DENTAL MEDICINE

Original Research

Assessing the morphological characteristics of teeth and dental arches as potential predictors of dental crowding

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Abstract

Background and aims. The early detection of dental crowding and its potential for aggravation is important during the clinical examination of mixed dentition patients, and these desiderates can be addressed by including among the clinically assessed items a series of accessible morphological characteristics of teeth and dental arches. The present study investigates possible correlations between morphological features of permanent teeth, widths of dental arches, and the onset of dental crowding during mixed dentition.

Methods. A selected group of 100 class I dental casts on mixed dentition was analyzed. The dental arches were grouped as spaced, normally aligned, and crowded. The dental parameters consisted of mesiodistal dimensions of permanent teeth and specific morphological features of permanent incisors and first molars. The anterior and posterior arch widths according to Pont indices were measured.

Results. Statistical analysis of data showed that mesiodistal dimensions of the permanent upper central incisors and lower incisors are significantly larger on severely crowded arches than on normally aligned arches; increased differences between mesiodistal dimensions of central and lateral permanent upper incisors and the presence of semi-shavel incisors and Carabelli cusps are associated with a greater extent of anterior crowding. The severely crowded arches presented significantly narrower anterior and posterior arch widths.

Conclusions. Increased mesiodistal dimensions of permanent incisors, the presence of incisors shoveling, the Carabelli cusps on upper first permanent molars, and narrowing of dental arches during the early mixed dentition period were associated with severe dental crowding in class I cases.

Keywords: dental crowding, early mixed dentition period, teeth morphological features, arch widths

DOI: 10.15386/mpr-2557

Manuscript received: 25.07.2022
Received in revised form: 31.10.2022
Accepted: 15.11.2022

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Background and aims

The specific demands related to an optimal quality of life are considered today basic elements of the natural needs of any human being. Simultaneously with the impressive advances in science and global socio-economic growth, the characteristics of physical appearance, including facial appearance, are becoming increasingly important at the individual level [1]. Among other components, the facial aesthetic is significantly influenced by the appearance of dental arches, both at rest and during facial dynamics (speech, smile) [2].

Dento-alveolar incongruence with crowding is a dento-maxillary anomaly associated sometimes with major implications on dental and facial aesthetics. Dental crowding occurs frequently in early childhood, with the eruption of the first permanent teeth, less often in the temporary dentition [3]. Although the concerns of parents and patients are usually primarily directed at the severity of the aesthetic impairment in adulthood, the persistence of the dento-alveolar incongruence with crowding creates more difficult conditions for oral hygiene, which can favor over time the increase of the prevalence of carious lesions and periodontal damage in the respective area, with a consecutive decrease on viability expectations of the involved teeth [2,4,5].

The prevalence of dento-maxillary anomalies is constantly increasing among the general population (according to published data malocclusions affect over 80% of individuals), ranking third among oro-dental diseases, after dental caries and periodontal diseases; according to some authors, more than half of the dento-maxillary anomalies would be accompanied by dental crowding [1,6].

Given the benefit of early detection of malocclusion traits, and in particular, of dental crowding and their potential for aggravation, the clinical examination of mixed dentition patients should contribute to the proper depiction of those cases that could benefit more from early orthodontic interceptive treatment, to improve the patient's quality of life and to reduce the duration and complexity of orthodontic treatment at an older age [7,8]. A potential method to perform a better clinical examination is to include among the investigated items a series of accessible morphological characteristics of teeth and dental arches, more frequently correlated with the onset of dental crowding, according to scientific published data.

Dental crowding represents a clinical consequence of the lack of coordination between the size of teeth and the arch dimensions. The study published by Bernabé and Flores-Mir in 2006 concluded that mesiodistal crown dimensions and modified crown proportions are the principal responsible for the onset of dental crowding [9]. The research conducted by Arif and coworkers suggested that sums of mesiodistal crown dimensions are not significantly different between crowded and non-crowded arches and that reduced arch lengths may contribute to dental crowding [10].

Dental arches transverse deficiencies are also regarded as a major contributor to the onset of dental crowding, yet in many cases, mild or moderate transverse imbalances of the maxilla are not recognized and not properly addressed with orthodontic therapy [11,12]. One of the preferred methods for the assessment of arch transversal development is represented by Pont's index, a series of measurements performed on plaster dental casts [13].

