

Prevalence of Tooth Transposition

A Meta-Analysis

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ABSTRACT

Objective: To synthesize currently existing data and investigate the prevalence of tooth transposition as well as its relation to gender, dental arch, and quadrant occurrence.

Materials and Methods: Several electronic databases were searched in order to identify the potentially relevant studies. Initially, 591 papers were retrieved. After applying specific inclusion and exclusion criteria, nine studies were eligible for inclusion in this evaluation. Meta-analysis was performed by determining the event rate and the 95% confidence intervals estimated by the random effect model.

Results: Analysis of the data of the primary studies revealed that tooth transposition has a mean prevalence of 0.33%. This prevalence seems to be the same between the two genders. However, tooth transposition appears more frequently in the maxilla than in the mandible and more unilaterally than bilaterally.

Conclusion: Tooth transposition is a rare phenomenon that affects various populations, including across genders, in a similar manner. Some maxillary predisposition exists, and its unilateral occurrence is higher than that of bilateral. (*Angle Orthod.* 2010;80:275–285.)

KEY WORDS: Tooth transposition; Prevalence; Meta-analysis

INTRODUCTION

Tooth transposition is considered a rare condition and is usually related to eruption disturbances of the teeth and to the subsequent abnormal occlusal relationships.¹ More specifically, tooth transposition is defined as the positional interchange of two neighboring teeth and especially of their roots, or the development or eruption of a tooth in a position normally occupied by a non-neighboring tooth.² Therefore, tooth transposition is a peculiar type of ectopic eruption in which each ectopic tooth changes the normal order of the tooth sequence in the dental arch.³

The prevalence of tooth transposition varies considerably in the existing literature—from 0.09% to 1.4%^{1,4}—and has not been analyzed by an integrated

approach. Systematic reviews and meta-analyses can summarize the results of other studies and provide the readers with some indication of where the weight of the evidence lies. These study designs may, therefore, produce and defend conclusions based on the best available evidence or in some cases may conclude that the evidence currently available does not allow for any conclusions.⁵

Therefore, the aim of this study was to perform a systematic evaluation in an evidence-based manner to increase the insight into the prevalence of tooth transposition through a meta-analytic procedure in order to identify any possible associations between the prevalence of tooth transposition and the type of population and gender in which it occurred, as well as its dental arch and quadrant localization.

MATERIALS AND METHODS

Detailed search strategies were developed⁵ to identify potentially relevant studies reporting data from patients presenting tooth transposition. Every effort to minimize any possible bias in the location of studies was made, and citations to potentially relevant studies from journal articles, dissertations, or conference proceedings were located by searching the appropriate electronic databases. In addition, to identify

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Accepted: June 2009. Submitted: May 2009.

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Table 1. The Electronic Databases Searched and the Search Strategy Used in the Meta-Analysis (as of December 17, 2008)

Electronic Databases	Search Strategy	No. of Hits per Database
MEDLINE <i>Searched via PubMed (1950–12/17/2008)</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	582
EMBASE <i>Searched via Science Direct with the aid of SCIRUS (1974–12/17/2008)</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	225
Cochrane Central Register of Controlled Trials <i>Searched via the Cochrane Library on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	3
Google Scholar Beta <i>Searched on 12/17/2008</i>	“tooth transposition”	71
	“teeth transposition”	7
	“dental transposition”	16
	“incisor transposition”	25
	“canine transposition”	81
	“cuspid transposition”	5
	“premolar transposition”	60
	“bicuspid transposition”	0
	“molar transposition”	4
	“transposed tooth”	12
	“transposed teeth”	42
	“transposed incisor”	0
	“transposed canine”	9
	“transposed cuspid”	3
	“transposed premolar”	6
	“transposed bicuspid”	0
	“transposed molar”	0
	In total, among them some in common	341
ISI Web of Knowledge for UK users <i>Searched on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	43
Evidence-Based Medicine <i>Searched on 12/17/2008</i>	“tooth transposition”	0
	“teeth transposition”	0
	“dental transposition”	0
	“incisor transposition”	0
	“canine transposition”	0
	“cuspid transposition”	0
	“premolar transposition”	0
	“bicuspid transposition”	0
	“molar transposition”	0
	“transposed tooth”	0
	“transposed teeth”	0
	“transposed incisor”	0
	“transposed canine”	0
	“transposed cuspid”	0
	“transposed premolar”	0
	“transposed bicuspid”	0
	“transposed molar”	0
	In total	0
Scopus <i>Searched via Elsevier on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	0
Windows Live Academic <i>Searched on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	0
LILACS database <i>Searched on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	Refers to the PubMed results 582
Bibliografia Brasileira de Odontologia <i>Searched on 12/17/2008</i>	“tooth transposition”	0
	“teeth transposition”	0
	“dental transposition”	0
	“incisor transposition”	0
	“canine transposition”	0
	“cuspid transposition”	0
	“premolar transposition”	0
	“bicuspid transposition”	0
	“molar transposition”	0
	“transposed tooth”	0

