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Fluktuirajuća asimetrija zubnih lukova u slučaju različitih malokluzija

Fluctuating Dental Arch Asymmetry in Different Malocclusion Groups

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Sažetak
Svrha: Željelo se usporediti stupanj fluktuirajuće asimetrije (FA) zubnih lukova između pacijenata s anomalijama klase I, II i III. **Ispitanici i metode:** Uzorak je obuhvaćao slučajno odabrane gipsane modele 131 pacijenta – 39 s klasom I (19 muških i 20 ženskih), 57 s klasom II (23 muška i 34 ženska) i 35 s klasom III (20 muških i 15 ženskih). Dentalni modeli skenirani su i digitalizirani skenerom ATOS II SO. Mjerenja zuba i zubnih lukova obavljena su softverom ATOS viewer verzije 6.A.2. Mjereno je šest širina i pet dužina zubnih lukova. FA je procijenjena u obliku složenog indeksa ukupne težinske asimetrije (TWA). Za komparaciju razlika među skupinama korištena je analiza varijance. **Rezultati:** Složene TWA mjere fluktuirajuće asimetrije za varijable zubnih lukova bile su najviše u klasi III i najniže u klasi I. Ispitanici su pokazivali viši stupanj asimetrije od ispitanica. Asimetrija zubnih lukova bila je viša u mandibuli negoli u maksili u svim skupinama malokluzija. **Zaključci:** TWA vrijednosti bile su niske, ali su se značajno razlikovale među skupinama malokluzija. Anomalija klase III pokazivala je više vrijednosti FA-e od onih u klasi I i klasi II. Viša FA-e zubnih lukova u Angleovoj klasi III može se smatrati indikatorom povećane razvojne nestabilnosti u slučaju te malokluzije zbog visokoga genetskog i okolišnog stresa tijekom ranog razvoja.

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Uvod

Ortodontske anomalije sve su češća pojava u suvremenim populacijama. Mnogobrojne malokluzije nastaju kao kombinacija dentalne i skeletne disharmonije, ali najčešći problem je nedostatna potporna kost (veličina zubnog luka) za smještaj idealnog rasporeda zuba (veličina zuba), što rezultira diskrepancijom između veličine zuba i veličine zubnih lukova (1, 2). Etiologija ortodontskih anomalija vrlo je kompleksna. Smatra se da meziodistalne dimenzije zubnih kruna pridonose diskrepanciji između veličine zuba i veličine zubnih lukova i one pokazuju pozitivne korelacije sa zbijenošću zuba. Među mnogim etiološkim čimbenicima važna je i diskrepancija između veličina zuba i zubnih lukova i relativne veličine zuba (3 – 5).

Razvoj normalne okluzije zahtijeva uravnotežen i proporcionalan dentalni i kraniofacijalni rast. Različiti okolišni i genetski stresni čimbenici mogu uzrokovati otklon od razvojnoga puta i pojavu ortodontske anomalije. Općenito se smatra da je malokluzija heterogeni entitet multifaktorske etiologije kod kojega su itekako važni genetski i okolišni čimbenici. Interakcija genetskih i okolišnih čimbenika odgovorna je za varijabilnost u ekspresiji malokluzija i širok spek-

Introduction

Malocclusion is an increasing phenomenon in contemporary populations. A large number of malocclusions may result from a combination of dental and skeletal disharmonies. However, they mostly occur due to insufficient supporting bone material (dental arch size) to accommodate the ideal arrangement of teeth (teeth size), creating tooth-size arch-size discrepancies (1, 2). The etiology of malocclusion is very complex. Crown dimensions are considered to contribute to tooth-size arch-size discrepancies and are positively correlated with crowding. The tooth-size arch-size discrepancies and a relative tooth size play an important role among a large number of etiological factors (3-5).

The development of normal occlusion requires a balanced and proportional dental and craniofacial growth. Different environmental and genetic stressors can cause deviations from the typical developmental trajectory and occurrence of malocclusion. In general, malocclusion is a heterogeneous entity caused by multifactorial etiology in which both genetic and environmental factors play an important role. The interaction of genetic and environmental factors is responsible for the variability in expression of malocclusion and a wide spec-

tar kliničke slike. Teški oblici malokluzija narušavaju izgled, poremećene su mastikatorne funkcije i smanjena kvaliteta života (1, 6, 7). Bolje razumijevanje temeljnog etiološkog mehanizma malokluzije važno je za napredak u prevenciji i liječenju ortodontskih anomalija.

U mnogobrojnim istraživanjima utvrđena je povezanost između veličine zubnih lukova i malokluzija. Postoje različiti aspekti veličina zuba i malokluzija. U suvremenim populacijama zapažen je opći sekularni trend povećanja veličine zuba i nedostatne potporne kosti za njihov smještaj (8).

Asimetrija zuba i zubnih lukova smatra se važnim čimbenikom koji pridonosi etiologiji malokluzija (9 – 11). Različiti razvojni poremećaji potiču pojavu različitih oblika asimetrije kao što su usmjerena asimetrija (DA), fluktuirajuća asimetrija (FA) ili antisimetrija (AS) (12 – 16). Neke asimetrije vrlo su suptilne i zahtijevaju primjenu vrlo preciznih metoda za njihovu detekciju. To se posebno odnosi na usporedbu parnih struktura kad se treba kvantificirati lijevo-desna asimetrija i prikazati kao usmjerena (DA) ili fluktuirajuća asimetrija (FA). FA bilateralno simetričnih struktura uvijek se uzima kao indikator razvojne nestabilnosti. Različiti stresni čimbenici mogu smanjiti stabilnost razvojnog procesa i omesti očekivani razvojni put. Kad adaptacijski kapacitet nekog organizma ne uspije ublažiti utjecaj tih stresnih čimbenika, razvojni proces rezultirat će povećanim otklonom od savršenog razvoja (15 – 19).