In a previously published study, we have concluded that dental crowding in the mixed dentition is associated both with decreased arch lengths, but also with variations of mesiodistal and buccolingual dimensions of permanent incisors and lower first molars [14].

The present research aimed:

- to investigate possible correlations between morphological characteristics of permanent teeth and dental crowding;
- to analyze the existence of dental arches transversal modifications, according to Pont's index, between crowded and non-crowded arches.

Methods

This cross-sectional study was performed on a group of selected dental casts, belonging to patients treated in the Orthodontic Department of the "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. Before treatment, each patient or legal guardian of the patient admitted to the clinic signed an informed consent form for releasing all diagnostic records for teaching and scientific purposes. Patients' personal information wwas anonymized and all data collected and analyzed for this research involved only measurements performed on dental casts. Since no interventional study on patients was conducted, the present research did not need ethical approval.

The authors R.D. and M-A. B. selected a group of 100 dental casts, observing a series of inclusion criteria:

- dental casts obtained before orthodontic treatment, with mixed dentitions, presenting at least one central, one lateral upper and lower permanent incisors and all permanent first molars;
- the presence of upper and lower temporary canines, first and second molars;
- class I malocclusions;
- casts with unaltered teeth formulas and teeth surfaces.

We excluded the dental casts with other types of dentitions (deciduous, permanent), dental casts presenting caries lesions, large restorations, important attrition, dental anomalies (supernumerary teeth, hypodontia, developmental disorders), class II or III malocclusions.

Using the space analysis method, the selected maxillary and mandibular dental arches were separately classified as normally aligned (NA), spaced (SpA), moderately crowded (MCA) or severely crowded arches (SCA) [15].

The dental and arch linear parameters were recorded by measuring each dental cast with a digital caliper with an accuracy of 0.01 mm; all data are recorded in millimeters (Figure 1).

Figure 1. The digital caliper used for cast measurements in this study.

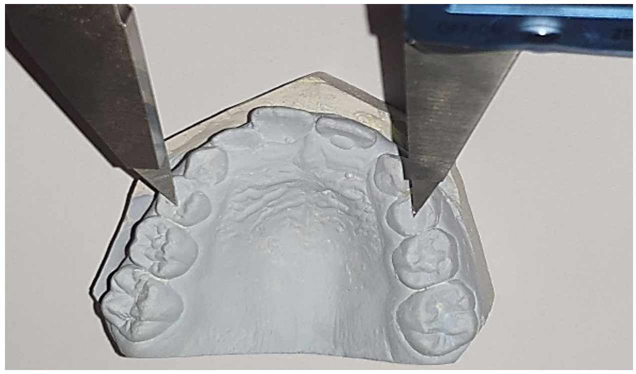
The mesio-distal diameters of all permanent teeth (incisors and first molars) were assessed with the digital caliper as the maximal distance between the approximal contact points, perpendicular to the long axis, and recorded in millimeters (Figure 2) [16].

The size of unerupted permanent canines and premolars, necessary for the space analysis procedure, was estimated using the Tanaka and Johnston prediction formulas [17].

Figure 2. Example of measuring the mesiodistal dimension of an upper central incisor.

With the same digital caliper were evaluated the arch widths according to Pont (Figure 3). All arch parameters were expressed on millimeters:

- maxillary anterior width – the distance from the deepest points of the grooves from the occlusal surfaces of the first temporary molars;
- maxillary posterior width – the distance from the central fossa of one upper permanent first molar to the other;
- lower anterior width - the distance measured at the level of bilateral contact points of primary lower molars;
- lower posterior width – the distance measured from the tip of the labial central cusp of one lower permanent first molar to the other. If the lower permanent first molars presented only two labial cusps, the measurement was performed on the tip of the labial distal cusp [18,19].