Table 1. Continued

Electronic Databases	Search Strategy	No. of Hits per Database
	“transposed teeth”	0
	“transposed incisor”	0
	“transposed canine”	0
	“transposed cuspid”	0
	“transposed premolar”	0
	“transposed bicuspid”	0
	“transposed molar”	0
	In total	0
Digital dissertations <i>Searched via UMI ProQuest on 12/17/2008</i>	(tooth OR teeth OR dental* OR incisor* OR canine* OR premolar* OR cuspid* OR bicuspid* OR molar*) AND transpos*	0
Conference Paper Index <i>Searched via Cambridge Scientific Abstracts (1982–12/17/2008)</i>	(tooth OR teeth OR dental*) AND transpose*	0
metaRegister of Controlled Trials (all registers) <i>Searched via www.controlled-trials.com on 12/17/2008</i>	(tooth OR teeth OR dental*) AND transpose*	0

potentially relevant unpublished or ongoing studies, the databases of research registers were researched. Table 1 presents the databases searched and outlines the search strategy used. This electronic search was conducted on December 17, 2008, after appropriate changes in vocabulary and the syntax rules of each database.

In addition to the electronic searches, manual searching was also performed by checking the references of the initially retrieved articles. When abstracts or full-text articles provided insufficient evidence, the corresponding authors were contacted. No restrictions were applied during the identification

procedure concerning the years considered, the publication status, or the language of the studies.

Studies appropriate for inclusion in the meta-analysis fulfilled specific criteria with regard to study design, participants’ characteristics, intervention characteristics, and principal outcome measures. The detailed inclusion and exclusion criteria are listed in Table 2.

Initially, the titles and abstracts of identified studies were reviewed. Any retrieved article was checked for data from patients presenting tooth transposition. Any investigation not fulfilling this criterion was excluded from further evaluation. If the reviewer could not

Table 2. Criteria for Selecting Studies to be Included in the Meta-Analysis

Criteria Category	Inclusion Criteria	Exclusion Criteria
Study design	<p>Studies included should regard tooth transposition, ie, the positional interchange of two neighboring teeth and especially of their roots, or the development or eruption of a tooth in a position normally occupied by a non-neighboring tooth.</p> <p>Studies included should have presented the exact size of the examined sample and the exact number of affected individuals.</p> <p>Studies included should not apply any restrictions for the investigated types of tooth transposition.</p>	<p>Studies regarding tooth transmigration, ie, canines, usually mandibular and unerupted, crossing the midline.</p> <p>Studies concerning malpositions or impactions but not tooth transposition.</p> <p>Studies concerning various aspects of cleft lip and palate, since this condition represents a major and very specific field, and they therefore would require an individual assessment.</p> <p>Studies regarding third molars, as they tend to be unstable teeth or congenitally missing.</p> <p>Studies not reporting the size of the examined sample.</p> <p>Studies presenting treatment options, etiology and prevention, classification, or various theories about tooth transposition.</p> <p>Author replies.</p> <p>Case reports or reports of cases.</p> <p>Case series.</p> <p>Studies investigating for specific types of tooth transposition.</p>
Participants’ characteristics	<p>The affected individuals should have presented a true transposition.</p>	<p>Study samples where tooth transposition resulted from following application of ultrasonics on the bony tissue of the lower jaw.</p>