Smatra se da simetričan razvoj dentalnih i kraniofacijalnih struktura znači ravnotežu i homeostazu s dobrim izgledima za razvoj dobre okluzije. Povećani otkloni od simetrije znakovi su razvojne nestabilnosti koja povećava izglede za razvoj malokluzije (4, 10, 11, 19 – 22). To zapažanje može imati kliničke implikacije jer povećana asimetrija pridonosi razvoju malokluzije.

FA se smatra potencijalnom mjerom veličine stresa kojem je neka osoba bila izložena i odrazom genotipskog svojstva da ublaži djelovanje toga stresa. Razvojna nestabilnost koja rezultira asimetrijom može biti uzrokovana smanjenom genetskom kontrolom razvojnih procesa. Asimetrija struktura zuba i zubnih lukova znači odstupanje od harmoničnog razvoja i može također pridonijeti razvoju malokluzije. Neke osobe mogu pokazivati viši stupanj genetske osjetljivosti na različite okolišne stresore, što će se manifestirati kao povećana razina fluktuirajuće asimetrije nekih kraniofacijalnih struktura. Neke varijable mogu pokazivati različitu razinu osjetljivosti na okolišne utjecaje.

Cilj ovog istraživanja bio je procijeniti fluktuirajuću asimetriju dimenzija zubnih lukova kod ortodontskih pacijenata. Također se željelo evaluirati veličinu i prirodu fluktuirajuće dentoalveolarne asimetrije kod ortodontskih pacijenata s anomalijama klase I, II i III.

trum of clinical pictures in affected individuals. Severe forms of malocclusion lead to distorted appearance, impaired masticatory function, and decreased quality of life (1, 6, 7). Better understanding of the underlying etiological mechanism of malocclusion is important for the progress in prevention and treatment of orthodontic anomalies.

Numerous reports have found an association between the dental arch size and malocclusions. There are different aspects of tooth size and malocclusion. In general, secular trends toward increasing tooth size and insufficient supporting bone to accommodate teeth have been observed in recent populations (8).

The asymmetry in tooth size and dental arch asymmetry were recognized as important contributing factors to the etiology of malocclusion (9-11). Different developmental disturbances lead to the emergency of different forms of asymmetry such as directional (DA), fluctuating (FA) or antisymmetry (AS) (12-16). Some asymmetries are subtle and require the use of very precise methods for their detection. It particularly relates to the comparison of paired structures when left-right asymmetries have to be quantified and presented as either directional (DA) or fluctuating asymmetry (FA). Fluctuating asymmetry of bilaterally symmetric structures is always taken as an indicator of developmental instability. Different stressors can diminish the stability of developmental process and interfere with expected developmental path. When adaptive capability of an organism fails to buffer the effects of disturbing stressors, the developmental processes will result in increased deviation from perfect development (15-19).

It is considered that symmetrical development of dental and craniofacial structures means balance and homeostasis with good chances for development of good occlusion. Increased deviations from symmetry are the signs of developmental instability which increases the chance for development of malocclusion (4, 10, 11, 19-22). This observation can have clinical implication since an increased asymmetry could contribute to the development of malocclusion.

FA is considered to be a potential measure of the degree of stress experience by an individual, as well as a reflection of the genotype's ability to compensate for that stress. Developmental instability that results in asymmetry can be caused by decreased genetic control over developmental processes. Asymmetry of dental and dental arch structures means deviation from harmonious development and can also contribute to the development of malocclusion. Some individuals can display higher degrees of genetic susceptibility to different environmental stressors, which will manifest as an elevated level of fluctuating asymmetry in some craniofacial structures. Some variables may display different levels of sensitivity to environmental influences.

The aim of this study was to assess the fluctuating asymmetry of dental arch dimensions in orthodontic patients. The objective was also to evaluate the extent and nature of fluctuating dentoalveolar asymmetry in orthodontic patients with Class I, II, and III malocclusions.

Materijal i metode

Uzorak je obuhvaćao slučajno odabrane gipsane dentalne modele 131 pacijenta (62 muška i 69 ženskih) Zavoda za ortodonciju Stomatološkog fakulteta Sveučilišta u Zagrebu. Distribucija ispitanika prema spolu i tipu malokluzije prikazana je u tablici 1. Srednja dob ispitanika bila je od 14.9 ± 2.1 godina za klasu I, 14.2 ± 1.4 za klasu II i 17.8 ± 2.9 za klasu III. Dentalni modeli skenirani su sustavom ATOS II SO (*small objects*) (GoM mbh, Braunschweig, Njemačka) prema metodi koju je opisala dr. Šlaj (23, 24). Stvoreni su 3D virtualni modeli, a sve mjere izračunate su softverom ATOS viewer, verzija 6.A.2.

