# Accuracy of two dental age estimation methods in the Indian population – A meta-analysis of published studies

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KEYWORDS

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## ABSTRACT

**Background:** Dental age estimation using radiographic methods have gained considerable attention in the recent past. Although several such methods exist, Demirjian's method and Willems' method are very popular and have been used extensively. Whether these methods are applicable to the Indian population is not known.

**Methods:** A search of Pubmed, Embase and Google Scholar search engines was done using specific keywords to identify studies using Demirjian's and Willems' methods in the Indian population. Studies published up to July 2018 were considered, and after thorough review, 20 eligible studies were identified. Meta-analysis of data obtained from these articles was conducted on 3668 children for Demirjian's method and 3144 children for Willems' method. The weighted mean differences for both of these methods at 95% confidence intervals were assessed to identify the accuracy of each method in predicting the chronological age.

**Results:** Demirjian's method was found to consistently overestimate the age in Indian population, irrespective of the gender. The overestimation was in the order of few months. Willems' method resulted in underestimation of the age, although this was comparatively minimal in the order of 30 to 40 days.

**Conclusion:** Willems' method produced more accurate age which was very close to the chronological age, both in boys and girls. In contrast, Demirjian's method suffered from marked overestimation. Willems' method appears to be more suited to use in the Indian population.

## INTRODUCTION

Age estimation in forensic odontology has received considerable attention in the last few decades. Various age estimation methods have been proposed in the past, although only a few of these have gained widespread acceptance. A wide range of criteria have been used for dental age estimation. Some rely on histological characteristics in the teeth, while many others rely on information obtained through radiographs. The radiographic methods have a distinct advantage since the technique is less invasive and can readily be used in live or dead subjects. Radiographic methods of dental age estimation include Demirjian's method, Nolla's method, Willems' method, Kvaal's method, etc.[1] However, most of these methods rely on the degree of mineralization of the developing teeth, and accurate age estimation up to only around 21 years of age (the

age at which most 3rd molars completely mineralize) is possible. Considering that forensic age estimation is mostly used for determining the age of minors for legal purposes, these radiographic methods are still very relevant in spite of this apparent limitation.

Among the various methods of radiographic dental age estimation, Demirjian's method[2] and Willems' method[3] are more commonly used. A quick literature search will reveal numerous studies using either of these two methods. However, many such studies have noticed that these age estimation methods are not applicable worldwide and need further adjusting to suit the population under investigation.[4] Population specific standards are therefore important. Since the original Demirjian's method and Willems' method were introduced based on French-Canadian and Belgian study populations respectively, their applicability to the Indian population needs to be verified. Various studies from different parts of India have been reported using these two age estimation methods in the past. Therefore, a systematic collection of studies published from India that used either or both of these age estimation methods was conducted, followed by a meta-analysis of the data.

## METHODOLOGY

Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines were followed.[5] A research question following the PICO framework was first prepared as follows: Is Demirjian method (intervention) more accurate in estimating the age (outcome) when compared with Willems method (comparison), in Indian children (population)? This systematic review is registered with PROSPERO International prospective register of systematic reviews with the registration number CRD42018110536. The protocol can be accessed here: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018110536

The literature search was performed using specific keywords (Demirjian, Willems, age estimation, children) in different combinations in Pubmed, Embase, Google Scholar, and Google search engine. The keywords were intentionally picked to be as inclusive as possible in order to ensure that no relevant study would be missed out. An example of a search strategy used in Pubmed database is as follows: *Demirjian[All Fields] OR Willems[All Fields] AND "age estimation"[All Fields]*. Websites of known forensic odontology journals were also visited and the archives searched using the same keywords. Cross references from the included studies were also searched. Only studies published in English language up to July 2018 were included.

