruptiva por arcada.* ***Materiales y Método:*** *Se realizó un estudio observacional, prospectivo y transversal (marzo–julio 2024) en niños de 4 a 15 años atendidos en la Facultad de Odontología de la Universidad de Buenos Aires y en cuatro consultorios privados de CABA. Se consideró erupcionada una pieza cuando al menos una cúspide o borde incisal atravesó el epitelio gingival. Las edades medias se estimaron mediante el método de Kärber, con intervalos de confianza (IC) del 95 %, y la secuencia se estableció ordenando dichas medias.* ***Resultados:*** *Se evaluaron 1.063 niños (532 mujeres) con una edad media de 9,9 ± 2,6 años. Los primeros dientes en erupcionar fueron los incisivos centrales inferiores y los últimos los segundos molares superiores. No se observaron diferencias entre hemiarcadas. Las piezas del grupo incisivo-canino inferior erupcionaron significativamente antes que sus homólogas superiores. Las niñas presentaron erupción más temprana que los varones, con diferencias significativas en todas las piezas excepto incisivos centrales superiores y primeros molares superiores e inferiores. La secuencia superior fue 6–1–2–4–3–5–7 en niñas y 6–1–2–4–5–3–7 en niños; en la mandíbula fue 1–6–2–3–4–5–7 en niñas y 1–6–2–4–3–5–7 en niños, con proximidad cronológica entre canino y premolares en algunas comparaciones.* ***Conclusión:*** *En esta muestra, la erupción inició con los incisivos centrales inferiores, fue simétrica, más precoz en niñas y más temprana en el grupo incisivo-canino inferior, con estabilidad secuencial en ambos sexos durante el primer período transicional y variaciones en el segundo.*

Palabras clave: *erupción dentaria - dentición permanente - niño - estudios transversales*

To cite: Toscano MA , Anchava JA, Cortese SG, Biondi AM. Chronology and sequence of permanent tooth eruption in children in Buenos Aires City. Acta Odontol Latinoam. 2026 Jun 26;39(1):93-100. https://doi.org/10.54589/aol.39/1/93

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Received: February 2026
Accepted: June 2026

INTRODUCTION

Tooth eruption is a long, complex physiological process, closely related to the growth and development of craniofacial structures. It is a dynamic process that includes tooth embryological development (odontogenesis), movement in the jaws, and fitting in the arches until occlusal functionality is attained. Three phases can be identified in this process: the pre-eruptive phase, from the beginning of odontogenesis until the crown is fully formed; the pre-functional eruptive phase, which begins with root formation and is completed when the tooth establishes contact with its antagonist; and the functional eruptive phase, which begins with this contact and continues during the masticatory function. The point at which the tooth pierces the oral mucosa and becomes visible in the oral cavity is called dental emergence. It occurs during the pre-functional eruptive phase, and is generally identified as “tooth eruption”[1].

Various factors influence the sequence and timing of tooth emergence. A strong genetic component has been identified in eruptive chronology[2], while longitudinal studies have shown associations between general corporeal growth and time of tooth emergence[3]. Moreover, recent research has reported that body mass index and nutritional status may be related to variations in eruptive chronology and sequence[4,5]. At population level, global evidence shows regional differences in mean ages of eruption, suggesting the possible influence of environmental and socio-economic factors[6].

Eruption chronology refers to the approximate time, expressed in years and months, at which the emergence of a permanent tooth is usually expected. Knowledge of eruption chronology enables the establishment of mean parameters and ranges of normality, facilitating identification of early or late eruption and the adoption of timely therapeutic measures[7]. Eruption sequence refers to the order in which teeth emerge in each jaw, and plays an essential role in harmonious jaw development and establishment of functional occlusion, being key to early orthodontic planning[7].

Although eruptive chronology suggests mean ages, classic studies have noted that each tooth presents a wide range of normality, wherefore moderately early or late eruption does not necessarily imply a pathological alteration[8]. In this context, clinical interpretation of tooth emergence requires consideration of both individual variability and populational patterns[6].

The timing and sequence of permanent tooth eruption have been widely studied globally due to their relevance to clinical diagnosis, therapeutic planning, and understanding populational variations in tooth development[6]. Both longitudinal and cross-sectional studies have been conducted with the aim of identifying reference patterns. Longitudinal studies enable direct observation of eruption timing, and provide greater precision, though they involve high costs and lengthy follow-up periods[3,9]. On the other hand, cross-sectional studies record the eruptive status at a given time of the pre-functional phase, and are the most often used in populational studies[10-15].