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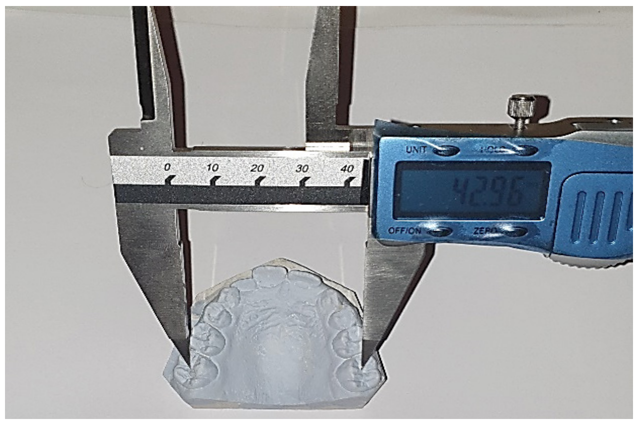

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Figure 3. Exemplification of the measurement of maxillary Pont Indices: **a.** upper anterior width; **b.** upper posterior width.

Each dental cast was examined for the detection of some specific morphological characteristics of permanent teeth, classified according to the Arizona State University Dental Anthropology System.

From the morphological features of upper and lower permanent incisors, we scored the shoveling feature (presence of oral marginal ridges). This morphologic characteristic was scored according to the Arizona State University Dental Anthropology System [20].

Assessing the appearance of marginal oral ridges, the incisors evaluated on the selected casts were scored as:

- 0 - none (no specific morphology on oral surfaces of upper and lower permanent incisors, no detectable oral marginal ridges);
- 1 - flat (very slight prominences of approximal oral ridges, which can be seen and palpated);
- 2 - trace (marginal ridges are easily seen);
- 3 - semi-shavel (more elevated marginal oral ridges, with a tendency to converge at the cingulum level).

The upper first permanent molars were examined for the presence of Carabelli's trait on the mesiopalatal surface of cusp 1:

- 0 - the surface is smooth;
- 1 - a groove is present on the specified surface;
- 2 - a pit is present on the surface;
- 3 - a small Y-shaped depression is present on the surface;
- 4 - a large Y-shaped depression is present on the surface;
- 5 - a small cusp is present on the surface;
- 6 - a medium-sized cusp is present on the surface [20].

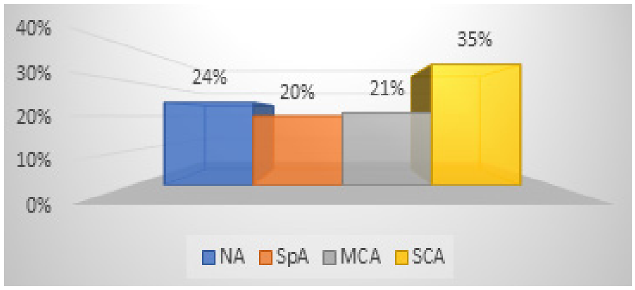
At the level of mandibular first permanent molars, we scored the number of cusps, regardless of their size. The evaluated lower permanent first molars presented 4 or 5 cusps.

The measurement errors were estimated five days after the first assessment by randomly selecting 10 dental casts and measuring again the dental and arch parameters. The two groups of measurements were compared with the Pearson correlation ratio, their concordance being high (r between 0.971 and 0.982, p<0.005).

All data were manually introduced in Excel tables and their statistical analysis was performed using the PSPP free software. The Kolmogorov-Smirnov test was used to test the normality of the distribution of the continuous variables. Given the normal distribution of acquired data, inferential statistical analysis was performed using parametric tests. The one-way analysis of variance (ANOVA) and the post hoc Bonferroni test were applied to evaluate differences in teeth and arch parameters between crowded, spaced, and normal aligned arches. The chi-square test was used to evaluate the differences between observed and expected morphological traits of permanent teeth on crowded and non-crowded arches. Statistical correlations between teeth and arch parameters values and arch discrepancies values were performed using the Pearson correlation parametric test. The probability level for accepting the statistical significance of the test results was set at 5% [21].

Results

In our study group, the crowding was more frequent at the maxilla, with more than half of dental arches being affected by crowding (21% moderately crowded arches and 35% severely crowded arches). 24% of maxillary arches were normally aligned, and 20% of them were spaced. In the mandible, 26% of dental casts were spaced according to total space analysis, 40% of archers were well aligned, 16% of lower arches were moderately crowded, and 18% were severely crowded (Figure 4).



