Original Article

Dental anomalies in different growth and skeletal malocclusion patterns

Clarissa Christina Avelar Fernandez[a]; Christiane Vasconcellos Cruz Alves Pereira[b]; Ronir Raggio Luiz[c]; Alexandre Rezende Vieira[d]; Marcelo De Castro Costa[e]

ABSTRACT

Objectives: To evaluate prevalence, distribution, and sexual dimorphism of dental anomalies (DA) among different skeletal malocclusions (SM) and growth patterns (GP) under the hypothesis that specific clinical patterns exist and may indicate common etiological roots.

Materials and Methods: A total of 1047 orthodontic records of patients older than 8 years were evaluated. The SN-GoGn angle was used to classify GP (hypodivergent, normal, and hyperdivergent), and the ANB angle was used to verify SM (Angle Classes I, II, and III). These assessments were done from lateral cephalometric radiographs. DA were diagnosed using panoramic radiographs by one calibrated investigator. Odds ratios, chi-square, and Student's *t*-tests were used.

Results: Of the subjects, 56.7% were female, with mean age of 16.41 ($\pm$10.61) years. The prevalence of DA was 15.7%. Impaction and tooth agenesis were the most prevalent DA, with relative frequencies of 14.4% and 9.7%, respectively. DA were most prevalent in Class III SM (80.8%) and in hypodivergent GP (82.5%), although this was not statistically significant. Tooth agenesis ($P < .01$) and microdontia ($P = .025$) were significantly more common among hypodivergent GP and Class III SM, respectively.

Conclusions: The results of this study support the idea that DA are preferentially associated with certain patterns of malocclusion. (*Angle Orthod.* 2018;88:195–201.)

KEY WORDS: Dental anomaly; Malocclusion; Orthodontics

INTRODUCTION

Single gene disorders often affect facial structures and the dentition, strongly suggesting that the same genetic components are involved in the postnatal growth of facial structures affecting both craniofacial and occlusal relationships and dental development.[1–7] There is a great demand for the dental profession to address the consequences of disturbances in craniofacial and occlusal relationships. Orthodontic treatment is sometimes combined with surgical intervention to correct malocclusion and improve individual self-perception. Limited tools are available for the profession to help early identification of a pattern of growth that will lead to undesirable craniofacial and occlusal relationships. Early identification could lead to early intervention and potentially prevention of more severe disturbances.

Oftentimes, disturbances in craniofacial and occlusal relationships appear together with dental anomalies,[8–11] thus complicating therapy.[12] Furthermore, dental anomalies cause functional, occlusal, and esthetic problems[12,13] that can result in oral health impairment.[14] Dental anomalies are clinical alterations resulting from disturbances during the tooth formation process.[15] The clinical manifestations of dental anomalies include

[a] PhD student, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

[b] Instructor, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

[c] Associate Professor, Institute for Studies in Public Health, IESC, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

[d] Professor, Department of Oral Biology, School of Dental Medicine, University of Pittsburgh, Penn.

[e] Adjunct Professor, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

Corresponding author: Dr Clarissa Christina Avelar Fernandez, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro, 325 Professor Rodolpho Paulo Rocco Street, Cidade Universitária, Ilha do Fundão, Rio de Janeiro, RJ, Brazil
(e-mail: clarissaavelar@yahoo.com.br)

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different degrees of severity, ranging from mild to severe cases, represented by disturbances in the number, size, shape, position, and structure of the teeth.[15,16] Its prevalence can range from 5.46% to 74.7%,[15,17] because of different ethnicities and diagnostic criteria.[14,15,18] Both genetic and environmental factors have been suggested to contribute to the development of dental anomalies.[12,16,19]

It is important to know the frequency, distribution, and determinants of health conditions in specific populations for the purposes of disease control and prevention. This would lead to more accurate diagnosis and possible early intervention. Also, it enables valid comparisons between different populations. In the case of malocclusion, using dental developmental abnormalities to better understand genotype-phenotype correlations may provide a new tool for management and counseling of a subset of clinical presentations. A similar approach has been proposed for cleft lip and palate.[20] Faced with the complexity regarding the etiology of dental anomalies, the distinct characteristics of each skeletal malocclusion and the few studies that have investigated both,[15] the aims of this study were to evaluate the association between prevalence, distribution, and sexual dimorphism of dental anomalies among different skeletal malocclusions and growth patterns. Subsequently, the purpose was to determine if the malocclusion phenotype and associated dental anomalies could be linked in order to identify additional clinical definitions that would enable the prediction of future occlusal relationships.