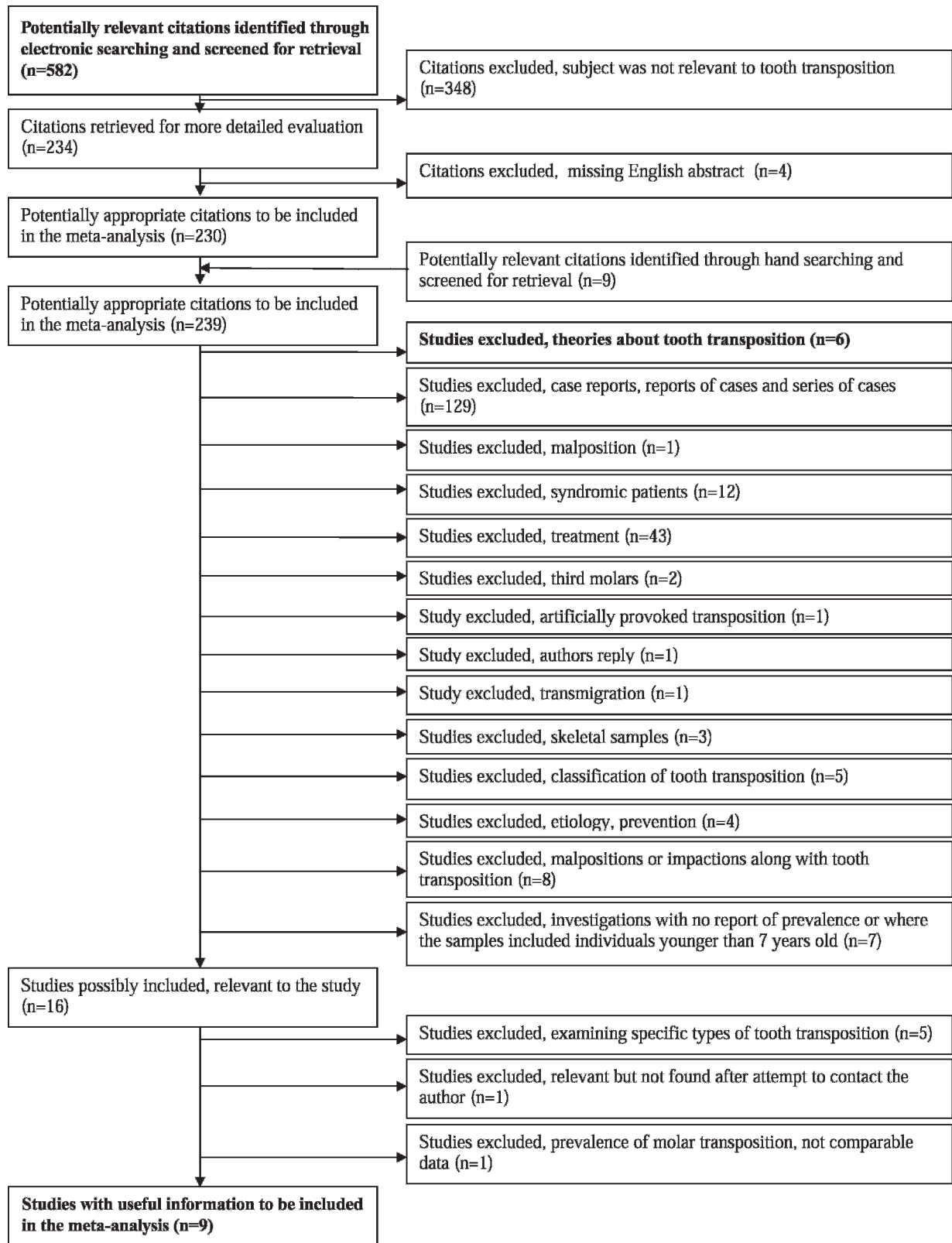


Figure 1. Flow diagram of the retrieved studies through the selection process.

Table 3. Possible Sources of Bias According to Higgins and Green⁷ and Parameters to Consider for the Present Meta-Analysis

Sources of Bias		Parameters to Consider
Selection bias	Need to control for confounders	<ol style="list-style-type: none"> 1. Size of the initial sample. The validity of each sample according to its size and the subsequent margin of error were estimated applying the formula $n = [(Z \times Z) \times p \times (1 - p)] / (E \times E)$, where n = sample size, Z = Z-value for 95% confidence interval, p = best guess of the prevalence of tooth transposition derived from the average prevalence reported in the literature (0.42%), and E = margin of error (15). 2. Sample origin (pupils, dental population, orthodontic population). Different origins of the initial samples might imply different prevalence of tooth transposition, ie, orthodontic patients might present a higher prevalence of tooth transposition in comparison with pupils, given that generally orthodontic problems are more frequent in orthodontic patients than in general population. 3. Focus on a specific type of transposition. Studies investigating for a specific type of tooth transposition within a sample of patients might have ignored any other type of tooth transposition present in the same sample. Therefore, the prevalence of the specific type of tooth transposition might differ from the general prevalence of all types of tooth transposition. 4. Undetermined age of the sample. In early ages tooth transposition cannot be securely diagnosed and, therefore, some cases of pseudotransposition might be included as true tooth transposition.
Performance bias	Need to evaluate the validity of the measurement of the exposure to the intervention of interest	Method of patient evaluation. Evidence of the presence of true tooth transposition might vary, including detection through panoramic or intraoral periapical radiographs or/and clinical examination.

decide on the eligibility of a study by examining the title and the abstract, the full text of the article was retrieved. Furthermore, duplicate citations, such as dissertations that formed the basis of published trials, conference abstracts of published trials, case reports, reports of cases, case series, or review articles, were discarded. For the remaining articles, the corresponding full text was retrieved for further evaluation. These were evaluated in duplicate by two reviewers working independently (Dr Papadopoulos and Dr Chatzoudi). Evaluation of the interreviewer agreement during the

selection procedure was assessed by kappa score. All the above-mentioned processes were not performed blinded, because scientific evidence does not strongly recommend masked assessment.⁶ Any remaining differences were resolved through mutual agreement.

