Research Article

Epidemiological Profile of Non-Syndromic Tooth Agenesis and Associated Transposition among Iraqi Orthodontic Patients: A Clinic-Based Study

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Abstract

Background: Non-syndromic tooth agenesis and tooth transposition are uncommon anomalies that may arise from similar developmental irregularities during early odontogenesis. The understanding of their occurrence (individually and together) can support diagnosis and strategic clinical management, enhance diagnostic accuracy, and inform treatment planning. ***Objectives***: To assess the prevalence and spatial patterning of permanent tooth agenesis (omitting third molars) among orthodontic patients in Fallujah, Iraq; evaluate variation by sex, arch, and laterality; and document cases in which agenesis occurrence coincides with tooth transposition. ***Methods***: We performed a retrospective, clinic-based cross-sectional study of 1,240 consecutive patients aged 12–43 years who presented for orthodontic assessment or treatment at a private clinic in Fallujah between 2017 and 2024. Records and panoramic radiographs were assessed using consistent operational criteria. Descriptive statistics with 95% confidence intervals were computed; between-group comparisons involved chi-square tests, and an odds ratio was estimated to quantify the sex effect. ***Results***: Tooth agenesis affected 10.48% of patients (95% CI 8.9–12.3); the prevalence was greater in females (11.98%) than in males (6.99%, $p<0.05$). Missing teeth clustered mainly in maxillary lateral incisors (36.0%) and mandibular second premolars (31.2%), with bilateral agenesis more common than unilateral. Three female patients had agenesis with maxillary canine–first premolar transposition (two bilateral, one unilateral), suggesting a developmental association. ***Conclusions***: Hypodontia was relatively frequent with clear sex (and site)-specific patterns; its co-occurrence with transposition calls for early tailored multidisciplinary care and population-representative studies using CBCT and genetic/family history assessment.

Keywords: Hypodontia, Prevalence, Tooth agenesis, Tooth transposition.

النمط الوبائي لغياب الأسنان الدائم غير المتلازمي وترافقه مع تبدّل مواضع الأسنان لدى مرضى تقويم الأسنان العراقيين: دراسة سريرية

الخلاصة

الخلفية: تداخل الأسنان غير المتلازمة وتبدل مواضع الأسنان هما شذوذان غير شائعان قد ينشآن من اضطرابات تطورية مماثلة خلال تكوين السن المبكر. و حدوثها (بشكل فردي وجماعي) يمكن أن يدعم التشخيص والمعالجة السريرية الاستراتيجية، ويعزز دقة التشخيص، ويثري في تخطيط العلاج. **الأهداف**: تقييم انتشار ونمط التوازن الدائم للأسنان (مع حذف الضروس الثالثة) بين مرضى تقويم الأسنان في الفلوجة، العراق؛ تقييم التفاوت حسب الجنس، والقوس، والجانبية؛ وتوثيق الحالات التي يتزامن فيها حدوث التراجع مع انتقال الأسنان. **الطرائق**: أجرينا دراسة مقطعية بأثر رجعي قائمة على العيادة شملت 1,240 مريضا متتاليا تتراوح أعمارهم بين 12 و43 عاما وقدموا لتقييم أو علاج تقويم الأسنان في عيادة خاصة في الفلوجة بين عامي 2017 و2024. تم تقييم السجلات والصور الشعاعية البانورامية باستخدام معايير تشغيلية متسقة. تم حساب الإحصاءات الوصفية بفترات ثقة 95٪؛ تضمنت المقارنات بين المجموعات اختبارات كاي-تربيع، وتم تقدير نسبة الاحتمالات لقياس تأثير الجنس. **النتائج**: أثرت فترة الانتشار على 10.48٪ من المرضى (فترة الثقة 95٪ 8.9–12.3)؛ وكان الانتشار أعلى بين الإناث (11.98٪) مقارنة بالذكور (6.99٪، p<0.05). تجمعت الأسنان المفقودة بشكل رئيسي في القواطع الجانبية في الفك العلوي (36.0٪) والضواحي الثانية الفكية (31.2٪)، مع وجود انعدام ثنائي الأسنان أكثر شيوعا من الجانب الأحادي. ثلاث مريضات تعرضت لضعف في التوازن مع انتقال العلوي إلى الضحك الأمامي الأول (اثنان على جانبين، وواحد أحادي)، مما يشير إلى ارتباط تطوري. **الاستنتاجات**: كان انخفاض المرض شائعا نسبيا مع أنماط واضحة للجنس (والموقع)؛ وتكراره مع النقل يتطلب رعاية متعددة التخصصات ودراسات ممثلة للسكان مبكرا باستخدام CBCT وتقييم التاريخ الجيني/العائلي.

