

Dental Arch Dimensions in a Matched Pairs Study of Hypodontia Patients and Controls

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ABSTRACT

Background: Hypodontia is a common variation in tooth number, which presents treatment challenges. It is associated with changes in tooth size and shape and this paper explores possible concurrent changes in dental arch morphology.

Design: Images of the study models of sixty patients with 1 to 5 congenitally absent permanent teeth (other than third molars) and their matched controls were analysed using a 2D image analysis method. Measurements of the dental arches were the arch circumference, arch length, intercanine width, intermolar width and the depth of the palatal vault.

Results: The hypodontia patients had significantly smaller arch circumference, arch length and intercanine width in the upper arch than controls. Greater reductions in males were seen compared to their control group, highlighting sex differences. The different locations of the congenitally missing teeth had different impacts on the dental arch parameters.

Conclusions: This study provides background for treatment planning by showing that hypodontia does influence the dimensions of the dental arches. Different parameters are affected to different degrees related to the interacting factors of arch, sex and the location of the congenitally absent teeth. These findings are compatible with the development of the dental arches as a complex system with a network of interacting factors.

Introduction

Hypodontia is a common variation of tooth number in the population. In the permanent dentition approximately 25% of individuals have 1 or more congenitally missing third molars and some 3.5% to 7% of the population have hypodontia of other

permanent teeth [1-6]. The condition is more frequent in females and approximately 90% of affected patients have less than 4 permanent teeth, other than third molars, congenitally absent. The condition can present challenges requiring careful long term

treatment planning and care involving general practice, paediatric dentistry, orthodontics and restorative dentistry. Variations in tooth size and shape are well established in patients with congenitally missing teeth and may also occur in other components of the stomatognathic system [7-9]. As part of an international collaboration investigating the aetiology and clinical implications of hypodontia, this paper explores dental arch morphology in mild or moderate hypodontia. The dental arches and the dentition are two closely related components of the stomatognathic system, which develop in anatomical proximity over an extended time period from early in utero to early adulthood. The dental arches and the dentition are both complex systems, whose development is determined by multiple interactions between genetic, epigenetic, and environmental factors [10-12]. Interactions continue as development progresses through cellular, soft tissue and mineralisation stages to the emergence of the mature phenotype [9]. Hypodontia is an outcome of these complex interactions [13].

Similarly, in addition to genetic factors, the dimensions and shape of the dental arch are influenced by the configuration of the underlying basal bone and the actions of prenatal and postnatal environmental factors [14-17]. Postnatal environmental factors that have been identified include: the intraoral and circumoral musculature [18,19], sucking habits [20], postural and breathing patterns [21] and early loss of primary teeth [22]. There have been varying results in previous studies of dental arch morphology in patients with hypodontia. Woodsworth, et al. [23] found no significant differences in hypodontia patients compared to controls, Paulino, et al. [24] found greater intercanine and intermolar distances in the permanent dentition of adolescent and young adult men than in women, while Nelson, et al. [7] and Higgins [25] report the upper arch depth and chords were significantly reduced. They found greater differences in severe hypodontia. Sex differences are present in arch dimensions [26] and the degree of change in

hypodontia may vary between male and female patients. Moreover, the differences may be greater in the upper arch than the lower [27] and may be influenced by the location of the congenitally missing teeth [7]. The aim of the present study is to investigate dental arch dimensions using a well validated 2D image analysis system [7,28,29] in a sample of hypodontia patients and matched controls to determine if there are any differences and, if so, how these relate to the sex of the patient, the location of the congenitally missing teeth and the upper and lower arches.