MATERIALS AND METHODS

Sample Selection

Available for this study were 1521 records of orthodontic patients who were treated from 2000 to 2013 at the clinics of the Department of Orthodontics, School of Dentistry, Federal University of Rio de Janeiro (UFRJ) and Brazilian Dental Association Rio de Janeiro Section. This study was approved by the local Ethics Committee for Research (Hospital Universitário Clementino Fraga Filho–HUCFF/UFRJ, No., 619 096). This article was developed following the STROBE guidelines for observational studies.

Inclusion and Exclusion Criteria

Patients 8 years of age and older, whose dental records contained initial panoramic and lateral cephalometric radiographs with good quality, enabling the visualization of all teeth and surrounding structures, photos, and study casts, were analyzed. The maximum age limit of the sample was 25 years, and all of the orthodontic files had complete dental clinical history of the patient, such as exodontia, rehabilitation treatment with prostheses, and implants. For every anomaly, the inclusion criteria was that at least one permanent tooth was affected. Patients who presented a history of trauma, cleft lip and/or palate, syndromes, endocrine imbalances, and/or metabolic disorders, these being sporadic or hereditary, were excluded.

After the inclusion and exclusion criteria were applied, the final sample consisted of 1047 patient records. From the total of 1521 patients, 474 were excluded because of the absence of panoramic and lateral cephalometric radiographs (39.7%), absence of panoramic radiographs (27%), incomplete medical history (15.6%), absence of lateral cephalometric radiographs (14.1%), and age less than 8 years (3.6%). To address the hypothesis that dental anomalies were more commonly found in individuals with skeletal malocclusion and based on the known frequencies of both conditions in the studied population, it was determined that at least 273 subjects would be needed to show a difference of at least moderate effect size with an alpha of .05.

Characterization of Growth Pattern and Skeletal Classification

To characterize growth patterns, the values of the mandibular plane angle measured in the cephalometric radiograph (SN-GoGn) were used according to Steiner[21]:

- SN-GoGn angle $<32^\circ$ = hypodivergent,
- SN-GoGn angle $= 32^\circ$ = normal, and
- SN-GoGn angle $>32^\circ$ = hyperdivergent.

The skeletal classification was defined by using the values of the sagittal intermaxillary angle (SNA – SNB = ANB), according to the cephalometric standard for skeletal type as recommended by Steiner[21]:

- ANB angle with values between 0° and 4° = Class I,
- ANB angle with values $>4^\circ$ = Class II, and
- ANB angle with values $<0^\circ$ = Class III.

Diagnosis of Dental Anomalies

Using the initial panoramic radiograph, photos, and study casts, five types of dental anomalies were defined:

- Tooth number alterations: agenesis (including hypodontia and oligodontia, excluding third molars) and supernumerary teeth
- Tooth size alterations: microdontia and macrodontia
- Tooth position alterations: impaction (excluding third molars), transposition, inversion, prolonged retention, delayed eruption, and ectopic eruption

- Tooth shape alterations: dilacerations of the root, dilacerations of the crown, odontoma, taurodontism, accessory cusp, fusion, gemination, enamel pearl, and dens invaginatus
- Tooth structure abnormalities: amelogenesis imperfecta and dentinogenesis imperfecta

Information about age, sex, and ethnicity were also collected from the dental records. All clinical data were collected by a single calibrated investigator.

