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SYSTEMATIC REVIEW

Assessment of dental age estimation methods applied to Brazilian children: a systematic review and meta-analysis

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Objectives: To review the scientific literature of studies on dental age estimation methods applied to Brazilian children.
Methods: A systematic literature review was designed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and registered in PROSPERO (CRD42020136170). Six scientific databases were used as primary search sources (PubMed, Scopus, LILACS, SciELO, Embase and Web of Science) and two databases (Open Grey and Open Thesis) were searched to partially select the "grey literature." Only cross-sectional studies were included. The risk of bias was assessed by means of Joanna Briggs Institute Critical Appraisal Tools for Systematic Reviews. The standardized mean difference (SMD) between the estimated dental and chronological ages was meta-analysed via random effects model.
Results: The search resulted in 2,527 studies, from which 13 met the eligibility criteria. Out of the eligible studies, 76.92% had low risk of bias and high methodological quality. Ten studies provided proper information to be included in the meta-analysis.The methods and their SMD between estimated and chronological ages were: Willems'=0.05, Lilequist and Lundberg'*s* = −0.11, Nolla'*s* = 0.22, Mornstad'*s* = 0.27, Cameriere'*s* = −0.31, Demirjian'*s* = 0.74 and Haavikko'*s* = −0.87.
Conclusion: Although originally trained in populations worldwide, most of the international methods for radiographical dental age estimation had optimal performance in Brazilian children.
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Introduction

The progressive development of teeth and bones is used in clinical and legal fields as a source of age information.[1] In clinical field, the obtained information may be useful to support therapeutic decisions and treatment planning,[2] especially in orthodontics, pediatric dentistry and oral medicine.[3] In the legal field, applications extend to forensic dentistry mainly when it comes to knowledge related to clandestine migration, child sexual abuse and identification of unknown bodies.[4] Specifically, dental development figures as the parameter of choice for age

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estimation of children,[5] in which deciduous teeth are sequentially replaced by permanent ones. This process covers an interval that ends around the age of 15: a period landmarked by the complete rhizogenesis of the permanent dentition,[6] except third molars.[7]

Several methods have been designed over the last decades to assess dental development in children,[8,9]most of them relying on radiographical analysis.[10] In practice, the analyses are based on techniques to classify teeth into ordinal developmental stages.[11–13] Other methods rely on measurements of tooth-size ratios.[14]The populations sampled to develop such methods represent one of the backbones for dental age estimation.[15] In general, reference and test samples originate from country-specific populations, such as the Belgian children sampled in Willems' method[9] and the Italian children in Cameriere's method.[8] Optimal outcomes are expected if these methods are applied in their country of origin.[16] However, translating the applicability of the methods to other populations is needed.[15,16] In this context, validation studies emerged in the field.[17]

The Brazilian population figures among the most used in validation studies.[18–22] The rationale behind this phenomenon may be explained by the continental size of the country, its different regions and the number of inhabitants (nearly 210 million); the high number of dentists[23] (over 330 thousand) and forensic dentists (over 770); and, sadly, the national rate of homicides.[24] Knowing which method is the best to estimate the dental age of Brazilians is challenge.

Based on the several validation studies of dental age estimation in Brazilian children and the uncertainty surrounding the applicability of international methods in this population, this study aimed to review the scientific literature in order to compare chronological age and dental age estimated from radiographical methods. The considered null hypothesis is that most of the international radiographical dental age estimation methods do not apply to Brazilian children.

Methods

Study design and ethical aspects

A systematic literature review was designed according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[25] and based on Cochrane[26] standards. The systematic review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) in April 2019 under the registration number CRD42020136170. This study was performed with ethical clearance.

Research question and eligibility criteria

The research question was established based on population (P), variable (V) and outcome (O) information as follows: "Are the international radiographic methods for dental age estimation (V) effective (O) for application in Brazilian children (P)?"

