

Global distribution of malocclusion traits: A systematic review

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Objective: Considering that the available studies on prevalence of malocclusions are local or national-based, this study aimed to pool data to determine the distribution of malocclusion traits worldwide in mixed and permanent dentitions.

Methods: An electronic search was conducted using PubMed, Embase and Google Scholar search engines, to retrieve data on malocclusion prevalence for both mixed and permanent dentitions, up to December 2016.

Results: Out of 2,977 retrieved studies, 53 were included. In permanent dentition, the global distributions of Class I, Class II, and Class III malocclusion were 74.7% [31–97%], 19.56% [2–63%] and 5.93% [1–20%], respectively. In mixed dentition, the distributions of these malocclusions were 73% [40–96%], 23% [2–58%] and 4% [0.7–13%]. Regarding vertical malocclusions, the observed deep overbite and open bite were 21.98% and 4.93%, respectively. Posterior crossbite affected 9.39% of the sample. Africans showed the highest prevalence of Class I and open bite in permanent dentition (89% and 8%, respectively), and in mixed dentition (93% and 10%, respectively), while Caucasians showed the highest prevalence of Class II in permanent dentition (23%) and mixed dentition (26%). Class III malocclusion in mixed dentition was highly prevalent among Mongoloids.

Conclusion: Worldwide, in mixed and permanent dentitions, Angle Class I malocclusion is more prevalent than Class II, specifically among Africans; the least prevalent was Class III, although higher among Mongoloids in mixed dentition. In vertical dimension, open bite was highest among Mongoloids in mixed dentition. Posterior crossbite was more prevalent in permanent dentition in Europe.

Keywords: Prevalence. Malocclusion. Global health. Population. Permanent dentition. Mixed dentition.

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INTRODUCTION

Angle introduced his famous classification of malocclusion in 1899.¹ Now the World Health Organization estimates malocclusions as the third most prevalent oral health problem, following dental caries and periodontal diseases.²

Many etiological factors for malocclusion have been proposed. Genetic, environmental, and ethnic factors are the major contributors in this context. Certain types of malocclusion, such as Class III relationship, run in families, which gives a strong relation between genetics and malocclusion. Likewise is the ethnic factor, where the bimaxillary protrusion, for example, affects the African origin more frequently than other ethnicities. On the other hand, functional adaptation to environmental factors affects the surrounding structures including dentitions, bone, and soft tissue, and ultimately resulting in different malocclusion problems. Thus, malocclusion could be considered as a multifactorial problem with no specific cause so far.³

A search in the literature for studies on prevalence of malocclusion and related factors revealed that most of these epidemiological investigations were published between the 1940s and the 1990s. Thereafter, publications have been turned into focusing more on determination of treatment needs, treatment techniques and mechanisms, and treatment outcomes.⁴

Epidemiological studies play a pivotal role in terms of determining the size of the health problems, providing the necessary data and generating and analyzing hypotheses of associations, if any. Through these valuable information, the priorities are set and the health policies are developed.⁵ Hence, the quality of these epidemiological studies must be evaluated crucially and it will be valuable to pool their results, whenever possible.

In this regard, there has been a continuous increase in conducting critical analyses for the published epidemiological health studies. The aim behind this is to generate a more precise and trusted evidence on the health problem under investigation using strict criteria for quality analysis. However, few have been conducted in orthodontics. The objective of the current study, therefore, was to present a comprehensive estimation on the prevalence of malocclusion in different populations and continents.

MATERIALS AND METHODS

Search method

A literature search in PubMed, Embase, and Google Scholar search engines was conducted up to December 2016. The following search terms were used: 'Prevalence', 'Malocclusion', 'Mixed dentition', and 'Permanent dentition'. In addition, an electronic search in websites of the following journals was conducted: Angle Orthodontist, American Journal of Orthodontics and Dentofacial Orthopedics, Journal of Orthodontics, and European Journal of Orthodontics.

Studies that fulfilled the following criteria were included:

- 1) Population-based studies.
- 2) Sample size greater than 200 subjects.
- 3) Studies that evaluated malocclusion during mixed and/ or permanent dentitions.
- 4) Studies that used Angle's classification of malocclusion.
- 5) Studies that considered the following definitions of the specified malocclusion characteristics: "abnormal overjet" if more than 3mm; "reverse overjet" when all four maxillary incisors were in a crossbite; "abnormal overbite" if more than 2.5 mm (for deep bite) and if less than 0 mm (for open bite); and "posterior crossbite" when affecting more than two teeth. The malocclusion traits included were: Angle Classification (Class I / II / III), overjet (increased / reversed), overbite (deep bite / open bite), posterior crossbite, based on the above mentioned definitions for these traits.