Studies were included if they met the following criteria:

- Original research studies (cross-sectional or non-cross-sectional in design)
- Studies using either or both the original Demirjian's method (1973) or original Willems' method (2001)
- Study relevant to the research question
- Full reports only (abstracts or conference proceedings without full report were not included)
- Study participants only less than 18 years of age (those that included subjects beyond this age were also considered for inclusion only if they provided data according to different age groups)
- Study population belonging to India

Studies were excluded if:

- the population being studied did not belong to India
- the population being studied was medically compromised or with developmental anomalies
- modified Demirjian's or Willems' methods were used exclusively
- the data provided was insufficient to compute statistics [mean, standard deviation (SD) and sample size were not provided]
- the language of publication was other than English

Both reviewers (HP and NK) extracted essential data from all the 20 selected studies, independently, in a Microsoft Excel sheet. The data that were extracted included first author name, year of study, place of study, age estimation methods used, sample sizes, chronological age of the study population (mean and standard deviation), and dental age of the study population (mean and standard deviation). Wherever available, the dental and chronological ages were also recorded according to gender.

Based on the data tabulated from the selected studies, the following comparisons were done:

- Mean difference in dental age (DA) versus chronological age (CA) using Demirjian's method
- Mean difference in dental age (DA) versus chronological age (CA) using Willems' method

The quality of the included articles was assessed independently by another reviewer, using QUADAS-2 (Quality Assessment Tool for Diagnostic Accuracy Studies).[6] QUADAS-2 uses a set of questions divided under four domains (patient selection, index test, reference standard, and flow and timing) to assess the risk of bias and applicability of each included study. All included studies were found to have a low risk of bias.

## STATISTICAL METHODS

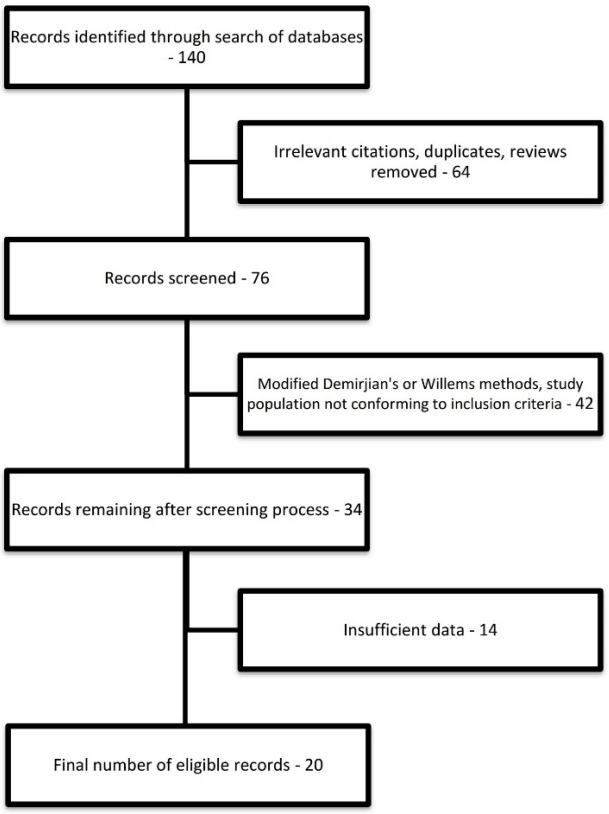
The above outcomes were assessed independently for the entire population, for boys and for girls. Mean difference (MD) with 95% confidence interval (CI) and p-values were calculated for the data extracted, using Cochrane RevMan v5.3 software. Tau and $I^2$ test were performed in all the datasets to evaluate the heterogeneity of the samples, based on which either a random effects model or a fixed effects model was used to compute the MD and CI. An $I^2$ value greater than 50% or a significant Tau value ($p < 0.05$) was considered suggestive of a heterogenous sample, and random effects analysis was used in such cases. For samples that were homogenous, a fixed effects model was used to determine the MD.

