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Tooth Size Discrepancies and Dental Asymmetry in Different Malocclusions

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ABSTRACT

Malocclusion results from a combination of dental and skeletal disharmonies. Tooth size discrepancy (TSD) and dental asymmetry may play a significant role in the etiology of malocclusion. The aim of this study was to compare the degree of dental asymmetry among patients with Class I, II, and III malocclusions and to correlate measures of asymmetries to the anterior and overall Bolton's discrepancies. The samples comprised 131 patients aged 13 – 20 years (62 males and 69 females) with different types of malocclusions (39 Class I, 57 Class II, and 35 Class III). All measurements were performed on 3D virtual models using ATOS viewer version 6.A.2 software (GoM mbH, Braunschweig, Germany). Crown length and width of 14 teeth in each dental arch were taken. The Bolton's ratios and total weighted asymmetry (TWA) were calculated. The analysis of variance was used to compare differences between groups. Pearson's correlations were used to assess associations between the measures of TWA and the Bolton's ratios. The means for the Bolton's ratios between different types of malocclusion showed no significant differences. The TWA values were low but they differed significantly between the groups of malocclusion. Composite TWA measures of fluctuating asymmetry for dental variables were the highest in Class III, and lowest in Class I malocclusion. Males displayed a higher degree of asymmetry than females. The mean values of the Bolton's total ratio showed the strongest correlation with TWA of MD tooth size in maxilla ($P < 0.01$). TWA affects the Bolton's ratio and may be associated with the etiology of malocclusions. The highest FA in Class III indicates that patients with this class of malocclusion may experience higher levels of genetic and environmental stress in the course of early craniofacial development.

Key words: *Tooth size discrepancies, fluctuating dental asymmetry, malocclusions*

Introduction

Malocclusion results from a complex interaction of hereditary and environmental factors. Not only can malocclusion pose cosmetic issues, but it can become an important issue in the modern society. If jaw length does not match tooth size or if teeth are not proportional, the development of normal occlusion is not possible. Abnormalities in tooth size and shape lead to disturbances, thus preventing the development of good occlusion[1]. Disproportions between tooth size or tooth size discrepancy (TSD) may play a significant role in the etiology of malocclusion. TSD cause deviations from the arrangement of the teeth relative to the line of occlusion and lead to malocclusion development[1, 2]. Both mesiodistal (MD) and buccolingual (BL) crown dimensions tend to be significantly larger in malocclusion than in normal occlusion. Although the causes of malocclusion are obscure in most instances, one contributing factor may be tooth size[3-5].

In order to achieve a good occlusion it is important to provide harmonious development of teeth and craniofacial complex. The influence of harmful environmental factors during development of dentoskeletal structures reduces developmental homeostasis and causes appearance of developmental "noise". Its effect is manifested as an increased deviation from the symmetrical development. Therefore, increased asymmetry is a good indicator of stress influence during development and deviation from harmonious and symmetric development[6-10].

Development of malocclusion is considered to be primarily a genetic problem[1, 11]. The nature of malocclusion is heterogeneous; hence multifactorial etiology with both hereditary and environmental factors is widely accepted. A wide spectrum of variations in clinical picture of malocclusion is the result of interactions of these factors. Maloc-

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clusion represents a social burden because it may lead to the distorted appearance, impaired masticatory function or even problems in social life with decreased quality of life[12, 13].

Possibly, tooth size itself is not the problem but rather a relative size of the teeth. Research has shown that there is a secular trend toward increasing tooth size and, also, that there are higher frequencies of tooth size discrepancies in contemporary populations[14]. Numerous studies have shown increased discrepancies between tooth size in different malocclusion groups[2-5, 15, 16]. Significant differences in the Bolton's ratios were established between males and females. Males usually display greater discrepancies in tooth size of upper and lower jaws[3-5].

The increased level of tooth and dental arch asymmetries also contribute to the etiology of malocclusions[17-19]. Deviations from symmetrical development lead to the emergence of different forms of asymmetry: directional (DA), fluctuating (FA), and antisymmetry (AS). Directional and fluctuating asymmetries occur in the course of development due to the effects of environmental and genetic stressors[6-10]. Quantification of the degree of asymmetry provides assessment of the degree of harmful environmental effects on the development of analyzed structures. Fluctuating asymmetry is always taken as an indicator of developmental instability. Deviation from the harmonious symmetric development is not only the result of the influence of environmental factors. The level of genetic susceptibility of an individual to the effects of different stressors has played an important role in the final development of the phenotype. Fluctuating asymmetry increases in the conditions of decreased developmental stability when adaptive modifications fail to buffer stress [9, 10, 20-22]. The increased variability of some quantitative morphological traits appears because of the following two related reasons: increased level of stress an individual is exposed in the course of development and the level of its genetic sensitivity to stress effects[22, 23].