Materials and Methods

This study was approved by the Ethics Committee of the Scientific Research of the George Emil Palade University of Medicine, Pharmacy, Science and Technology of Targu-Mures (Approval no. 60/07.03.2018). The participants gave their written informed consent. Sixty patients with hypodontia, 40 females and 20 males, having a mean age of 15.40 ± 2.85 years were included. The criteria for inclusion were the congenital absence of one to five permanent teeth, excluding third molars and that the formed permanent teeth were fully erupted. Diagnosis was based on dental history, clinical examination and orthopantomograms. Exclusion criteria were the presence of any other congenital conditions, syndromes, or a history of orthodontic treatment or tooth extraction. The same number of controls with complete permanent dentitions, matched for sex, age, ethnicity and exclusion criteria were also studied. Mean age in the control group was 15.48 ± 2.87 years. In order to examine the possible influence of location of the congenitally missing teeth anterior (26 cases) and posterior (31 cases) hypodontia subgroups were formed. Anterior hypodontia was defined as missing upper and lower incisors and/or canines. Posterior hypodontia was defined as missing upper and lower premolars and/or molars, excluding third molars. For these subgroups age- and sex- matched controls were selected from the control group (Figure 1).

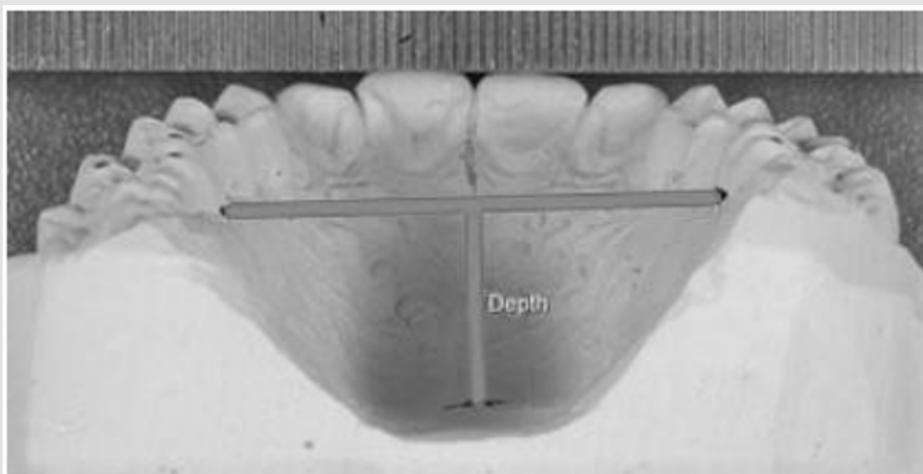


Figure 1: Image of measuring the depth of the palatal vault.

Table 1: Definition of measured parameters.

Type of measurement	Description
Arch length	The distance between the contact points of the central incisors and the line drawn between the most mesial surface points of the first molars.
Inter canine width	Distance between the cuspal tips of the canines.
Intermolar width	Distance between the most buccal cervical point (used as landmarks) of the first molars.
Arch circumference	A polyline drawn through the mesial and distal contact points of teeth from the distal side of the first molar on one side of the arch to the distal surface of the opposite first molar.
Depth of the palatal vault	The deepest point of the vault was assessed visually and marked with a black pen, the model was positioned perpendicular on the stand and captured this way. The most palatal cervical points of upper first molars were connected and a perpendicular was drawn on that line to the black point.

Alginate impressions (Ypeen Premium, SpofaDental) were taken for each individual from the upper and the lower arch. Study models were made from dental stone (FujiRock, GC). Images of the study models were taken with a digital camera (Nikon D3100, Nikon Corporation, Japan) and macro lens (Tamron SP AF-S 90 mm f/2.8). The camera was fixed above the dental cast, on an adjustable stand (Kaiser 5360, Kaiser Fototechnik, Germany) with two fixed led bulbs providing standard lighting conditions. Images of the dental arches were transferred using View NX2 (Nikon Corporation) and processed by the Image Pro Insight 9.3 software (Media Cybernetics, USA). Each image taken included a ten-millimeter scale for calibration and the measurements were made directly on the images. The 2D measurements of the dental arches were the arch circumference, arch length, intercanine width, intermolar width and the depth of the palatal vault. The definitions used for these measurements are given in (Table 1). The measurements were all carried out by the first author. Intraoperator and interoperator reproducibility was determined using the upper and lower models of 8 individuals. Three trained operators carried out the procedures

Table 2: Intraclass correlation coefficients.

	Arch length	Inter canine width	Intermolar width	Arch circumference	Depth of the palatal vault
For intraoperator reliability	0.98	0.99	0.98	0.99	0.93
For interoperator reliability	0.98	0.98	0.95	0.98	0.91

Table 3: Mean values of measured parameters for all hypodontia patients compared with matched controls for both upper and lower arches; SD=Standard Deviation.