Reliability

For the diagnosis of dental anomalies and values of the SNA, SNB, ANB, and SN-GoGn angles, reliability was assessed considering the gold standard evaluator, a specialist in orthodontics with more than 15 years of experience (Dr Pereira). The gold standard evaluator performed the diagnosis of 30 individuals using the panoramic radiographs (to assess dental anomalies) and the lateral cephalometric radiographs (to assess the angles measured), with the aid of a negatoscope in a dark and quiet room. Subsequently, a single evaluator (Dr Fernandez) performed the same diagnosis under the same conditions to compare the results. In an interval of 15 days, a repetition of these same steps was performed by the investigators to obtain interexaminer and intraexaminer reliability statistics.

Statistical Analysis

Data were analyzed using SPSS version 20.0 (Statistical Package for Social Sciences, SPSS Inc, Chicago, Ill). Agreement between the investigator and the gold standard evaluator was determined by Kappa index (for the panoramic radiograph) and intra-class correlation index (for the lateral cephalometric radiograph). The frequency and percentage distribution of each dental anomaly among the sample were calculated. Data such as sex, ethnicity, age, dental anomalies, and most affected teeth were tested using chi-square or Fisher exact tests with a significance level of 5%. Odds ratios were calculated to evaluate the intensity and direction of the association between sex and craniofacial parameters (growth pattern and skeletal classification) in the individuals with dental anomalies. Student's *t*-test was used to compare the differences between the groups with and without dental anomalies.

RESULTS

The prevalence of dental anomalies in the final sample of 1047 patient dental records was 15.7% (n = 127). Of the total patients, 56.7% (n = 594) were female and 64.9% (n = 680) were black, with a mean age of 16.41 ± 10.61 years. Sex and ethnicity were not statistically significantly different between individuals with or without dental anomalies. It was found that 3.08 (±1.93) teeth were affected per patient on average, and more than one dental anomaly (different or equal types) was observed in approximately half of the individuals with dental anomalies (51.2%). Regarding the reliability of the assessments made, the Kappa index was .93 and the intraclass correlation was .87, suggesting excellent reliability.

Table 1 shows the characterization and distributions of dental anomalies by sex. Impaction (excluding third molars) and tooth agenesis (excluding third molars) were the most prevalent dental anomalies, with frequencies of 14.4% and 9.7%, respectively. Fusion and impaction were more commonly found in males ($P = .047$ and $P < .01$, respectively). The average number of teeth affected per patient and the most commonly affected teeth among the most prevalent dental anomalies in the sample are summarized in Table 2. The maxillary left canine (n = 32) was the tooth most commonly impacted, and the maxillary right lateral incisor was the most commonly absent tooth (n = 24).

In the study sample, 48.1% of the individuals were Class I, 39.4% were Class II, and 12.4% were Class III. Regarding growth patterns, 16.3% were hypodivergent, 7.4% were normodivergent, and 76.3% were hyperdivergent. Table 3 shows the distribution of the most prevalent dental anomalies among skeletal malocclusions and growth patterns. Dental anomalies were most prevalent in the skeletal Class III malocclusion pattern (80.8%) and in the hypodivergent growth pattern (82.5%). Tooth agenesis ($P < .01$) and microdontia ($P = .025$) were most commonly found in the hypodivergent growth pattern and skeletal Class III malocclusions pattern, respectively. Additional clinical definitions were proposed based on the associated or more frequent dental anomalies (Table 4).

DISCUSSION

The study of dental anomalies in patients with different skeletal malocclusion patterns may serve as the basis for future genetic studies and help in elucidating their etiology.[13,15,16] Disturbances in the molecular mechanisms related to craniofacial and occlusal relationships may be linked to malocclusion and dental anomalies.[13] Many studies reported the association between dental anomalies and skeletal malocclusions,[13,19] and their genetic background is widely known.[17] So, it is possible that certain dental anomalies and specific skeletal malocclusion patterns share the same genetic contributions.[16] Although there have been some reports on the incidence of dental anomalies in individuals with malocclusion, no attempts have been made to characterize a phenotype-

Table 1. Frequency of Dental Anomalies by Sex[a]