The inclusion criteria consisted of cross-sectional studies that investigated dental age estimation in Brazilian children younger than 16 years of age. Dental development was assessed as the parameter of choice. Deciduous, mixed, and permanent dentitions were examined by radiographical means. No restriction of year (from inception to search date), language or status of publication (*e.g.,* ahead of print) was applied.The exclusion criteria consisted of studies with children that had bilateral missing teeth, visible bone lesions in the maxilla or mandible, and known systematic disease.

Source of information and search

Primary data sources were PubMed, Scopus, LILACS, SciELO, Embase and Web of Science. Open Grey and Open Thesis were used to partially retrieve the "grey literature" and minimize selection and publication bias. Medical Subject Headings (MeSH), Descriptors in Health Sciences (DeCS) and Embase Subject Headings (Emtree) were used to build-up a search string. Boolean operators "AND" and "OR" were implemented to combine and restrict different terms (Table 1). The search was performed in April, 2019, and updated in January, 2020.

Selection of studies

The selection of studies was performed in four stages.

In the first stage, the identification of studies after literature search in databases was performed. The obtained results were imported to EndNote Web™ software (Thomson Reuters, Toronto, Canada), in which duplicates were removed. The remaining studies were exported to Microsoft Word™ 2016 (Microsoft™ Ltd, Washington, USA) for manual removal of duplicates. Before the second stage, a calibration exercise was carried out for training the reviewers for the selection of studies based on eligibility criteria. In the second stage, the reviewers were requested to allocate as eligible or not a sample of 20% of the studies. After achieving an appropriate level of concordance (inter examiner agreement of Kappa ≥0.81), the reviewers independently performed the exclusion of studies per title. Disagreement between reviewers were discussed with a third reviewer to reach consensus. In this phase, the reviewers were not blind for the names of authors and journals. In the third stage, the abstracts were read for the application of exclusion criteria. Titles that met the objectives of the study but did not have abstracts available proceeded to the next phase. In the fourth stage, preliminary eligible studies had their full texts read and evaluated for eligibility. Studies filtered out in this phase were separately registered with their inherent reasons for exclusion.