Mjerenja veličina zubnih lukova provedena su na virtualnim trodimenzionalnim dentalnim modelima (slika 1.). Središnja nepčana linija u gornjoj čeljusti definirana je kao spojnica točaka koje označuju prednje rafe sa sjekutićnim otvorom – *foramen incisivum* i najvidljivije posteriorne oznake medijalne palatinalne rafe. Mandibularna sredina dobivena je kao projekcija maksilarne središnje linije na mandibularni model koristeći se prednjom i stražnjom referentnom točkom. Modeli su stavljeni u okluziju (slika 2.) i središnja palatinalna osovina s maksilarnog zubnog luka prenesena je na mandibularni model da se odredi mandibularna središnja linija. Širine i dužine zubnih lukova mjerene su prema metodi koju su opisali Cassidy i suradnici (21) (slika 3.). Središnja palatinalna rafa bila je referentna za transverzalne mjere. Širine zubnih lukova izračunate su kao udaljenosti od mjernih točaka na svakom zubu okomito na središnju palatinalnu rafu (slika 3. A). Dužine zubnih lukova mjerene su paralelno sa središnjom palatinalnom rafom. Definirano je pet dužina za kvantifikaciju različitih segmenata zubnog luka i ukupnoga zubnog luka (slika 3. B).

Ukupna težinska asimetrija (TWA) izračunata je primjenom jednadžbe koju su predložili Palmer i Strobeck (14). TWA širine i dužine zubnih lukova analizirana je kao složena mjera ukupne fluktuirajuće asimetrije zubnih lukova. Asimetrija je izračunata za svaku osobu na temelju razlika između aritmetičkih sredina mjera prema formuli:

$$TWDA = \sum^{(1\text{-}6)} |L - R| / (L + R/2).$$

Prema tome, TWA je suma apsolutnih težinskih asimetrija za sve mjere zubnih lukova kod svake osobe. Istaknuto je da takva složena mjera asimetrije može biti mnogo učinkovitija u procjeni razvojne nestabilnosti od tradicionalnog pri-

Materials and methods

The samples comprised randomly selected plaster dental casts of 131 patients (62 males and 69 females) from the Department of Orthodontics, School of Dental Medicine, University of Zagreb, Croatia. The distribution of subjects according to sex and malocclusion group is shown in Table 1. The mean age of subject ranged from 14.9±2.1 year for Class I, 14.2±1.4 for Class II, and 17.8±2.9 for Class III. 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 (23, 24). 3D virtual models were created, scanned and digitized using ATOS viewer version 6.A.2 software.

Measurements of dental arch dimensions were taken from virtual three-dimensional dental models (Figure 1). The palatal symmetry axis was obtained by connecting the incisive papilla with most visible posterior landmark over the median palatal raphe. The mandibular midline was obtained as a projection of the maxillary midline to the mandibular model using the anterior and posterior reference points. The models were placed into occlusion (Figure 2) and the midpalatal axis from maxillary arch was transferred onto the mandibular model to determine the mandibular midline. Dental arch widths and depths were measured according to the method described by Cassidy et al. (21) (Figure 3). The median palatal raphe was the reference point for transverse measurements. Dental arch widths were calculated as a distance from the landmarks on each tooth type orthogonal to midpalatal raphe (Figure 3A). Arch depths were measured parallel with the mid palatal raphe. Five depths were defined to quantify various segments of the dental arch and the whole arch (Figure 3B). Total weighted asymmetry (TWA) was calculated using equation suggested by Palmer and Strobeck (14). Total weighted asymmetry (TWA) of dental arch width and dental arch depth was analyzed as a composite measure of total fluctuating asymmetry of dental arches. The asymmetry was calculated for each individual based on the differences between the antimeric teeth according to the following equation:

$$TWDA = \sum^{(1\text{-}6)} |L - R| / (L + R/2).$$

Therefore, the TWA is the sum of absolute weighted asymmetries for all dental arch measurements in each individual. It was pointed out that such composite measures of asymmetry may be a more effective means of assessing developmental in-

Tablica 1. Struktura uzorka
Table 1 Structure of the sample

Malokluzija • Malocclusion	Spol • Sex				Ukupno • Total (N = 131)	
	Muški • Males (N = 62)		Ženski • 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
Ukupno • Total	62	100.0	69	100.0	131	100.0
χ^2 - test	χ^2 = 2.496		df = 2		P = 0.287	

Legenda: N – veličina uzorka; n – broj ispitanika s malokluzijom
Legend: N – sample size; n – number of subjects with malocclusion

stupa analize pojedinačnih varijabli (4, 10, 12, 14, 19, 25). Za komparaciju razlika među skupinama korištena je analiza varijance (ANOVA).

Rezultati

Usporedba ukupne težinske asimetrije širina zubnih lukova (TWW) prikazana je na tablici 2. Značajno viša razina fluktuirajuće asimetrije bila je u slučaju anomalije klase III negoli anomalija klase I i klase II. Fluktuirajuća asimetrija u mandibuli za sve tipove malokluzija bila je značajno viša negoli u maksili za oba spola (slika 4).

stability than the traditional approach of analysis of single variables (4, 10, 12, 14, 19, 25). The analysis of variance (ANOVA) was used to compare differences between the groups.