Dental Anomalies	n (%)			*P* Value	Odds Ratios (95% Confidence Intervals)
	Males	Females	Total		
Total of dental anomalies	65 (7.5)	62 (6.8)	127 (15.7)	.255	1.17 (0.87–1.57)
Tooth agenesis	28 (6.2)	50 (8.4)	78 (9.7)	.172	0.72 (0.44–1.16)
Supernumerary	14 (3.1)	17 (2.9)	31 (3.8)	.829	1.08 (0.53–2.22)
Microdontia	14 (3.1)	29 (4.9)	43 (5.3)	.148	0.62 (0.32–1.19)
Macrodontia	3 (0.7)	2 (0.3)	5 (0.6)	.449	1.97 (0.33–11.86[b])
Impaction	61 (9.8)	55 (8.9)	116 (14.4)	<.01*	1.72 (1.34–2.20)
Transposition	13 (2.9)	21 (3.5)	34 (4.2)	.547	0.81 (0.40–1.63)
Inversion	3 (0.7)	5 (0.8)	8 (1)	.741	0.78 (0.19–3.30)
Prolonged retention	—	3 (0.5)	3 (0.4)	.130	—[c]
Delayed eruption	9 (2)	8 (1.3)	17 (2.1)	.417	1.48 (0.57–3.88)
Ectopic eruption	5 (1.1)	3 (0.5)	8 (1)	.270	2.20 (0.52–9.25[b])
Root's dilaceration	8 (1.8)	14 (2.4)	22 (2.7)	.509	0.74 (0.31–1.79)
Crown's dilaceration	—	1 (0.2)	1 (0.1)	.382	—[c]
Odontoma	2 (0.4)	1 (0.2)	3 (0.4)	.413	2.63 (0.24–29.09[b])
Taurodontism	1 (0.2)	—	1 (0.1)	.252	—[c]
Accessory cusp	2 (0.4)	2 (0.3)	4 (0.5)	.785	1.31 (0.18–9.35[b])
Fusion	3 (0.7)	—	3 (0.4)	.047*	—[c]
Pearl enamel	—	1 (0.2)	1 (0.1)	.382	—[c]
Dens invaginatus	1 (0.2)	—	1 (0.1)	.252	—[c]
Amelogenesis imperfecta	1 (0.2)	1 (0.2)	2 (0.2)	.847	1.31 (0.08–21.03[b])

[a] *P* values are based on chi-square test.
[b] Unstable numbers due to low frequency.
[c] Odds ratios not calculated due to frequency = 0.
* Statistically significant ($P > 0.05$).

genotype correlation based on a more sophisticated clinical definition. Such an association may contribute to more accurate treatment predictions and to genetic studies. The next step in this work would be to investigate genetic links between dental anomalies and skeletal malocclusion and growth patterns.

The main limitation of this study was the exclusion of 31.16% of the sample due to incomplete dental records. The panoramic and lateral cephalometric radiographs were extremely important to the inclusion and diagnosis criteria of the studied records. The treatment of skeletal malocclusion is challenging because of the difficulty of predicting final facial growth, in addition to the long treatment time involved and the cost that it represents. This challenge becomes even greater in the presence of dental anomalies, which compromise normal function and esthetics. In this context, the need for understanding the molecular mechanisms involved in the etiology of dental anomalies and skeletal malocclusions justifies further study. The current results suggest that dental anomalies are easily detected by routine radiographic examination at

Table 2. Most Frequent Dental Anomalies and Their Most Affected Teeth[a]

Dental Anomalies	n (%)	Mean No. of Affected Teeth Per Individual (SD)	Most Affected Teeth, n (%)
Tooth agenesis	78 (9.7)	2.27 (±2.19)	UR lateral incisor, 24 (30.8) UL lateral incisor, 22 (28.2) LL second premolar, 21 (26.9)
Supernumerary	31 (3.8)	1.23 (±0.56)	UL paramolar, 9 (29) Mesial tooth, 5 (16.1) UR paramolar, 4 (12.9) LL central incisor, 4 (12.9)
Microdontia	43 (5.3)	1.37 (±0.72)	UL lateral incisor, 16 (37.2) UR lateral incisor, 9 (20.9) UL third molar, 7 (16.3)
Macrodontia	6 (0.6)	1.20 (±0.45)	LR lateral incisor, 2 (40) UL central incisor, 2 (40) UL lateral incisor, 1 (20) LL lateral incisor, 1 (20)
Impaction	116 (14.4)	1.93 (±0.9)	UL canine, 32 (21.2) UR canine, 31 (20.5) LL second premolar, 27 (17.9)

[a] UR indicates upper right; UL, upper left; LR, lower right; LL, lower left.