Table 1 Strategies for database search

Database	*Search Strategy (April, 2019)*	*Results*
PubMed http://www.ncbi.nlm.nih.gov/pubmed	((“Forensic Odontology” OR “Forensic Dentistry” OR “Forensic Science” OR “Age Estimation” OR “Age Determination” OR “Dental Age” OR “Estimation Techniques” OR “Chronological Age” OR “Age Estimative” OR “Forensic Sciences” OR “Science, Forensic”) AND (“Dentistry” OR “Oral Medicine” OR “Odontology” OR “Odontology” OR “Dentition” OR “Teeth” OR “Tooth” OR “Stomatognathic System”) AND (“Brazil” OR “Brazilian” OR “Brazilians” OR “Brazilian People” OR “Brazilian Population”))	243
Scopus http://www.scopus.com/	((((“Forensic Odontology” OR “Forensic Dentistry” OR “Forensic Science” OR “Age Estimation”) AND (“Dentistry” OR “Oral Medicine” OR “Odontology”) AND (“Brazil” OR “Brazilian”)))	81
	(((“Age Determination” OR “Dental Age” OR “Estimation Techniques” OR “Chronological Age”) AND (“Dentition” OR “Teeth”) AND (“Brazilians” OR “Brazilian People”)))	12
	((((“Age Estimative” OR “Forensic Sciences” OR “Science, Forensic”) AND (“Tooth” OR “Stomatognathic System”) AND (“Brazilian Population”)))	4
LILACS http://lilacs.bvsalud.org/	tw:(((“forensic odontology” OR “forensic dentistry” OR “forensic science” OR “age estimation” OR “age determination” OR “dental age” OR “estimation techniques” OR “chronological age” OR “age estimative” OR “forensic sciences” OR “science, forensic”) AND (“dentistry” OR “oral medicine” OR “odontology” OR “odontology” OR “dentition” OR “teeth” OR “tooth” OR “stomatognathic system”) AND (“Brazil” OR “brazilian” OR “brazilians” OR “brazilian people” OR “brazilian population”))) AND (instance:”regional”)	1,539
	tw:(((“determinación de la edad” OR “odontología forense” OR “medicina legal” OR “determinación de la edad por los dientes”) AND (“odontología” OR “medicina oral” OR “dientes” OR “diente” OR “dentición”) AND (“brasileños” OR “brasileño” OR “brasil”))) AND (instance:”regional”) [*Spanish*]	36
	tw:(((“odontologia forense OR “determinação da idade” OR “determinação da idade pelos dentes” OR “medicina legal”) AND (“odontologia” OR “medicina oral” OR “dentes” OR “dente” OR “dentição”) AND (“brasil” OR “brasileiros” OR “brasileiro”))) AND (instance:”regional”) [*Portuguese*]	25
SciELO http://www.scielo.org/	((“Forensic Odontology” OR “Forensic Dentistry” OR “Forensic Science” OR “Age Estimation”) AND (“Dentistry” OR “Oral Medicine” OR “Odontology”) AND (“Brazil” OR “Brazilian”))	6
	((“Age Determination” OR “Dental Age” OR “Estimation Techniques” OR “Chronological Age”) AND (“Dentition” OR “Teeth”) AND (“Brazilians” OR “Brazilian People”))	2
	((“Age Estimative” OR “Forensic Sciences” OR “Science, Forensic”) AND (“Tooth” OR “Stomatognathic System”) AND (“Brazilian Population”))	1
Web of Science http://apps.webofknowledge.com	((“Forensic Odontology” OR “Forensic Dentistry” OR “Forensic Science” OR “Age Estimation” OR “Age Determination” OR “Dental Age” OR “Estimation Techniques” OR “Chronological Age” OR “Age Estimative” OR “Forensic Sciences” OR “Science, Forensic”) AND (“Dentistry” OR “Oral Medicine” OR “Odontology” OR “Odontology” OR “Dentition” OR “Teeth” OR “Tooth” OR “Stomatognathic System”) AND (“Brazil” OR “Brazilian” OR “Brazilians” OR “Brazilian People” OR “Brazilian Population”))	64
Embase https://www.embase.com	('forensic odontology' OR 'forensic dentistry' OR 'forensic science' OR 'age estimation' OR 'age determination' OR 'dental age' OR 'estimation techniques' OR 'chronological age' OR 'age estimative' OR 'forensic sciences' OR 'science, forensic') AND ('dentistry' OR 'oral medicine' OR 'odontology' OR 'dentition' OR 'teeth' OR 'tooth' OR 'stomatognathic system') AND ('brazil' OR 'brazilian' OR 'brazilians' OR 'brazilian people' OR 'brazilian population')	259
OpenGrey http://www.opengrey.eu/	(“Age determination” OR “Age estimative” OR “Estimation techniques”) AND (“Brazil” OR “Brazilian population”)	1
OpenThesis http://www.openthesis.org/	((“Age determination” OR “Age estimative” OR “Estimation techniques”) AND (“Brazil” OR “Brazilian population”))	254
TOTAL		2,527

Data extraction
The following data were extracted: the identification of the study (authorship, year and region of publication), sample size and sex distribution, dental age estimation method and specific outcomes, namely the mean chronological age of the sample, the mean dental age and the difference between both. In order to establish standards for data extraction, two reviewers were requested to extract the data from an eligible study under the supervision of a third reviewer.

Risk of bias of eligible studies
The risk of bias based on the quality of each eligible study was assessed with "The Joanna Briggs Institute (JBI) Critical Appraisal tools for use in JBI Systematic Reviews" for cross-sectional studies.[27] Based on PRISMA guidelines,[25] two reviewers independently read and analysed each study. Each study was classified according to the percentage of positive answers to the questions of JBI tool. High risk of bias was registered when the study answered positive up to 49% of the questions; moderate risk of bias fit within 50–69% of positive answers; and low risk of bias was found when positive answers were above 70%.