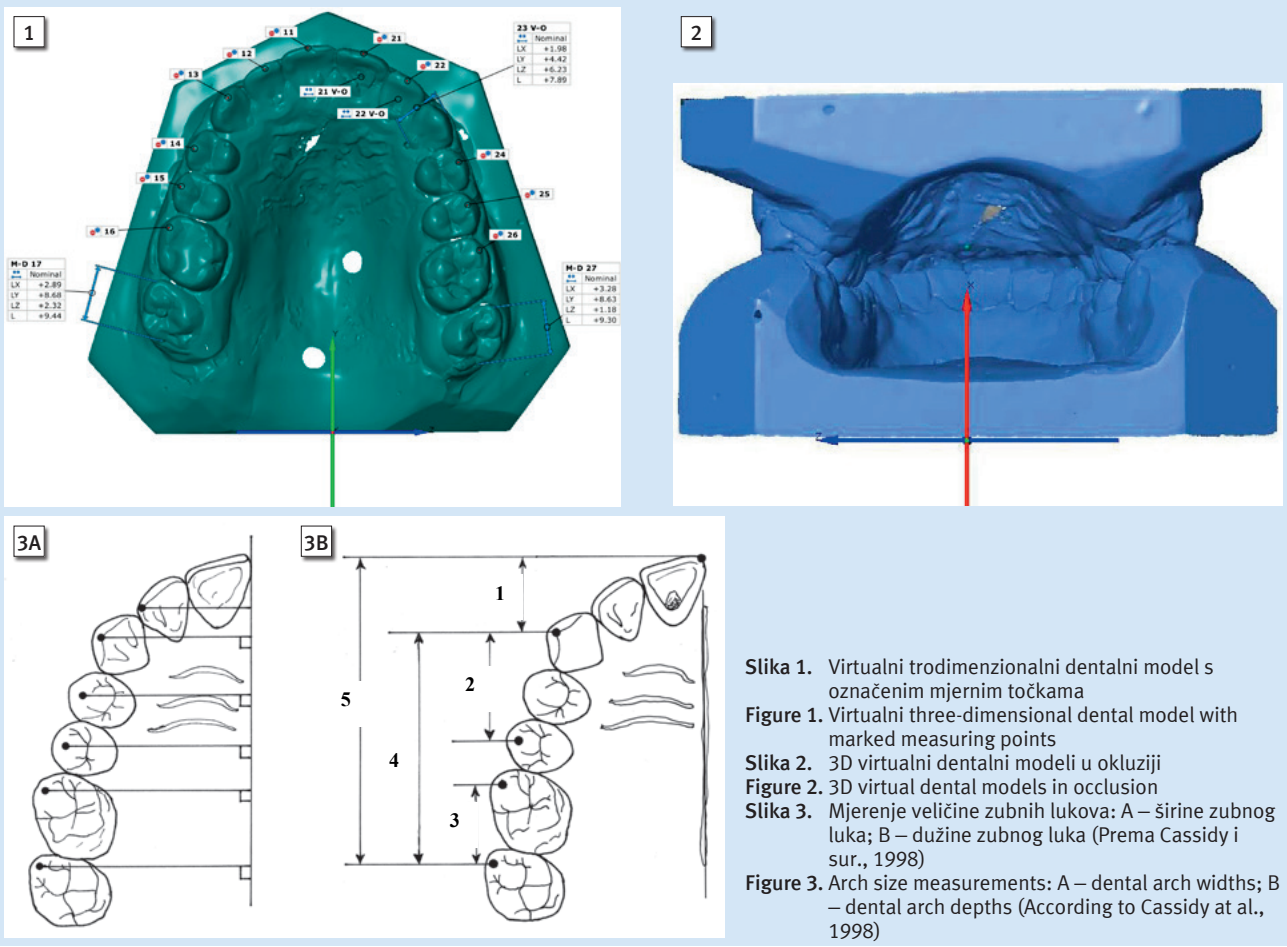
Results

The comparison of total weighted asymmetry of the widths of dental arches (TWW) is presented in Table 2. The levels of fluctuating asymmetry were found to be significantly higher in Class III than in Class I and Class II malocclusion. Fluctuating asymmetry in mandible for all types of malocclusion was considerably higher than in maxilla in both sexes (Figure 4).

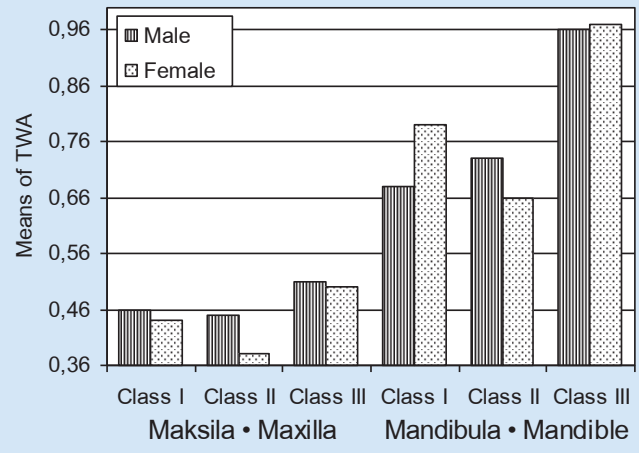
Tablica 2. Komparacija ukupne težinske asimetrije širina zubnih lukova (TWW) između različitih tipova malokluzija
Table 2 Comparison of total weighted asymmetry of dental arch widths (TWW) between different malocclusion groups