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INTRODUCTION

Hypodontia, also termed tooth agenesis or the congenital absence of teeth, is among the most prevalent craniofacial anomalies, characterized by the developmental absence of one or more teeth buds. The growth and development of the dentition are driven by a multilevel interaction of hereditary, epigenetic, and environmental drivers such as trauma, infection, radiation, and certain medications [1–4]. Both dentitions (deciduous and permanent) may be implicated [5]. Depending on severity, tooth agenesis may span as little as one tooth absent to complete anodontia. Excluding third molars, hypodontia is missing one to five teeth; oligodontia, over five missing; and anodontia, the total lack of teeth [6]. The global prevalence of tooth

agenesis (excluding third molars) ranges from 1.6% to 11.2% [7,8], with evidence of a gradual increase over recent decades. Following third molars, mandibular second premolars show the greatest prevalence of agenesis, then maxillary lateral incisors and maxillary second premolars [9]. In contrast, some literature cites mandibular incisors as the leading site of teeth agenesis [10]. The literature reported a female predominance over males [3,6,11–14]. Clinically, hypodontia is commonly associated with microdontia, ectopic eruption, and tooth transposition [15]. These anomalies may lead to esthetic, functional, and occlusal problems, creating considerable difficulties for orthodontic and restorative management that often necessitate a multidisciplinary approach [8,11,16,17]. In addition to tooth agenesis, tooth transposition (a rare positional anomaly involving the swap of two neighboring teeth within the same quadrant) has been thought to arise from similar developmental mechanisms to hypodontia. Both anomalies are believed to result from disturbances in dental lamina formation or neural crest cell migration during early odontogenesis. Previous studies have proposed that tooth agenesis, transposition, and impaction represent variable expressions within a single underlying developmental field defect [18,19]. However, reports describing their co-occurrence within the same individuals are rare, particularly in Middle Eastern populations. So, understanding this relationship is essential, as it may reveal underlying genetic and morphogenetic mechanisms affecting tooth development. Early disruptions in dental lamina formation or neural crest cell migration are thought to affect both anomalies. Prior studies suggest that agenesis, transposition, and impaction are phenotypic variants within the same developmental field. Early identification of such anomalies is useful in enabling timely orthodontic intervention and minimizing functional and esthetic sequelae [4]. Therefore, the present study aims to: Determine the frequency and patterning of non-syndromic tooth agenesis in orthodontic patients in Fallujah, Iraq. Evaluate sex- and arch-related differences in prevalence. Document and analyze the coexistence of hypodontia with tooth transposition as a potential developmental correlation.

Hypothesis

It is hypothesized that the prevalence of hypodontia differs by sex and arch and that its association with transposition supports the concept of a shared developmental origin between these anomalies.

METHODS

Study design and setting

A retrospective cross-sectional study was conducted at a private orthodontic clinic in Fallujah, Iraq (from January 2017 to December 2024). Reporting in accordance with the STROBE guidelines for cross-sectional research [17].

Study sample

Out of 1,496 orthodontic patient records reviewed, 1,240 were included in the final analysis, whereas 256 were excluded.

Exclusion criteria

Age below 12 years. Syndromic cases or systemic disorders (e.g., cleidocranial dysplasia). History of facial trauma or permanent-tooth extraction (except third molars). Poor-quality panoramic radiographs.

Inclusion criteria

Age $\geq$ 12 years (complete early mixed dentition). Absence of craniofacial or genetic abnormalities affecting tooth development. No prior extraction of permanent teeth other than third molars.