The quality of nonrandomized trials cannot be evaluated in the same way as for randomized controlled trials.⁷⁻⁹ Various criteria have been suggested to critically appraise their validity, which can be applied to other types of studies; however, a great deal of judgment is necessary.¹⁰ The possible sources of

Table 4. Exclusion Criteria and Number of Excluded Articles in This Meta-Analysis

Exclusion Criteria	Number of Excluded Articles
Subject not relevant to tooth transposition	348
Studies with missing English abstract	4
Case reports, reports of cases, or case series	129
Authors replies	1
Skeletal samples regarding recent or ancient skulls	3
Syndromic patients	12
Transmigration of teeth	1
Malpositions of teeth	1
Tooth transposition after application of ultrasonics	1
Third molars as they tend to be unstable teeth or congenitally missing	2
Theories about tooth transposition	6
Classification of tooth transposition	5
Etiology or prevention of tooth transposition	4
Treatment of tooth transposition	43
Studies regarding malpositions or impactions along with tooth transposition	8
Studies with no report of prevalence or in which the samples included individuals aged younger than 7 years	7
Studies relevant but with no available data even after contacting the authors	1
Studies on prevalence of molar transposition, because these teeth cannot easily be distinguished between each other	1
Studies investigating for specific types of tooth transposition	5
Total	582

Table 5. Types of Tooth Transposition Investigated in the Source Studies Included in the Meta-Analysis

bias and the parameters to consider in nonrandomized trials, as discussed in Higgins and Green,¹⁰ were considered in this investigation and presented in Table 3.

The retrieved data was analyzed by means of specially designed software, the Comprehensive Meta-Analysis (Biostat Inc, Englewood, NJ).

The random effects method for meta-analysis, which takes into consideration the heterogeneity of the data, was used to combine the prevalence of transposition according to the approach of Borenstein et al.⁹ The

Table 6. Characteristics of Studies Included in the Meta-Analysis

No.	Study ^a	Source	Sample Size, Patients	Sample Origin	Age
1.	Budai et al ¹⁶	Electronic searching (PubMed, Embase, Google Scholar Beta)	2736	Patients visited the Department of Pedodontics and Orthodontics of Semmelweis University between 1998 and 2003.	Undetermined sample age. Undetermined age of the affected.
2.	Chattopadhyay & Srinivas ¹⁹	Electronic searching (PubMed, Embase, Google Scholar Beta)	4933	Patients visiting SDM College of Dental Sciences in Dharwad, India, between August and October 1993. All the patients were Kannadigas.	Undetermined sample age. Age of the affected between 16 and 50 y.
3.	Dahl ²⁰	Manual searching	8000	Patients attended orthodontic clinic in Germany between 1957 and 1975.	Undetermined sample age. Age of the affected between 8 and 18 y.
4.	Kavadia-Tsatala et al ¹⁷	Electronic searching (PubMed)	2518	Patients attended two private orthodontic clinics in Thessaloniki, Greece.	Undetermined sample age. Age of the affected between 12 and 16.
5.	Hatzoudi & Papadopoulos ¹	Manual searching and electronic searching (PubMed, Google Scholar Beta)	1113	Patients visited private dental practice in Drama, Greece, between 2001 and 2006.	Mean sample age 36.10 y (min 13.1, max 73.0). Age of the affected: 28 y.
6.	Onyeaso & Onyeaso ⁴	Electronic searching (PubMed, Google Scholar Beta)	361	Schoolchildren from 167 public and 109 private schools in Ibadan city, Oyo state, Nigeria.	Sample age between 11 and 12 y. Age of the affected between 11 and 12 y.
7.	Ruprecht et al ¹⁸	Electronic searching (PubMed)	1581	College of Dentistry, King of Saud University, Saudi Arabia.	Undetermined sample age. Age of the affected between 11 and 35 y.
8.	Umwani & Ojo ²¹	Electronic searching (PubMed)	8120	Patients attended private dental clinic, residents of Benin city, Nigeria, and its environs.	No restrictions applied in the included age of the sample, ie, all ages included. Age of the affected between 11 and 40 y.
9.	Yilmaz et al ²²	Electronic searching (PubMed, Google Scholar Beta)	5486	Patients attended the Department of Oral Diagnosis and Radiology, University of Süleyman Demirel, between April 2003 and March 2004.	Undetermined sample age. Age of the affected between 9 and 45 y.

