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ACTA
STOMATOLOGICA
CROATICA
www.ascro.hr

Acta stomatol Croat. 2018;52(3):227-237.
DOI: 10.15644/asc52/3/6

IZVORNI ZNANSTVENI RAD
ORIGINAL SCIENTIFIC PAPER

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Dužinski prediktori rotacijskog obrasca rasta lica na hrvatskoj populaciji s anomalijom skeletne klase III

Linear Predictors of Facial Rotation Pattern in Croatian Subjects with Skeletal Class III Malocclusion

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Sažetak

Svrha: Željelo se s pomoću rendgenkefalometrijske analize ustanoviti mogu li dužinske vrijednosti maksile, mandibule i kranijalne baze biti prediktori rotacijskog obrasca rasta lica na uzorku ispitanika hrvatske populacije s anomalijom skeletne klase III. **Ispitanici i metode:** Ispitivani uzorak sastojao se od 201 laterolateralne snimke glave (111 ženskih, 90 muških) učinjene prije početka ortodontske terapije, a dobivene su iz baze podataka pacijenata Zavoda za ortodonciju Stomatološke klinike Kliničkoga bolničkog centra Zagreb. Sva mjerenja klasificirana su u pet kategorija: kranijalna baza, skeletni maksilarni i skeletni mandibularni odnosi, međučeljusni sagitalni i vertikalni odnosi. Za procjenu rotacijskog obrasca rasta lica korišteno je pet modela multiple linearne regresije. **Rezultati:** Efektivna dužina mandibule bila je najznačajniji prediktor rotacijskog obrasca rasta lica pri čemu je povećana dužina u velikoj mjeri predisponirala tendenciju vertikalnom obrascu rasta. Nije pronađena značajna spolna dihotomija, osim u četvrtom modelu gdje je posteriorna rotacija maksile povezana sa ženskim spolom. **Zaključci:** Prediktori rotacijskog obrasca rasta lica pronađeni u ovoj studiji mogli bi pomoći ortodontima u odluci o vremenu i vrsti terapiji pacijenata hrvatske populacije s anomalijom skeletne klase III.

Zaprimljen: 21. svibnja 2018.
Prihvaćen: 15. srpnja 2018.

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Ključne riječi
malokluzija u III. Angleovu razredu; kosti lica; kefalometrija; asimetrija lica

Uvod

Malokluzije klase III privlače pozornost kliničara već stotinama godina zbog složenosti terapije, mogućeg recidiva uvjetovanog individualnim rastom i razvojem te zbog velikog utjecaja na estetiku lica. Incidencija recidiva koja se navodi u literaturi čak je do 50 % (1). Otegutni čimbenik za dijagnozu i planiranje terapije malokluzije klase III jest i njezina etiološka raznovrsnost. Genetski i okolišni čimbenici pridonose malokluziji klase III. Uz to, koristeći se analizama povezanosti i istraživanja povezanosti, identificirani su različiti lokusi i sumnjivi geni (2 – 9). Asimetrija zuba i zubnih lukova također se smatra važnim čimbenikom koji pridonosi etiologiji svih malokluzija općenito (10 – 12). Škrinjarić i suradnici (13) u svojem su istraživanju o fluktuirajućoj asimetriji zaključili da je najviša fluktuirajuća asimetrija u slučaju anomalije klase III, što upućuje na to da su pacijenti s tom malokluzijom tijekom ranog razvoja izloženi najvišoj razini genetskog

Introduction

Class III malocclusions have been harnessing the attention of clinicians for hundreds of years due to the complexity of therapy, the possibility of relapses conditioned by individual growth and development and due to their great influence on facial esthetics. The incidence of relapse is reported in one article up to 50% (1). Additionally, etiologic diversity makes it more difficult to diagnose and plan the therapy. Genetic and environmental factors are considered the cause of Class III malocclusions. Diversity of loci and suspicious genes have been identified using the linkage analysis and association studies (2-9). The tooth size and dental arch asymmetry were also recognized as important contributing factors to the etiology of malocclusions (10-12). In their research on fluctuating dental arch asymmetry, Škrinjarić et al. (13) concluded that the highest fluctuating asymmetry appeared in Class III anomalies, which suggest that patients with this malocclui okolišnog stresa.