Table 3. Distribution of Dental Anomalies Among Skeletal Malocclusions and Growth Patterns

	Skeletal Malocclusion Pattern, n (%)				Growth Pattern, n (%)			
Dental Anomalies	Class I	Class II	Class III	*P* Value	Hypodivergent	Normal	Hyperdivergent	*P* Value
Total	14 (8.1)	17 (11.1)	120 (80.8)	.537	124 (82.5)	21 (13.1)	6 (4.4)	.077
Tooth agenesis	44 (8.7)	24 (5.8)	10 (7.7)	.244	22 (12.9)	1 (1.3)	55 (6.9)	.003*
Supernume-rary	14 (2.8)	14 (3.4)	3 (2.3)	.772	7 (4.1)	5 (6.5)	19 (2.4)	.080
Microdontia	19 (3.8)	13 (3.1)	11 (8.5)	.025*	11 (6.4)	4 (5.2)	28 (3.5)	.190
Macrodontia	2 (0.4)	2 (0.5)	1 (0.8)	.860	—	1 (1.3)	4 (0.5)	.383
Impaction	73 (48.3)	60 (39.7)	18 (11.9)	.235	13 (8.6)	15 (9.9)	123 (81.5)	.969

* Statistically significant ($P > .05$).

6 to 8 years of age and may facilitate a more accurate diagnosis and perhaps a need for early intervention.

Different frequencies are reported in the literature for dental anomalies.[12,14,15,18,19,22] Some authors attribute these conflicting results to differences in ethnicity, diagnostic criteria,[18,19] and environmental and nutritional factors.[18] Thongudomporn and Freer[22] observed 74.7% of dental anomalies in 111 orthodontic patients, and invagination was the most prevalent anomaly.[18] Uslu et al.[15] observed 40.3% of dental anomalies among orthodontic patients having tooth agenesis, evagination, and invagination as the most common dental anomalies. In the present study, a lower prevalence of anomalies was observed (15.7%), and impaction (excluding third molars) and tooth agenesis (excluding third molars) were the most commonly found. It is likely that these differences are due to the different populations studied (ie, Australian vs Brazilian vs Turkish) and different dental anomaly definitions.

In relation to sex, some reports suggest no statistically significant differences between males and females in the prevalence of dental anomalies.[15,19] Kathariya et al.[12] found significant sex differences only for tooth agenesis, microdontia, and accessory cusp. The prevalence of dental anomalies was greater in males than in females in the current study. In addition, fusion and impaction showed statistically significant differences between sexes, which disagrees with previous studies.[12,15,19] The conflicting findings may be due to ethnic variations and sample sizes.

In the present study, the most prevalent dental anomaly was impaction (14.4%), followed by tooth

Table 4. Clinical Definitions Based on Skeletal Malocclusion Patterns Used in the Literature and Proposed Subphenotypes Based on Skeletal Malocclusion, Growth Patterns, and Dental Anomalies