Inter-populational variations in mean ages of eruption have been recorded, even though eruptive sequence tends to be relatively stable among different regions[16]. Given that most available studies have been conducted in specific geographic contexts, and that each population has particularities conditioned by its biological and sociocultural setting, it is essential to generate updated local data upon which to base local parameters. In Argentina, recent information on eruptive chronology and sequence is limited, especially in urban populations. The aims of this study were to estimate mean age of eruption of all permanent teeth except third molars in children from Buenos Aires City (CABA); to identify the eruptive sequence for each jaw, and to compare mean age of eruption according to sex, jaw and laterality.

MATERIALS AND METHOD

A descriptive, prospective cross-sectional study was designed and submitted to the Ethics Committee of Buenos Aires University’s School of Dentistry for approval (CETICA-FOUBA 003/2024). A non-probabilistic convenience sample was used, consisting of children of both sexes, aged 4 to 15 years, who received care at the Department of Comprehensive Children’s Dentistry at Buenos Aires University’s School of Dentistry and at four private offices in Buenos Aires City from March to July 2024. All permanent teeth except third molars were evaluated. Patients who provided assent and whose legal guardians signed informed consent were included.

Exclusion criteria were any systemic or local alterations that could modify the eruption pattern, such as syndromes, endocrine disorders, nutritional deficiencies, cleft palate, amelogenesis imperfecta, severe hypomineralization, history of dental trauma, premature loss of predecessor tooth, ongoing orthodontic treatment, agenesia, severe fluorosis, lack of space, presence of supernumerary teeth, odontogenic or non-odontogenic cysts or tumors.

Previously trained and calibrated researchers (Kappa index > 0.90) selected patients based on anamnesis, and clinical and radiographic (panoramic X-ray) examination. A tooth was considered erupted when at least one cusp or the incisal edge of the crown had pierced the gingival epithelium[17].

Patient sex (female, male) and chronological age were recorded. Age was calculated from date of birth to the time of the examination, and expressed in decimal format for analysis. Teeth were identified following the World Dental Federation (FDI) nomenclature.

Mean ages of dental eruption and standard error were estimated using Kärber's method, as described by Hayes and Mantel[18], based on data grouped into three-month age intervals. A 95 % confidence interval (CI 95 %) was calculated for each mean. Differences were considered statistically significant ($\alpha = 0.05$) when the 95 % confidence interval of a mean did not include the compared mean, following the criterion proposed by Hernández et al.[12]. Eruptive sequence was established by placing mean ages of eruption in ascending order.

RESULTS

The sample consisted of 1,063 children (532 girls and 531 boys), mean age 9.9 ± 2.6 years.

The first teeth to erupt were the lower central incisors, while the last to emerge were the upper second molars. There was a general trend towards mandibular teeth erupting before their homologous maxillary teeth. This difference was statistically significant only for the incisor and canine groups. No significant difference was found between left and right hemiarches on either upper or lower jaw (Table 1).

Comparison according to sex showed that girls presented earlier eruption than boys. In the upper jaw, this difference was statistically significant for all teeth except central incisors and first molars (Table 2). In the lower jaw, the difference was not significant only for first molars. The greatest difference between sexes was observed for lower canines, with a discrepancy of 9 months for the right hemiarch and 8 months for the left hemiarch (Table 3).

During the first transitional period, the eruptive sequence was similar in both sexes. In the upper jaw, the first molar preceded the central incisor and lateral incisor. In the lower jaw, the central incisor erupted before the first molar and the lateral incisor.

During the second transitional period, there were slight variations between sexes. In the upper jaw, girls presented eruption of the canine before the second premolar, while in boys, both erupted almost simultaneously.

In the lower jaw in girls, canine erupted before – though almost simultaneously to – the first premolar. In boys, the first premolar erupted before the canine. In both sexes, the eruptive sequence concluded with the upper second molars.

DISCUSSION

Permanent tooth eruption is a dynamic physiological process influenced by genetic, systemic, environmental and local factors[2,19]. The current study excluded any conditions with potential to modify the eruption pattern, enabling the results to be interpreted within physiological development parameters, reducing any potential biases associated to pathological alterations.