Prevalencija anomalija klase III varira između različitih etničkih skupina – raspon je od 0 do 26 % (14). U azijskoj populaciji je veća negoli u ostalima (15). Kineska i malezijska populacija imaju razmjerno visoku prevalenciju – 16 % (14), odnosno 17 % (14). Većina afričke populacije pokazala je razmjerno nisku prevalenciju, iako je u dvjema zemljama pronađena veća učestalost anomalija klase III (16). Nedavna istraživanja pokazala su raspon od 2 do 6 % za europsku populaciju (14).

Vertikalni obrazac rasta kod pacijenata sa skeletnom klasom III vrlo je važan čimbenik i treba ga se razmotriti pri određivanju dijagnoze i detaljnog plana te vremena terapije. Schudy (17) je istraživao interakciju horizontalnih i vertikalnih displazija lica i na temelju SN – MP kuta odredio proporcije prema kojima razlikujemo prosječne facijalne tipove i one ekstremne. Podijelio je uzorak od 120 pacijenata u tri skupine na temelju njihova SN – P kuta i uveo izraz *divergencija lica* za metodu indikacije vertikalne varijacije. Dva ekstremna tipa divergencije lica opisana su kao *hiperdivergentan* za osobe s velikim kutom mandibularne ravnine prema kranijalnoj bazi i *hipodivergentan* za one s malim kutom mandibularne ravnine prema kranijalnoj bazi. Ostali pojmovi koji su korišteni za opisivanje različitih tipova vertikalnog obrasca rasta lica su *povećani i smanjeni kut* (high and low angle) koji također upućuju na stupanj divergencije lica, zatim dugo ili kratko lice na temelju linearnih mjerenja visine lica. Jarabakov omjer određuje postotak prednje i stražnje proporcije lica. Taj se odnos dobiva sljedećom formulom: stražnja visina lica/prednja visina lica x 100. Prednja visina lica mjeri se od točke *nasion* do točke *menton,* a stražnja od točke *sela* do točke gonion. Vrijednosti između 62 i 65 % upućuju na prosječno lice, veći postotak se vidi u slučajevima smanjenoga kuta (*low angle*), a manji postotak upućuje na povećani kut (*high angle*)(18).

Uzimajući u obzir plan terapije, upitno je treba li početi s ranom terapijom ili to učiniti tek nakon završetka rasta i razvoja. Bilo bi dobro da se može predvidjeti mogućnost ishoda terapije prije njezina početka zbog različitih smjerova terapije – samo ortodontski ili ortodontsko-kirurški slučajevi. Mnogi su autori zaključili da su ispitanici s manjim gonijalnim kutom i hipodivergentnim obrascem rasta imali dobru prognozu, a da su oni s vertikalnim, hiperdivergentnim obrascem rasta pokazali lošu prognozu nakon ranog liječenja malokluzije klase III (19, 20).

Svrha istraživanja bila je ustanoviti s pomoću rendgenkefalometrijske analize mogu li dužinske vrijednosti maksile, mandibule i kranijalne baze biti prediktori rotacijskog obrasca rasta na uzorku ispitanika hrvatske populacije s anomalijom skeletne klase III.

Ispitanici i postupci

Uzorak

Uzorak ove retrospektivne studije sastojao se od 201 ispitanika s anomalijom klase III (90 muškaraca i 111 žena; dob od 12 do 20 godina; srednja dob 15 ± 3 godine). Uzorak je dobiven iz baze podataka pacijenata Zavoda za ortodonci-

sion are under the greatest influence of genetic and environmental stressors during early growth and development.

The prevalence of Class III malocclusion shows the great variety in different ethnic groups, ranging from 0-26% (14), being highest in the Asian population (15). Chinese and Malaysian population showed a relatively high prevalence: 16% (14) and 17% (14), respectively. The lowest prevalence is found in the African population, although the higher frequency of Class III malocclusion was found in two countries (16). Recent studies showed a range of 2% to 6% among European population (14).