Symmetry of dental and craniofacial structures can be recognized as balance resulting in greater chances for good occlusion, while increased fluctuating asymmetry predicts greater likelihood of development of malocclusion [4, 18, 19, 23-25]. The increased level of tooth and dental arch asymmetries also contribute to the etiology of malocclusion. An increased genetic susceptibility to environmental stressors can lead to increased developmental instability and elevated levels of FA in various structures such as tooth size and dental arch dimensions.

The purpose of this study was to compare the degree of dental asymmetry among patients with Class I, II, and III malocclusions and to correlate measures of asymmetries with anterior and the overall Bolton's discrepancies.

Materials and Methods

The samples for this study comprised dental plaster casts of 131 patients aged 13 – 20 years (62 males and 69 females) from the Department of Orthodontics, School of Dental Medicine, University of Zagreb, Croatia. The distribution of subjects according to gender and malocclusion group is shown in Table 1. Dental models were scanned and digitized using ATOS II SO (»small objects«) scanning technology (GoM mbh, Braunschweig, Germany) according to the method described by Šlaj[26, 27]. 3D virtual models were created and all measurements were computer generated using ATOS viewer version 6.A.2 software.

TABLE 1
STRUCTURE OF THE SAMPLE

Malocclusion	Gender				Total (N = 131)	
	Males (N = 62)		Females (N = 69)			
	n	%	n	%	n	%
Class I	19	30,6	20	29,0	39	29,8
Class II	23	37,1	34	49,3	57	43,5
Class III	20	32,3	15	21,7	35	26,7
Total	62	100,0	69	100,0	131	100,0

Legend: N – sample size; n – number of subjects with malocclusion

Tooth crown mesiodistal (MD) and buccolingual (BL) dimensions of 14 teeth were measured in each dental arch on 3D virtual models. Mesiodistal and buccolingual dimensions of all teeth were measured by the same author. Only undamaged teeth were measured. The MD dimension was considered to be the greatest distance between the contact points on the aproximal surfaces of the tooth crown, and BL distance was taken as the length perpendicular to the MD dimension at greatest crown width. All measurements were taken using common procedure described and suggested by Moorrees and Reed[27]. The anterior and overall Bolton's ratios were calculated.

Fluctuating asymmetry was assessed by calculating the total weighted asymmetry (TWA) between pairs of all antimere teeth in one jaw. The calculation of TWA was performed using procedure suggested and described by Palmer and Strobeck[7, 8]. A composite measure of total weighted dental (fluctuating) asymmetry (TWDA) was calculated separately for MD dimensions (TWMDA) and BL dimensions (TWBLA) for each individual based on the differences between the antimeric teeth according to the following equation:

$$\mathbf{TWDA = \sum^{(1-7)} |L - R| / (L + R/2).}$$

Therefore, the TWDA is the sum of absolute weighted asymmetries for all seven tooth measurements in each individual. It was pointed out that such composite measures of asymmetry may be a more effective means for assessing developmental instability than the traditional approach of analysis of single variables[4, 6, 8, 18, 22, 29]. Analysis of variance (ANOVA) was used to compare differences in groups. The Pearson's correlation coefficients were calculated to test associations between the measures of FA and the Bolton's ratios.

Results

The means for the anterior Bolton ratio between different types of malocclusion showed no statistically significant differences (Table 2). The anterior Bolton ratio for Class I malocclusion was higher in boys and for Class III malocclusion was higher in girls (Figure 1). The mean in males with Class I malocclusion (78.75 ± 2.86) was higher than the mean in females (77.65 ± 2.49). However, the difference was not significant. Females with Class III malocclusion displayed a higher mean anterior ratio (78.62 ± 3.22) than males with Class III (77.67 ± 2.90).