A study was excluded if it was conducted in a clinical/hospital-based setting and/or targeted malocclusion prevalence in primary dentition or in a population with specific medical problem.

Characteristics of all studies⁶⁻⁵⁸ analyzed were formulated similar to that used in analysis of epidemiological studies^{59,60} (Table 1).

Critical appraisal of the included studies was done based on a modified version of STROBE checklist^{61,62} comprising seven items related to: study design, study settings, participants criteria, sample size, variable description, and outcome measurements. The quality of the studies was categorized into weak (≤ 3), moderate (4 or 5) and high quality (≥ 6), as described in Table 2.

Table 1 - Characteristics of the included studies.

| No | Author | Year | Sample | Age | Gender | Country | Region | Race | Population |
|----|-----------------------------------------|------|--------|-----------|----------------|-----------|---------|------------|------------------|
| 1 | Massler and Frankel ⁶ | 1951 | 2758 | 14-18 | M=1238, F=1520 | America | America | Caucasian | Schoolchildren |
| 2 | Goose et al. ⁷ | 1957 | 2956 | 7-15 | Not mentioned | Britain | Europe | Caucasian | Schoolchildren |
| 3 | Mills ⁸ | 1966 | 1455 | 8-17 | M=719, F=736 | America | America | Caucasian | Schoolchildren |
| 4 | Grewe et al. ⁹ | 1968 | 651 | 9-14 | M=322, F=329 | America | America | Caucasian | Community |
| 5 | Helm ¹⁰ | 1968 | 1700 | 6-18 | M=742, F=958 | Denmark | Europe | Caucasian | Schoolchildren |
| 6 | Thilander and Myrberg ¹¹ | 1973 | 6398 | 7-13 | M=3093, F=3305 | Sweden | Europe | Caucasian | Schoolchildren |
| 7 | Foster and Day ¹² | 1974 | 1000 | 12 | Not mentioned | Britain | Europe | Caucasian | Schoolchildren |
| 8 | Ingervall et al. ¹³ | 1978 | 389 | 21-54 | M=389, F=0 | Sweden | Europe | Caucasian | Military service |
| 9 | Helm and Pryds ¹⁴ | 1979 | 1536 | 14-18 | Not mentioned | Denmark | Europe | Caucasian | Schoolchildren |
| 10 | Lee et al. ¹⁵ | 1980 | 2092 | 17-21 | M=1281, F=811 | Korea | Asia | Mongoloids | Community |
| 11 | Gardiner ¹⁶ | 1982 | 479 | 10-12 | Not mentioned | Libya | Africa | Caucasian | Community |
| 12 | De Muñiz ¹⁷ | 1986 | 1554 | 12-13 | M=655, F=899 | Argentina | America | Caucasian | Schoolchildren |
| 13 | Kerosuo et al. ¹⁸ | 1988 | 642 | 11-18 | M=340, F=302 | Tanzania | Africa | Africans | Schoolchildren |
| 14 | Woon et al. ¹⁹ | 1989 | 347 | 15-19 | Not mentioned | China | Asia | Mongoloids | Community |
| 15 | Al-Emran et al. ²⁰ | 1990 | 500 | 14 | M=500, F=0 | Saudia | Asia | Caucasian | Schoolchildren |
| 16 | El-Mangoury and Mostafa ²¹ | 1990 | 501 | 18-24 | M=231, F=270 | Egypt | Africa | Caucasian | Community |
| 17 | Lew et al. ²² | 1993 | 1050 | 12-14 | Not mentioned | China | Asia | Mongoloids | Schoolchildren |
| 18 | Tang ²³ | 1994 | 201 | 20 | Not mentioned | China | Asia | Mongoloids | Community |
| 19 | Harrison and Davis ²⁴ | 1996 | 1438 | 7-15 | Not mentioned | Canada | America | Caucasian | Community |
| 20 | Ng'ang'a et al. ²⁵ | 1996 | 919 | 7-15 | M=468, F=451 | Kenya | Africa | Africans | Community |
| 21 | Ben-Bassat et al. ²⁶ | 1997 | 939 | 6-13 | M=442, F=497 | Israel | Asia | Caucasian | Schoolchildren |
| 22 | Proffit et al. ²⁷ | 1998 | 14000 | 8-50 | Not mentioned | America | America | Caucasian | Community |