Meta-analysis
Meta-analysis was carried out in order to compare the difference between chronological and dental ages. Eligible studies that provided information about sample size, mean age and standard deviation were included in the meta-analysis. The Hedge's standardized mean differences (SMD) in years between estimated dental age and chronological age was calculated. Positive SMD values indicate that the dental age overestimates the chronological age, while negative values indicate underestimation.

The meta-analysis model was fit using random effects model to account for the high heterogeneity between studies. Three measures of heterogeneity were used: i) the τ^2 statistic; ii) the I^2 statistic; and ii) the H^2 statistic. The τ^2 statistic represents the variance between study, the I^2 refers to the percentage of variability caused by heterogeneity excluding sampling error, while the H^2 indicates the level of heterogeneity between study (H^2 = 1 indicates homogeneity).[28] Considering that the studies used different methods to estimate the dental age, analyses were stratified according to the method. An overall estimate was produced for each method.

All analyses were performed with Stata V.16.1 software (StataCorp., College Station, TX, USA).

Results

Selection of studies
The initial search found 2527 studies (including the "grey literature"), out of which 2193 were not duplicates. Careful title reading excluded 2026 studies (not fitting to the topic of the research question). 167 studies remained for abstract reading—leading to 150 exclusions. These studies were removed for not fitting to the research topic (n = 88); for not using radiographical methods for dental age estimation (n = 2); for estimating age in subadults instead of children (n = 1); for being designed as literature review (n = 7), case report (n = 3), pilot study (n = 1) and laboratorial study (n = 15); and for sampling a population outside Brazil (n = 36). One study was added after search update. The remaining 18 studies were read in full. Five studies were excluded with reasons Supplementary Material 1. 13 studies were included in the qualitative analysis, while 10 were eligible for meta-analysis (Figure 1).

Characteristics of the studies
The studies were published between 1965 and 2019 and were conducted in four Brazilian regions: three in the Northeast,[28–30] seven in the Southeast,[5,20–22,31–33] two in the South[17,18] and one in the Central-Western[38]region. Demirjian's[6](DEM) method was the most used (five studies), followed by Cameriere's[8](CAM) (four studies), Nolla's[13](NOL) (three studies), Nicodemo's[34](NIC) (two studies), Lilequist and Lundberg's[35](LIL) (two studies), Willems'[9](WIL) (one study), Haaviko's[36](HAA) (one study) and Mornstad's[37](MOR) (one study). The sample size between studies varied from 156 to 1.491 participants (total = 7538, mean = 560) (Table 2).

Risk bias of eligible studies
Three studies presented moderate risk of bias,[28,32,38] while the others presented low risk of bias based on their methodological quality,[5,17,18,20–22,29–31,33] indicating high percentage of answers with "yes" to the questions from the JBI tool[27] (Table 3).

Meta-analysis
10 out of the 13 eligible studies (76.92%) in this systematic review provided enough information to be meta-analysed (Figure 2). Since some studies used more than one dental age estimation method, the meta-analysis comprised 16 assessments and seven methods.

Five dental age estimation methods (CAM, DEM, LIL, NOL and WIL) provided dental age estimates that were statistically similar to the chronological age of the sampled participants. It must be noted that the five methods presented high heterogeneity between their performance (I^2 >96%), except for WIL that was used in one study[23] and had no heterogeneity. The three methods that presented the smallest SMD were WIL (0.05 years; 95% CI: −0.04; 0.14), LIL (−0.11 years; 95% CI −0.62; 0.30) and NOL (0.22 years; 95% CI −0.22; 0.65, respectively).