Skeletal malocclusion types used in epidemiological/genetic studies[a]	Additional skeletal malocclusion and growth pattern subphenotypes based on dental anomalies
All types of malocclusion	Skeletal malocclusions with normal growth pattern • With/without multiple dental anomalies • With/without tooth malposition (giroversion, impaction)
Skeletal Class I malocclusion Normal relationship between the maxilla and the mandible skeletal bases	Skeletal Class I malocclusion with hypo-divergent or hyper-divergent growth pattern • With/without tooth agenesis • With/without microdontia or macrodontia or supernumerary teeth • With/without tooth malposition • With/without multiple anomalies
Skeletal Class II malocclusion Normal maxilla and undergrowth of the mandible or overgrowth of the maxilla and normal mandible or overgrowth of the maxilla and undergrowth of the mandible	Skeletal Class II malocclusion with Hypo-Divergent or hyperdivergent growth pattern • With/without tooth agenesis • With/without microdontia or macrodontia or supernumerary teeth • With/without tooth malposition • With/without multiple anomalies
Skeletal Class III malocclusion Normal maxilla and overgrowth of the mandible or undergrowth of the maxilla and normal mandible or undergrowth of the maxilla and overgrowth of the mandible	Skeletal Class III malocclusion with hypodivergent or hyperdivergent growth pattern • With/without tooth agenesis • With/without microdontia or macrodontia or supernumerary teeth • With/without tooth malposition • With/without multiple anomalies

[a] Altug-Atac and Erdem (2007); Uslu et al. (2009).

agenesis (9.7%). These dental anomalies have been previously described as the most prevalent dental abnormalities, but with a considerably different prevalence (13.2% and 39.6%, respectively)[12] when compared with this study. According to Uslu et al.,[15] impaction was the fifth most prevalent dental anomaly in a Turkish orthodontic sample. Two main theories have been suggested to explain impaction: the guidance theory that is based on local predisposing causes and the genetic theory that considers a genetic cause for impaction.[23] However, these were associated neither to skeletal malocclusion nor different growth patterns, which may indicate impaction is due to a decrease of arch perimeter.

Tooth agenesis has been frequently studied,[24–29] and its prevalence ranges from 4.8% to 26%.[12,14,15,17–19] According to the literature, the most affected teeth aside from third molars are the second premolars, followed by the upper lateral incisors.[12,14,15,18,19] In the current study, the prevalence of agenesis was 9.7% when third molars were not included, and it was the third most observed dental anomaly. The maxillary lateral incisors and the mandibular left second premolars were the most commonly affected teeth, corroborating the previous studies.[12,14,15,18,19]

Giroversion (tooth rotation) has been defined as a dental anomaly of position.[15,18,22] However, some orthodontists do not consider this to be the case, because giroversion is likely related to the space availability in the dental arch when the tooth erupts. In this study, the sample was considered with and without giroversion, and the difference in frequency changed only three percentage points when all anomalies were considered (from 15.7% to 18.7%), with only 24 individuals presenting giroversion alone (data not shown).

One of the interesting findings of this study was the association between microdontia and skeletal Class III malocclusion. The maxillary teeth were more often affected by this dental anomaly, and it may be suggested that this finding can be explained by the presence of maxillary deficiency, which is one of the features of the skeletal Class III malocclusion. Also, it is known that there is a high frequency of dental crowding in patients with hypodivergent growth patterns.[30] It may be hypothesized that lack of adequate arch perimeter increases the likelihood of agenesis, which was the dental anomaly found to be associated with a hypodivergent growth pattern. Another explanation proposed for the decrease of arch perimeter is the early loss of deciduous teeth,[30] which was not possible to evaluate in this study.

Despite the association between dental anomalies and skeletal malocclusion patterns, few studies have investigated this clinical presentation.[13,15,16] To the best of our knowledge, this is the first study that evaluated the association of dental anomalies with different skeletal malocclusions and growth patterns to suggest additional clinical definitions. Table 4 features the phenotypes that are proposed for future study aiming to define phenotype-genotype correlations. The hypothesis is that more homogeneous groups will allow for higher statistical power in these kinds of analyses. These phenotypes are the result of the expression of genes, the influence of environmental factors, and the possible interaction between them. These are essential to the success of genetic studies that depend on a well-characterized phenotype. Aside from the present study, previous reports[13,18,22] support the hypothesis that the same genes and/or pathways may contribute to certain types of dental anomalies and skeletal malocclusions. However, a genetic study has yet to be performed to associate them.

CONCLUSIONS

- Microdontia was associated with the skeletal Class III malocclusion pattern, and tooth agenesis was associated with the hypodivergent growth pattern.
- These may be explained by possible disturbance in the proliferation and development during odontogenesis or due to genetic influences.

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