Many populational studies aimed at identifying patterns of eruptive chronology and sequence have used cross-sectional designs due to their methodological, logistic and economic feasibility[12,13,15,20-25]. Although longitudinal studies enable more direct individual monitoring of the eruption process, they require long observation periods and greater resources[10]. Moreover, exact determination of the time of tooth emergence is complex in both kinds of design[10]. In this context, it has been demonstrated that profiles of mean eruption age obtained by cross-sectional studies can provide estimates that are comparable to those from longitudinal studies, as long as appropriate statistical methods are employed[6,26].

Mean ages of eruption were estimated using Kärber's method, as described by Hayes and Mantel[18], which has been widely used in populational studies with grouped data. This procedure enables calculation of mean age of tooth emergence based on accumulated

Table 1. Mean age of eruption for upper and lower permanent teeth expressed in decimal years and in years and months, with their 95 % confidence intervals.

Upper jaw				Lower jaw			
Tooth	CI LL	Mean	CI UL	Tooth	CI LL	Mean	CI UL
1.1	6.87	7.01 (7 y)	7.16	**4.1**	5.71	5.88 (5 y, 10 m)	6.05
2.1	6.79	6.96 (6 y, 11 m)	7.13	**3.1**	5.79	5.95 (5 y, 11 m)	6.12
1.2	7.78	7.92 (7 y, 11 m)	8.06	**4.2**	7.03	7.18 (7 y, 2 m)	7.33
2.2	7.80	7.94 (7 y, 11 m)	8.08	**3.2**	6.97	7.12 (7 y, 1 m)	7.26
1.3	11.07	11.24 (11 y, 2 m)	11.42	**4.3**	10.25	10.40 (10 y, 4 m)	10.55
2.3	10.95	11.12 (11 y, 1 m)	11.29	**3.3**	10.29	10.45 (10 y, 5 m)	10.61
1.4	10.27	10.43 (10 y, 5 m)	10.59	**4.4**	10.22	10.37 (10 y, 4 m)	10.53
2.4	10.22	10.38 (10 y, 4 m)	10.53	**3.4**	10.22	10.37 (10 y, 4 m)	10.52
1.5	11.11	11.29 (11 y, 3 m)	11.46	**4.5**	11.00	11.17 (11 y, 2 m)	11.33
2.5	11.00	11.16 (11 y, 1 m)	11.32	**3.5**	11.00	11.17 (11 y, 2 m)	11.34
1.6	6.20	6.36 (6 y, 4 m)	6.52	**4.6**	6.12	6.27 (6 y, 3 m)	6.42
2.6	6.26	6.41 (6 y, 4 m)	6.57	**3.6**	6.19	6.34 (6 y, 4 m)	6.49
1.7	11.98	12.16 (12 y, 1 m)	12.34	**4.7**	11.79	11.98 (11 y, 11 m)	12.18
2.7	11.92	12.11 (12 y, 1 m)	12.30	**3.7**	11.74	11.94 (11 y, 11 m)	12.14

CI LL: lower limit of confidence interval; CI UL: upper limit of confidence interval.

proportions distributed in age intervals —three months, in this case— providing a reliable estimate without the need for complex statistical models. Its use in dentistry has been validated in multiple studies[12,13,27], supporting its applicability in the current study. Although some authors have used Probit regression models to estimate mean age of tooth emergence in cross-sectional studies[8,25,28,29], both methods provide consistent estimates in studies with dichotomic data, facilitating comparison between populations analyzed under different statistical approaches.

The results of the current study partially agree with the classic eruption tables described by Hurme[8], and Lo and Moyers[30], as well as with more recent studies conducted on Latin American and European populations[12-14]. Compared to classic references for the Caucasian population, the transitional period towards permanent dentition began and ended at similar mean ages; however, there was a difference in the first tooth to emerge. While Hurme[8] reported that the first tooth was the lower first molar, in our sample, the lower central incisor was the first to erupt. This finding agrees with Sturdivant et al.[31], who reported that the first permanent tooth to emerge may be a molar or an incisor, with predominance of the incisor in 64 % of cases.

Significantly earlier eruption in girls, bilateral symmetry and mandibular precedence were patterns that were consistent with those reported in the international literature[11-14,22-24,27,32]. Girls presented earlier mean ages of eruption for most tooth groups; nevertheless, no statistically significant difference was observed for upper central incisors or for upper and lower first molars.