## RESULTS

Our initial search resulted in the identification of 140 potentially valid citations. After duplicates were removed (n=64), we were left with 76 citations. Full texts of these 76 citations were accessed and both the reviewers (HP and NK) went through the methodology in each of them to assess their validity for inclusion in our study. This screening resulted in the exclusion of 42 records, since they used either revised Demirjian's or revised Willems' methods or because the study population was not from India. From the remaining 34 citations, another 14 had to be finally excluded because they did not provide enough data (mean, SD and sample size were not provided) for inclusion in the meta-analysis. The final number of eligible citations was 20 (Fig 1).[7-26]

Five[8,9,14,17,18] out of the 20 included studies had data for both Demirjian's method and Willems' method, nine[7,10-13,15,16,19,20] had data for Demirjian's method only, and six[21-26] had data for Willems' method only. Out of the 14 studies that had used Demirjian's method for age estimation, only 10 [7-11,13-15,17,19] had gender specific data. Similarly, out of the 11 studies with Willems method of age estimation, only 10[8,9,14,17,21-26] had gender specific data. A summary of important findings from the included studies is given in Table 1. Most studies reported that Demirjian's method significantly overestimated the age in their sample.

**Figure 1**. PRISMA flowchart




Meta-analysis was performed on the 20 included studies with the data extracted. Age estimation using original Demirjian's method was done in a total of 3668 children whose chronological age was between 4 and 18 years. Of these, gender specific data was available for 1722 boys and 1426 girls. The pooled sample size for age estimation using Willems method was 3144 children ranging from 5 to 17 years in chronological age. Gender specific data was available for 1617 boys and 1415 girls in this population. It was found that the data for Demirjian's age estimation were considerably heterogenous, so a random effects model was used to compute MD. Data for Willems age estimation were more homogenous, and hence a fixed effects model was used to compute MD for these values.