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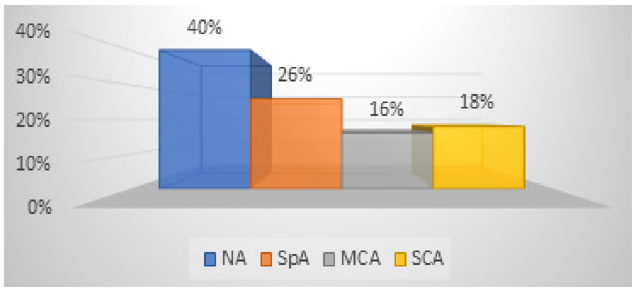

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Figure 4. **a.** crowding distribution among maxillary dental arches; **b.** crowding distribution among mandibular dental arches; NA = normally aligned arches, SpA = spaced arches, MCA = moderately crowded arches; SCA = severely crowded arches.

The age of selected patients ranged from 7 to 10 years 11 months; their median age was 8 years 8 months. Regarding gender distribution, 66% of patients were girls, and 34% were boys.

The data assessing teeth dimensions measured on the selected dental casts are included in table I. Permanent teeth dimensions were analyzed as averages of homologous teeth. The mesio-distal dimensions of the maxillary central incisors and the central and lateral mandibular incisors presented statistically significant differences between crowded and non-crowded arches. The ratios of the mesio-distal widths of central and lateral incisors were also statistically evaluated, and these parameters presented significant variations correlated with the onset of maxillary crowding.

Table I. Mesio-distal mean dimensions and standard deviations (mm) of permanent incisors and first permanent molars recorded in the four subgroups (statistical significance depicted by ANOVA analysis).

Dental Arch			Mesio-distal width of central incisors (mm)	Mesio-distal width of lateral incisors (mm)	Ratios of mesiodistal widths of central and lateral incisors	Mesiodistal width of permanent first molars (mm)
Maxilla (100 arches)	normal aligned arches (NA)	Mean	8.57	6.72	1.28	10.31
		SD	0.61	0.55	0.07	0.66
	spaced arches (SpA)	Mean	8.67	7.00	1.24	10.34
		SD	0.53	0.42	0.06	0.71
	moderately crowded arches (MCA)	Mean	8.73	6.99	1.25	10.19
		SD	0.48	0.43	0.05	0.47
	severely crowded arches (SCA)	Mean	8.98	6.89	1.31	10.27
		SD	0.54	0.54	0.08	0.51
	p-value		0.030*	0.222	0.003*	0.876
Mandible (100 arches)	NA	Mean	5.47	5.97	0.92	10.45
		SD	0.42	0.38	0.04	0.59
	SpA	Mean	5.45	6.01	0.91	10.32
		SD	0.33	0.30	0.04	0.57
	MCA	Mean	5.48	6.03	0.91	10.28
		SD	0.25	0.45	0.04	0.71
	SCA	Mean	5.74	6.30	0.91	10.57
		SD	0.31	0.40	0.05	0.40
	p-value		0.043*	0.021*	0.859	0.400

*p < 0.05 statistically significant

Table II. The p values of subgroup comparisons of teeth parameters obtained with the Post Hoc Bonferroni test.

Dental Arch		Mesiodistal width of central incisors	Mesiodistal width of lateral incisors	Ratios of mesiodistal widths of central and lateral incisors	Mesiodistal width of permanent first molars
Maxilla (100 arches)	NA-SpA	1.000	0.423	0.516	1.000
	NA-MCA	1.000	0.467	1.000	1.000
	NA-SCA	0.030*	1.000	0.621	1.000
	SpA-MCA	1.000	1.000	1.000	1.000
	SpA-SCA	0.287	1.000	0.005*	1.000
	MCA-SCA	0.594	1.000	0.023*	1.000
Mandible (100 arches)	NA-SpA	1.000	1.000	1.000	1.000
	NA-MCA	1.000	1.000	1.000	1.000
	NA-SCA	0.049*	0.015*	1.000	1.000
	SpA-MCA	1.000	1.000	1.000	1.000
	SpA-SCA	0.049*	0.085	1.000	1.000
	MCA-SCA	0.240	0.224	1.000	0.857

*p < 0.05 statistically significant

The post hoc Bonferroni test was used to further explore teeth dimensions' differences between crowded, spaced, and aligned dental arches; its results are presented in table II. Severely crowded maxillary arches presented significantly larger permanent central incisors than the normally aligned maxillary arches and increased width incisors ratios than the spaced and moderately crowded maxillary arches. Regarding lower arches, the Bonferroni test revealed that the severely crowded arches presented statistically significant larger incisors than the spaced and normally aligned ones.