| 23 | Dacosta ²⁸ | 1999 | 1028 | 11-18 | M= 484, F=544 | Nigeria | Africa | Africans | Community |
| 24 | Saleh ²⁹ | 1999 | 851 | 9-15 | M=446, F=405 | Lebanon | Asia | Caucasian | Schoolchildren |
| 25 | Esa et al. ³⁰ | 2001 | 1519 | 12-13 | M=772, F=747 | Malaysia | Asia | Mongoloids | Schoolchildren |
| 26 | Thilander et al. ³¹ | 2001 | 4724 | 5-17 | M=2371, F=2353 | Colombia | America | Caucasian | Health center |
| 27 | Freitas et al. ³² | 2002 | 520 | 11-15 | M=250, F=270 | Brazil | America | Caucasian | Schoolchildren |
| 28 | Bataringaya ³³ | 2004 | 402 | 14 | M=141, F=261 | Uganda | Africa | Africans | Schoolchildren |
| 29 | Onyeano ³⁴ | 2004 | 636 | 12-17 | M=334, F=302 | Nigeria | Africa | Africans | Schoolchildren |
| 30 | Tausche et al. ³⁵ | 2004 | 197 | 6-8 | M=970, F=1005 | Germany | Europe | Caucasian | Schoolchildren |
| 31 | Abu Alhaja et al. ³⁶ | 2005 | 1003 | 13-15 | M=619, F=384 | Jordan | Asia | Caucasian | Schoolchildren |
| 32 | Ali and Abdo ³⁷ | 2005 | 1000 | 7-12 | M=501, F=499 | Yemen | Asia | Caucasian | Schoolchildren |
| 33 | Behbehani et al. ³⁸ | 2005 | 1299 | 13-14 | M=674, F=625 | Kuwait | Asia | Caucasian | Schoolchildren |
| 34 | Ciuffolo et al. ³⁹ | 2005 | 810 | 11-14 | M=434, F=376 | Italy | Europe | Caucasian | Schoolchildren |
| 35 | Karaiskos ⁴⁰ | 2005 | 395 | 9 | Not mentioned | Canada | America | Caucasian | Schoolchildren |
| 36 | Ahangar Atashi ⁴¹ | 2007 | 398 | 13-15 | Not mentioned | Iran | Asia | Caucasian | Community |
| 37 | Gelgör et al. ⁴² | 2007 | 810 | 11-14 | M=1125, F=1204 | Turkey | Europe | Caucasian | Health center |
| 38 | Jonsson et al. ⁴³ | 2007 | 829 | 31-44 | M=342, F=487 | Iceland | Europe | Caucasian | Schoolchildren |
| 39 | Josefsson et al. ⁴⁴ | 2007 | 493 | 12-13 | Not mentioned | Sweden | Europe | Caucasian | Schoolchildren |
| 40 | Ajayi ⁴⁵ | 2008 | 441 | 11-18 | M=229, F=212 | Nigeria | Africa | Africans | Schoolchildren |
| 41 | Mtaya ⁴⁶ | 2008 | 1601 | 12-14 | M=632, F=969 | Tanzania | Africa | Africans | Schoolchildren |
| 42 | Borzabadi-Farahani et al. ⁴⁷ | 2009 | 502 | 11-14 | M=249, F=253 | Iran | Asia | Caucasian | Schoolchildren |
| 43 | Daniel et al. ⁴⁸ | 2009 | 407 | 9-12 | M= 191, F=216 | Brazil | America | Caucasian | Schoolchildren |
| 44 | Šidlauskas and Lopatienė ⁴⁹ | 2009 | 1681 | 7-15 | M=672, F=1009 | Lithuania | Europe | Caucasian | Schoolchildren |
| 45 | Alhammadi ⁵⁰ | 2010 | 1000 | 18-25 | M=500, F=1000 | Yemen | Asia | Caucasian | Schoolchildren |
| 46 | Bhardwaj et al. ⁵¹ | 2011 | 622 | 16-17 | M= 365, F=257 | India | Asia | Caucasian | Schoolchildren |
| 47 | Nainani and Relan ⁵² | 2011 | 436 | 12-15 | M= 224, F=212 | India | Asia | Caucasian | Schoolchildren |
| 48 | Bugaighis et al. ⁵³ | 2013 | 343 | 12-17 | M=169, F=174 | Libya | Africa | Caucasian | Schoolchildren |
| 49 | Kaur et al. ⁵⁴ | 2013 | 2400 | 13-17 | M=1192, F=1208 | India | Asia | Caucasian | Schoolchildren |
| 50 | Reddy et al. ⁵⁵ | 2013 | 2135 | 6-10 | M=1009, F=1126 | India | Asia | Caucasian | Schoolchildren |
| 51 | Bilgic F et al. ⁵⁶ | 2015 | 2329 | 12.5-16.2 | M=1125, F=1204 | Turkey | Europe | Caucasian | Schoolchildren |
| 52 | Gupta et al. ⁵⁷ | 2016 | 500 | 12-17 | M=1125, F=1204 | India | Asia | Caucasian | Schoolchildren |
| 53 | Narayanan et al. ⁵⁸ | 2016 | 2366 | 10-12 | M=1281, F=1085 | India | Asia | Caucasian | Schoolchildren |

M = male; F = female.