^a Authors are in alphabetical order.

choice of this model was based on the assumption that the variability in the studies retrieved could influence the effects under investigation. Nevertheless, to further identify the extent of heterogeneity, the Cochran test for homogeneity and the I^2 test were calculated to check for heterogeneity and inconsistency, respectively. Subgroup analyses were performed implementing the approach of Deeks et al.¹¹

Publication bias was assessed by preparing a funnel plot. Funnel plot asymmetry was inspected graphically and measured numerically using the approach proposed by Egger et al.¹² and Sterne et al.^{13,14} Evidence of asymmetry was based on $P < .10$.

RESULTS

The flow diagram of the retrieved studies is presented in Figure 1. Following utilization of the above-mentioned search strategy, 591 studies were initially identified (582 through electronic searching and nine through manual searching). After applying the specific inclusion and exclusion criteria, 582 articles were excluded for various reasons, and only nine studies were considered as appropriate to be included in the meta-analysis. The exclusion criteria and the number of excluded articles are listed in detail in Table 4. The kappa score for the overall agreement

Table 6. Extended

Gender Distribution	Diagnosis	Transpositions Investigated	Reported Prevalence
Undetermined sample gender distribution. Undetermined gender of the affected.	Panoramic radiographs taken to confirm the true tooth transposition.	12 patients with various types of tooth transposition: 10 patients with Mx. 2 patients with Mn. Among the 12 patients, 1 transposition was bilateral, the rest were unilateral.	0.43%
Undetermined sample gender distribution. Gender distribution of the affected: 5 females/16 males.	Panoramic and intraoral periapical radiographs taken to confirm true tooth transposition.	21 patients with various types of tooth transposition: 1 patient with unilateral Mn.C.I2 6 patients with unilateral Mx.C.P1 10 patients with unilateral Mx.C.I2 4 patients with bilateral Mx.C.I2	0.41%
Sample gender distribution: 74.12% females/25.88% males. Gender distribution of the affected: 1 female/0 males.	Panoramic radiographs taken to confirm tooth transposition	1 patient with bilateral Mx.C.I2	0.09%
Undetermined sample gender distribution. Gender distribution of the affected: 7 females/9 males.	Panoramic radiographs taken to confirm true tooth transposition.	16 patients with various types of tooth transposition: 6 patients with unilateral Mx.C.P1 5 patients with unilateral Mx.C.I2 1 patient with bilateral Mx.C.I2 4 patients with unilateral Mn.C.I2	0.64%
Undetermined sample gender distribution. Undetermined gender of the affected.	Periapical radiographs taken to confirm true tooth transposition.	10 patients with tooth transposition. Undetermined types of tooth transpositions.	0.13%
Sample gender distribution: 52.63% females/47.37% males. Gender distribution of the affected: 1 female/1 male.	Clinical evaluation performed to confirm true tooth transposition. No radiographs taken.	2 patients with tooth transposition. Undetermined types of tooth transpositions.	1.4%
Sample gender distribution: 43.33% females/56.67% males. Gender distribution of the affected: 2 females/0 males.	Panoramic radiographs or complete mouth radiographic survey taken to confirm true tooth transposition.	2 patients with unilateral Mx.C.P1.	0.13%
Undetermined sample gender distribution. Gender distribution of the affected: 7 females/4 males.	Clinical accountancy of the full complement of teeth to confirm tooth transposition. Periapical x-rays when necessary to differentiate true transposition from pseudotransposition.	11 patients with various types of tooth transposition: 1 patient with unilateral Mx.C.I2. 4 patients with unilateral Mn.C.I2. 1 patient with bilateral Mx.C.P1. 2 patients with bilateral Mx.C.I2. 1 patient with bilateral Mn.C.I2. 1 patient with Mx.C.P1 and Mx.I2P1. 1 patient with Mn.C.I1 and Mn.C.I2.	0.14%
Undetermined sample gender distribution. Gender distribution of the affected: 10 females/11 males.	Survey in panoramic radiographs to diagnose true tooth transposition and then clinical examination.	21 patients with various types of tooth transposition: 1 patient with unilateral Mx.C.P2 1 patient with unilateral Mx.C.I1. 4 patients with unilateral Mx.C.P1. 4 patients with unilateral Mn.C.I2. 1 patient with bilateral Mx.C.P1 1 patient with bilateral Mx.C.I2.	0.38%

