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Relationship between the order of permanent tooth eruption and the predominance of motor function laterality: a cross-sectional study☆

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KEYWORDS
Children;
Permanent dentition;
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Abstract
Objectives: To assess whether the order of permanent tooth eruption may be a useful indicator of motor function laterality.
Methods: We conducted a cross-sectional study in schoolchildren aged 6–8 years old evaluated in the annual school-based routine dental health examinations conducted by the staff of the primary care centre of an urban district in Barcelona, Spain. We also evaluated hand, foot, eye, and auditory lateralities using a battery of simple exercises. Bivariate and multivariate analysis of data was performed.
Results: The study sample included 388 children, 51.3% female, with a mean age of 6.5 years. Right laterality was the predominant side in every variable under study, especially in tooth eruption (310 children; 80%), handedness (349; 89.9%), and footedness (337; 86.8%). In the bivariate analysis, we found a statistically significant association of tooth eruption laterality with handedness and footedness, and of tooth eruption laterality with ocular and auditory lateralities ($p < .001$). In the multivariate analysis, tooth eruption laterality and foot laterality were independent variables significantly associated with hand laterality. The diagnostic accuracy of tooth eruption laterality and foot laterality in relation to hand laterality as reference, showed a similar sensitivity and positive and negative predictive values, but the specificity of dentition laterality was higher (79% versus 66%).

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Conclusions: Laterality in the order of dental eruption is a useful indicator of right or left motor function laterality in developing individuals that may be particularly helpful to determine the main dominance in cases of crossed laterality.

PALABRAS CLAVE
Infancia;
Dentición permanente;
Lateralidad funcional;
Erupción dental

Correlación entre el patrón de erupción de la dentición definitiva y la predominancia de la lateralidad de la función motriz: un estudio transversal

Resumen
Objetivos: Evaluar si el orden de la erupción dental es un buen indicador de la lateralidad motora.
Métodos: Estudio transversal en escolares de ambos sexos de 6 a 8 años sometidos a las revisiones orales rutinarias anuales realizadas en los colegios incluidos en un área de atención primaria urbana en Barcelona (España). También se evaluaron las lateralidades de manos, pies, ojos y oídos mediante una serie de ejercicios simples. Se realizaron análisis bivariantes y multivariantes de los datos.
Resultados: La muestra comprendió 388 escolares, 51,3% niñas, con una edad media de 6,5 años. La lateralidad derecha predominó en todas las variables de estudio, especialmente en la dentición (310 escolares; 80%), la mano (349; 89,9%) y el pie (337; 86.8%). En el estudio bivariante se observó una asociación estadísticamente significativa ($p < 0{,}001$) entre la lateralidad de la dentición y la de la mano y el pie, así como entre la lateralidad de la dentición y las lateralidades de oído y de ojo. En el estudio multivariante, las lateralidades de la dentición y del pie se asociaron significativamente a la lateralidad de la mano. En lo concerniente a la precisión de la lateralidad de la dentición y del pie como prueba diagnóstica de la lateralidad de la mano, ambas mostraron una sensibilidad y valores predictivos positivos y negativos similares, pero la especificidad de la lateralidad de la dentición fue mayor (79% versus 66%).
Conclusiones: La lateralidad en el orden de la erupción dental es un buen indicador para determinar la lateralidad motora durante el desarrollo, que podría ser particularmente útil para ayudar a precisar la lateralidad más predominante en casos de lateralidad cruzada.

Introduction

Learning disability is an umbrella term used to describe disorders characterized by difficulties in a broad spectrum of tasks, in particular listening, reading, writing, mathematical calculation, coordination, memorization and social functioning.[1] These difficulties can manifest in isolation or in varying combinations and can range from mild to severe.[2,3] Early diagnosis and appropriate treatment of underlying conditions in children with learning disabilities are essential for them to achieve academic success.[4] The estimated prevalence of learning disabilities in children varies depending on the population under study and the methods used to identify cases, but learning problems manifest in approximately 5% of school-aged children, with a lifetime prevalence of 9.7% observed in children in the United States.[5] Dyslexia, which affects a complex range of skills related to reading and language, is the most frequent learning disability, diagnosed in 80% of all individuals with learning disabilities.[6,7]