Table 2 - STROBE -based quality analysis of the included studies.

| No | Author | Study design | Setting | Participants | Sample size | Variables description | Outcome measurement | Statistical analysis | Total score |
|----|-----------------------------------------|--------------|---------|--------------|-------------|-----------------------|---------------------|----------------------|-------------|
| 1 | Massler and Frankel ⁶ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 2 | Goose et al. ⁷ | X | ✓ | ✓ | X | X | ✓ | ✓ | 4 |
| 3 | Mills ⁸ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 4 | Grewe et al. ⁹ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 5 | Helm ¹⁰ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 6 | Thilander and Myrberg ¹¹ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 7 | Foster and Day ¹² | X | X | ✓ | X | ✓ | ✓ | ✓ | 4 |
| 8 | Ingervall et al. ¹³ | X | X | ✓ | X | ✓ | ✓ | ✓ | 4 |
| 9 | Helm and Pryds ¹⁴ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 6 |
| 10 | Lee et al. ¹⁵ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 11 | Gardiner ¹⁶ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 12 | De Muñiz ¹⁷ | X | ✓ | ✓ | X | X | ✓ | ✓ | 4 |
| 13 | Kerosuo et al. ¹⁸ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 14 | Woon et al. ¹⁹ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 15 | Al-Emran et al. ²⁰ | X | ✓ | ✓ | X | X | ✓ | ✓ | 4 |
| 16 | El-Mangoury and Mostafa ²¹ | X | ✓ | ✓ | X | X | ✓ | ✓ | 4 |
| 17 | Lew et al. ²² | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 18 | Tang ²³ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 19 | Harrison and Davis ²⁴ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 20 | Ng'ang'a et al. ²⁵ | X | ✓ | ✓ | ✓ | X | ✓ | ✓ | 6 |
| 21 | Ben-Bassat et al. ²⁶ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 22 | Proffit et al. ²⁷ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 23 | Dacosta ²⁸ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 24 | Saleh ²⁹ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | 5 |
| 25 | Esa et al. ³⁰ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 6 |
| 26 | Thilander et al. ³¹ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 27 | Freitas et al. ³² | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 28 | Bataringaya ³³ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 7 |
| 29 | Onyeaso ³⁴ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 30 | Tausche et al. ³⁵ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 31 | Alhaja et al. ³⁶ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 32 | Ali and Abdo ³⁷ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 33 | Behbehani et al. ³⁸ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 6 |
| 34 | Ciuffolo et al. ³⁹ | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 35 | Karaiskos ⁴⁰ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 36 | Ahangar Atashi ⁴¹ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 37 | Gelgör et al. ⁴² | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 38 | Jonsson et al. ⁴³ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 7 |
| 39 | Josefsson et al. ⁴⁴ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 40 | Ajayi ⁴⁵ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 41 | Mtaya ⁴⁶ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 7 |
| 42 | Borzabadi-Farahani et al. ⁴⁷ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 43 | Daniel et al. ⁴⁸ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 6 |
| 44 | Šidlauskas and Lopatienė ⁴⁹ | X | X | ✓ | X | ✓ | ✓ | ✓ | 4 |
| 45 | Alhammadj ⁵⁰ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 46 | Bhardwaj et al. ⁵¹ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | 5 |
| 47 | Nainani and Relan ⁵² | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | 5 |
| 48 | Bugaighis et al. ⁵³ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 49 | Kaur et al. ⁵⁴ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | 5 |
| 50 | Reddy et al. ⁵⁵ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | 5 |
| 51 | Bilgic F et al. ⁵⁶ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | 6 |
| 52 | Gupta et al. ⁵⁷ | X | ✓ | ✓ | X | X | ✓ | ✓ | 4 |
| 53 | Narayanan et al. ⁵⁸ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | 5 |

Statistical analysis

Prevalence rates, by different variables, were presented as means and standard deviations (SD), with the minimum and maximum values. The data were checked for normal distribution using Kolmogorov-Smirnov test. As the distribution was not normal, analyses were conducted using non-parametric tests. Kruskal-Wallis test was used for comparisons between more than two groups. Mann-Whitney U test was used for pair-wise comparisons between groups whenever Kruskal-Wallis test was significant. Spearman's coefficient was calculated to determine the correlations, if any, between different variables. All tests were supposed to be two-tailed, and the power and the significance values were set at 0.8 and 0.05, respectively. Statistical analysis was performed with IBM® SPSS® Statistics for Windows software, version 21 (Armonk, NY: IBM Corp.)