Malokluzija • Malocclusion	Maksila • Maxilla						Mandibula • Mandible					
	Muški • Males			Ženski • Females			Muški • Males			Ženski • Females		
	N	M	s. d.	N	M	s. d.	N	M	s. d.	N	M	s. d.
1) Klasa I • Class I	18	0.464	0.053	18	0.446	0.053	18	0.678	0.107	18	0.789	0.789
2) Klas II • Class II	17	0.452	0.041	30	0.383	0.041	17	0.729	0.104	30	0.655	0.655
2) Klasa III • Class III	12	0.514	0.063	13	0.503	0.063	12	0.964	0.113	13	0.974	0.974
Klasa I : III • Class I : III	t = 2.313 P = 0.028 *			t= 2.731 P = 0.011 **			t = 7.015 P < 0.0001 ***			t= 4.175 P = 0.0002 ***		
Klasa II : III • Class II : III	t= 2.774 P = 0.009 ***			t = 7.454 P < 0.0001 ***			t= 5.784 P < 0.0001 ***			t = 9.072 P < 0.0001***		

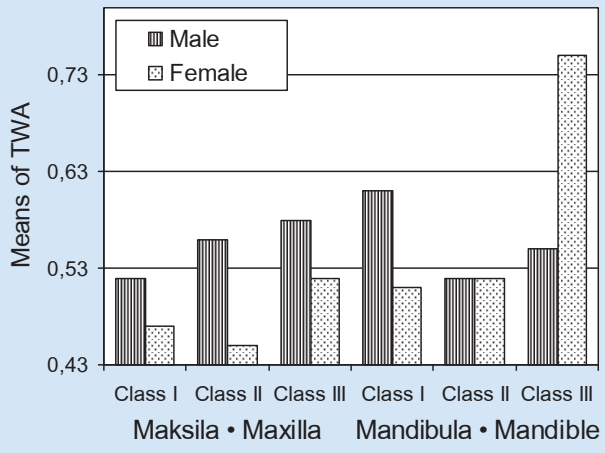
Legenda: N – veličina uzorka; M – aritmetička sredina FA-e; s.d. – standardna devijacija
Legend: N – sample size; M – mean of FA; s.d. – standard deviation



Slika 1. Virtualni trodimenzionalni dentalni model s označenim mjernim točkama
Figure 1. Virtualni three-dimensional dental model with marked measuring points
Slika 2. 3D virtualni dentalni modeli u okluziji
Figure 2. 3D virtual dental models in occlusion
Slika 3. Mjerenje veličine zubnih lukova: A – širine zubnog luka; B – dužine zubnog luka (Prema Cassidy i sur., 1998)
Figure 3. Arch size measurements: A – dental arch widths; B – dental arch depths (According to Cassidy at al., 1998)



Slika 4. Ukupna težinska asimetrija širina zubnog luka
Figure 4. Total weighted asymmetry of dental arch widths



Slika 5. Ukupna težinska asimetrija dužina zubnog luka
Figure 5. Total weighted asymmetry of dental arch depths

Tablica 3. Komparacija ukupne težinske asimetrije dužina zubnih lukova (TWD) između različitih tipova malokluzija
Table 3. Comparison of total weighted asymmetry of dental arch depths (TWD) between different malocclusion groups

Malokluzija • Malocclusion	Maksila • Maxilla						Mandibula • Mandible					
	Muški • Male			Ženski • Female			Muški • Male			Ženski • Female		
	N	M	s. d.	N	M	s. d.	N	M	s. d.	N	M	s. d.
1) Klasa I • Class I	18	0.516	0.080	18	0.470	0.080	19	0.609	0.085	20	0.507	0,107
2) Klasa II • Class II	17	0.555	0.055	30	0.454	0.062	19	0.521	0.085	28	0.516	0.088
2) Klasa III • Class III	12	0.578	0.065	13	0.516	0.091	18	0.547	0.087	12	0.746	0.140
Klasa I : III • Class I : III	t = 1.939 P = 0.0626 N.S.			t= 1.492 P = 0.147 N.S.			t = 2.192 P = 0.0351 *			t= 7.074 P < 0.0001 ***		
Klasa II : III • Class II : III	t= 0.709 P = 0.484 N.S.			t = 2.604 P = 0.0128 **			t= 0.919 P = 0.364 N.S.			t = 8.086 P < 0.0001 ***		

Legenda: N – veličina uzorka; M – aritmetička sredina FA-e; s.d. – standardna devijacija
Legend: N – sample size; M – mean of FA; s.d. – standard deviation

Tablica 3. pokazuje razlike asimetrije dubine zubnih lukova između skupina malokluzija. Nisu utvrđene značajne razlike u maksili, ali ispitanici su pokazivali veću asimetriju od ispitanica. U mandibuli su ispitanici pokazivali viši TWD u klasi I, a ispitanice su pokazivale značajno višu asimetriju u klasi III negoli u klasama I i II. Fluktuirajuća asimetrija bila je viša za klasu III u obje čeljusti (slika 5.).

Rasprava

Sve mjere u ovom istraživanju dobivene su na trodimenzionalnim virtualnim modelima. Neka dosadašnja istraživanja pokazala su da se mjere dobivene na 3D virtualnim modelima mogu smatrati pouzdanima i komparabilnima s onima dobivenima konvencionalno s pomoću digitalnih pomičnih mjerki. Obje metode pokazuju visok stupanj podudarnosti i reproducibilnosti (24, 26, 27).