**Table 1.** Key findings of all included studies

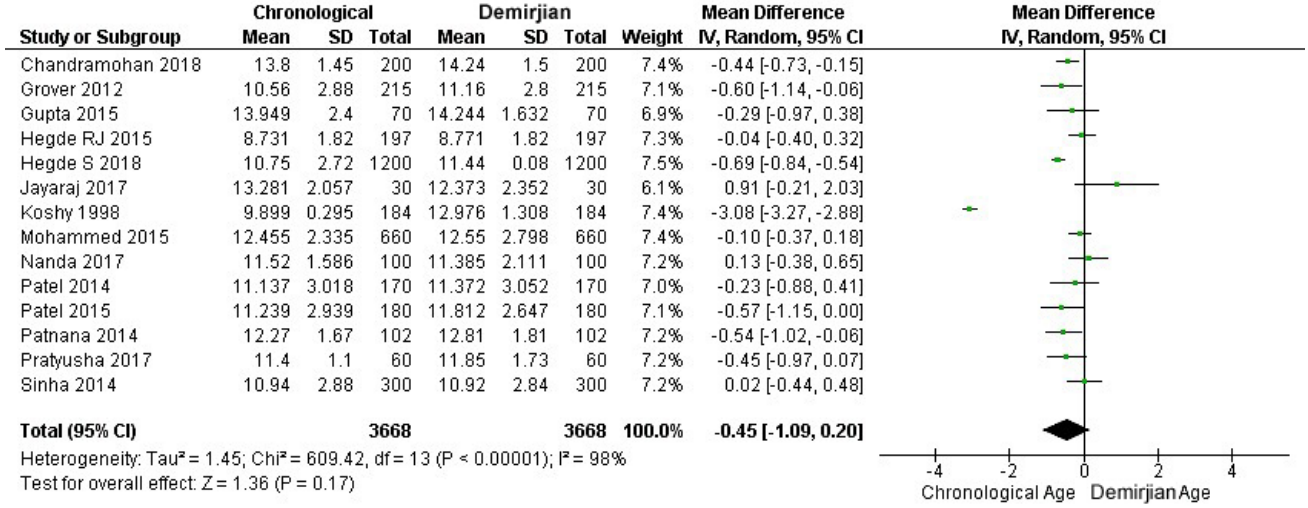
| Study | Study population from | Age estimation methods used | Sample details | | | Age range | Key findings and conclusions |
|---|---|---|---|---|---|---|---|
| | | | Total | Male | Female | | |
| Chandramohan 2018[7] | Karnataka | Demirjian's method | 200 | 95 | 105 | 11 to 16 | Significant overestimation by Demirjian's method was noticed in all age groups. A correction factor of +/- 0.5 was suggested. |
| Grover 2012[8] | Haryana | Demirjian's and Willems' methods | 215 | 102 | 113 | 6 to 15 | Both methods showed overestimation of age, but Willems' method was more accurate than Demirjian's method in both genders |
| Gupta 2015[9] | Haryana | Demirjian's and Willems' methods | 70 | 37 | 33 | 9 to 16 | Willems' method was better in estimating the age of Indian males. Demirjian's method was better for Indian females. |
| Hegde RJ 2015[10] | Maharashtra | Demirjian's method | 197 | 115 | 82 | 6 to 12 | Demirjian method produced overestimation of dental age by 2 days in boys and 37 days in girls. |
| Hegde S 2018[11] | Rajasthan | Demirjian's original and revised 7-tooth and 4-tooth methods | 1200 | 699 | 501 | 5 to 15 | All 4 methods produced overestimation. Revised 7-tooth method was most accurate of all. |
| Jayaraj 2017[12] | Karnataka | Demirjian's method | 30 | 15 | 15 | 6 to 18 | Demirjian's method was more accurate and consistent among the 6-18 year old children living in Mangalore district. |
| Koshy 1998[13] | Karnataka | Demirjian's method | 184 | 93 | 91 | 5 to 15 | Demirjiian's method was not applicable in South Indian children. Overestimation by 3.04 years in boys and 2.82 years in girls was determined. |
| Mohammed 2015[14] | Andhra Pradesh | Demirjian's, Willems', Nolla's and adopted Haavikko's methods | 660 | 330 | 330 | 6 to 16 | Demirjian's method overestimated age, while Willems' underestimated. All four methods were reliable in estimating age. |
| Nanda 2017[15] | Himachal Pradesh | Demirjian's method | 100 | 49 | 51 | 9 to 14 | There was good correlation between chronological age and dental age, especially in males. |
| Patel 2014[16] | Gujarat | Demirjian's method | 170 | 85 | 85 | 4 to 16 | Age estimation using Demirjian's method was found to be accurate for the population studied. |