RESULTS

Two thousands nine hundreds and seventy seven studies were found to be potentially relevant to the study. The flow diagram (Fig 1) describes the process of articles retrieval; 255 articles were excluded due to duplication. The main cause of dropping of the retrieved articles was removal of irrelevant titles (2,348). The final closely related were 374 articles published between years 1951 and 2016. After reading their abstracts, only 53 articles (Table 1) fulfilled the inclusion criteria and were included in the subsequent analyses.

The results of the critical appraisal of the included studies are presented in Table 2. The total quality score ranged from 4 to 7. Thirty eight studies (72%) were considered of moderate quality and fifteen (28%), of high quality. The most common drawbacks among all studies were failure to declare the study design (whether it is of cross-sectional, follow-up, etc.) and lack of sample size calculation.

In permanent dentition (Table 3), the global distributions of Class I, Class II, and Class III were 74.7%, 19.56% and 5.93%, respectively. Increased and reverse overjet was recorded in 20.14% and 4.56%, respectively. Regarding vertical malocclusions, the observed deep overbite and open bite were 21.98% and 4.93%, respectively. Considering the transverse occlusal discrepancies, the posterior crossbite affected 9.39% of the total examined sample.

Regarding the distribution of malocclusion in adults according to geographical location (Table 4), four continents classification system was considered, in which Americas are considered as one continent. In permanent dentition, Europe showed the highest prevalence of Class II and posterior crossbite (33.51% and 13.8%, respectively), and the lowest prevalence of Class I (60.38%). This was applied to mixed dentition regarding Class I and Class II. No statistically significant differences in prevalence of Class III, increased overjet, reversed overjet, deep bite and open bite between the four geographic areas were reported.

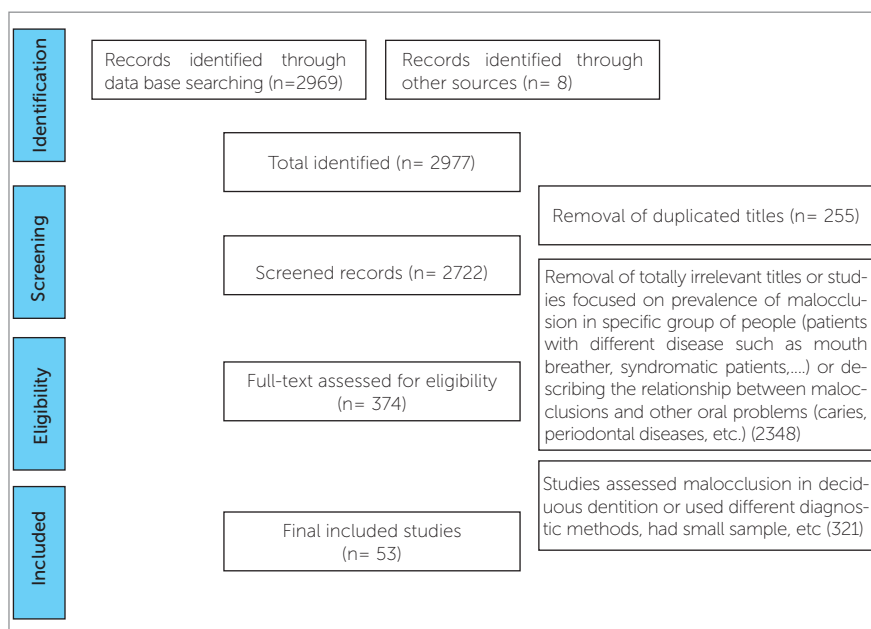


Figure 1 - Flowchart of the literature selection process.

Table 3 - Global prevalence of malocclusion in permanent and mixed dentitions

| Dimension | Malocclusion form | Permanent dentition | | | | Mixed dentition | | | |
|------------------|---------------------|---------------------|------|-------|-------|-----------------|------|-------|-------|
| | | Min | Max | Mean | SD | Min | Max | Mean | SD |
| Antero-posterior | Class I | 31 | 96.6 | 74.7 | 15.17 | 40 | 96.2 | 72.74 | 16 |
| | Class II | 1.6 | 63 | 19.56 | 13.76 | 1.7 | 58 | 23.11 | 14.94 |
| | Class III | 1 | 19.9 | 5.93 | 4.69 | 0.7 | 12.6 | 3.98 | 2.75 |
| | Increased overjet | 1.6 | 48.4 | 20.14 | 11.13 | 9.4 | 35.7 | 23.01 | 7.56 |
| | Reversed overjet | 0 | 20.1 | 4.56 | 5.26 | 0.4 | 11.9 | 3.65 | 3.67 |
| Vertical | Deep bite | 2.2 | 56 | 21.98 | 14.13 | 3.5 | 57.1 | 24.34 | 14.54 |
| | Open bite | 0.1 | 15 | 4.93 | 3.97 | 0.29 | 25.1 | 5.29 | 5.9 |
| Transverse | Posterior crossbite | 4 | 32.2 | 9.39 | 5.04 | 3.72 | 29.1 | 11.72 | 7.22 |