Outcome measurements

Demographic and clinical data were collected for tooth agenesis, transposition, and impaction.

Operational Definitions

Hypodontia: congenital missing of 1–5 permanent teeth (apart from third molars) [21]. Oligodontia: congenital absence of six or more permanent teeth [22]. Unilateral/Bilateral: absence on one or both sides of the same tooth type [23]. Tooth Transposition: swap location between two neighboring teeth within one quadrant, verified clinically and radiographically [18]. Only complete maxillary canine–first premolar transpositions were included (Figure 1).
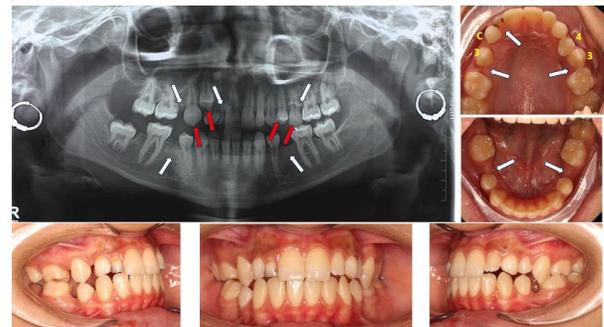

Figure 1: Representative panoramic and intraoral images. White arrows indicate missing teeth; red arrows indicate maxillary canine–first premolar transpositions. Intraoral photographs correspond to the same quadrants as the panoramic views.

Radiographic evaluation

A VistaVox digital panoramic unit (DÜRR Dental, Bietigheim-Bissingen, Germany) set to 70 kVp, 10 mA, and a 14-second exposure time was used to perform a panoramic exam on all of the subjects. Radiographs

presenting motion artifacts or suboptimal image quality were excluded from the analysis. Each image was carefully evaluated under standardized viewing conditions to identify missing, transposed, or impacted teeth.

Examiner calibration and reliability

A single calibrated orthodontist evaluated all radiographs. For reliability, 10% of the radiographs were reassessed after 14 days, and Cohen's κ was calculated [19].

Ethical considerations

Ethical approval was gained from the Ethical Approval Committee at the College of Medicine, University of Anbar, Iraq (Ref. No. 239; 26 December 2024). All procedures complied with the Declaration of Helsinki [21]. Written informed consent was obtained from all patients or their parents before inclusion in the study.

Statistical analysis

Data analyses were done using IBM SPSS Statistics v26.0. the prevalence and 95% confidence intervals were assessed using the exact binomial method. Chi-square differentiates categorical variables (sex, arch, side). For the count of missing teeth per patient, Poisson or negative binomial models may be reported; when used, results are presented as incidence rate ratios (IRR) with 95% confidence intervals. Thus, with two-tailed $p < 0.05$, it was regarded as statistically significant.

RESULTS

A total of 1,240 orthodontic patients met the inclusion criteria (age range 12–43 years; mean age 20.7 years).

The cohort comprised 868 females (70%) and 372 males (30%). The prevalence of non-syndromic tooth agenesis (apart from third molars) was 10.48% (with 95% CI 8.9–12.3). It was higher in females than in males (Table 1).

Table 1: Overall and stratified prevalence of tooth agenesis (95% CI)

Category	Prevalence (%)	95% CI
Total (n= 1240)	10.48	8.9–12.3
Female (n= 868)	11.98	10.0–14.3
Male (n= 372)	6.99	4.8–10.1
Maxilla (n= 88)	7.10	5.7–8.5
Mandible (n= 42)	3.39	2.4–4.4

Bilateral absence predominated over unilateral absence. 95% CIs were assessed with the exact binomial method (Clopper–Pearson). Patients may contribute to both arches; arch-specific percentages are not mutually exclusive. A significantly higher prevalence of tooth agenesis was observed in females compared to males, as demonstrated by the Chi-square test (p = 0.009), confirming a statistically significant sex difference, as shown in Table 2.