Measured parameter	Hypodontia (mm±SD) (n=60)	Control (mm±SD) (n=60)	p value	F-ratio
UPPER ARCH				
Arch circumference	95.45±5.23	98.63±4.81	0.001	11.80
Arch length	24.95±2.60	26.41±1.76	0.001	12.75

separately, including image capture, calibration and measurement of selected dimensions, on 2 occasions, 2 weeks apart. Statistical analysis was performed using MedCalc (MedCalc Software Ltd). After excluding outliers, normal distribution of the data was confirmed (Shapiro-Wilk test of normality). Intraclass Correlation Coefficients (ICC) were determined to assess reproducibility of measurements. Correlations were also calculated between the number of missing teeth and the arch parameters. Significance of the differences was assessed using one-way ANOVA test, two-way ANOVA test with Bonferroni correction and Pearson’s correlation coefficient. The significance level was set to 0.05.

Results

The intra-operator and inter-operator reproducibility was excellent, with all ICC values being higher than 0.9. (Table 2). In the overall hypodontia group there were 29 patients with one congenitally absent tooth, 23 with two, 2 with three and 6 patients with four congenitally absent teeth. Lower second premolars were the most often missing teeth, followed by the upper lateral incisors, upper second premolars, lower first incisors and lower second molars. In the subgroups, for anterior hypodontia 13 female and 13 male cases were found, with upper lateral and lower central incisors missing. For posterior hypodontia 24 female and 7 male cases were found, with upper and lower second premolars and lower second molars missing. Three cases had both anterior and posterior congenitally missing teeth and were not included in either subgroup. When all hypodontia cases were compared to matched controls, significant differences were detected both in upper and lower arch parameters. Arch circumference, arch length and intercanine width values were significantly smaller in the hypodontia group for the upper arch than in controls. The more teeth that were missing, the lower the upper arch circumference was. In the lower arch intermolar width values were significantly higher in the hypodontia group than in controls (Table 3). More significant differences were seen in male patients than in female patients in the upper arch, although the interaction between the sources of variation was not significant in every case.

Inter canine width	32.83±3.16	34.82±2.04	<0.001	15.80
Inter molar width	53.65±2.56	54.21±3.13	0.28	1.15
Depth of the palatal vault	14.48±2.16	14.18±2.10	0.44	0.59
LOWER ARCH				
Arch circumference	87.91±5.46	88.19±5.02	0.77	0.08
Arch length	21.00±2.25	21.73±1.84	0.054	3.76
Inter canine width	26.42±1.94	26.67±2.17	0.50	0.44
Inter molar width	52.71±2.26	51.47±2.88	0.01	6.82

Inter molar width differences were significant in women (p=0.02), while in men arch length differences (p=0.008) were significant in the lower arch (Table 4). For the anterior hypodontia subgroup in the upper arch statistically significant smaller arch circumference, arch length and inter canine widths values were found in the hypodontia patients (Table 5). In the lower arch significantly greater inter molar width values were seen in the posterior hypodontia subgroup than in matched controls (Table 6). The analysis of variance highlighted differences also between the anterior and posterior case subgroups. The upper arch circumference and the upper inter canine widths was significantly lower in the anterior subgroup than in the posterior subgroup for hypodontia cases (p<0.001). Significant negative correlations

were detected between the number of missing teeth and other parameters. All statistically significant results are shown in (Table 7). When correlating the upper arch parameters for all cases with the number of missing teeth, significant negative correlations with the inter molar width were seen. The higher the number of missing teeth, the lower the upper inter molar width was. On the other hand, when looking for correlations based on sex, strong negative correlations were detected only in men and only in the upper arch (Table 7). Regarding the anterior hypodontia subgroup, both the upper and lower arches showed significant correlations between the number of congenitally missing teeth and some of the parameters (Table 7).

Table 4: Mean values of measured parameters for females and males with hypodontia compared to matched controls; *significantly lower than values from the control group, when interpreting separately.