The morphological characteristics (permanent incisors shoveling, Carabelli's trait on the permanent first molars, number of cusps on lower first permanent molars) depicted on the permanent teeth are presented in table III.

The arch widths, assessed according to Pont indices, presented significant differences between crowded and non-crowded arches, both on maxillary and mandibular casts. These results are included in table IV.

Table III. Distribution of morphological features on permanent teeth (differences between crowded and non-crowded arches evaluated with chi-square test).

Dental Arch		Incisors shoveling			Presence of Carabelli's trait on the mesiopalatal surface of cusp 1 of permanent first molars			
		flat	trace	semishavel	no trait	small Y-shaped depression	small cusp	medium-sized cusp
Maxilla (100 arches)	NA (%)	16	2	25	14	0	4	6
	SpA (%)	4	8	40	2	0	10	8
	MCA (%)	4	15	9.5	3	0	12	6
	SCA (%)	10	15	28.6	5	0	18	10
	Total (%)	34	40	26	24	2	44	30
	p value	< 0.001*			0.002*			
		Incisors shoveling			The number of cusps of the permanent first molars			
		flat	trace	semishavel	4 cusps			5 cusps
Mandible (100 arches)	NA (%)	10	20	10	12			28
	SpA (%)	12	6	8	4			22
	MCA (%)	6	8	2	2			14
	SCA (%)	6	6	6	2			16
	Total	34	40	26	20			80
	p-value	0.290			0.231			

*p < 0.05 statistically significant

Table IV. Anterior and posterior arch width mean dimensions and standard deviations (mm) in the four subgroups (statistical significance depicted by ANOVA analysis).

Dental Arch			Anterior width (mm)	Posterior width (mm)
Maxilla (100 arches)	NA	Mean	34.06	45.13
		SD	2.46	3.17
	SpA	Mean	35.67	46.11
		SD	1.82	1.87
	MCA	Mean	33.58	43.95
		SD	1.60	1.47
	SCA	Mean	33.66	44.93
		SD	1.85	2.03
	p-value		0.002*	0.012*
Mandible (100 arches)	NA	Mean	35.55	46.03
		SD	1.95	2.17
	SpA	Mean	37.03	48.71
		SD	1.70	2.94
	MCA	Mean	34.40	45.02
		SD	2.05	2.13
	SCA	Mean	35.06	45.54
		SD	1.39	2.13
	p value		<0.001*	<0.001*

*p < 0.05 statistically significant

The p values obtained after subgroup comparison of arch dimensions with the Post Hoc Bonferroni Test are included in table V and depicted significant differences between transversal dimensions of crowded arches and spaced arches.

Table V. The p values of subgroup comparisons of arch widths obtained with the Post Hoc Bonferroni test.

Dental Arch		Anterior width	Posterior width
Maxilla (100 arches)	NA-SpA	0.048*	0.903
	NA-MCA	1.000	0.496
	NA-SCA	1.000	1.000
	SpA-MCA	0.006*	0.016*
	SpA-SCA	0.003*	0.045*
	MCA-SCA	1.000	1.000
Mandible (100 arches)	NA-SpA	0.010*	<0.001*
	NA-MCA	0.205	0.951
	NA-SCA	1.000	1.000
	SpA-MCA	<0.001*	<0.001*
	SpA-SCA	0.004*	<0.001*
	MCA-SCA	1.000	1.000

*p < 0.05 statistically significant

The Pearson parametric correlation test revealed low statistically significant correlations between mesiodistal teeth dimensions and transversal arch values, on one hand, and the other hand, with arch discrepancies values (Table VI). The highest r values were obtained for positive correlations between transversal dimensions of lower arches and mandibular discrepancy values.

Table VI. The values of r Pearson coefficient assessing statistical correlations between permanent teeth mesiodistal dimensions, transversal arches dimensions, and the values of arch discrepancies.