U ovom istraživanju izračunata je ukupna težinska asimetrija (TWA) kao zbroj asimetrija za pojedine mjere kod svake osobe. Prema Palmeru i Strobecku (14) takva složena mjera asimetrije mnogo je prikladnija za procjenu razvojne nestabilnosti negoli mjere fluktuirajuće asimetrije za pojedinačne varijable. Rezultati ovog istraživanja nisu pokazali značajnu fluktuirajuću asimetriju za varijable zubnih lukova, ali su za-

Table 3 shows differences in asymmetry of dental arch depths between malocclusion groups. It was found that there was no significant difference in maxilla, but males displayed greater asymmetry than females. Male subjects' mandibles showed higher TWD in Class I, while females displayed significantly higher asymmetry in Class III than in Class I and Class II. Fluctuating asymmetry was higher for Class III in both jaws (Figure 5).

Discussion

All measurements in the present study were obtained on three dimensional virtual models. Some previous studies showed that measurements obtained on 3D models can be considered reliable and comparable to those obtained with digital calipers in conventional way. Both methods showed a high degree of concordance and reproducibility (24, 26, 27).

In this study, a composite measure of total weighted dental (fluctuating) asymmetry (TWA) was calculated as the sum of asymmetries for particular measurements in each individual. According to Palmer and Strobeck (14) 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 significant fluctuating asymmetry for dental arch

pažene značajne razlike u veličini fluktuirajuće asimetrije između pojedinih tipova malokluzija te između gornje i donje čeljusti.

Neka dosadašnja istraživanja pokazala su višu asimetriju maksilarnih u odnosu na mandibularne zuba (28 – 31). Harris i Nweeia (28) pronašli su značajno višu asimetriju zubnih veličina kod ispitanica negoli ispitanika. Maksilarni zubi bili su asimetričniji u meziodistalnim dimenzijama od mandibularnih. Oni su zapazili da se uzorak asimetrije usko podudara s morfogenetskim poljima zuba, što upozorava na važnost genetskih i ontogenetskih uzoraka u humanoj denticiji. Ujedno su zapazili višu FA-u distalnijih zuba u čeljusti (premolara i molara) (28).

Fluktuirajuća asimetrija zubnih lukova pokazala je više vrijednosti u mandibuli negoli u maksili. Ukupna težinska asimetrija širine zubnih lukova (TWW) bila je mnogo veća u mandibuli negoli u maksili u svim vrstama malokluzija. Vrijednosti TWW-a bile su najviše kod ispitanika s anomalijom klase III. Anteroposteriorni stupanj asimetrije dužine maksilarnih zubnih lukova bio je veći kod muških negoli ženskih ispitanika. Vrijednosti TWA-e u mandibuli za dužine zubnih lukova bile su najveće za klasu III kod ispitanica. Rezultati pokazuju da je donja čeljust osjetljivija na djelovanje okolišnog i genetskog stresa. Čini se da je gornja čeljust otpornija na djelovanje stresa i pokazuje nižu razinu asimetrije.

Kaur i suradnici (32) analizirali su ukupnu težinsku asimetriju zubnih kruna (TWDA) i uočili značajne korelacije s transverzalnim maksilarnim dimenzijama. Slučajevi s povećanom TWDA-om imali su povećanu zbijenost zuba, asimetriju oblika zubnih lukova i transverzalne devijacije u zubnim lukovima. Povećanu TWDA pratila je povećana zbijenost zuba i asimetrija zubnih lukova koja se pripisuje povećanoj razvojnoj nestabilnosti.

Asimetrija dentalne okluzije može biti pokazatelj poremećaja u genetskoj kontroli razvoja i/ili utjecaju okolišnih čimbenika (33). Stupanj asimetrije odražava stupanj genetskog kanaliziranja dentoalveolarnog razvoja. Scanavini i suradnici (34) utvrdili su visoku asimetriju dimenzija zubnih lukova u mandibuli i maksili. Isti rezultati dobiveni su i u nekim drugim studijama (35, 36). Na mjere zubnih lukova utječu nasljeđe i okoliš, ali čini se da je uloga nasljeđa u tome mnogo veća. Istraživanja pokazuju visoku genetsku kontrolu transverzalnih mjera zubnih lukova (širina zubnih lukova), ali je utvrđen i značajan postnatalni doprinos okolišnih čimbenika (21, 33). Cassidy i suradnici (21) ustanovili su da veličina zubnog luka ima genetsku komponentu od 50 %. Najviša procjena nasljednosti od oko 60 % utvrđena je za širine zubnih lukova. Veličine zubnih lukova pokazuju značajne varijacije kod različitih tipova malokluzija. Utjecaj okolišnih čimbenika na varijable zubnih lukova također je značajan. Zubni lukovi se mijenjaju nakon nicanja i pomicanja zuba zbog pritiska mišića i oralnih navika, što zajedno pridonosi varijacijama veličine i oblika zubnih lukova (21).

Schaefer i suradnici (22) zapazili su razlike u veličini fluktuirajuće asimetrije zubnih lukova između gornje i donje čeljusti. Gornja čeljust pokazivala je višu FA-u zbog povećane osjetljivosti na razvojne smetnje u odnosu na donju čeljust. Zbog toga oni zaključuju da se fluktuirajuća asimetrija po-

variables. We have observed significant differences in magnitude of fluctuating asymmetry between malocclusion groups and between the upper and lower jaws.