TABLE 2
COMPARISON OF ANTERIOR BOLTON'S RATIO IN DIFFERENT MALOCCLUSIONS

Malocclusion	Males			Females			Total		
	N	M	s. d.	N	M	s. d.	N	M	s. d.
Class I	19	78,75	2,86	20	77,65	2,49	39	78,19	2,70
Class II	23	77,39	2,51	33	77,51	1,93	56	77,46	2,17
Class III	20	77,67	2,90	15	78,62	3,22	35	78,08	3,03
Total	62	77,90	2,77	68	77,80	2,43	130	77,85	2,59
F - test	**F = 1,491**			df1 = 5; df2 = 124			**P = 0,197 N.S.**		

Legend: N – number of subjects; M – mean (%); s.d. – standard deviation (%)

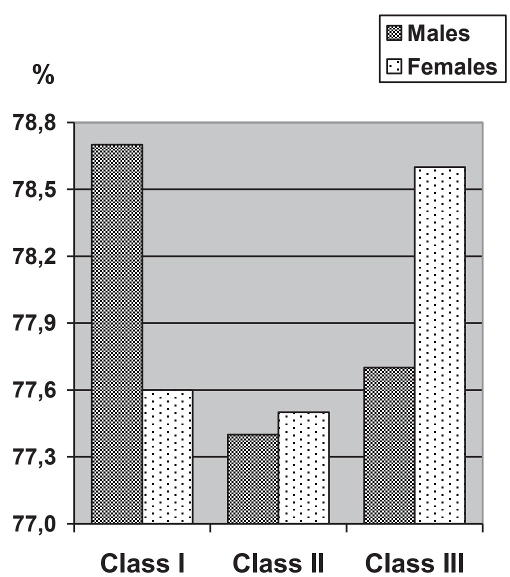

Fig. 1. Anterior Bolton's ratio in different malocclusins.

Table 3 shows a comparison of means for the overall Bolton's ratio between different malocclusions. Analysis of variance (ANOVA) has not revealed statistically significant differences. The overall Bolton's ratio was the highest in females with Class III malocclusion (Figure 2). The boys with Class I malocclusion displayed a higher overall Bolton's ratio than girls. However, none of those differences were statistically significant. The means of the Bolton's ratios in Class II did not show considerable differences between males and females. There were no significant differences in the anterior and overall Bolton's ratios between malocclusion groups neither between genders in the present study.

TABLE 3
COMPARISON OF OVERALL BOLTON'S RATIO IN DIFFERENT MALOCCLUSIONS

Malocclusion	Males			Females			Total		
	N	M	s. d.	N	M	s. d.	N	M	s. d.
Class I	19	91,89	1,99	19	91,24	1,61	38	91,57	1,81
Class II	22	90,94	1,71	33	91,50	2,23	55	91,27	2,04
Class III	15	90,92	3,12	12	92,23	2,50	27	91,50	2,88
Total	56	91,25	2,26	64	91,56	2,11	120	91,42	2,18
F - test	**F = 1,194**			df1 = 5; df2 = 114			**P = 0,317 N.S.**		

Legend: N – number of subjects; M – mean (%); s.d. – standard deviation (%)

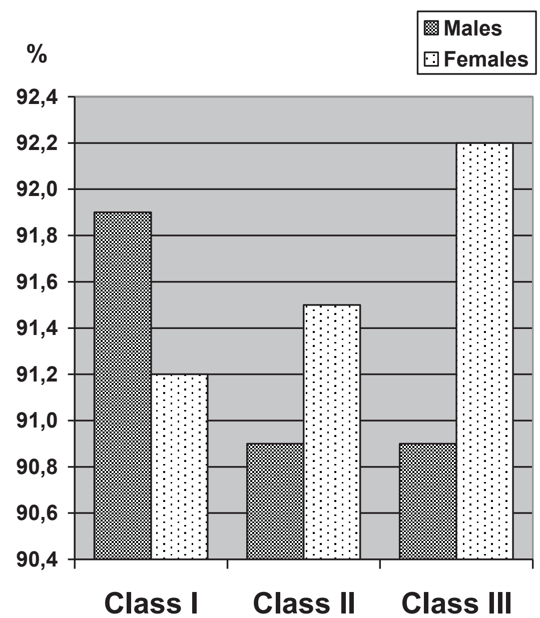

Fig. 2. Overall Bolton's ratio in different malocclusions.