Dental arch (N = 200)	Mesio-distal width of central incisors	Mesio-distal width of lateral incisors	Mesio-distal width of first permanent molars	Anterior arch width	Posterior arch width
Maxillary arch discrepancy	r = -0.241 p = 0.008*	r = 0.004 p = 0.483	r = - 0.043 p = 0.337	r = 0.343 p < 0.001*	r = 0.259 p = 0.005*
Mandibular arch discrepancy	r = -0.203 p = 0.022*	r = -0.277 p = 0.005*	r = -0.186 p = 0.129	r = 0.464 p < 0.001*	r = 0.448 p < 0.001*

*p < 0.05 statistically significant

Discussion

Dento-maxillary anomalies with crowding represent one of the major problems of the craniofacial region, considering its multiple secondary implications and its immediate and late consequences on oral health. The presence of untreated crowding arches at an adult age increases the difficulty of all future oral treatments, involving dental, restorative, and periodontal interventions.

Therefore, the orthodontic treatment of crowded dentition as early as possible has beneficial effects not only immediately but also in the long term on an individual's life. Before starting a treatment as complex as that of dental crowding, an essential factor of success is the exact determination of the cause of this anomaly, to properly select the therapeutic conduct and direction of treatment [3].

Dento-alveolar incongruence with crowding occurs due to the negative difference between the space available for permanent teeth eruption on the arch and the actual space needed to achieve proper dental alignment. In this clinical situation, there is not enough space for the teeth to erupt and align in a physiological position on the dento-alveolar arch; the outcome is represented by mild to severe discrepancies.

In the current population, there is a tendency of increasing the number of malocclusions with dental crowding; malocclusions with arch spacing are less frequent. However, the causes of dento-alveolar incongruence with crowding are not yet fully understood or unequivocally demonstrated [22].

The scientific published research demonstrated that there are many potential factors in the etiopathogenic of anterior crowded arches, and variation in tooth size is one of them. A series of studies, performed on primates, have shown a very low or even non-existent correlation between tooth size and jaw size [23].

Some researchers indicate that discrepancies among teeth size and arch size are frequently a problem induced by external factors during the growth and development of the craniofacial region, while studies on teenage tweens concluded that dental arch dimensions are primarily determined by genetic inheritance [24,25].

A contributing factor to dental crowding is represented by teeth mesiodistal dimensions, according to studies published by Bernabé and Flores-Mir, Bora et al [26,27]. Previous research conducted by Radniz concluded that the mesiodistal teeth dimensions are only one of the potential etiopathogenetic factors of dental crowding, along with variations in linear arch sizes [28].

Regarding possible correlations between dental morphology and arch crowding, studies conducted on permanent dentition and mixed dentition demonstrated the existence of variations in mesiodistal, buccolingual, and crown proportions of permanent incisors and lower permanent first molars in patients with arch crowding [14,26].

The involvement of permanent teeth morphology in the onset of malocclusions was reported in studies concerning patients with clefts, patients with supernumerary teeth, or other dental anomalies [29-31]. The coexistence of specific morphological teeth features and dental crowding was not yet investigated.

In a study conducted on Korean patients, Hwang concluded that increased teeth size and decreased arch widths contributed equally to dental crowding [32]. Similar results were reported in studies of McKeown and Mills, observing significant correlations between arch widths and dental crowding [33,34]. On the contrary, the results published by Bughaghis sustain the idea that dental crowding is more frequently correlated with large teeth than with smaller arch widths [35].

The present study evaluates morphological features of permanent teeth and dental arches as possible coexistent factors with dental crowding. For this purpose, we selected 100 class I dental casts in mixed dentition, with all permanent incisors and first molars present. The median age of the selected cases was 8 years and 8 months, 66% of them were girls.

The permanent teeth and arch dimensions were assessed with a digital caliper, and from the morphological features of permanent teeth scored by the Arizona State University Dental Anthropology System we selected the shavelling of incisors, the presence of Carabelli's trait on upper first permanent molars, and the number of cusps on lower first permanent molars.

From the 200 dental arches evaluated, the maxillary ones presented more frequently different degrees of crowding: 21% of maxillary arches were moderately crowded, and 35% of maxillary arches were severely crowded. In the mandible, 16% of lower arches were moderately crowded, and 18% were severely crowded. A study conducted on mixed dentition children from the general population found anterior crowding in the maxillary arch in 11.6% of cases and 38.9% of cases in the mandibular arch and another study conducted on teenagers from the general population reported 33.9% cases with maxillary crowding and 55.3% cases with lower anterior crowding [36,37].