Some previous studies showed higher asymmetry of maxillary than mandibular teeth (28-31). Harris and Nweeia (28) found significantly higher scores of asymmetry in females than males regarding tooth size. Maxillary teeth were more asymmetric in MD dimensions than mandibular teeth. Harris and Nweeia (28) observed that the pattern of asymmetry corresponds closely with morphogenetic fields of teeth pointing to the importance of genetic and ontogenetic patterns in human dentition. They also observed higher FA in more distal teeth (premolars and molars) (28).

The fluctuating asymmetry of dental arches showed higher asymmetry values in the mandible than in the maxilla. Total weighted asymmetry for dental arch widths (TWW) was much greater in the mandible than in the maxilla in all malocclusion groups. The values of TWW were the highest for subjects with Class III malocclusion. The anteroposterior degree or asymmetry of maxillary arch depths was greater in males than in females. TWA scores for dental arch depths in mandible were the greatest for Class III malocclusion in females. The results imply that the lower jaw is more sensitive to both environmental and genetic stress. The upper jaw appears to be better buffered and displays a lower amount of asymmetry.

Kaur et al. (32) studied the total weighted asymmetry and observed significant correlations with transverse maxillary dimensions. Cases with increased TWDA had increased crowding, arch form asymmetry and transverse deviations in dental arches. Cases with increased TWDA displayed increased crowding and arch form asymmetry due to developmental instability.

Asymmetries in dental occlusion may reflect disturbances in genetic control of development and/or influence of environmental factors (33). The degree of asymmetry can reflect the degree of genetic canalization of dentoalveolar development. Scanavini et al. (34) found higher asymmetry in dental arch dimensions in the mandible than in the maxilla. Similar findings were obtained in some other studies (35, 36). Dental arch measurements are influenced by heredity and environment but it seems that hereditary contribution plays much greater role. The results of some studies show high levels of genetic control for transverse arch measurements (dental arch widths) but considerable postnatal influences of environment was also established (21, 33). Cassidy et al. (21) stated that dental arch size has 50% of genetic component. The highest heritability estimates, about 60% on average, were obtained for dental arch widths. The size of dental arches shows considerable variations within different types of malocclusion. The influence of environmental factors on dental arch variables is also significant. Dental arches change after teeth emergence. The movement due to muscular pressures and oral habits contribute to the variations in size and shape of dental arches (21).

Schaefer et al. (22) observed differences in the magnitude of fluctuating asymmetry for dental arches between the upper and lower jaw. The upper jaw displayed higher FA due

većava u obje čeljusti zbog okolišnog stresa, a genetski stres dodatno povećava FA-u u donjoj čeljusti. Zapažanja u tom istraživanju da varijable zubnih lukova kod klase III pokazuju veću FA-u, upućuje na povezanost s većim stresom (genetskim i/ili okolišnim) tijekom ranog dentoalveolarnog razvoja. Povećana genetska osjetljivost na okolišni stres može rezultirati povećanom razvojnom nestabilnošću i povećanom razinom FA-e u različitim strukturama kao što su dimenzije zubnih lukova. Livshits i Kobyliansky (18) ističu da neke genetske komponente mogu učiniti nekoga osjetljivijim na pojavu asimetrije u različitim strukturama, a vanjski čimbenici utječu na stupanj u kojem će se svaka strukturna asimetrija manifestirati.

Prema Garnu i suradnicima (20) asimetrija može biti glavni čimbenik koji pridonosi pojavi malokluzije. Značajna asimetrija znači disbalans, a više uravnotežene i više simetrične osobe imaju veću vjerojatnost za razvoj dobre okluzije. Pacijenti s povećanom fluktuirajućom asimetrijom imaju zbijenije zube i mnogo izraženiju ortodontsku anomaliju.

Sprowls i suradnici (4) utvrdili su pozitivne korelacije ukupne dentalne asimetrije (TWDA) s položajnom dentalnom asimetrijom. Smatraju da povećana asimetrija oblika zubnih lukova može biti povezana sa zbijenošću zuba i povećanom razvojnom nestabilnosti. Osobe s većom asimetrijom pokazuju jače izražen oblik malokluzije zbog povećane razvojne nestabilnosti i jačeg djelovanja okolišnih perturbacija. Sprowls i suradnici (4) zapazili su povećanu dentalnu zbijenost u slučajevima s povećanom fluktuirajućom dentalnom asimetrijom. Oni smatraju da je utvrđivanje stupnja fluktuirajuće ili usmjerene asimetrije kod ortodontskih pacijenata jednako važno kao i utvrđivanje Boltonovih nerazmjera (4).

Schaefer i suradnici (22) zapazili su da se značajna usmjerena asimetrija pojavljuje zajedno s fluktuirajućom asimetrijom u okolnostima povećanog stresa te zato smatraju da obje asimetrije – FA i DA, mogu biti indikatori razvojne nestabilnosti (15, 16, 22). Obje vrste asimetrije dinamički su povezane jer postoji mogućnost prelaska iz DA-e u FA-e (15, 22). Dodatnu potporu tome zapažanju daje nalaz povezanosti DA-e i FA-e u slučaju facijalne asimetrije sa specifičnim genima (37 – 39).