The comparison of fluctuating dental asymmetry between different malocclusion groups is shown on Table 4. There were no statistically significant differences in fluctuating asymmetry between patients with different malocclusions. Fluctuating asymmetry expressed as a total weighted dental asymmetry (TWDA) for MD and BL dimensions of all teeth was greater in maxilla than in mandible (Table 4 and Figure 3). The results show differences in means for different types of malocclusion. Both males and females displayed a significantly greater asymmetry in maxilla in Class III malocclusion than in Class I ($P < 0.001$) and Class II ($P < 0.01$). Males with Class III in mandible displayed a significantly higher asymmetry than in Class I ($P < 0.01$). There were no significant differences in mandible between groups of malocclusion in females. Males displayed a higher degree of asymmetry than females.

TABLE 4
COMPARISON OF TOTAL WEIGHTED DENTAL ASYMMETRY (TWDA) BETWEEN DIFFERENT MALOCCLUSION GROUPS

Malocclusion	Maxilla						Mandible					
	Males			Females			Males			Females		
	N	M	s.d.	N	M	s. d.	N	M	s. d.	N	M	s. d.
Class I	18	0,238	0,022	18	0,238	0,022	19	0,232	0,020	19	0,230	0,020
Class II	16	0,246	0,024	28	0,242	0,018	20	0,249	0,019	26	0,227	0,017
Class III	10	0,283	0,030	8	0,295	0,033	16	0,245	0,022	11	0,229	0,026
Class I : III	t = 4,553 P = 0,0001 ***			t= 5,219 P < 0,0001 ***			t = 2,722 P = 0,009 ***			t= 0,543 P = 0,590 N.S.		
Class II : III	t= 3,279 P = 0,0034 ***			t = 6,023 P < 0,0001 ***			t= 1,830 P = 0,076 N.S.			t = 0,118 P = 0,906 N.S.		

Legend: N – sample size; M – mean of FA; s.d. – standard deviation

The present study assessed correlations between the Bolton's ratios and asymmetry of dental dimensions in different types of malocclusion (Table 5). Since there were no significant differences in means for the anterior and overall Bolton ratios in different malocclusion groups, all patients were combined for the purpose of calculation of correlation coefficients. The correlation between FA for MD dental dimensions in the upper jaw (TWMDU) and the overall Bolton's ratio was statistically highly significant ($P < 0.01$). A significant correlation was also observed between asymmetry of MD dimensions in the maxilla and asymmetry of BL dental dimensions in the mandible (TWBLL) ($P < 0.05$).

Discussion

It is considered that the development of good occlusion requires tooth size in both dental arches to be proportional[1]. The vast majority of people have the teeth that are proportional in size. Only about 5% of people have tooth size discrepancies. Proffit et al. [1] consider that the size of upper lateral incisors is the most common cause of tooth discrepancies, but it could be due to the variations of other teeth.

The relationship of mesiodistal width of maxillary teeth to the mandibular teeth is calculated as the anterior and overall Bolton's ratio. It plays a crucial role in the formation of proper occlusion without crowding or diastemas. Tooth measurements for the Bolton's ratios and dental asymmetry calculation in the present study were obtained on virtual three-dimensional models. Some previous studies have shown that measurements taken on virtual 3D models provide precise and reliable results comparable to those obtained with digital callipers[27, 30, 31]. Nalcaci et al[32] found the Bolton's ratios calculations to be precise and reliable on 3D models as well as those obtained in traditional way. They concluded that Bolton's analysis can be performed reliably using digital models.

The results of this study did not show any significant differences in means for the anterior and overall Bolton's ratios in different malocclusion groups. Greater values

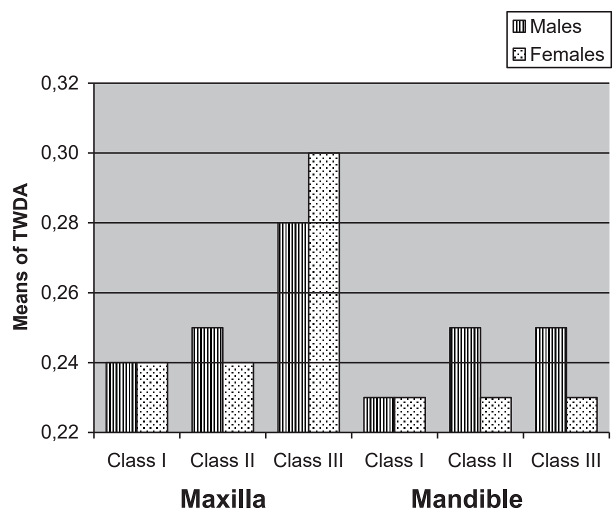

Fig. 3. Total weighted dental asymmetry (TWDA) of tooth size in different malocclusion groups.