For a correct diagnosis, timing and therapy plan in patients with Class III malocclusion, it is very important to look attentively at the vertical growth pattern. Schudy (17) investigated the interaction of horizontal and vertical facial dysplasias and determined the proportions by which he differentiated the average versus extreme facial types based on the SN-MP angle. He divided his sample of 120 patients into three groups based on their SN-MP angle and coined the phrase "facial divergence" as a method of indicating vertical variation. The two extremes of facial divergence were described as "hyperdivergent" for individuals with increased mandibular plane angle and "hypodivergent" for individuals with decreased mandibular plane angle. Other terms which have been used to describe different vertical facial types include high and low angle, which also refer to the degree of facial divergence, and long or short facial types, based on linear measurements of facial height. The Jarabak ratio shows the relation between the anterior (N-Me) and posterior facial height (S-Go). The formula is obtained by dividing the posterior facial height with anterior facial height, then multiplying by hundred. Values between 62-65% point to an average face, a higher percentage is seen in low angle cases, while smaller percentage points to high angle cases. (18).

Considering the therapy plan it is controversial whether to start treatment immediately or to defer it until the growth is completed. Due to different procedures during therapy, it would be easier if we could immediately know whether the case could be resolved only by orthodontists, or by surgeons and orthodontists. Many authors agreed that a favorable outcome of an early treatment of Class III malocclusion is associated with a smaller gonial angle and a hypodivergent growth pattern while an unfavorable outcome is connected with vertical growth pattern (19,20).

The aim of this study was to determine whether the linear values of the maxilla, mandible and cranial base could be predictors of facial rotation pattern in a Croatian population with Class III malocclusion by cephalometric radiographic method.

Subjects and methods

Sample

The sample of this retrospective study consisted of 201 patients with Class III malocclusion

(90 male and 111 female; aged 12-20 years; mean age 15±3 years) and they were obtained from the archives of the ju Stomatološke klinike Kliničkoga bolničkog centra Zagreb. Pregledano je više od tisuću laterolateralnih snimki glave.

Inkluzijski kriteriji istraživanja:

1) visoka kvaliteta laterolateralnih snimki glave
2) dob između 12 i 20 godina
3) hrvatska populacija
4) ANB kut manji od 0,5°
5) Witsova vrijednost manja od 0 mm za djevojčice i -1 mm za dječake.

Normativ za vrijednost ANB kuta uzet je iz dosadašnjih studija za hrvatsku populaciju s normalnom okluzijom (21).

Ispitanici s prisilnim zagrizom, kraniofacijalnim sindromima, rascjepom, traumom, hipodoncijom te oni koji su već bili na ortodontskoj terapiji, nisu uzeti u razmatranje.

Etičko povjerenstvo Stomatološkog fakulteta u Zagrebu odobrilo je ovo istraživanje zato što su pacijenti pregledani za rutinske dijagnostičke potrebe i buduće planiranje ortodontskog liječenja. Svi pacijenti ili njihovi roditelji (ako su mlađi od 18 godina) potpisali su informirani pristanak kojim su odobrili korištenje svojih radiograma.

Kefalometrijska analiza

Laterolateralne snimke glave dobivene su u standardiziranim uvjetima – u položaju maksimalne interkuspidacije, koristeći se olive kefalostatom za stabilizaciju (medijske žarišne udaljenosti fokusa 1,55 m; detektor do sredine udaljenosti 0,125 m). Upotrijebljena su dva uređaja. Dvadeset kefalograma učinjeno je Planmeca PM 2002 CC Prolineom (Planmeca, Helsinki, Finska). Ti analogni kefalogrami digitalizirani su Scan Makerom i900 (Microtek, Willich, Njemačka). Još 181 kefalogram pohranjen je na CD-ROM-u u digitalnom formatu i snimljen ortopantomografom OP200D (Instrumentarium Oy, Tuusula, Finska) s prosječnim vremenom ekspozicije od 10 sekunda i pri vrijednostima od 85 kV do 13 mA.