| Patel 2015[17] | Gujarat | Demirjian's and Willems' methods | 180 | 90 | 90 | 6 to 17 | Willems' age estimation method proved to be more accurate and consistent than Demirjian's method. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Patnana 2014[18] | Andhra Pradesh | Demirjian's, Haavikko's and Willems' methods | 102 | NA | NA | 6 to 14 | Demirjian's method overestimated age, while Willems' underestimated. Dental age estimation by Willems' method found to be most accurate. |
| Pratyusha 2017[19] | Andhra Pradesh | Demirjian's, Cameriere's and modified Cameriere's methods | 60 | 30 | 30 | 9 to 14 | Chronological age was close to dental age in modified Cameriere's method. |
| Sinha 2014[20] | Uttar Pradesh | Demirjian's and Nolla's methods | 300 | 150 | 150 | 6 to 15 | Demirjian's method was applicable to all age groups in both genders with better accuracy than Nolla's method. |
| Hegde 2016[21] | Rajasthan | Willems' method (original and modified) | 1200 | 699 | 501 | 5 to 15 | Original Willems method was more accurate in estimating age of boys, while modified Willems was better in girls. Both methods were appropriate to use. |
| Kapoor 2017[22] | Himachal Pradesh | Willems' method | 55 | 30 | 25 | 6 to 14 | Willems method was more accurate than skeletal age estimation method. Willems method can be accurately applied to estimate chronological age. |
| Mohammed 2014[23] | Andhra Pradesh | Willems' method | 332 | 166 | 166 | 6 to 16 | Willems method underestimated age of males by 0.69 years and females by 0.08 years. Willems method can be used to generate dental age in individuals with unknown chronological age. |
| Priya 2015[24] | Tamil Nadu | Willems' method | 60 | 30 | 30 | 13 to 15 | Underestimation was observed when Willems method was used, both in males and females. Willems method may be suitable in the studied population. |
| Rajeev 2018[25] | Kerala | Willems' method | 60 | 30 | 30 | 8 to 16 | Significant correlation was noticed between dental age and chronological age. Willems method was better applied for males than females. |
| Sathawane 2017[26] | Chattisgarh | Demirjian's 8-tooth method and Willems' method | 210 | 103 | 107 | 7 to 16 | Overestimation by Willems method, and underestimation by Demirjian's 8-tooth method was observed. However, both methods showed close correlation with chronological age. |