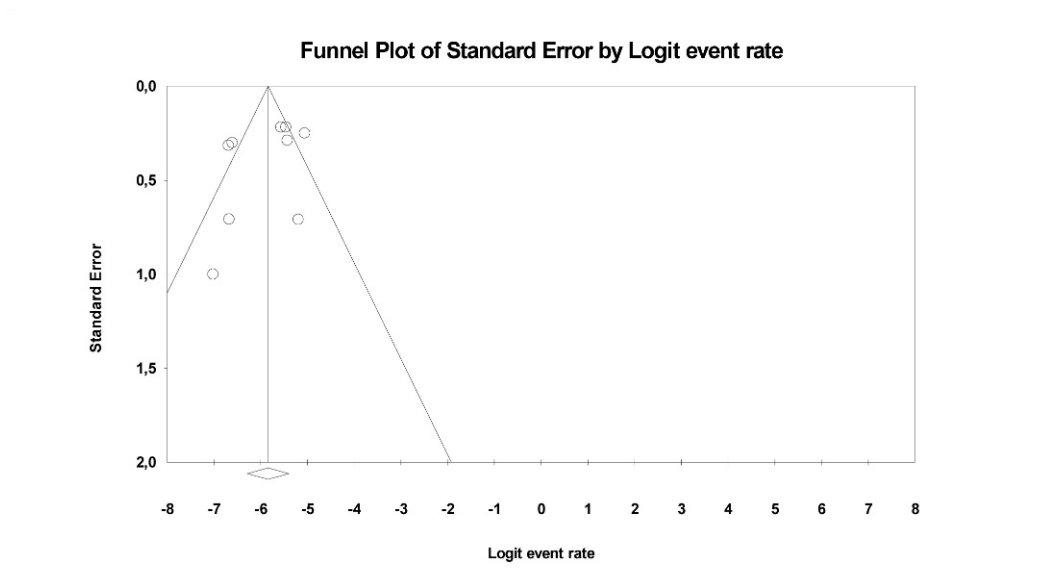


Figure 2. Funnel plot analysis.

between the two investigators before reconciliation was 0.851 (asymptotic standard error 0.085).

The exact types of tooth transposition investigated in the studies included in this meta-analysis are presented in detail in Table 5, and their characteristics in Table 6.

In only one⁴ out of the nine studies under evaluation, the sample included was relatively small (under 500 patients) and allowed for a margin of error approximately 0.051.¹⁵ In four studies^{1,16-18} the sample was quite adequate, consisting of 1000 to 4500 patients and allowing for a margin of error between 0.018 and 0.029.¹⁵ In the remaining four studies,¹⁹⁻²² the samples were relatively big, including more than 4500 patients and allowing for a margin of error between 0.011 and 0.014.¹⁵

In one study⁴ the samples were selected from school populations (pupils), in three studies^{16,17,20} the samples were retrieved from university orthodontic departments or private orthodontic practices (orthodontic patients), and in the remaining five studies^{1,18,19,21,22} the samples

were derived from dental schools or private dental practices (dental patients). The inclusion of studies investigating tooth transposition on dental or orthodontic patients represents selection bias, since these samples may not be representative of the underlying population.

In one study⁴ the diagnosis of tooth transposition was based solely upon clinical examination, whereas in the remaining eight studies^{1,16-22} there was a radiographic confirmation of the transposition. These different methods of diagnosis might imply a detection bias as well.

In six studies^{16-20,22} the ages of the individuals in the sample were undetermined, whereas in one study²¹ all ages were included in the sample under investigation. However, tooth transposition cannot be securely diagnosed in individuals aged younger than 7 years. Thus, the inclusion in the analysis of studies that have possibly investigated individuals aged younger than 7 years might imply a kind of selection bias.

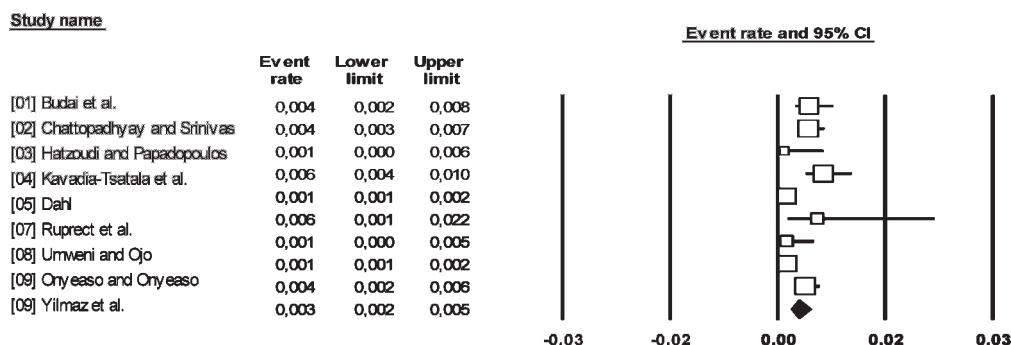


Figure 3. Forest plot for the prevalence of tooth transposition (Q -value = 31.96, I^2 = 74.975).