The aetiology of learning disabilities is multifactorial, including genetic, intrauterine, perinatal, and postnatal factors, but the cause of mild learning problems remains unknown in half of the cases.[8,9] It has been hypothesised that delayed neurological development resulting in the lack of a dominant hemisphere is involved in dyslexia.[10,11] Although there are conflicting opinions on the role of brain laterality, it has been suggested that inadequate brain asymmetry could interfere with normal learning skills, independently of the association of laterality with behavioural disorders.[12,13] Some clinical studies have reported compromised brain lateralization in children with attention-deficit/hyperactivity disorder (ADHD),[14] and there has been a growing interest on the link between crossed laterality (which refers to people whose hand, eye, foot, or ear dominance are not uniformly right- or left-sided) and academic achievement.[15,16] Although the available evidence is fragmentary, laterality-specific training and rehabilitation are commonly used in the field of education in children with developmental dyslexia and learning disabilities.[17,18]

On the other hand, there is evidence in the literature of an association between laterality in permanent tooth eruption and functional lateralities (eyedness, handedness and footedness),[19,20] suggesting that tooth eruption patterns may be indicators of handedness.[21] Studies of tooth

replacement patterns may provide insight into the development of motor lateralization, and their findings may also assist clinicians in the early detection of learning disabilities associated with crossed laterality.[22] We conducted a cross-sectional study with the aim of contributing further information on the potential link between tooth replacement and crossed laterality, testing the hypothesis that the order of permanent tooth eruption can be a reliable parameter to determine motor function laterality.

Methods

Study design and participants

We designed a cross-sectional study to assess the potential association of the order of permanent tooth eruption with motor laterality. We calculated that a sample of 385 subjects selected at random would be sufficient to detect differences with a confidence level of 95% and a precision of 5%, for an assumed proportion in the population of approximately 50%. We included children of both sexes aged 6–8 years that underwent the routine annual dental check by staff of the Casc Antic primary care centre in Barcelona, Spain, during the 2014 academic year. All participants were enrolled in one of 4 elementary schools of the public education system of Catalonia, Spain, located in the catchment area of the centre. We included children that were healthy, defined as absence of any acute of chronic condition based on the medical history and absence of active infection at the time of the examination that could interfere with the outcomes of the assessments. We excluded children with motor impairment or behavioural or mental disorders, children with oral health problems, such as infection or toothache, at the time of the assessment, and children deemed ineligible by the attending clinician. The study was approved by the Clinical Research Ethics Committee of the Foundation University Institute for Primary Health Care Research Jordi Gol i Gurina (IDIAPJGol) (code P09/85, approved on September 30, 2009), and by the Ethics Committee of the Universitat Internacional de Catalunya (code ORT-ECL-2011-03,NF, approved on June 23, 2015). We obtained written informed consent from the principals of the participating schools, the administration of the primary care centre and the parents or legal guardians of the participants.

Study protocol

We assessed the type of dentition (primary or mixed) and order of eruption, comparing both sides of the dental arches. We defined laterality as earlier eruption of the central and/or lateral incisors and/or first molars (both superior and inferior) in the left or right hemiarches. All dental examinations were performed by one of the authors (A. Veloso). We assessed intrarater reliability by analysing 50 examinations of children that did not participate in the study, each examined twice with an intervening period of 1 month between the first and second examination, and found a 100% agreement (kappa statistic = 1).

Motor laterality tests included hand, foot, eye, and ear evaluations. The hand evaluation included 8 actions: throwing a ball, getting a ball from the floor, using an eraser, crumpling a piece of paper, brushing teeth, combing hair, picking up a glass, and inserting objects in a box. The foot evaluation included 4 actions: kicking a ball, dragging an eraser along the floor, getting a ball from underneath a table, and kicking with the foot. Eye laterality was assessed by having participants look through a hole cut in a piece of paper, through a tube, through the hole in the bow of a key and through a keyhole. Finally, ear preference was evaluated by having participants listen to a cellular phone, listen to something said in a soft voice, bring an ear close to a door and bring a watch close to the ear. We recorded data on the findings of the dental examination and motor laterality assessments in a case report form designed specifically for the study.

Table 1 Dentition, hand, foot, ocular and auditory laterality in 388 children aged 6 to 8 years.