Kefalometrijska analiza obavljena je softverom DOLPHIN IMAGE (v.11.0). Kako bi se spriječila pogreška povećanja i snimka kalibrirala u softveru Dolphin da bismo dobili realne linearne vrijednosti, snimke su učinjene metalnom kalibracijskom pločicom ugrađenom u kefalostat i dvije točke reproducirane na glavnom filmu.

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The inclusion criteria were as follows: 1. high quality of pretreatment lateral cephalograms, 2. age between 12 and 20 years, 3. Croatian ethnicity, 4. ANB angle less than 0.5°, 5. Wits appraisal of less than 0 mm for girls and less than: -1 mm for boys.

The standard of the ANB value was derived from a previous study on subjects of Croatian ethnicity with normal occlusion (21).

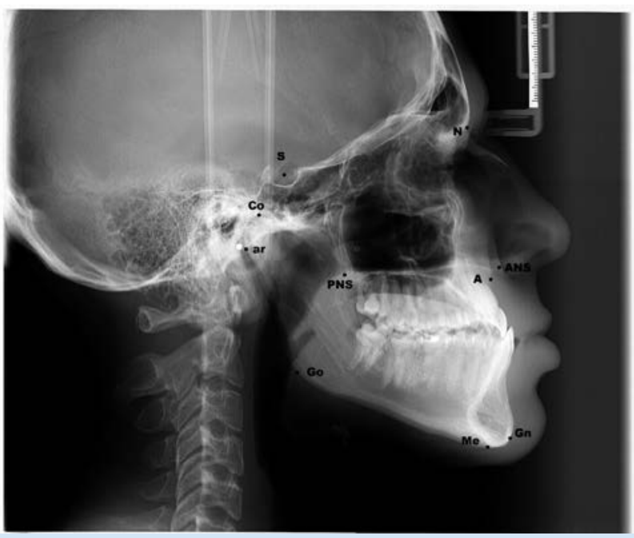
Patients who exhibited an anterior mandibular shift, craniofacial syndromes, clefts, trauma, hypodontia and those who had already received orthodontic therapy were excluded.

The Ethics Committee of the School of Dental Medicine approved this study, as the patients were examined for routine diagnostic needs and future orthodontic treatment planning. All patients or their parents (if the patients were under 18) signed an informed consent form authorizing the use of their radiograms.

Cephalometric analysis

Lateral cephalograms were obtained under standardized conditions: in the maximal intercuspal position, using ear rods for stabilization (median plane focal distance: 1.55 m; detector to midsagittal distance: 0.125 m). Two devices were used. Twenty cephalograms were taken with a Planmeca PM 2002 CC Proline (Planmeca, Helsinki, Finland). Analog cephalograms were digitized using a Scan Maker i900 (Microtek, Willich, Germany). 181 digital ephalograms were stored on a CD-ROM in digital format and were taken with an Orthopantomograph OP200D (Instrumentarium Oy, Tuusula, Finland) with an average exposure time of 10 seconds and at values of 85 kV – 13 mA.

Cephalometric analysis was performed with DOLPHIN IMAGE software (v.11.0). To prevent magnification error and to calibrate each cephalogram in the DOLPHIN software to obtain real linear values, pictures were taken with a metal calibration ruler incorporated in the cephalostat and two ruler points reproduced on the headfilm.