UPPER ARCH						
Measured parameter	Female (n=40)		Male (n=20)		Interaction between sources of variation (sex and case/control)	
	Hypodontia (mm±SD)	Control (mm±SD)	Hypodontia (mm±SD)	Control (mm±SD)	p value	F-ratio
Arch circumference	95.58±5.42	97.39±3.99	95.16±4.90*	101.09±5.44	0.03	4.52
Arch length	24.88±2.60*	26.02±1.63	25.10±2.67*	27.24±1.80	0.25	1.31
Inter canine width	32.94±3.15*	34.18±1.72	32.56±3.27*	36.17±2.02	0.02	5.03
Inter molar width	53.27±2.63	53.50±2.71	54.41±2.28	55.63±3.48	0.36	0.81
Depth of the palatal vault	13.84±1.80	13.72±0.22	15.77±2.30	15.11±2.86	0.49	0.45
LOWER ARCH						
Measured parameter	Female (n=40)		Male (n=20)		Interaction between sources of variation (sex and case/control)	
	Hypodontia (mm±SD)	Control (mm±SD)	Hypodontia (mm±SD)	Control (mm±SD)	p value	F-ratio
Arch circumference	87.04±4.93	86.68±4.73	89.67±6.16	91.21±4.25	0.33	0.95
Arch length	21.05±2.15	21.22±1.76	20.90±2.49*	22.77±1.58	0.03	4.68
Inter canine width	26.25±1.92	26.19±1.98	26.74±1.99	27.64±2.25	0.22	1.47
Inter molar width	52.11±2.02**	50.83±2.91	53.91±2.27	52.74±2.42	0.91	0.01

**significantly higher than values from the control group, when interpreting separately; SD=Standard Deviation.

Table 5: Mean values of measured parameters in upper arch for anterior and posterior hypodontia subgroups and matched controls; †3 patients were excluded from this section as they had both anterior and posterior hypodontia; SD=Standard Deviation.

Measured parameter	Hypodontia (mm±SD)	Control (mm±SD)	p value	F-ratio
Anterior Hypodontia Group (n=26) †				
Arch circumference	93.51±4.86	99.82±5.34	<0.001	18.95
Arch length	24.42±2.55	26.74±1.88	0.001	13.56
Inter canine width	31.66±3.51	35.30±2.07	<0.001	19.25
Inter molar width	53.72±2.36	55.15±3.65	0.1	2.66
Depth of the palatal vault	14.39±2.53	14.74±2.56	0.62	0.23
Posterior Hypodontia Group (N=31) †				
Arch circumference	97.09±5.21	97.87±4.11	0.51	0.43
Arch length	25.34±2.71	26.32±1.64	0.09	2.97
Inter canine width	34.10±2.18	34.50±2.00	0.47	0.51
Inter molar width	53.86±2.68	53.57±2.46	0.66	0.19
Depth of the palatal vault	14.53±1.91	13.63±1.60	0.05	4.00

Table 6: Mean values of measured parameters in lower arch for anterior and posterior hypodontia subgroups and matched controls; †3 patients were excluded from this section as they had both anterior and posterior hypodontia; SD=Standard Deviation.

Measured parameter	Hypodontia (mm±SD)	Control (mm±SD)	p value
Anterior Hypodontia Group (N=26) †			
Arch circumference	89.04±5.61	90.04±5.32	0.51
Arch length	21.29±2.33	22.25±1.96	0.11
Inter canine width	26.37±1.95	27.33±2.01	0.08
Inter molar width	53.21±2.15	52.39±2.78	0.24
Posterior Hypodontia Group (n=31) †			
Arch circumference	87.28±5.15	87.03±4.40	0.83
Arch length	20.74±2.12	21.46±1.66	0.14
Inter canine width	26.46±1.92	26.26±2.23	0.70
Inter molar width	52.43±2.21	50.84±2.82	0.01

Table 7: Statistically significant negative correlations between the number of missing teeth and different parameters.