***Meta-analysis of studies using Demirjian's method of age estimation***

When the overall population of 3668 children was considered, it was observed that most of the studies showed an overestimation of age by Demirjian's method (Chronological age lesser than Dental age; CA-DA in negative values). The study by Jayaraj et al.[12] was significantly different in that it reported a marked underestimation of age by Demirjian's method. The overall weighted mean difference (WMD) was found to be -0.45 years, indicating that the Demirjian method overestimated the dental age by nearly 5.5 months as compared to the chronological age (Fig. 2).

**Figure 2.** Comparison of Demirjian's dental age with the chronological age of the entire population




In boys, it was found that the WMD was -0.74 years, suggesting that Demirjian's method overestimated dental age by almost 9 months in male children. With the exception of Mohammed et al.[14] and Hegde et al.[10], all the remaining studies individually reported similar overestimation by Demirjian's method (Fig. 3).

In girls, the difference between chronological age and Demirjian dental age was comparatively less than in boys. However, Demirjian's method still overestimated the dental age by almost 6 months in girl children (WMD = -0.51 years). Similar findings were noticed in the individual studies, although Gupta et al.[9], Nanda et al.[15] and Pratyusha et al.[19] reported either an underestimation or no difference in DA as compared to CA in female children (Fig. 4).

**Figure 3.** Comparison of Demirjian's dental age with chronological age in boys

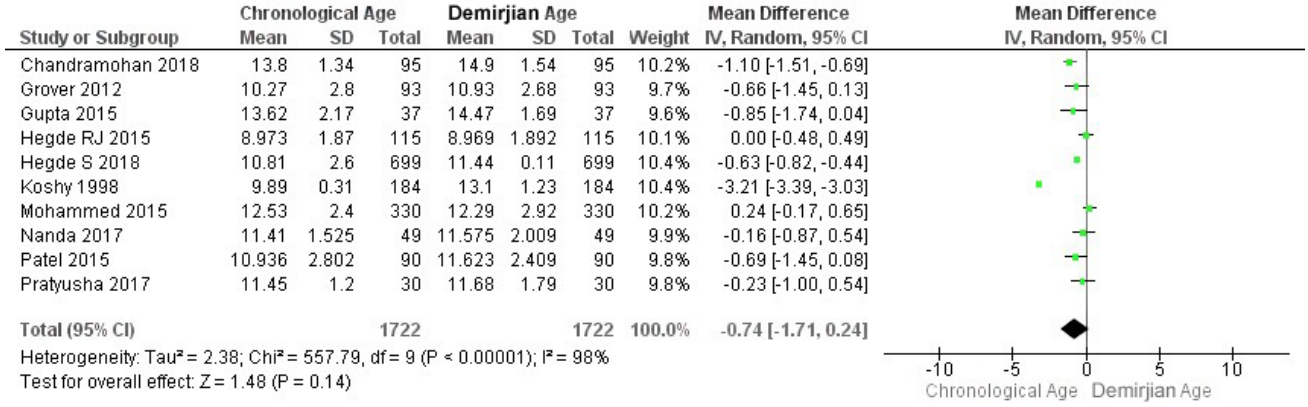
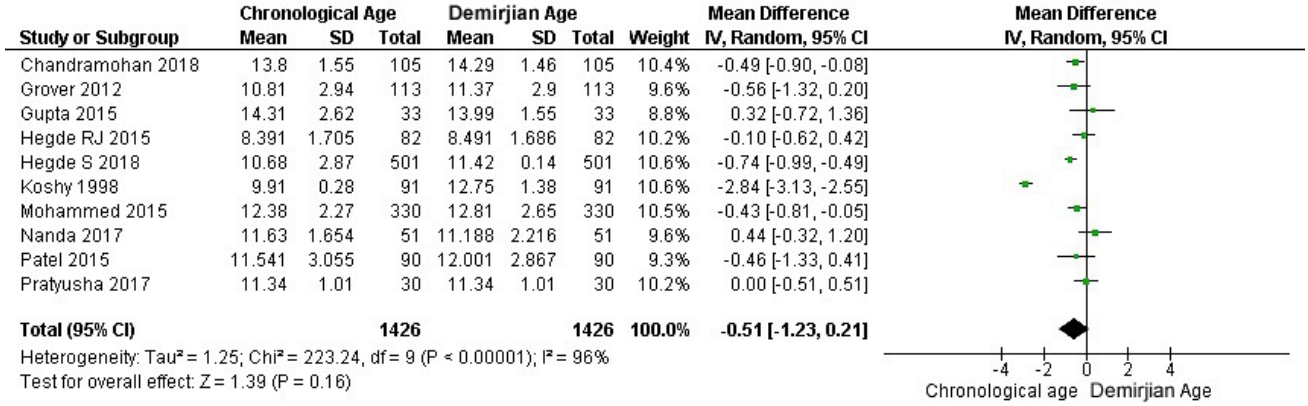