Slika 1. Kefalometrijske točke korištene u ovom istraživanju: S – *sella*; N – *nasion*; Co – *condilion*; Ar – *articulare*; A – točka A (*subspinale*); ANS – *spina nasalis anterior*; PNS – *spina nasalis posterior*; Gn – *gnathion*; Go – *gonion*; Me – *menton*

Figure 1 Landmarks used in the study: S indicates Sella; N,nasion; Co, condilion; ar, articulare; A, point A (subspinale); ANS, anterior nasal spine; PNS, posterior nasal spine; Gn, gnathion; Go, gonial intersection; Me, menton

Na svakom kefalogramu je deset kefalometrijskih točaka koje označavaju tvrda tkiva (slika 1). Iz tih točaka zabilježeno je i analizirano 13 angularnih i linearnih mjerenja. Sva mjerenja su klasificirana u pet kategorija za analizu – kranijalna baza, skeletni maksilarni i skeletni mandibularni odnosi, sagitalni međučeljusni i vertikalni odnosi (tablica 1.). Kao mjera za svrstavanje u kategoriju obrasca rasta lica korištena su tri parametra – Bjorkov, Jarabakov i N N – Me : S – Go omjer. Ako su barem dva upućivala na isti obrazac rasta, pacijent je svrstan u dotičnu kategoriju.

On each cephalogram, ten cephalometric landmarks, representing hard tissues, were identified (Figure 1). From these landmarks, thirteen angular and linear measurements were recorded and analysed. The measurements were divided into five categories for analysis: cranial base, skeletal maxillary and skeletal mandibular relationships, sagittal intermaxillary and vertical relationships (Table 1). To determine the vertical growth pattern, the Bjork and Jarabak analysis and N-Me/S-Go were used. If at least two parameters indicated the same growth pattern, the patient was classified in that category.

Tablica 1. Pet kategorija za analizu
Table 1 Five categories for the analysis

Kranijalna baza • Cranial base
Linearno • Linear: S – N, S – Ar
Angularno • Angular: N – S – Ar
Skeletne maksilarne varijable • Maxillary skeletal relationships variables
Linearno • Linear: Co – A
Angularno • Angular: S – N : ANS – PNS
Skeletne mandibularne varijable • Mandibular skeletal relationships variables
Linearno • Linear: Co – Gn, Ar – Go, Go – Gn
Angularno • Angular: Me – Go – Ar, Me – Go : S – N
Sagitalni međučeljusni odnosi • Intermaxillary relationships variables
Angularno • Angular: ANS – PNS : Me – Go
Vertikalni odnosi • Vertical relationships
Linearno • Linear: N – Me, S – Go
Omjer • Ratio: S – Go : N – Me (%)

Statistička analiza

Statistička analiza obavljena je u komercijalnom programu Statistical Package for Social Sciences (verzija 10,0, SPSS, Čikago, SAD). Razina značajnosti postavljena je na P vrijednost < 0,05. Normalnost svih kefalometrijskih varijabli upotrijebljenih za multivarijatne testove potvrđena je Shapiro-Wilkovim testom. Nakon deskriptivne statistike korištena je višestruka linearna regresijska analiza za procjenu jesu li dužinske vrijednosti maksile, mandibule i kranijalne baze prediktori obrasca rasta lica u slučaju anomalija skeletne klase III. S obzirom na to da dob i spol mogu utjecati na rezultate i zbunjivati, njihovo značenje također je testirano i uključeno u analizu.

Da bismo testirali pogrešku mjerenja za kefalometrijske varijable u ovom istraživanju, 30 slučajno odabranih lateralnih kefalograma ponovno su analizirani mjesec dana poslije – to je učinio isti ispitivač – te su ponovno mjereni intraklasnim korelacijskim koeficijentom (ICC) s pripadajućim 95-postotnim intervalima pouzdanosti, pogreškom mjerenja (engl. *measurement error* – ME), najmanjom detektabilnom promjenom (engl. *smallest detectable change* – SDC), granicom slaganja (engl. *limits of agreement* – LoA) i udjelom razlika između dvaju mjerenja koja se nalaze unutar granica slaganja. ME je izračunat prema Blandu i Altmanu kao drugi korijen rezidualnog prosječnog kvadrata iz analize varijance (22).

Reproducibilnost ispitivača u mjerenju bila je znatna do izvrsna (ICC = 0,65 – 1,00). Pogreška mjerenja bila je niska (raspon 0,12 – 3,01) i uvijek je bila manja od biološke varijabilnosti pripadajuće varijable.