Sexual dimorphism was more evident at the beginning of the second transitional period, at the time of canine and premolar emergence. This may be related to the earlier pubertal growth peak in females. The most outstanding finding was the

Table 2. Mean age of eruption for upper permanent teeth in girls and boys, expressed in decimal years and in years and months, with their 95 % confidence intervals.

Upper jaw - Girls				Upper jaw – Boys			
Tooth	**CI LL**	**Mean**	**CI UL**	**Tooth**	**CI LL**	**Mean**	**CI UL**
1.1	6.71	6.94 (6 y, 11 m)	7.17	**1.1**	6.90	7.09 (7 y, 1 m)	7.28
2.1	6.72	6.95 (6 y, 11 m)	7.18	**2.1**	6.77	6.98 (6 y, 11 m)	7.18
1.2	7.62	7.82 (7 y, 9 m)	8.01	**1.2**	8.00	8.20 (8 y, 2 m)	8.41
2.2	7.70	7.89 (7 y, 10 m)	8.09	**2.2**	7.98	8.18 (8 y, 2 m)	8.39
1.3	10.70	10.94 (10 y, 11 m)	11.18	**1.3**	11.24	11.54 (11 y, 6 m)	11.83
2.3	10.77	11.02 (11 y)	11.27	**2.3**	11.25	11.49 (11 y, 5 m)	11.73
1.4	10.04	10.26 (10 y, 3 m)	10.47	**1.4**	10.52	10.75 (10 y, 9 m)	10.98
2.4	9.99	10.21 (10 y, 2 m)	10.43	**2.4**	10.49	10.71 (10 y, 8 m)	10.92
1.5	10.97	11.26 (11 y, 3 m)	11.52	**1.5**	11.28	11.53 (11 y, 6 m)	11.77
2.5	10.83	11.11 (11 y, 1 m)	11.39	**2.5**	11.20	11.42 (11 y, 5 m)	11.64
1.6	6.07	6.33 (6 y, 3 m)	6.58	**1.6**	6.34	6.53 (6 y, 6 m)	6.72
2.6	6.13	6.39 (6 y, 4 m)	6.66	**2.6**	6.39	6.57 (6 y, 6 m)	6.76
1.7	11.81	12.00 (12 y)	12.20	**1.7**	12.03	12.28 (12 y, 3 m)	12.54
2.7	11.74	12.00 (12 y)	12.20	**2.7**	12.05	12.30 (12 y, 3 m)	12.55

CI LL: lower limit of confidence interval; CI UL: upper limit of confidence interval.

difference of approximately 8 or 9 months in the eruption of the lower canine, which was significantly earlier in girls.

The data also confirmed the tendency toward symmetrical bilateral eruption and earlier emergence of mandibular teeth than their homologous maxillary teeth, with statistically significant differences for the incisor and canine groups. Studies such as Almonaitiene et al.[28] and Bruna del Cojo et al.[15] also report significant differences between jaws for these groups, with precedence of lower teeth.

Most studies agree that the upper second molar is the last permanent tooth to erupt[11-13,23,24,33], a pattern that was confirmed in the current sample. In contrast, the first tooth to emerge is more variable. Some studies, like ours, describe the lower central incisor as the first tooth[28], whereas others report the lower first molar[21,22,32], sometimes with minimum differences in time between them[12,13]. These variations may be attributed to populational differences, secular changes, and the interaction of genetic, environmental and nutritional factors[34].

In relation to eruption sequence per arch, during the first transitional period, the pattern in the upper jaw matched reports by most authors[10-13,15,21,25,32,33,35]. For the second upper transitional period, Lo and Moyers[30] described the most prevalent sequence as 6–1–2–4–5–3–7 (48.72 %), followed by 6–1–2–4–3–5–7 (11.87 %). In the current study, the former matched the male sample, while the latter matched the female sample.

In the lower arch, the central incisor preceded the first molar in both sexes, in agreement with various authors[11-13,15,21,25,28]. In contrast, Taboada and Medina[33], in a Mexican population, and Diamanti and Townsend[36], in an Australian population, described simultaneous eruption of the central incisor and first molar in the male sample, while Ayala et al.[35] and Esan et al.[29] reported variations according

Table 3. Mean age of eruption for lower permanent teeth in girls and boys, expressed in decimal years and in years and months, with their 95 % confidence intervals.