TABLE 5
PEARSON'S CORRELATION COEFFITIENTS (ALL PATIENTS COMBINED)

	BOL1	BOL2	TWMDU	TWMDL	TWBLU	TWBLL
BOL1	1.000	**.646*** **	-.123	-.050	.045	-.147
BOL2	**.646*** **	1.000	**-.265** **	-.078	-.022	.032
TWMDU	-.123	**-.265** **	1.000	.093	.156	**.216* **
TWMDL	-.050	-.078	.093	1.000	.017	-.044
TWBLU	.045	-0.22	.156	.017	1.000	.063
TWBLL	-.147	.032	**.216* **	-.044	.063	1.000

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Legend: **BOL1** – anterior Bolton ratio; **BOL2** – overall Bolton ratio; **TWMDU** – total weighted asymmetry of MD tooth dimensios in upper jaw; **TWMDL** - total weighted asymmetry of MD tooth dimensios in lower jaw; **TWBLU** - total weighted asymmetry of BL tooth dimensios in upper jaw; **TWBLL** - total weighted asymmetry of BL tooth dimensios in lower jaw.

of the anterior and overall Bolton's ratio were observed in boys for Class I malocclusion and in girls for Class III malocclusion. However, these differences were not significant. Some previous studies on tooth size discrepancies in different malocclusions obtained controversial results. Many studies showed no significant differences in means of the Bolton's ratios between different malocclusions[33-39].

A great number of studies[2,3,15,40,41] showed that there was a tendency toward an elevated Bolton's ratio for Class III malocclusion. Arauja and Souki[15] found a significantly greater anterior Bolton's ratio for Class III than for Class I and II. In Class III malocclusion slightly greater mean Bolton's ratios were observed[3]. Tooth sizes are under high genetic control and it can be assumed that heredity might have a strong influence on tooth size discrepancy. Some studies showed high heritability of the anterior and overall Bolton's ratios[19]. Baydaş et al.[19] pointed out that both asymmetry and differences in tooth size have significant influence on Bolton's ratios.

In this study, a fluctuating asymmetry of teeth was analyzed as a composite measure of total weighted asymmetry (TWA). It was calculated as the sum of asymmetries for particular measurements in each individual. According to Palmer and Strobeck[8] such composite measures of asymmetry are much more effective for assessing developmental instability than measures of fluctuating asymmetry for individual variables. The results of this study did not show a significant fluctuating asymmetry for dental variables. We have observed significant differences in magnitude of fluctuating asymmetry between malocclusion groups and between the upper and lower jaw. Maxillary teeth displayed greater asymmetry than mandibular teeth in all groups of malocclusion, and the greatest asymmetry was observed for subjects with Class III malocclusion. The finding of greater FA in maxillary teeth for all malocclusion groups points to the fact that maxillary teeth are more sensitive to developmental stress than mandibular teeth. Greater asymmetry of maxillary teeth than mandibular counterparts was found in some other studies as well[17, 40-42].

In the present study, females displayed greater asymmetry for maxillary teeth in Class III malocclusion. Gender differences in Class I and Class II were not so apparent. Harris and Nweeia[40] found significantly greater asymmetry in females than males regarding tooth size. Maxillary teeth were more asymmetric in MD dimensions than mandibular teeth. The pattern of asymmetry corresponded closely to morphogenetic fields of teeth indicating the importance of genetic and ontogenetic patterns in human dentition. Additionally, the above mentioned researchers observed a higher FA in more distal teeth (premolars and molars) [40].

The increased degree of FA of MD tooth dimensions in Class III may result from higher environmental or genetic stress in the course of early development. It is considered that teeth with later development and with longer periods in soft tissue during development can be more affected by environmental disturbances and show greater FA[40, 43]. Khalaf et al.[42] observed that mesiodistal dimensions of teeth show the greatest symmetry.

The observation made in this study that tooth variables in Class III display greater FA suggests an association with greater stress (genetic and/or environmental) in the course of early dentoalveolar development. An increased genetic susceptibility to environmental stress can lead to increased developmental instability and elevated levels of FA in various structures such as teeth size and dental arch dimensions.