Table 2: Distribution of tooth agenesis by sex

Sex	Affected	Not affected	Total
Females	104(11.98)	764(88.02)	868(70)
Males	26(6.99)	346(93.01)	372(30)
Total	130(10.48)	1110(89.52)	1240(100)
p-value	0.009*	0.009*	0.009*

Values are presented as frequency and percentage. * Pearson chi-square test.

Across all missing teeth, absence of the maxillary lateral incisor was the most frequent finding (36.0%), and then the mandibular second premolar (31.2%). Remaining agenesis involved other tooth types at lower frequencies (Table 3, Figure 2).

Table 3: Distribution of missing teeth by tooth type (FDI notation)

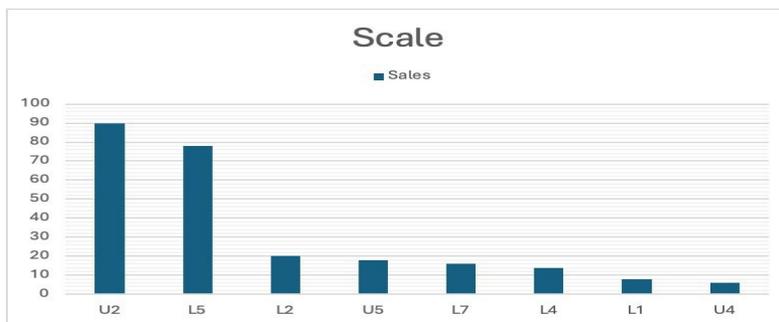| Tooth (FDI)	Teeth (n)	All missing teeth (%)	Patients (n)	% of sample (n=1240)	Laterality (R/L/Bil)
UR2 / UL2	90	36.0	68	5.48	R=20, L=26, Bil=22
LR5 / LL5	78	31.2	42	3.38	R=0, L=6, Bil=36
LR2 / LL2	20	8	10	0.8	R=0, L=0, Bil=10
UR5 / UL5	18	7.2	14	1.13	R=0, L=10, Bil=4
LR7 / LL7	16	6.4	10	0.8	R=4, L=0, Bil=6
LR4 / LL4	14	5.6	10	0.8	R=6, L=0, Bil=4
LR1 / LL1	8	3.2	4	0.32	R=0, L=0, Bil=4
UR4 / UL4	6	2.4	6	0.48	R=6, L=0, Bil=0
Total	250	100	164	13.2	R+L=78, Bil=84

Figure 2: Frequency distribution of missing teeth by tooth type (total missing teeth = 250).

About 37% of affected patients had one missing tooth, and 50% of affected patients had two missing teeth, while the remaining ≈14% of affected patients had 3-8 missing teeth (Table 4). Three female patients exhibited concurrent hypodontia and tooth transposition, all

involving the maxillary canine–first premolar region (Table 5). Two cases showed bilateral canine–first premolar transposition; one case was unilateral (left). In one of the bilateral cases, the upper right first premolar was impacted.

Table 4: Number of missing teeth per patient by sex

Missing teeth/patient	Female	Male	Total
1	42(40.38)	6(23)	48(36.92)
2	44(42.3)	20(76.92)	64(49.23)
3–4	6(5.76)	0(0.0)	6(4.61)
≥5	12(11.52)	0(0.0)	12(9.23)
Total patients with agenesis	104(100)	26(100)	130(100)

Values are presented as number and percentage.

Table 5: Summary of hypodontia with transposition cases

Case	Pattern of Tooth Agenesis	Pattern of Tooth Transposition
1	Maxillary right lateral incisor missing; maxillary second premolars bilaterally absent; mandibular second premolars bilaterally absent.	Bilateral maxillary canine–first premolar transposition
2	The same as in case 1.	Bilateral maxillary canine–first premolar transposition, with impaction of the maxillary right first premolar.
3	Maxillary right lateral incisors are missing; all maxillary and mandibular second premolars are absent bilaterally.	Unilateral (left) maxillary canine–first premolar transposition.