The mesiodistal dimensions of permanent teeth were analyzed as the average of mesiodistal dimensions of homologous teeth and the specific differences among the four subgroups (normally aligned, spaced, moderately crowded, and severely crowded arches) were further investigated using the Bonferroni Post Hoc analysis. Our results showed that mesiodistal dimensions of the permanent upper central incisors and permanent lower incisors are significantly larger on severely crowded arches than on normally aligned arches. The recorded linear mean dimensions of permanent upper central incisors were 8.98 +/- 0.54 mm versus 8.57 +/- 0.61 mm (severely crowded arches versus normally aligned crowded arches); the mean dimensions of permanent lower central incisors were 5.74 +/- 0.31 mm versus 5.47 +/- 0.42 mm (severely crowded arches versus normally aligned crowded arches), respectively for permanent lower lateral incisors 6.30 +/- 0.40 mm versus 5.97 +/- 0.38 mm (severely crowded arches versus normally aligned crowded arches). These values, similar to those obtained by studies conducted on other samples, validate our methodology and reinforce the conclusions of our research [26].

For the first time, the present study introduced into the statistical analysis the ratio of mesiodistal widths of central and lateral incisors, and the results of ANOVA and Post Hoc Bonferroni analyses proved that patients with severely crowded arches presented increased mesiodistal incisors ratios than those with moderately crowded arches (1.31 +/- 0.08 versus 1.25 +/- 0.05). Based on these data, we can formulate the hypothesis that patients with augmented differences between mesiodistal dimensions of central and lateral permanent upper incisors could be more predisposed to a greater extent of anterior crowding.

Analyzing the morphological features of permanent teeth in the present sample, the crowded maxillary arches presented statistically significant more frequent semi-shavel incisors and Carabelli cusps on permanent first molars. No significant differences were recorded on lower arches regarding permanent teeth morphological features.

Regarding the transversal dimensions of upper and lower arches, statistically significant differences were recorded in crowded cases, compared to spaced arches. Important variations in transversal arch dimensions were registered: anterior upper widths 33.66 +/- 1.85 mm versus 35.67 +/- 1.82 mm; posterior upper widths 44.93 +/- 2.03 mm versus 46.11 +/- 1.87 mm; anterior lower widths 35.06 +/- 1.39 mm versus 37.03 +/- 1.70 mm; posterior lower widths 45.54 +/- 2.13 mm versus 48.71 +/- 2.94 mm (severely crowded arches versus spaced arches). Considering these consistent transversal alterations in severely crowded arches the present research sustains the hypothesis of the implications of narrow dento-alveolar arches on the onset of extreme dental crowding. Hussain et al. reported similar significant arch widths differences between crowded and non-crowded cases in a study conducted on 110 subjects, aged 15-23 years, and Clement and Faize, measuring 80 Class I dental casts with permanent dentition stated that spaced arches presented increased arch widths when compared to crowded arches [38,39].

In our study group, the values of arch discrepancies presented statistically significant low correlation coefficients with the mesio-distal teeth dimensions and the transversal arch widths according to the Pearson parametric test. Lower arches registered the highest r values for positive correlations between transversal dimensions and mandibular discrepancy. This relatively low magnitude of linear correlation between teeth parameters, arch parameters, and the extent of arch discrepancy demonstrate that linear tooth and arch parameters are not the only responsible factors for the onset of dental crowding on mixed dentition [40].

Conclusions

Based on these results, we can consider the following morphological characteristics of teeth and dental arches to be potential predictors of dental crowding in class I cases:

1. Large mesio-distal dimensions of the permanent upper central incisors and lower central and lateral incisors;
2. Augmented differences between mesio-distal dimensions of central and lateral permanent upper incisors; this feature could be associated with a greater extent of anterior crowding;
3. The existence of semi-shavel incisors and Carabelli cusps on upper permanent first molars;
4. Decreased upper and lower arch widths; it can be associated with extreme dental crowding.

From the practitioners' view, the study results have a significant clinical application during intraoral physical examination of mixed dentition patients, contributing to a primary evaluation of the risk of dentition crowding future development in cases without skeletal discrepancies.

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