**Figure 4.** Comparison of Demirjian's dental age with chronological age in girls




### *Meta-analysis of studies using Willems method of age estimation*

The overall sample size for Willems method of age estimation was 3144 children.

We found that among the 11 studies that had included Willems age estimation method, six reported overestimation, while the other five reported underestimation of dental age. The weighted mean difference determined using statistical methods was +0.09 years, indicating that Willems method underestimated the dental age by about 1 month (Fig. 5).

When boys were considered alone, the WMD was +0.11 years, which suggests that there was an underestimation by about 40 days using Willems method. Most of the studies included in the meta-analysis had similar findings of marginal underestimation or no difference in Willems DA as compared to CA, except Mohammed et al.,[14,23] who reported a marked underestimation in both of their studies (Fig. 6).

Among girls, the WMD was almost 0, which suggested that Willems DA was as close as possible to CA. Although some of the included studies showed a much higher variation in Willems DA, these studies had small sample sizes and carried less weightage when the WMD was calculated for the entire population (Fig. 7).

A summary of the findings of our meta-analysis is given in Table 2.

**Figure 5.** Comparison of Willems dental age with chronological age in the entire population

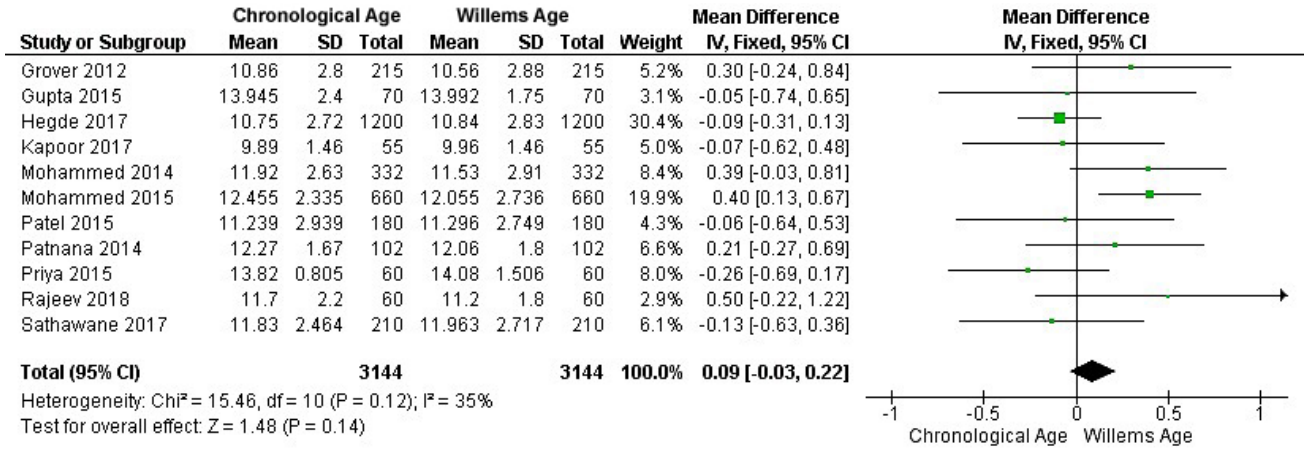


**Figure 6.** Comparison of Willems dental age with chronological age in boys

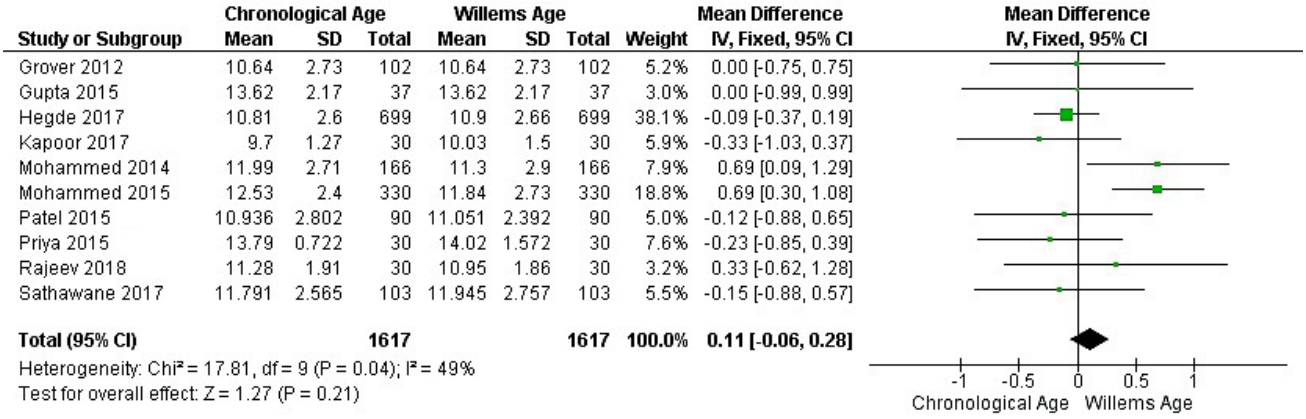



**Figure 7.** Comparison of Willems dental age with chronological age in girls

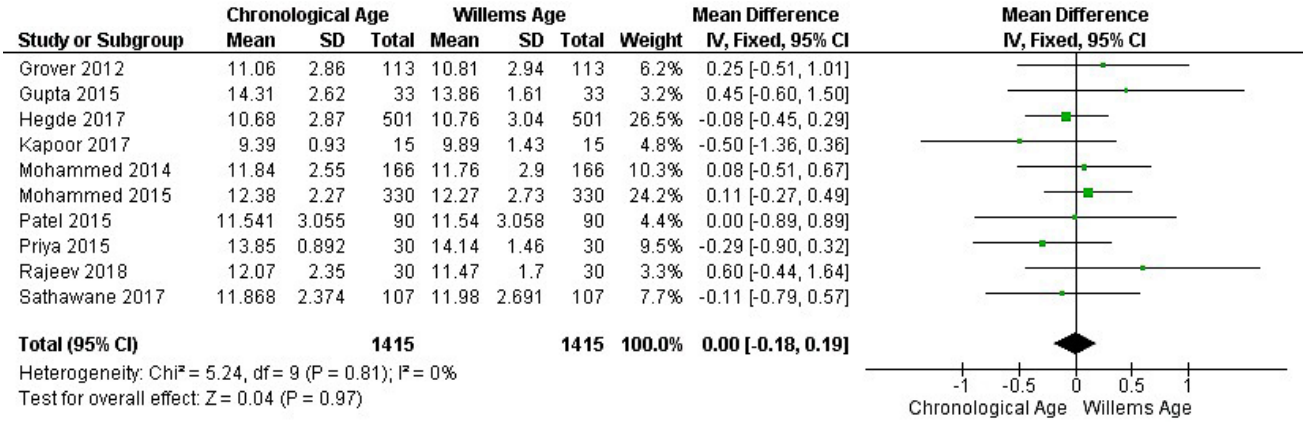



**Table 2.** Summary of key findings of our meta-analysis

| Population | Demirjian | Willems |
|---|---|---|
| Boys | Overestimation (0.74 years) | Underestimation (0.11 years) |
| Girls | Overestimation (0.51 years) | Negligible difference |
| Overall | Overestimation (0.45 years) | Underestimation (0.09 years) |

## DISCUSSION

Growth is an important indicator of the health and nutritional status of an individual, particularly a child. The physiological age, therefore, is deemed to be more important than the chronological age of an individual. The concept of physiological age is based on the degree of maturation of various tissue systems.[2] Although many methods of physiological age determination exist, skeletal age has been used ubiquitously for several decades. Different skeletal age estimation methods include the Greulich-Pyle (GP) Atlas method, the Tanner Whitehouse 2 (TW2) method and the Gilsanz-Ratibin (GR) Atlas method.[27] However, it has been recognized that skeletal maturation is far more influenced by external environmental factors and hormonal influences than dental maturation is. Therefore, interest in dental age

estimation as a reliable method has been on the rise in the past few decades.

Dental development and maturation, like skeletal development and maturation, shows variations between populations. Some of the commonly used dental age estimation methods have been proposed on the basis of standardizations derived from non-Indian population data. It is therefore questionable whether these methods hold good for the Indian population. Hence, we performed a systematic review and meta-analysis of all published data that used two popular dental age estimation methods (Demirjian's method and Willems' method) in the Indian population.