The HAA method underestimated the chronological age by −0.87 standard deviations (95% CI: −0.98; −0.77), while MOR method overestimated by 0.27 standard deviations (95% CI: 0.18; 0.36). The highest SMD observed among all the studies was the overestimation

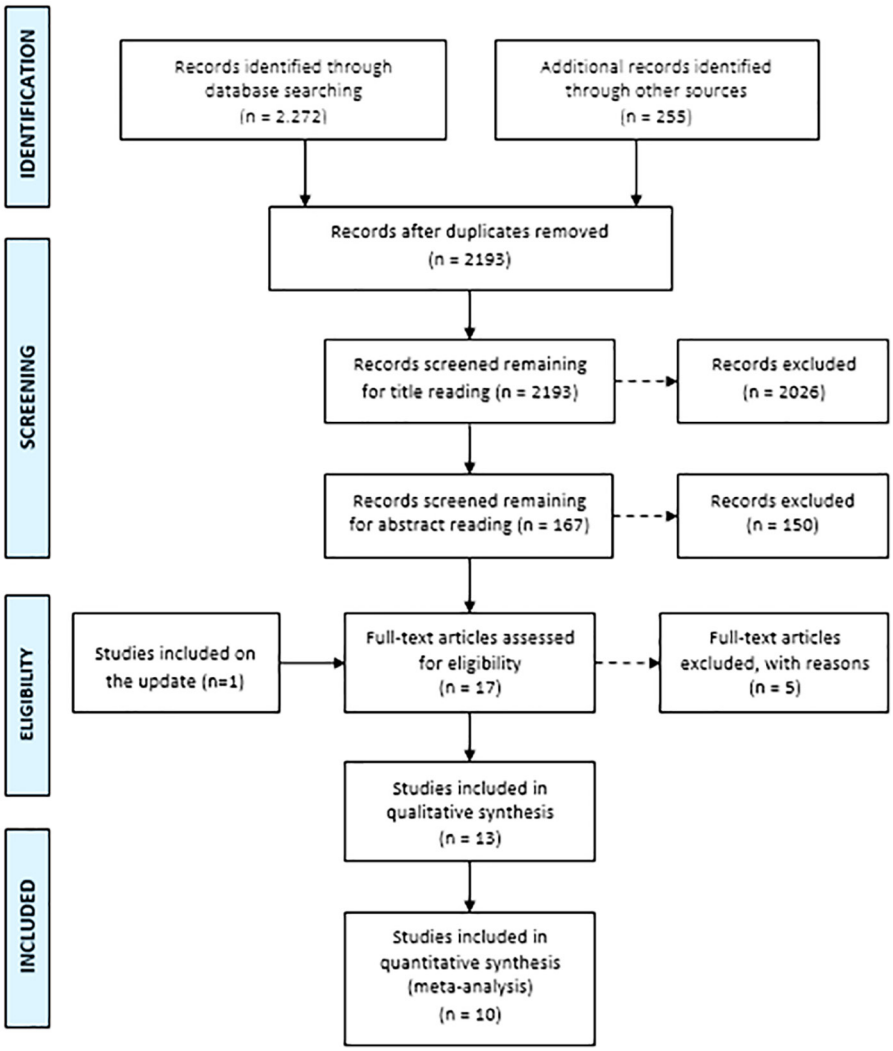

Figure 1 Flowchart of the systematic review process structured according to PRISMA[25]

of 1.81 standard deviations (95% CI: 1.65; 1.98) by the DEM method.

Discussion

Dental age estimation studies are usually focused on specific topics. Some propose new methods[6,8]; while others apply these methods in different populations aiming for validation[18]; sometimes they have a fundamental design to test statistics[7,39] or techniques[10,40]; and, more rarely, they report cases.[41,42] Since the early 2000s, validation studies evidently amplified the scientific literature in the field. In general, these studies investigated the applicability and performance of pre-established methods in populations that were different from the original. The increasing number of validation studies led to a new type of study within the dental age estimation literature—the systematic reviews with or without meta-analyses. Systematic reviews could test the performance of one method in different populations, but could also focus on finding out which method has the best performance for a given population, which was the case of our systematic review. Our aim was to assess the performance of dental age estimation methods in Brazilian children. To the best of our knowledge, this is the first systematic literature review and meta-analysis of dental age estimation methods applied to Brazilians. This study had level 2A of scientific evidence with recommendation level B according to the Oxford Centre for Evidence-Based Medicine.[43]