DISCUSSION

The overall prevalence of non-syndromic tooth agenesis in this orthodontic cohort was 10.48% (95% CI ≈ 8.9–12.3%), which lies toward the upper end of the global range typically reported when third molars are excluded (≈1.6–11.2%) [1]. This estimate is highly coinciding with reviews indicating higher prevalences in clinic-based (orthodontic) samples than in community surveys expressing referral patterns and concentration of developmental anomalies among patients seeking treatment [2]. Although making direct comparisons is constricted by heterogeneity in sampling frames, age thresholds, and diagnostic criteria, our estimate seems convergent with regional records from Middle Eastern orthodontic populations, supporting the external validity of our results for the regional clinical context [3–4]. A significantly greater prevalence was noticed in females (11.98%) than in males (6.99%) (crude association: OR 1.8; 95% CI 1.16–2.84). Potential explanations for observed female predominance include (i) sex-modulated signalling during early odontogenesis affecting susceptible tooth germs, (ii) developmental timing differences that increase case detection in females at adolescent ages, and (iii) differential care-seeking, with girls and young women more likely to present for orthodontic evaluation. This female excess is consistent with previous epidemiology and likely reflects biological and ascertainment effects [5–6]. The maxillary lateral incisor (36.0%) and mandibular second premolar (31.2%) were the most reported missing teeth, a distribution that coincides with many epidemiological studies and is consistent with the developmental field theory, wherein these units show greater vulnerability to perturbations of the dental lamina [7–8]. From a clinical point of view, maxillary lateral incisor agenesis requires early decision-making regarding space management (canine substitution or space opening or lateral incisor replacement), and for mandibular second premolar

agenesis, guiding the extraction sequences, anchorage, and long-term occlusal planning [9]. A unique contribution of this study is the reporting of three female cases with concurrent teeth agenesis and transposition in the maxillary canine–first premolar region (two bilateral, one unilateral). The clustering of agenesis and transposition within the same dentitions supports the hypothesis that these conditions can represent variable phenotypic expressions of shared developmental defects (likely arising from early perturbations of dental lamina formation or neural crest cell migration) [10–14]. This coexistence has been infrequently reported in regional literature; our series expands Middle Eastern evidence and highlights practical implications for biomechanical considerations, root proximity risks, and finishing strategies. Accordingly, panoramic scanning (and CBCT when warranted) and patient specific orthodontic mechanics are recommended [15–17].

Strengths and Limitations

Strengths include a large clinical cohort (n= 1240) over several years, standardized panoramic evaluation, and sex-differentiated analyses. The study also contributes novel, systematically described cases of hypodontia associated with transposition, adding to the regional literature [18–20]. Regarding study limitations, this single-center, clinic-based sample may limit external generalizability [17]. CBCT confirmation for ambiguous findings was not systematically performed and is recommended for future studies.

Clinical Relevance and Future Directions

Early identification of hypodontia patterns is crucial for esthetic and functional planning. In lateral incisor agenesis, early agreement on space closure or replacement can keep the midline from moving and stop problems with the canine roots; in second-premolar

agenesis, the needs for extraction planning and anchorage must be carefully balanced [23]. Given the observed co-occurrence with transposition, clinicians should anticipate eruption-path deviations and plan multidisciplinary care. Future work should incorporate multivariable modeling (age, arch, laterality) and, where feasible, genetic/family-history assessment to explore contributions of PAX9, MSX1, AXIN2, EDA, and related pathways [16].

Conclusion

Non-syndromic tooth agenesis in this orthodontic cohort showed an overall prevalence of 10.48%, with a higher frequency in females; three female cases also exhibited concurrent canine–premolar transposition, indicating a potential developmental linkage. The maxillary lateral incisor and mandibular second premolar were the teeth that were most often missing. This shows that both the teeth and the arch can be susceptible, which has direct effects on space management, anchorage mechanics, and multidisciplinary management. Clinically, early detection and specific biomechanical strategies are essential to optimize aesthetic and functional results. Future work recommended to include community-based, prospective studies with standardized diagnostics, multivariable modelling, and genetic/family-history reporting to obtain unbiased population estimates and illuminate underlying etiologic links between agenesis and transposition.

Conflict of interests

The authors declared no conflict of interest.

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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