The findings of our review suggest that the original Willems' method gave dental ages that were very close to the chronological ages of the subjects. Although Willems method underestimated the age, especially in boys, this underestimation was marginal. In contrast, the original Demirjian's method produced a significant overestimation in the Indian population. It is our opinion that the original Willems method may be used for age estimation for forensic or anthropological purposes in the Indian population, if the levels of accuracy reported here are acceptable.

Both Demirjian's and Willems' methods have been revised in the past to improve accuracy of age estimation. The original Demirjian's method uses seven mandibular teeth on the left side for dental age estimation. Chaillet and Demirjian modified the original method to incorporate the use of 3rd molars and published regression formulae for dental age estimation.[28] Acharya, however, determined that this 8 teeth method was also inaccurate for the Indian population, and derived new regression formulae to suit the Indian population.[29] Similarly, the original Willems method used the seven mandibular left teeth and had gender-specific data for dental maturity scores. Willems et al revised the same in the year 2010 and published new charts with gender-neutral dental maturity scores for the seven teeth.[30] The applicability of these modified age estimation methods has been poorly studied in the Indian population until date.

Studies in the past have determined that Willems method is suitable to use in Japanese children,[31] children from the Former Yugoslav Republic of Macedonia,[32] Turkish children,[33] etc. in addition to the original study population of Belgium. Our findings suggest that Willems method is also equally applicable to the Indian population. It is possible that with more population data and improved standardization, Willems method can be made more useful on a global scale.

It is important to acknowledge that there are some pitfalls in the included studies, and in many similar age estimation studies reported previously. Very few studies in the past have reported the standard procedure for determining the chronological age of their samples. Since most studies report an underestimation or overestimation in the range of days or few months, it is essential that the chronological age be established as accurately as possible. Also, we found that many published studies had incomplete data, which resulted in the rejection of almost 14 such reports in our meta-analysis. It is important that authors and editors realize that at least a bare minimum of data needs to be published to ensure that the findings may be consolidated at a later date.

## CONCLUSIONS

Willems' method predicted the chronological age more accurately than Demirjian's method in the Indian population, irrespective of gender. It may be used for age determination for forensic purposes if the levels of accuracy are acceptable. Further studies from other regions of India would help determine whether any modifications or corrections are needed, or whether this method may be used as is.

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