13 studies met the eligibility criteria of this review. The restricted number of studies was justified since we selected only those that sampled children and used radiographical methods for the assessment of dental age information. As depicted from the introductory section of this manuscript, Brazil is a large country that hosts 19% of the dentists worldwide. The number of specialists interested on radiographical dental age estimation

Table 2 Summary of the main characteristics of the eligible studies

Author, year	*Region*	*Sample (n)*	*Participants*	*Mean age ±SD (years)*	*Method*
Carvalho et al., 1990	Southeast	156	78♀ 78♂	n.r.	Demirjian
Eid et al., 2002	Southeast	689	368♀ 321♂	9.96 ± 1.98 ♀ 9.93 ± 1.98 ♂	Demirjian
Kurita et al., 2007	Northeast	360	180♀ 180♂	11.33 ± 2.57 ♀ 11.32 ± 2.53 ♂	Nolla and Nicodemo
Maia et al., 2010	Northeast	1,491	821♀ 670♂	n.r.	Demirjian
Oliveira et al., 2010	Central-West	200	100♀ 100♂	n.r.	Nicodemo
Fernandes et al., 2011	Southeast	160	94♀ 66♂	10.2 ± 2.7 ♀ 10.6 ± 2.3 ♂	Cameriere
Franco et al., 2013	South	941*	547♀ 447♂	n.r.	Willems
Vieira et al., 2016	Northeast	300	151♀ 149♂	11.68 ± 3.29	Demirjian
Benedicto et al., 2018	South	1,009	622♀ 387♂	11.72 ± 1.58[a] 12.37 ± 1.91[b] 12.17 ± 1.76[c]	Haaviko[a] Lilequist and Lundberg[b] Mornstad[c]
Lopes et al., 2018	Southeast	403	235♀ 168♂	n.r.	Nolla Demirjian
Machado et al., 2018	Southeast	234	126♀ 108♂	11.27 ± 2.28	Cameriere
Mazzili et al., 2018	Southeast	612	322♀ 290♂	10.00 ± 3.04	Cameriere
Da Luz et al., 2019	Southeast	930	564♀ 366♂	12.17 ± 1.76[d] 11.94 ± 1.73[b] 12.17 ± 1.76[e] 12.17 ± 1.77[f]	Cameriere[d] Lilequist and Lundberg[b] Nolla[e] Nolla[f]

n: number of participants; ♀: females; ♂: males; n.r.: not reported by the author; SD: standard deviation; *: the original sample size was 1357, but 941 fit to the inclusion criteria of the present review.
superscript letters between mean age and methods were used to indicate that different methods were used in the same study.

also may be high. For instance, Brazil has 27,939 orthodontists, 8893 paediatric dentists, 5199 oral radiologists and 777 forensic dentists.[44] This scenario contributes to the proliferation of population-based research focused on dental age estimation in the country.

Most of the eligible studies (53.84%) were from the Southeast region. This phenomenon is explained by the fact that 44% of the Brazilian population is located there,[45] as well as nearly one-third of the dentists[44] and some of the most prominent dentistry courses of the country. Since human growth and dental development are traditional research areas in Maxillofacial Radiology, a high prevalence of studies in regions with evident dedication to this field was expected. Another characteristic of the eligible studies was that Demirjian's was the most prevalent method. This method is well-known, since it has been used since 1973 for dental age estimation.[6] The accuracy of the method, however, is uncertain. Studies worldwide indicate that the DEM method tends to overestimate dental age.[19,46] In a systematic literature review,[47] authors revealed that this method significantly overestimated age in male and female children—the overall mean difference considering different populations ranged between 7 and 8 months. Similarly, the DEM method overestimated the age in four out of five eligible studies in the present review. Overestimations reached 1.5[29] and 1.8[20] standard deviations in two studies. Overestimating children's age in practice could drastically affect treatment planning when it comes to decisions that involve knowledge of patient's maturity. From a forensic perspective, judicial decisions about rights of accessing health care and education, adoption and even sexual abuse in childhood could be hampered.