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences software (version 10.0, SPSS, Chicago, SAD). The level of significance was set at P-values of < 0.05.

The normality of all cephalometric variables used for multivariate tests was confirmed using the Shapiro-Wilk test. After deriving descriptive statistics, multiple linear regression analysis was used to study the associations between linear measurements of maxilla, mandible and cranial base and facial growth rotation. As age and gender may influence the results and act as confounders, their significance was also tested for inclusion in the analysis.

To test the measurement error for the cephalometric variables used in this study, the lateral cephalograms of 30 randomly selected patients were redigitized 1 month later by the same examiner and were measured again using intraclass correlation coefficients (ICCs) with their respective 95% confidence intervals, measurement errors (MEs), smallest detectable changes (SDCs), limits of agreement (LoAs) and the relationship between the differences of the two measurements that were within the limits of agreement.

ME was measured according to the procedure described by Bland and Altman as the square root of the mean square error from an analysis of variance (22).

Intraexaminer reproducibility was substantial to excellent (ICC=0.65-1.00). Measurement error was low (0.12-3.01) and was always lower than the biological variability of the associated variables.

Rezultati

Model multiple linearne regresije za predikciju obrasca rasta lica procijenjenu Jarabakovim omjerom

Univarijatne korelacije prikazane su u tablici 2. Uz kontrolu spola, dužinske vrijednosti maksile, mandibule i kranijalne baze statistički su značajni prediktori rotacijskog obrasca rasta lica procijenjenog Jarabakovim omjerom ($p < 0,001$). Cijeli regresijski model objašnjava 69,3 % varijabiliteta rotacijskog rasta lica. Najveći samostalni doprinos objašnjenju varijabiliteta rotacijskog rasta lica daje visina ramusa (Ar – Go) i efektivna dužina mandibule (Co – Gn) koje objašnjavaju 46,8 i 34,3 % varijabiliteta. Najmanji je udjel u objašnjavaju dužina prednje lubanjske jame (S – N) i maksile (Co – A) - od 3,1 i 4,8 % (tablica 3.). Tendencija prema horizontalnom obrascu rasta povezana je sa smanjenjem S – N-a i povećanjem stražnje lubanjske jame (S – Ar), povećanjem Co – A-e, visine ramusa i dužine mandibularnog korpusa (Ar – Go) te

Results

The multiple linear regression model for prediction of facial rotation pattern estimated by the Jarabak's ratio

Univariate correlations are presented in Table 2. With the control of gender, linear measurements of the maxilla, mandible and cranial base are statistically significant predictors of facial growth rotation estimated by the Jarabak's ratio ($p<0.001$). The entire regression model accounts for 69.3% of variability of the facial growth rotation. The largest independent contribution to the explanation of rotation pattern variability is the height of the ramus (Ar-Go) and the effective length of the mandible (Co-Gn) accounting for 46.8 and 34.3% of the variability. The length of anterior cranial base (S-N) and the length of maxilla (Co-A) (3.1 and 4.8%) (Table 3) had the smallest contribution. The horizontal growth pattern tendency was associated with shorter S-N, longer posterior cranial base length (S-Ar), longer Co-A, longer Ar-

Tablica 2. Spearmanove korelacije
Table 2 Spearman's correlation

		Jarabak	s-n	s-ar	co-a	ar-go	go-gn	co-gn	Spol • Gender	Dob • Age
Jarabak	r	1.000	0.112	0.362	0.211	0.418	-0.008	0.005	-0.050	0.049
s-n	r		1.000	0.475	0.820	0.576	0.691	0.708	-0.219	0.289
s-ar	r			1.000	0.597	0.413	0.483	0.549	-0.229	0.315
co-a	r				1.000	0.572	0.759	0.781	-0.205	0.316
ar-go	r						0.495	0.745	-0.172	0.530
go-gn	r						1.000	0.870	-0.135	0.447
co-gn	r							1.000	-0.209	0.570
gender	r								1.000	-0.058
age	r									1.000
Jarabak	p	.	0.056	<0.001	0.001	<0.001	0.456	0.472	0.242	0.243
s-n	p		.	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
s-ar	p			.	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
co-a	p				.	<0.001	<0.001	<0.001	0.002	<0.001
ar-go	p					.	<0.001	<0.001	0.007	<0.001
go-gn	p						.	<0.001	0.028	<0.001
co-gn	p							.	0.001	<0.001
Spol • Gender	p								.	0.205
Dob • Age	p									.