	Laterality	
	Right, *n* (%)	Left, *n* (%)
Dentition	310 (80%)	78 (20.1%)
Hand	349 (89.9%)	39 (10.0%)
Vision	251 (64.7%)	137 (35.3%)
Foot	337 (86.8%)	51 (13.1%)
Hearing	287 (73.9%)	101 (26.0%)

Statistical analysis

We have expressed categorical variables as frequencies and percentages and continuous variables as mean and standard deviation (SD), and compared categorical variables using the χ^2 test with the Yates correction. We assessed the association between dental laterality and motor function laterality (hand, foot, eye, hearing) with 2×2 contingency tables. We fitted a logistic regression model to assess the independent effect of the study variables on the predominance of motor function laterality, with hand laterality as the dependent variable. We calculated the sensitivity, specificity and positive and negative predictive values of tooth eruption and foot laterality as predictors of hand laterality. We also analysed the association of hand and tooth eruption lateralities and of hand and foot lateralities by sex. We considered a prevalence of right-handedness in the study sample of 0.9. The data were analysed with the software STATGRAPHICS Plus® version 5.1 (Statistical Graphics Corp., 2001). We defined statistical significance as a *p*-value of less than 0.05.

Results

The sample included 388 children, 189 male and 199 female, with a mean age of 6.5 years (SD, 0.867). As can be seen in Table 1, the right side was dominant in every variable under analysis, more specifically, in tooth eruption in 310 children (80%), handedness in 349 (89.9%), and footedness in 337 (86.8%). The bivariate analysis revealed a statistically significant relationship between dentition laterality and handedness and foot laterality (Fig. 1) as well as between dentition laterality and eye and auditory lateralities (Fig. 2) ($P < 0.001$).