Table 4 - Prevalence of malocclusion in different geographic locations.

| Variable | Permanent dentition | | | | | | | | P-value | |
|------------------|---------------------|-------|--------|-------|-------|-------|--------|-------|---------|--------|
| | America | | Africa | | Asia | | Europe | | | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | | |
| Antero-posterior | Class I | 78.53 | 8.56 | 83.68 | 12.48 | 78.93 | 9.77 | 60.39 | 16.76 | 0.019* |
| | Class II | 15.25 | 7.06 | 11.45 | 9.08 | 12.26 | 4.28 | 33.51 | 17.73 | 0.016* |
| | Class III | 6.23 | 2.68 | 4.75 | 4.6 | 6.32 | 6.46 | 6.2 | 2.75 | 0.5 |
| | Increased overjet | 16.67 | 5.61 | 21.4 | 13.91 | 19.79 | 10.5 | 20.79 | 12.38 | 0.9 |
| | Reversed overjet | 2.26 | 2.17 | 3.47 | 2.89 | 6.09 | 7 | 4.37 | 4.96 | 0.829 |
| Vertical | Deep bite | 11.13 | 6.41 | 25.83 | 18.96 | 23.83 | 12.95 | 21.56 | 13.33 | 0.227 |
| | Open bite | 5.03 | 4.32 | 6.34 | 3.12 | 4.01 | 3.86 | 4.92 | 4.82 | 0.378 |
| Transverse | Posterior crossbite | 7.08 | 2.24 | 7.9 | 1.78 | 8.27 | 2.65 | 13.08 | 7.93 | 0.029* |
| Mixed dentition | | | | | | | | | | |
| Antero-posterior | Class I | 69.98 | 19.67 | 90 | 6.11 | 72.78 | 10.29 | 63.95 | 13.77 | 0.035* |
| | Class II | 27.22 | 20.22 | 7.5 | 5.71 | 21.42 | 10.4 | 31.95 | 12.47 | 0.024* |
| | Class III | 2.78 | 0.84 | 2.48 | 0.59 | 5.76 | 3.91 | 3.53 | 1.21 | 0.226 |
| | Increased overjet | 21.12 | 8.23 | 21.23 | 11.3 | 25.09 | 7.62 | 23.02 | 5.12 | 0.841 |
| | Reversed overjet | 3.9 | 5.01 | 5.25 | 4.22 | 4.35 | 3.63 | 1.33 | 0.9 | 0.348 |
| Vertical | Deep bite | 14.98 | 7.73 | 23.3 | 15.5 | 22.09 | 9.97 | 37.4 | 17.62 | 0.122 |
| | Open bite | 5.57 | 3.09 | 8.3 | 5.31 | 4.5 | 7.79 | 4.18 | 5.79 | 0.077 |
| Transverse | Posterior crossbite | 10.67 | 8.26 | 12.13 | 6.62 | 17.77 | 8.47 | 12.45 | 6.54 | 0.832 |

*: Significant at $P \leq 0.05$.

In permanent stage of dentition by ethnic groups, the highest prevalences of Class I malocclusion and open bite (89.44% and 7.82%, respectively) were reported among African population, although the difference of the latter was not statistically significant. However, the highest prevalence of Class II (22.9%) was reported among Caucasians. Otherwise, no statistically significant differences were found in prevalence of Class III, increased overjet, reversed overjet, deep bite and posterior crossbite between the three main populations (Table 5).

The global distributions of Class I, Class II, and Class III in mixed dentition stage were 72.74%, 23.11% and 3.98%, respectively. The prevalence figures of increased and reverse overjet were 23.01% and 3.65%, respectively. Deep overbite and open bite cases were reported in 24.34% and 5.29%, respectively. Posterior crossbite represented 11.72% of the total pooled studies (Table 3).

Regarding prevalence of malocclusion in mixed dentition according to geographical location (Table 4), Africa showed the highest prevalence of Class I (90%)

but the lowest prevalence of Class II malocclusions (7.5%). The highest prevalence figures of Class II, Class III, and open bite malocclusions were reported in Europe (31.95%), Asia (5.76%), and Africa (8.3%), respectively. Deep bite was significantly higher in Europe (37.4%) compared to other geographical areas.