Tablica 3. Model multiple linearne regresije za predikciju obrasca rasta procijenjenu Jarabakovim omjerom stražnje i prednje visine lica
Table 3 Multivariate linear regression model for prediction of rotational growth pattern estimated by Jarabak's ratio posterior and anterior facial height

	Nestandardizirani koeficijent B • Non-standardized coefficient B	Std. pogreška • Standard error	Standardizirani koeficijent Beta • Standardized coefficient Beta	Sig.	Korelacije • Correlations		
					Nultog reda • Zero order	Parcijalna • Partial	Semiparcijalna • Semipartial
(konstanta) • (Constant)	62.066	2.768		<0.001			
s-n	-0.296	0.066	-0.323	<0.001	0.112	-0.307	-0.176
s-ar	0.494	0.058	0.428	<0.001	0.362	0.524	0.335
co-a	0.314	0.057	0.466	<0.001	0.211	0.371	0.218
ar-go	0.901	0.052	1.196	<0.001	0.418	0.782	0.684
go-gn	0.346	0.051	0.647	<0.001	-0.008	0.436	0.264
co-gn	-0.720	0.048	-1.822	<0.001	0.005	-0.733	-0.586
Spol • Gender	-0.135	0.356	-0.016	0.706	-0.050	-0.027	-0.015

$R=0.839$; $R^2=0.703$; Prilagođeni • Adjusted $R^2=0.693$; $p<0.001$

smanjenjem Co – Gn-a (tablice 2 i 3). Spol nije značajan prediktor rotacijskog obrasca rasta lica. Dob pozitivno linearno korelira sa svakom linearnom varijablom (raspon r = 0,29 – 0,57) te je u multiploj regresiji stvarala problem multikolinearnosti zbog čega nije uključena u analizu.

Model multiple linearne regresije za predikciju obrasca rasta lica procijenjenu inklinacijom mandibularne ravnine na kranijalnu bazu

Cijeli regresijski model objašnjava 60,5 % varijabiliteta rotacijskog rasta lica (p < 0,001; tablica 4.). Uz kontrolu spola, tendencija prema vertikalnom obrascu rasta povezana je s povećanjem S – N-a i smanjenjem S – Ar-a, Co – A-e, Ar – Go-a, Go – Gn-a te povećanjem Co – Gn-a. Najveći samostalni doprinos objašnjenju varijabiliteta rotacijskog rasta lica daju Ar – Go i Co – Gn koji objašnjavaju 29,4 i 51,3 % varijabiliteta. Najmanji je udjel u objašnjenju S – N-a i S – Ar-a od 2,2 i 2,8 %. Spol ponovno nije značajan prediktor obrasca rotacijskog rasta lica, ali ni dob zbog problema multikolinearnosti, pa nisu uključeni u analizu.

Go, longer length of mandibular corpus (Go-Gn) and shorter Co-Gn. The age positively linearly correlated with each linear variable (range r = 0.29-0.57) and it was creating a problem of multicollinearity in the multiple regression analysis, which is why it was not included in the analysis.

The multiple linear regression model for prediction of facial rotation pattern estimated by angle between the mandibular plane and cranial base

The mandibular plane angle model accounted for 60.5% of the varibility in facial rotation pattern (p<0.001; Table 4). With the control of gender, the vertical growth pattern tendency was associated with longer S-N and decreased S-Ar, Co-A, Ar-Go,Go-Gn and increased Co-Gn. Ar-Go and Co-Gn contributed the most (29.4 and 51.3%, respectively). The S-N and S-Ar (2.2 and 2.8%) had the smallest contribution. Again, gender was not a significant predictor and age was not included due to multicolinearity problem.