Table 7. Results of the Meta-Analysis (Random Effects Model) for the Prevalence of Tooth Transposition with Regard to the Various Subgroups, Including the Number of the Source Studies, the Effect Sizes with the 95% Confidence Intervals, the Assessment of Heterogeneity, and the Statistical Significance

	No. of Source Studies	Effect Size and 95% Confidence Interval			Heterogeneity		P-Value
		Point Estimate	Lower Limit	Upper Limit	Q-Value	df (Q)	
Type of tooth transposition							
Pupils	5	0.002	0.001	0.005	0.996	2	.608
Dental patients	3	0.003	0.002	0.007			
Orthodontic patients	1	0.006	0.001	0.034			
Gender							
Males	3	0.002	0.001	0.010	0.021	1	.884
Females	3	0.003	0.001	0.007			
Dental arch occurrence							
Maxilla	7	0.003	0.002	0.004	10.948	1	.001
Mandible	7	0.001	0.000	0.001			
Unilateral/bilateral occurrence							
Unilateral	7	0.003	0.002	0.004	14.718	1	.000
Bilateral	7	0.001	0.000	0.001			
Maxillary unilateral	7	0.003	0.002	0.004	12.677	1	.000
Mandibular unilateral	7	0.001	0.000	0.001			
Maxillary bilateral	7	0.001	0.000	0.001	3.005	1	.083
Mandibular bilateral	7	0.000	0.000	0.001			
Quadrant occurrence							
Maxillary right	6	0.001	0.000	0.001	3.594	1	.058
Maxillary left	6	0.002	0.001	0.003			
Mandibular right	6	0.0004	0.0002	0.0009	0.058	1	.810
Mandibular left	6	0.0005	0.0002	0.0009			

Publication bias was first assessed visually with a funnel plot analysis (Figure 2). Because studies of varying sample sizes were included in the meta-analysis, the Egger linear regression method was also used (intercept = -1.857 , 95% CI = -5.727 to 2.012 ; $t = 1.134$; $df = 7$; 2-tailed $P = .293$).¹³ Although an indication of asymmetry was observed in the funnel plot, no evidence of publication bias was found.

The results of the meta-analysis concerning the general prevalence of tooth transposition, as well as for the various subgroups, are presented in Table 7. The general prevalence of tooth transposition following evaluation of the nine studies included in the meta-analysis was 0.33% (Figure 3).

The prevalence of tooth transposition in pupils and dental and orthodontic patients was found to be 0.20%, 0.30%, and 0.60%, respectively, and presented no statistically significant differences among these three different subgroups ($P = .608$).

Further, the prevalence of tooth transposition did not differ statistically between males (0.20%) and females (0.30%) ($P = .884$), is more pronounced in the maxilla (0.003) than in the mandible (0.001) ($P = .001$), and takes place more frequently unilaterally (0.30%) than bilaterally (0.10%) ($P = .000$). Furthermore, this unilateral occurrence is more pronounced in the maxilla (0.30%) than in the mandible (0.10%) ($P =$

.000). However, the maxillary bilateral occurrence of tooth transposition (0.10%) was not significantly higher than the mandibular bilateral one (0.00%) ($P = .083$).

Finally, the prevalence of tooth transposition did not differ statistically between the maxillary left (0.20%) and right quadrant (0.10%) ($P = .058$) or between the mandibular left (0.05%) and right quadrant (0.04%) ($P = .810$).

DISCUSSION

In the present study, every effort to minimize any possible selection bias was made by developing a precise protocol that was followed during the study.⁵ In detail, the search strategy was performed for the time period 1951–2008, including electronic searching of the most important electronic databases of the medical literature as well as manual searching. Efforts to identify potentially relevant unpublished or ongoing studies were made by searching the databases of research registers. In addition, when abstracts or full-text articles provided insufficient information, the corresponding authors were contacted. In fact, in two cases the authors were contacted about providing us with detailed data of their investigations.^{17,23} The authors of the first study¹⁷ sent all the necessary information; however, no reply was received from the authors of the second study,²³ and consequently this

article was excluded from the current meta-analysis. No restrictions were applied during the identification process for the years considered, the publication status, or the language of the studies. However, studies in non-English languages with missing English abstracts were excluded (four studies in total). Several inclusion and exclusion criteria have been applied in order to select the appropriate studies to be included in the analysis. The selection procedure was accomplished independently by two authors, and the outcomes were analyzed to address any methodological inconsistencies. Potential biases concerning the eligibility and quality of the original studies to be included in the analysis were resolved through mutual agreement. Evaluation of the interviewer agreement before reconciliation was assessed by kappa score and proved to be excellent.