In mixed dentition, African population showed the highest prevalence of Class I (92.47%), but the lowest prevalence of Class II malocclusions (5.1%), while Caucasians showed the lowest prevalence of open bite (3.7%). Mongoloid showed significantly higher prevalence of Class III (10.95%). No significant differences in the prevalence of other malocclusions were found between different ethnicities (Table 5).

The prevalence of Class II was observed less frequently in permanent than in mixed dentition (19.56 ± 13.76 and $23.11 \pm 14.94\%$, respectively), while the prevalence of Class III was observed more frequently in permanent than in mixed dentition (5.93 ± 4.96 and 3.98 ± 2.75 , respectively).

Table 5 - Prevalence of malocclusion in different races

| Variable | | Permanent dentition | | | | | | P-value |
|------------------|---------------------|---------------------|-------|------------|-------|--------------------|-------|---------|
| | | Africans | | Caucasians | | Mongoloids | | |
| | | Mean | SD | Mean | SD | Mean | SD | |
| Antero-posterior | Class I | 89.44 | 9.34 | 71.61 | 15.15 | 74.87 | 9.68 | 0.027* |
| | Class II | 6.76 | 4.99 | 22.9 | 14.07 | 14.14 | 4.43 | 0.006* |
| | Class III | 3.8 | 4.67 | 5.92 | 4 | 9.63 | 9.02 | 0.228 |
| | Increased overjet | 14.62 | 6.22 | 22.29 | 11.77 | 12.87 | 6.78 | 0.132 |
| | Reversed overjet | 3.5 | 2.93 | 3.99 | 5.11 | 10.87 | 6.68 | 0.122 |
| Vertical | Deep bite | 19.02 | 15.81 | 22.95 | 14.07 | 19.5 | 16.6 | 0.587 |
| | Open bite | 7.82 | 2.24 | 4.52 | 4.17 | 3.27 | 2.89 | 0.074 |
| Transverse | Posterior crossbite | 7.2 | 1.61 | 10.08 | 5.64 | 7.53 | 0.31 | 0.149 |
| Mixed dentition | | | | | | | | |
| Antero-posterior | Class I | 92.47 | 4.41 | 70.39 | 14.78 | 66.75 | 1.77 | 0.02* |
| | Class II | 5.1 | 3.8 | 25.91 | 14.86 | 22.1 | 0.85 | 0.028* |
| | Class III | 2.4 | 0.69 | 3.53 | 1.86 | 10.95 | 2.33 | 0.045* |
| | Increased overjet | 16.4 | 7.21 | 23.62 | 7.3 | 27.45 | 11.67 | 0.305 |
| | Reversed overjet | 3.9 | 3.97 | 3.15 | 3.59 | 8.5 | 1.77 | 0.217 |
| Vertical | Deep bite | 26.37 | 17.43 | 24.35 | 15.13 | 21.25 | 10.11 | 1 |
| | Open bite | 10 | 5 | 3.7 | 3.77 | 14.15 | 15.49 | 0.035* |
| Transverse | Posterior crossbite | 10.77 | 7.39 | 11.64 | 7.49 | 16.2 (one case) | | 0.689 |

*: Significant at $P \leq 0.05$.

DISCUSSION

Global, regional and racial epidemiological assessment of malocclusions is of paramount importance, since it provides important data to assess the type and distribution of occlusal characteristics. Such data will aid in determining and directing the priorities in regards to malocclusion treatment need, and the resources required to offer treatment—in terms of work capacity, skills, agility and materials to be employed. In addition, assessment of malocclusion prevalence by different populations and locations may reflect existence of determining genetic and environmental factors. In line with that, the hypothesized tendency of changing prevalence of a specific type of malocclusion, such as Class II, from mixed to permanent dentition stage may give an indication about the effect of adolescent growth in correction of this problem. Finally, the availability of such global data will be important for educational purposes. Regional and/or racial-specific malocclusion may change the health policy toward developing the specialists' skills and offering the resources required for that malocclusion. It must be emphasized that the current study summarizes the global distribution of malocclusion in mixed and permanent dentitions based on data extracted from studies of moderate (72% of the included studies) to high (28%) quality. None of the included studies was of low quality.

The pooled global prevalence of Class I was the highest ($74.7 \pm 15.17\%$), ranging from 31% (Belgium) to 96.6% (Nigeria). It was higher among Africans (89.44%), but equivalent among Caucasians and Mongoloids (71.61% and 74.87%, respectively). This pattern of distribution was reported for both dentitions with slight differences. Noteworthy, the prevalence of Class I in permanent dentition of Mongoloids tends to increase with pubertal growth, mostly due to the associated tendency for Class II correction in this race specifically.