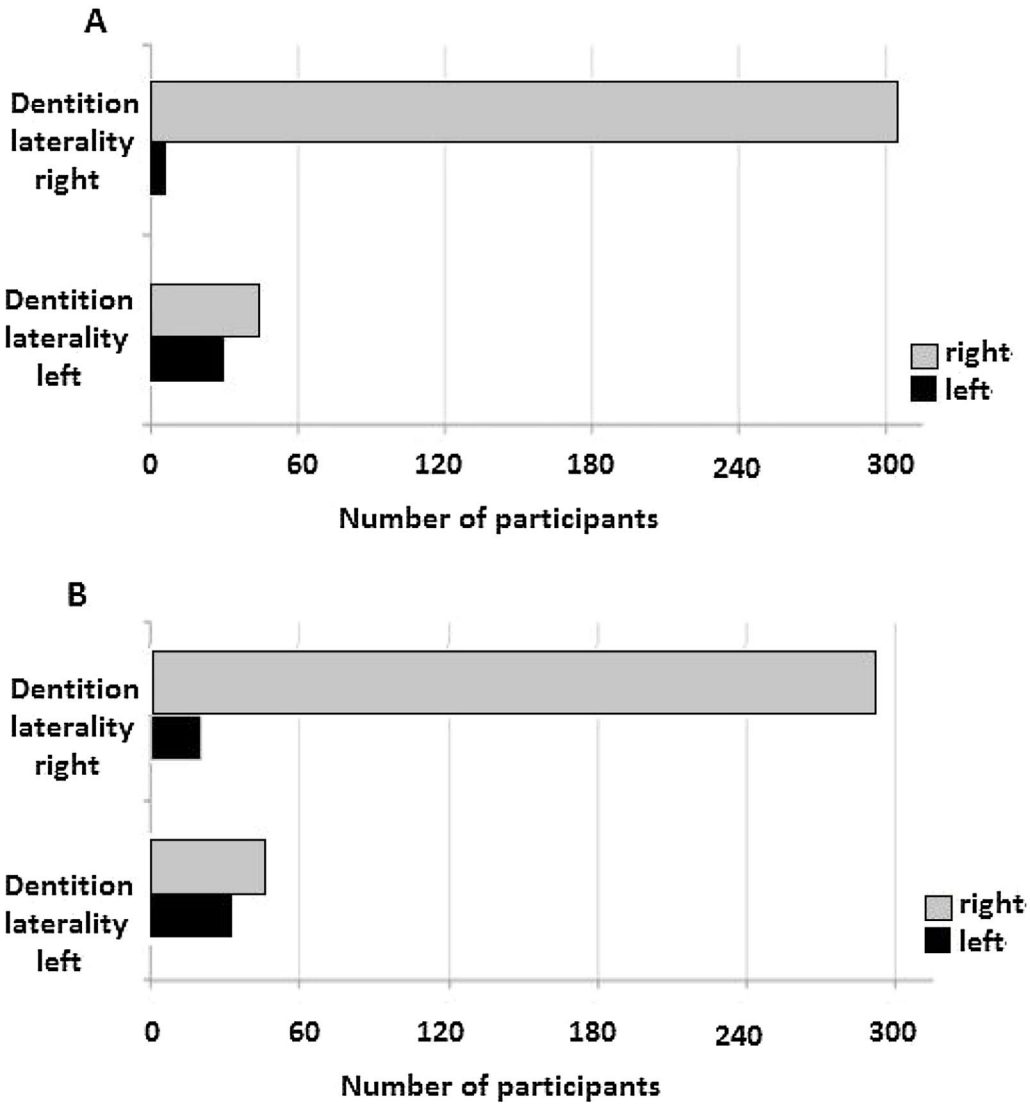

Figure 1 (A) Relationship between dentition laterality and handedness. (B) Relationship between dentition and footedness ($P < 0.001$).

Table 2 Results of multivariate analysis.

Variable	Coefficient (β)	Standard error (SE)	Wald χ^2	Degrees of freedom	*P* value	Exp (β)
Eye laterality	−0.94	0.99	0.98	1	0.344	0.39
Foot laterality	2.69	0.84	10.30	1	0.001	14.78
Auditory laterality	0.17	0.85	0.40	1	0.842	1.18
Dentition laterality	3.38	1.09	9.58	1	0.002	29.47

Constant: coefficient (β): −4.34, SE: 0.84; χ^2: 26.54; d.f.: 1; P 0,000; Exp (β): 0.013.

The multivariate analysis revealed that dentition laterality and foot laterality were independent variables significantly associated with hand laterality, with dentition laterality in particular being associated with a 29.47-fold increase in the probability of same-side hand laterality. The sensitivity and positive and negative predictive values of dentition laterality and foot laterality in the prediction of hand laterality were similar, but the specificity was higher for dentition laterality (79% vs 66%) (Table 3.

When it came to the analysis of the association between dentition and hand lateralities by sex, we found that dentition-hand crossed laterality was more prevalent in boys than in girls (9.5% vs 6.6%). We found similar results for hand-