Lower jaw - Girls				Lower Jaw - Boys			
Tooth	CI LL	Mean	CI UL	Tooth	CI LL	Mean	CI UL
4.1	5.38	5.70 (5 y, 8 m)	6.03	**4.1**	5.97	6.17 (6 y, 2 m)	6.37
3.1	5.65	5.86 (5 y, 10 m)	6.06	**3.1**	6.00	6.20 (6 y, 2 m)	6.41
4.2	6.87	7.10 (7 y, 1 m)	7.33	**4.2**	7.18	7.36 (7 y, 4 m)	7.54
3.2	6.85	7.07 (7 y, 1 m)	7.30	**3.2**	7.16	7.34 (7 y, 4 m)	7.51
4.3	9.91	10.12 (10 y, 1 m)	10.32	**4.3**	10.65	10.86 (10 y, 10 m)	11.07
3.3	9.96	10.19 (10 y, 2 m)	10.42	**3.3**	10.66	10.88 (10 y, 10 m)	11.09
4.4	9.99	10.20 (10 y, 2 m)	10.41	**4.4**	10.51	10.73 (10 y, 8 m)	10.95
3.4	9.99	10.20 (10 y, 2 m)	10.41	**3.4**	10.51	10.71 (10 y, 8 m)	10.92
4.5	10.82	11.04 (11 y)	11.26	**4.5**	11.19	11.42 (11 y, 5 m)	11.64
3.5	10.83	11.11 (11 y, 1 m)	11.39	**3.5**	11.16	11.40 (11 y, 4 m)	11.63
4.6	6.01	6.26 (6 y, 3 m)	6.50	**4.6**	6.23	6.41 (6 y, 4 m)	6.59
3.6	6.09	6.32 (6 y, 4 m)	6.55	**3.6**	6.23	6.41 (6 y, 4 m)	6.59
4.7	11.60	11.80 (11 y, 10 m)	12.03	**4.7**	11.92	12.18 (12 y, 2 m)	12.44
3.7	11.59	11.82 (11 y, 10 m)	12.05	**3.7**	11.97	12.23 (12 y, 2 m)	12.49

CI LL: lower limit of confidence interval; CI UL: upper limit of confidence interval.

to sex regarding the initial mandibular tooth. These discrepancies may be due to populational differences, methodological differences, and sexual dimorphism, in addition to the short chronological distance between the two teeth at the beginning of the first transitional period. During the second mandibular transitional period, the canine erupted slightly earlier than the first premolar in girls, while in boys, the first premolar preceded the canine, a pattern that agrees with the first and third most frequent sequences reported by Lo and Moyers[30] for said period.

A possible methodological limitation to this study is that the eruptive sequence was established by placing mean eruption ages in order. Lo and Moyers[30] reported that the standard deviation of mean times may vary considerably among teeth, which could lead to overlap among distributions and make absolute inferences difficult when the sequence is established based exclusively on means. Nevertheless, this approach has been widely used in cross-sectional populational studies and enables establishment of general trends that are comparable between studies.

Globally, the eruption sequence shows notable intercultural stability, despite some chronological variations between populations and cohorts. In European populations, a slightly earlier mean age for tooth emergence has been reported, particularly in more recent cohorts, with relative maintenance of the eruptive sequence between generations[9]. These observations highlight the need for availability of updated tables specific to each geographic and sociocultural context.

CONCLUSIONS

The findings of the current study provide updated reference values for eruptive chronology and sequence in children evaluated in an urban clinical context in Buenos Aires City. This information may contribute to timely diagnosis of alterations in dental development and to interceptive therapeutic planning.

In this sample from Buenos Aires City, permanent tooth eruption presented a harmonious sequential pattern, beginning in both sexes with lower central incisors. Mean ages were symmetrical between hemiarches, earlier in the lower incisor-canine group and significantly earlier in girls than boys. During the first transitional period, the eruptive sequence coincided in both sexes, while in the second, there were some variations according to sex for canines and premolars, ending with the eruption of the upper second molars. These results provide local reference values for the eruptive chronology and sequence in this population of children.

CONFLICTS OF INTEREST

The authors declare no potential conflict of interest regarding the research, authorship and/or publication of this article.

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