Evidence of true tooth transposition of the affected individuals was considered as an essential issue for a study to be included in this meta-analysis. Consequently, the method used for the diagnosis and evaluation of tooth transposition was taken into consideration. In most of the studies included in the meta-analysis, a radiographic examination by means of panoramic or intraoral periapical radiographs was undertaken to diagnose tooth transposition, whereas in only one of them⁴ the diagnosis was based mainly upon clinical evaluation. Although true tooth transposition can be detected quite easily even by means of clinical examination and palpation of the area of the roots of the corresponding teeth, an additional radiographic examination is desirable and usually recommended when conducting an evidence-based study. However, the possible selection bias that may have been inferred by including the above-mentioned study,⁴ where only clinical evaluation was performed to diagnose tooth transposition, was not considered as significant and therefore this study was included in the current evaluation.

Following critical appraisal of the inclusion and exclusion criteria applied in this investigation, every effort was done to select only the appropriate data of the primary studies. When these studies did not present adequate data for all variables under investigation, they were partly included in the analysis using only the corresponding data. Consequently, the number of the original studies included in the analysis was different for each variable under investigation.

The consistency of the initial samples is another issue that needs to be taken into consideration because in some of the samples the clear multi-ethnic background of the population investigated was not adequately assessed. In addition, the different sources of the selected samples (from schools, university departments, and/or private dental clinics) might involve a form of selection bias, suggesting that some

caution when interpreting the results of this study. In addition, selection bias might also have been introduced through the inclusion of studies with no information concerning the ages of the individuals under investigation, because tooth transposition cannot be securely diagnosed earlier than age 7.

According to the results of this investigation, the average prevalence of tooth transposition was found to be 0.33%. This percentage is lower compared with the corresponding ones found in other published reports in the existing literature concerning various ethnic groups (eg, 0.38% in Turkey,²² 0.40% in India,¹⁹ and 1.4% in Nigeria⁴), and higher than those found in reports from Greece (0.09%)¹ and Germany (0.13%).²⁰ All these figures suggest that tooth transposition might be considered a rare phenomenon.

There seem to be no statistically significant differences in the prevalence of tooth transposition between pupils and dental and orthodontic patients or between males and females. The latter is in contrast to the observations of some authors,^{2,21,24} who found that tooth transposition was more frequent in females than in males. Some of these authors proposed a hypothesis that gender-related genes may be responsible for tooth transposition.^{25,26} However, according to our evaluation this hypothesis could not be confirmed.

Further, maxillary occurrence of tooth transposition was found to be higher than the mandibular. The high bone density of the mandible might be responsible for a prohibition of the phenomenon of tooth transposition, and thus the higher incidence of maxillary occurrence. It is remarkable that the most common type of tooth transposition in the mandible takes place between the canines and lateral incisors, where the bone is more porous than in the posterior area. In contrast, the lower density of bone in the maxilla may enhance the incidence of tooth transposition as well as the variety of types of transposition (eg, between canines and first premolars, between canines and lateral incisors, between central and lateral incisors).²⁶⁻³⁰

In addition, it was also observed that the unilateral occurrence of tooth transposition is more frequent than the bilateral, and this agrees with previous reports in the literature.^{3,30-32} Although there is a genetic basis for tooth transposition (evidence for this might be the symmetrical occurrence of bilateral transposition^{19,26}), the expression of the corresponding genome usually follows the rule of asymmetry that applies for the whole body as well as for the orofacial structures. However, specific local factors, such as mechanical disturbances of the normal eruption path of the permanent teeth or trauma, may also lead to a unilateral expression of the genome,³³ whereas early extraction of deciduous teeth may also create a

developmental disharmony in the dental arch and, at times, tooth transposition.³⁴

Regarding the side quadrant localization of tooth transposition, no left- or right-side predilection in the maxilla or mandible was evident. In contrast, other authors found that tooth transposition occurred more frequently in the maxillary left side^{2,28} without, however, presenting any explanation that could justify this observation.

CONCLUSIONS

- Tooth transposition is a rare phenomenon (0.33%) with various—sometimes inexplicable—forms of manifestation.
- Its occurrence seems to have no specific gender predilection, but some maxillary predisposition exists. Its unilateral occurrence is considerably higher than the bilateral.

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