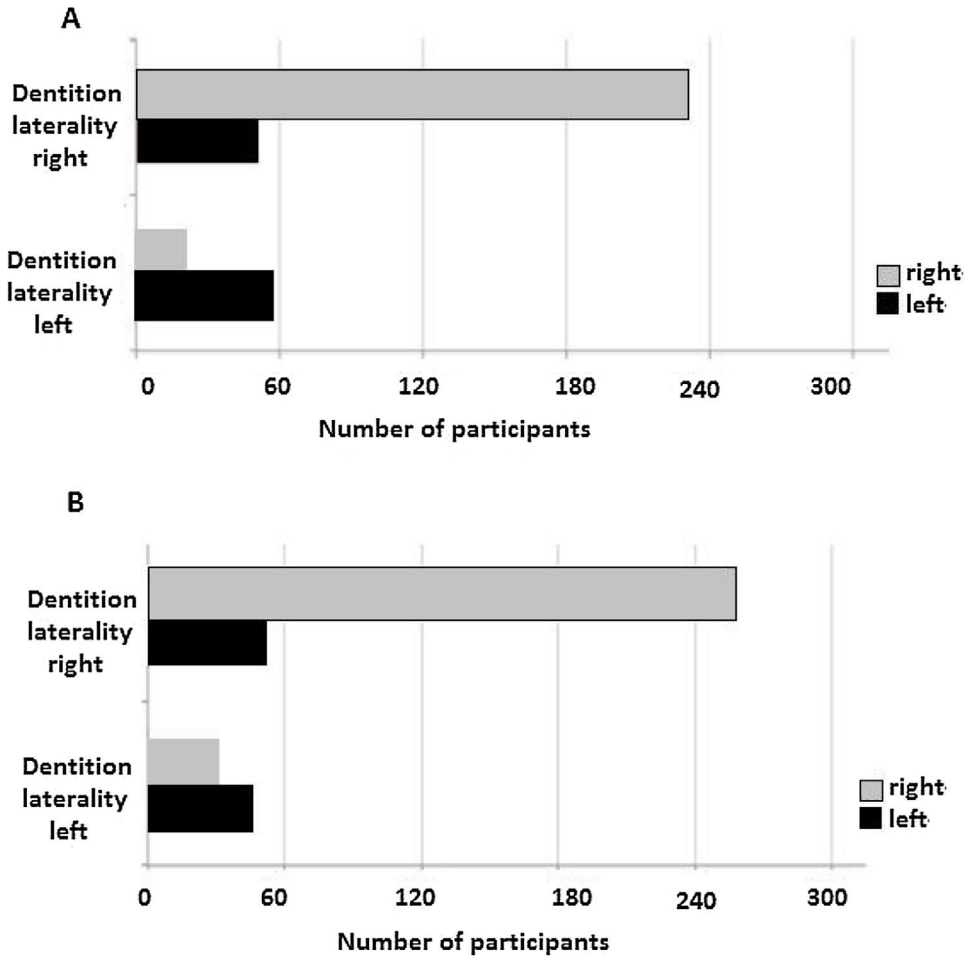

Figure 2 (A) Relationship between dentition and ocular laterality. (B) Relationship between dentition and auditory laterality ($P < 0.001$).

Table 3 Accuracy of dentition and foot laterality as predictors of hand laterality.

	Sensitivity	Specificity	Predictive value	
			Positive	Negative
Dentition laterality	92%	79%	97.5%	52%
Foot laterality	95%	66%	96%	59%

foot crossed laterality, which was also more prevalent in boys (8.9% vs 1.7%) (Table 2).

Discussion

This cross-sectional study assessed the association between tooth eruption laterality and motor laterality in 388 primary school children aged 6–8 years in the 4 schools located in the catchment area of the Casc Antic primary care centre. Although participants were not selected at random, the inclusion of all children aged 6–8 years in a city school district strengthens the external validity of our findings. Moreover, all measurements were made by a single clinician, which prevents interrater variability.

Our results indicate that the laterality of permanent tooth eruption can be considered a reliable indicator of motor function laterality, especially handedness and foot laterality. Foot laterality was also associated with handedness, but the correlation with dentition laterality was stronger. Also, the predominant side of dental eruption order appears to be the best parameter to predict the laterality of a child along with handedness, as dental laterality exhibited a high specificity, with no significant differences based on sex. These results in a large group of 388 children are consistent with previous findings in a cohort of 130 children using the same methododology.[21] Knowledge of the order of permanent dental eruption may be clinically relevant to determine unilateral dominance in children who have crossed laterality, as the establishment of lateral dominance

occurs at around 6 years of age.[23,24] On the other hand, it has been demonstrated reading and writing outcomes are poorer in children with cross-dominance to age-matched children with complete right- or left-sided dominance.[25,26]

There is little evidence on the relationship between dental eruption order and motor function laterality, and some of the shortcomings of previous studies are that laterality was evaluated in younger children, aged 3–5 years old, which may be too early to make this assessment, and that the order of tooth eruption order was evaluated indirectly by examination of photographs[19] or face-to-face interviews with the parents.[20] Also, the temporal pattern of permanent tooth eruption has been assessed in different populations in the context of routine dental checks, but without making comparisons to hand-foot-eye-auditory laterality. A survey of 2304 Greek patients found a trend of earlier tooth eruption in the lower jaw in both sexes and an earlier tooth eruption in girls.[27] A cross-sectional study of Spanish children and adolescents found that eruption of permanent teeth occurred earlier in girls compared to boys.[28] Earlier tooth eruption in girls has also been confirmed in other studies in different populations.[29,30] Thus, while there are studies assessing maxilla-jaw and male-female eruption patterns of the permanent dentition, few of them have focused on the relationship between dental eruption and predominance of motor function laterality.

In conclusion, our findings indicate that laterality in the order of tooth eruption is a useful indicator of right or left motor function laterality in children, which may be particularly helpful to determine unilateral dominance in cases of crossed laterality. Paediatricians, educators, and parents could benefit from knowledge on the association between dental eruption order and handedness. The time interval between ages 6 and 8 years is important in the somatic development of children, and the order of permanent tooth eruption may play a simple and easily accessible variable to check motor function laterality this period.

Author contributions

A. Veloso: study design and conception, data collection, analysis and interpretation and writing of manuscript.

J. R. Corcuera, C. Vázquez, J. López-Giménez, and F. Guinot: critical comments and approval of the final draft.

A. Puigdollers: study design and coordination, critical comments and approval of the final draft.

Conflict of interest

The authors declare that they have no conflict of interest.

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