Weaver i suradnici (39) istraživali su povezanost gena s dentoalveolarnim fenotipima kod osoba s ortodontskim anomalijama. Ustanovili su snažnu povezanost BMP3, Lats1 i SATB2 gena s fluktuirajućom asimetrijom zubnih lukova. Utvrđeno je da je gen BMP3 povezan s lijevo-desnim oblikovanjem razvoja kod sisavaca te da je važan za razvoj mandibularnog prognatizma. Taj nalaz djelomično pomaže objasniti značajno veću fluktuirajuću asimetriju kod osoba s mandibularnim prognatizmom u odnosu na ostale skupine malokluzija. Potrebna su daljnja istraživanja komparacije FA-e i DA-e istih dentoalveolarnih varijabli u obje čeljusti.

to higher sensitivity to developmental disturbances than the lower jaw. Schaefer et al. (22) concluded that fluctuating asymmetry increased in both jaws with environmental stress. However, genetic stress additionally increases FA in the lower jaw.

The observation in this study that dental arch variables in Class III display greater FA suggests an association with greater stress (genetic and/or environmental) during early dentoalveolar development. Increased genetic susceptibility to environmental stress can lead to increased developmental instability and elevated levels of FA in various structures such as dental arch dimensions. Livshits and Kobyliansky (18) stated that some genetic components could make an individual become more susceptible to the pressure of asymmetry in various structures. Besides, they stated that external factors could influence the degree to which each structural asymmetry is manifested.

According to Garn and coworkers (20) asymmetries may be a major contributing factor to malocclusion. Significant asymmetry means 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) obtained positive correlation of the TWDA with the positional dental asymmetries. They believed that increased arch form asymmetry may be associated with dental crowding and increased developmental instability. Individuals with greater asymmetry displayed more severe malocclusion due to developmental instability and higher effect of environmental perturbation. They observed an increase in dental crowding in cases with increased dental fluctuating asymmetry. Sprowls et al. (4) stated that establishing the degree of fluctuating or directional asymmetry in orthodontic patients is equally important as establishing Bolton discrepancies.

Schaefer et al. (22) observed that significant directional asymmetry co-occurred with fluctuating asymmetry in circumstances of increased stress. Therefore, they stated that both FA and DA could be indicators of developmental instability (15, 16, 22). Both types of asymmetries are dynamically inter-related because there is possibility of transition from DA to FA (15, 22). There is evidence to support the findings of associations of DA and FA in facial asymmetry with specific genes (37-39).

Weaver et al. (39) performed the study of gene association with dentoalveolar phenotypes in subjects with malocclusions. They found strong associations of the BMP3, Lats1, and SATB2 genes with fluctuating asymmetry of dental arches. The BMP3 gene was found to be associated with left to right patterning in mammalian development. This gene was found to be important for development of mandibular prognathism. This finding partly helps to explain considerably greater values fluctuating asymmetry 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.

Zaključci

Vrijednosti TWA-e bile su niske, ali su se značajno razlikovale između skupina različitih malokluzija. Složena mjera fluktuirajuće asimetrije (TWA) za varijable zubnih lukova bile su najviše za anomaliju klase III, a najniže za klasu I. Kad je riječ o razlikama između zubnih lukova, utvrđeno je da su asimetrije zubnih lukova značajno veće u mandibuli negoli u maksili u svim skupinama malokluzija. Ispitanici su pokazivali veći stupanj asimetrije od ispitanica. Najviša fluktuirajuća asimetrija u slučaju anomalije klase III upućuje na to da su pacijenti s tom malokluzijom izloženi najvišoj razini genetskog i okolišnog stresa tijekom ranog razvoja.

Sukob interesa

Autori nisu bili u sukobu interesa.

Conclusions

The TWA values were low but they differed significantly between the groups of malocclusion. Composite measures of fluctuating asymmetry (TWA) for dental and dental arch variables were the highest in Class III, and lowest in Class I malocclusion. Regarding the inter-arch differences, the teeth in the maxilla were more asymmetrical than the teeth in the mandible. Dental arch asymmetry was considerably greater in the mandible than in the maxilla in all malocclusion groups. Males displayed a higher degree of asymmetry than females. The highest fluctuating asymmetry in Class III malocclusion points to the fact that patients with Class III malocclusion experienced the highest level of genetic and environmental stress during early development.

Conflict of interest

None declared

Abstract

Objective: To compare the degree of dental arch fluctuating asymmetry (FA) among patients with Class I, II, and III malocclusions. **Subjects and methods:** The sample comprised randomly selected plaster casts of 131 patients: 39 Class I (19 males and 20 females), 57 Class II (23 males and 34 females), and 35 Class III (20 males and 15 females). Dental models were scanned and digitized using ATOS II SO. The measurements of the teeth and dental arches were taken using the ATOS viewer version 6.A.2 software. Six arch widths and five arch depths were measured. The FA was assessed as a composite index of total weighted asymmetry (TWA). The analysis of variance was used to determine whether there were any statistically significant differences between the groups. **Results:** Composite TWA measures of fluctuating asymmetry for dental arch variables were the highest in Class III, and lowest in Class I malocclusion. Males displayed a higher degree of asymmetry than females. The asymmetry degree was higher in the mandibular dental arches than in the maxillary dental arches in all malocclusion groups. **Conclusion:** The TWA values were low but they differed significantly between the groups of malocclusion. Class III malocclusion displayed higher FA values than Class I and Class II malocclusion. Higher FA of dental arches in Angle's Class III can be considered an indicator of increased developmental instability in this malocclusion due to high levels of genetic and environmental stress during the period of early development.

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