Parameter	Correlation Coefficient	p value
	(r value)	
UPPER ARCH		
All cases		
Inter molar width	-0.26	0.04
Men		
Arch circumference	-0.51	0.02
Arch length	-0.46	0.02
Inter molar width	-0.51	0.02
Anterior hypodontia cases		
Inter canine width	-0.49	0.01
LOWER ARCH		
All cases		
Arch circumference	-0.51	0.01
Arch length	-0.65	0.002
Anterior hypodontia cases		
Arch circumference	-0.42	0.03
Arch length	-0.49	0.01
Inter canine width	-0.49	0.01

No significant correlations were found for the posterior hypodontia subgroup.

Discussion

The validity of the study can be examining the nature and structure of the sample, the study design, the pattern of hypodontia in the subjects, the measurement techniques, the reproducibility found and the raw data. The sample is derived from a single ethnic group and is of a Dental Age [30] where the dental arches have developed to maturity in width and length [31,32]. The sample size is satisfactory as determined by power calculations [7] and the controls are matched for age, sex, and ethnicity. The matched pairs design and the pattern of congenitally missing teeth accords with previous studies [1,6,33]. The accuracy and validity of the 2D image analysis system used here has been established over a series of studies [7,12,28,33]. The hypodontia patients included in the present study had significantly smaller arch circumference, arch length and intercanine width in the upper arch than controls. This agrees with the findings of Nelson et al. [7] for their mild/moderate hypodontia group; in their severe hypodontia group the differences were greater. Bu, et al. [26] report similar results. In the present study the only significant difference in the lower arch was a larger intermolar width in the hypodontia group. This has previously been reported by Hobkirk, et al. [34], but not by Fekonja [27] and Higgins [25]. These contrasting findings could have arisen from difference in measurement techniques.

A possible explanation for a larger lower intermolar width could be increased tongue pressure in the lower molar region arising from the position of the tongue in response to the narrower upper arch [34]. Moreover, if the lower second premolars are congenitally absent, the lower second primary molars may be retained, preventing the forward movement of the first permanent molars, and holding them back in a wider arch. Arch dimensions in females and males were investigated separately because differences had been suggested by Berwig, et al. [35]. The present study also showed sex differences, with greater reductions in males compared to their control group. In the upper arch the male hypodontia patients had highly significant reductions in arch circumference, arch length, and intercanine width, while females had less difference in these three parameters from their controls. The location of the congenitally missing teeth had significant impact on the dental arch parameters. In the upper arch, when maxillary lateral incisors were congenitally absent, the arch circumference, arch length and intercanine width were all significantly reduced, suggesting that the presence or absence of these teeth may have a substantial effect during upper arch development.

While the growth of the maxilla is affected by the missing anterior teeth, in the posterior hypodontia group, in which

the maxillary second premolars were congenitally absent, no significant differences were found. In the lower arch the only significant difference was an increase in the intermolar width in the posterior hypodontia group in which the lower second premolars were absent. These changes in the dental arches occurred in those hypodontia patients most frequently encountered in clinical practice. A recent study of the orthodontic treatment of similar patients in a Western Australia private practice reported a trend away from space opening and prosthetic replacement to space closure over the years 2000 to 2017/18 [36]. The findings of the present basic science study suggest that within any such general trend, different treatment plans may be appropriate for individual patients. In (Tables 3-5) while the mean values for the arch circumference, arch length and intercanine width in the maxillary arch are all smaller for hypodontia patients than those of controls, the standard deviations are greater. This indicates more variation in the amount of space available, which will also be affected by the extent of reduction in the size and shape of the teeth present. In conclusion, the evidence from this study in relation to the aim shows that hypodontia does influence the dimensions of the dental arches. Different parameters in hypodontia patients are affected to different degrees: the upper arch is more affected than the lower; males are more affected than females and the location of the congenitally absent teeth is influential.

The changes are evidence of interactions between two complex adaptive systems, the dentition and the dental arches, that are components of the stomatognathic complex. They also interact with a third component, the tongue. The underlying factors in these interactions during development are genetic, epigenetic and environmental [13]. The question remains as to the relative influence of genes and genetic mutations that are common to both the teeth and the arches compared with the environmental effects arising from the congenital absence of teeth in specific locations, resulting in a lack of stimulus to bone growth. This study provides a basis for further investigations of this and other samples to examine this question further.

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