Because of the constant overestimation of the DEM method,[47] the WIL method was designed.[9] Comparative studies between DEM and WIL reflect the improvements made by the latter in the performance of dental age estimation. Outcomes of a meta-analysis[47] showed that the WIL method is able to reduce by nearly half the weighted mean difference between chronological and estimated ages compared to the DEM method. In another meta-analysis,[48] focused exclusively on the WIL method, the overall pooled difference was only 0.10 and 0.09 for males and females, respectively. The outcomes of the present meta-analysis confirmed that the WIL method achieved the best performance, with

Table 3 Risk of bias assessed by the Joanna Briggs Institute Critical Appraisal Tools for use in JBI Critical Appraisal Checklist for Analytical Cross-Sectional Studies[27]

Authors	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*% Yes*	*Risk*
Carvalho et al., 1990	-	√	√	√	√	√	-	√	87.5	Low
Eid et al., 2002	-	√	√	√	-	-	√	√	62.5	Moderate
Kurita et al., 2007	√	√	√	√	-	-	√	√	75	Moderate
Maia et al., 2010	√	√	√	√	-	√	√	√	100	Low
Oliveira et al., 2010	√	√	√	√	-	-	√	√	75	Moderate
Fernandes et al., 2011	√	-	√	√	√	√	√	√	87.5	Low
Franco et al., 2013	√	√	√	√	√	√	√	√	100	Low
Vieira et al., 2016	√	-	√	√	√	√	√	√	87.5	Low
Benedicto et al., 2018	√	√	√	√	√	√	√	√	100	Low
Lopes et al., 2018	√	√	√	√	√	√	√	√	100	Low
Machado et al., 2018	√	√	√	√	√	√	√	√	100	Low
Mazzili et al., 2018	√	√	√	√	√	√	√	√	100	Low
Da Luz et al., 2019	-	√	√	√	√	√	√	√	87.5	Low

Q1. Were the criteria for inclusion in the sample clearly defined? Q2. Were the study subjects and the setting described in detail? Q3. Was the exposure measured in a valid and reliable way? Q4. Were objective, standard criteria used for measurement of the condition? Q5. Were confounding factors identified? Q6. Were strategies to deal with confounding factors stated? Q7. Were the outcomes measured in a valid and reliable way? Q8. Was appropriate statistical analysis used? √: Yes; -: No.

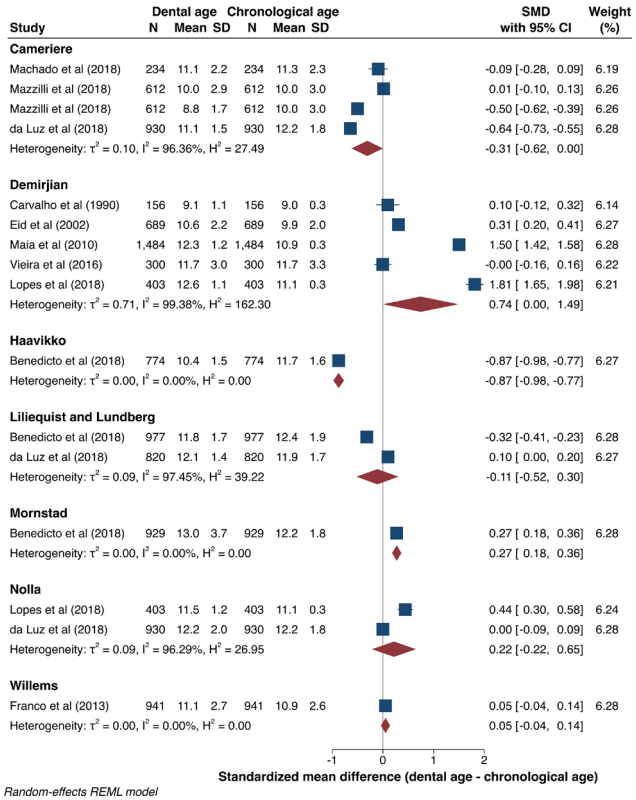

Figure 2 Forest plot of the meta-analysis showing the absolute number (n) of participants in each study, their mean dental and chronological ages and standard deviation (SD), as well as the standardized mean difference (SMD) between ages with 95% of CI.

overall SMD of only 0.05. However, this finding should be carefully interpreted because only one study using the WIL method was included in the quantitative analysis. In practice, the combination of the present and the past evidence-based studies strengthens the applicability of the WIL method for radiographical dental age estimation in children.