Kaur et al.[44] found an increased TWDA in cases with increased crowding and arch form asymmetry. Asymmetries in dental occlusion may reflect disturbances in genetic control of development and influence of environmental factors[45]. According to Garn and coworkers[24], asymmetries may be a major contributing factor to malocclusion. If a significant asymmetry exists, it leads to imbalance. More balanced and more symmetric patients have a greater likelihood for good occlusion. Patients with an increased fluctuating asymmetry tend to have more dental crowding and more severe malocclusion. Sprowls et al.[4] found that total weighted dental asymmetry (TWDA) had a statistically significant positive correlation with positional asymmetry. They observed an increase in dental crowding in cases with increased dental fluctuating asymmetry.

Schaefer et al.[25] observed that a significant directional asymmetry co-occur with fluctuating asymmetry in circumstances of increased stress levels. Therefore, they believe that both FA and DA can be an indicator of developmental instability[9, 10, 25]. Both kinds of asymmetries are dynamically inter-related because there is a possibility of transition from DA to FA[9, 25]. An additional evidence to support this observation are findings of associations of facial DA and FA with specific genes[46-48].

Weaver et al. [48] studied gene association with dentoalveolar phenotypes in subjects with malocclusions. They found strong associations of BMP3, Lats1, and SATB2 genes with fluctuating asymmetry of dental arches. BMP3 gene was found to be associated with left to right patterning in mammalian development. It is also important for development of mandibular prognathism. This partly explains the considerably greater fluctuating asymmetries in subjects with mandibular prognathism compared to other malocclusion groups. Further research is needed to compare both FA and DA for the same dentoalveolar variables in both jaws.

Conclusions

The TWA values were low but they differed significantly between the groups of malocclusion. Composite measures of fluctuating asymmetry (TWA) for dental variables were highest in Class III, and lowest in Class I malocclusion. Regarding the inter-arch differences, maxillary teeth were more asymmetrical than mandibular teeth. Males displayed a higher degree of asymmetry than females. The mean values of the Bolton's total ratio showed the strongest correlation with TWA of MD tooth size in maxilla (P < 0.01). Dental TWA affects the Bolton's ratio and may be associated with the etiology of malocclusions. The highest fluctuating asymmetry in Class III malocclusion points to the fact that patients with this type of malocclusion experienced the highest level of genetic and environmental stress in the course of early development.

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NESRAZMJERI ZUBNIH VELIČINA I FLUKTUIRAJUĆA DENTALNA ASIMETRIJA KOD RAZLIČITIH MALOKLUZIJA

S A Ž E T A K

Malokluzije nastaju zbog kombinacije dentalnih i skeletnih disharmonija. Nesrazmjeri zubnih veličina (TSD) i dentalna asimetrija mogu imati značajnu ulogu u etiologiji malokluzija. Svrha ovog istraživanja je bila komparirati stupanj dentalne asimetrije među pacijentima s malokluzijom klase I, II i III i korelirati mjere asimetrije s prednjim i ukupnim Boltonovim omjerima. Uzorak je obuhvaćao 131 pacijenta u dobi od 13 – 20 godina (62 muška i 69 ženskih) s različitim vrstama malokluzija (39 s klasom I, 57 s klasom II i 35 s klasom III). Sva su mjerenja provedena na 3D virtualnim modelima primjenom ATOS viewer softvera verzije 6.A.2 (GoM mbH, Braunschweig, Germany). Mjerene su dužine i širine zubnih kruna 14 zuba u svakoj čeljusti. Izračunati su Boltonovi omjeri i ukupna težinska asimetrija (TWA). Primjenjena je analiza varijance za komparaciju razlika među skupinama. Pearsonovi koeficijenti korelacija korišteni su za procjenu povezanosti između mjera TWA i Boltonovih omjera. Srednje vrijednosti Boltonovih omjera nisu pokazale značejne razlike među različitim vrstama malokluzija. Vrijednosti TWA su bile niske, ali su se značajno razlikovale među skupinama malokluzija. TWA, kao složena mjera fluktuirajuće asimetrije za dentalne varijable, bila je najviša kod malokluzije klase III, a najniža kod klase I. Dječaci su pokazivali viši stupanj asimetrije od djevojčica. Srednja vrijednost ukupnog Boltonovog omjera pokazivala je najjaču korelaciju s TWA meziodistalnih veličina zuba u maksili ($P < 0.01$). TWA utječe na Boltonov omjer i može biti povezana s etiologijom malokluzija. Najviša FA kod klase III ukazuje da bi pacijenti s tom malokluzijom mogli biti suočeni s višom razinom genetskog i okolinskog stresa tijekom ranog kraniofacijalnog razvoja.