The overall global prevalence of Class II was 19.56%. However, it was interesting to see a wide range from 1.6% (Nigeria) to 63% (Belgium). The lowest prevalence was reported for Africans 6.76% and the highest was reported for Caucasian (22.9%); the reported prevalence for Mongoloids was in-between (14.14%). The pattern of global distribution of Class II malocclusion by race was somewhat similar in mixed and permanent dentitions. With exception of African people (Africa), there is a tendency for correction of Class II with pubertal growth upon transition from mixed to permanent dentition.

Both, prevalence and growth correction of Class II, can be attributed to the genetic influence. Recent research emphasizes the pivotal role of genetic control over condylar cartilage and condylar growth.^{63,64}

The global prevalence of Class III was the lowest among all Angle's classes of malocclusion ($5.93 \pm 4.69\%$). The range was interestingly wide: 0.7% (Israel) to 19.9% (China). The corresponding figures for Caucasians, Africans and Mongoloids were 5.92, 3.8% and 9.63%, respectively. This pattern of global distribution of Class III applies to mixed and permanent dentitions. A tendency to develop this type of malocclusion appears to increase upon transition from mixed to permanent dentition among Africans and Caucasians, rather than among Mongoloids. The role of genetics must be emphasized. In fact, Class III malocclusion in Asians is mainly due to the mid-face deficiency, rather than mandibular prognathism.⁶⁵

The positive correlation found between Class II and increased overjet is logical. Simply, this is due to the fact that the most prevalent Class II malocclusion globally is Class II division 1.⁶⁶ Similarly, the positive correlation of Class III malocclusion with reversed overjet is related to skeletal base discrepancy with minimal dentoalveolar compensation.⁶⁷

The lowest prevalent malocclusion traits globally were reversed overjet and open bite (4.56 and 4.93, respectively). There is a high variation in prevalence of both traits as reported in the literature. Most of the studies reported that open bite trait is highly prevalent in African populations and low in Caucasian populations,^{17,18,20,25} in contrast to the reversed overjet, which reported to be prevalent in Mongoloids. In general, both traits are genetically determined.^{63,64}

An interesting finding was the higher prevalence of Class II malocclusion in the mixed dentition than in the permanent dentition. This could be explained by the fact that self-correction of a skeletal Class II problem might occur in the late mixed and early permanent dentition stage as a result of a potential mandibular growth spurt. However, a sound conclusion can't be drawn, as the present study was not prospective. In addition, the difference in leeway space between maxillary and mandibular arches, and residual growth in the permanent dentition stage could explain the higher prevalence of Class III malocclusion in the permanent dentition than in the mixed dentition, and the fact that the mandible might continue to grow till the mid- twenties.

The present pooled data showed a decrease in the prevalence of deep bite upon transition from mixed to

permanent dentition. Thilander et al,³¹ likewise, showed that increased overbite was more prevalent in the mixed dentition. Such an overbite reduction from the mixed to the permanent dentition is due to both occlusal stabilization involving full eruption of premolars and second molars, and the more pronounced mandibular growth.³⁵ This also explains the reduction in Class II cases as well as the increase in Class III cases (reverse overjet as well) during the period of changing dentition.

In addition to the importance of reporting global malocclusion, it is of an equal importance to report the worldwide orthodontic treatment needs. We planned to do so if the included studies had covered both issues. This was not the case, however, and hence we recommend addressing this latter issue with a similar systematic review.

CONCLUSIONS

1) Consistent with most of the included individual studies, Class I and II malocclusions were the most prevalent, while Class III and open bite were the least prevalent malocclusions.


2) African populations showed the highest prevalence of Class I and open bite malocclusions, while Caucasian populations showed the highest prevalence of Class II malocclusion.


3) Europe continent showed the highest prevalence of Class II among all continents.

4) Class III malocclusion was more prevalent in permanent dentition than mixed dentition, conversely finding for Class II, while all other malocclusions variables showed no difference between the two stages.

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ERRATUM: GLOBAL DISTRIBUTION OF MALOCCLUSION TRAITS: A SYSTEMATIC REVIEW

In the article “Global distribution of malocclusion traits: A systematic review”, with DOI 10.1590/2177-6709.23.6.40.e1-10, onl, published at *Dental Press J Orthod.* 2018 Nov-Dec;23(6):40.e1-10, in “Figure 1: Flowchart of the literature selection process.”, where it is written:

“Records identified through database searching (n=1969)”

Should be written:

“Records identified through database searching (n=2969)

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