LIL, NOL and MOR presented SMDs equal to −0.11, 0.22 and 0.27 standard deviations, respectively. From a global point of view, LIL and MOR are not often employed in dental age estimation studies and require more country-specific studies to better understand their performance. NOL, in the other hand, is broadly known and commonly used for radiographical dental age estimation. Ten studies that applied the NOL method were previously meta-analysed[49] and revealed average underestimation of 0.2 and 0.35 years for females and males, respectively. Despite the promising outcomes, careful interpretation must be considered because the authors did not distinguish children from subadults, including individuals up to 18 years of age in their study. Results of the present study (focused on the Brazilian population) were similar to results from other studies that comprised different populations.[49] However, one important aspect to be considered is that the LIL and NOL methods were applied by only two studies each, LIL among 1,797 individuals from the South and Southeast regions, and NOL among 1,333 individuals from the Southeast region. More studies with these methods, at present considered potentially reliable, are encouraged to understand their effects in a Brazilian population.

With a SMD slightly above 3.5 months between estimated and chronological ages, the CAM method also had good performance. A positive aspect of the meta-analysed outcomes of this method was the fact that it was applied in three studies, out of which one was tested twice with different formulae.[17] The scientific literature shows that, over time, the CAM method generally has a good performance. However, the method might be optimal if applied with country-specific formulae.[17] This phenomenon was observed in one of the eligible studies that found SMD of −0.5 years with the original formula and 0.01 years with the country-specific formula.[17] This

evidence focuses attention on the importance of investigating the effects of adaptations to the methods in order to have more accurate age estimates depending on the population. Claiming validation from a single application of a method in a small sample of Brazil may be risky because samples might be very different within the same country. Brazil has a strong background of miscegenation. In particular, the European ancestry figures as predominant in the entire country,[50] especially in the influence of colony-derived genetics, such as Portuguese and Spanish. Populations from the North of Brazil, however, present stronger traces of Native American ancestry, while in the Northeast African ancestry is more evident.[50] These characteristics of the Brazilian population highlight the importance of dedicated studies. More importantly, the optimal performance of adapted formulae confirms the importance of systematic reviews and meta-analyses to assess country-specific effects of international dental age estimation methods, as proposed in the present study.

Most of the eligible studies of this systematic review that were eligible for quantitative analysis (90%) had low risk of bias. This is a positive characteristic of the present study, but it should be considered and eventually counter balanced with the high heterogeneity of the methods (I^2 >96%), which is a limitation of this systematic review and meta-analysis. This aspect is a reminder to authors to propose or follow standardized protocols for conducting and reporting data in dental age estimation research. Future studies in the field are encouraged to test the effects of international methods of radiographical dental age estimation in other populations, especially because single studies might have only discrete validation power compared to multiple meta-analysed studies. This recommendation contributes both the clinical practice and the forensic routine. Professionals enrolled in these fields will benefit from standardized studies and reporting on radiographical dental age estimation by having a more understandable material to study. International readers must understand that the outcomes depicted in this study may be compared with those potentially obtained from systematic reviews and meta-analyses from other countries. For this reason, authors must be aware of the methods applied in their countries and must be interested in compiling information to find out what method has the best performance.

In conclusion, although originally designed from other populations, WIL, LIL, NOL and CAM radiographical methods were applicable for Brazilian children. This study supports dental age estimation practices with evidence-based information to aid the decision-making process for specific methods.

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