Tablica 4. Model multiple linearne regresije za predikciju obrasca rasta procijenjenu inklinacijom baze mandibule na kranijalnu bazu
Table 4 Multivariate linear regression model for prediction of rotational growth pattern estimated by inclination of the mandible in relation to the cranial base

	Nestandardizirani koeficijent B • Non-standardized coefficient B	Std. pogreška • Standard error	Standardizirani koeficijent Beta • Standardized coefficient Beta	Sig.	Korelacije • Correlations		
					Nultog reda • Zero order	Parcijalna • Partial	Semiparcijalna • Semipartial
(konstanta) • (Constant)	37.877	4.290		0.000			
s-n	0.339	0.102	0.271	0.001	-0.161	0.232	0.147
s-ar	-0.334	0.090	-0.212	<0.001	-0.222	-0.259	-0.166
co-a	-0.617	0.088	-0.672	<0.001	-0.266	-0.452	-0.313
ar-go	-0.976	0.080	-0.948	<0.001	-0.186	-0.660	-0.542
go-gn	-0.847	0.080	-1.159	<0.001	-0.122	-0.608	-0.473
co-gn	1.201	0.075	2.225	<0.001	0.053	0.757	0.716
Spol • Gender	0.443	0.551	0.037	0.422	0.018	0.058	0.036
R=0.786; R^2=0.618; Prilagođeni • Adjusted R^2=0.605; p<0.001							

Model multiple linearne regresije za predikciju obrasca rasta lica procijenjenu Bjorkovim poligonom

Nalaz regresije koji kao ishodnu varijablu uzima inklinaciju mandibularne ravnine na kranijalnu bazu, potvrđuje i regresija s Bjorkovim poligonom kao ishodom (tablica 5).

Multiple linear regression model for prediction of facial rotation pattern estimated by Bjork polygon

A finding of regression that as an initial variable assumes inclination of the mandibular plane in relation to the cranial base also confirms regression with Bjork polygon as the outcome, accountig for 60.6% of variability (Table 5).

Tablica 5. Model multiple linearne regresije za predikciju obrasca rasta procijenjenu Bjorkovim poligonom
Table 5 Multivariate linear regression model for prediction of rotational growth pattern estimated by Bjork polygon

	Nestandardizirani koeficijent B • Non-standardized coefficient B	Std. pogreška • Standard error	Standardizirani koeficijent Beta • Standardized coefficient Beta	Sig.	Korelacije • Correlations		
					Nultog reda • Zero order	Parcijalna • Partial	Semiparcijalna • Semipartial
(konstanta) • (Constant)	397.843	4.278		0.000			
s-n	0.340	0.102	0.272	0.001	-0.161	0.233	0.148
s-ar	-0.333	0.089	-0.211	<0.001	-0.222	-0.259	-0.165
co-a	-0.619	0.087	-0.674	<0.001	-0.267	-0.454	-0.315
ar-go	-0.977	0.080	-0.950	<0.001	-0.187	-0.661	-0.543
go-gn	-0.844	0.079	-1.158	<0.001	-0.121	-0.608	-0.472
co-gn	1.200	0.074	2.226	<0.001	0.054	0.758	0.716
Spol • Gender	0.445	0.550	0.038	.420	0.018	0.058	0.036
R=0.787; R^2=0.620; Prilagođeni • Adjusted R^2=0.606; p<0.001							

Model multiple linearne regresije za predikciju obrasca rasta lica procijenjenu inklinacijom maksilarne ravnine na bazu lubanje

Statistički značajni prediktori obrasca rotacijskog rasta maksile su S – N i S – Ar te spol (tablica 6.). Posteriorna rotacija maksile povezana je sa ženskim spolom, povećanjem S – N-a i smanjenjem S – Ar-a. Model opisuje 14,3 % varijabiliteta, a najznačajniji samostalni doprinos daje S – Ar (7,1 %).

Multiple linear regression model for prediction of facial rotation pattern estimated by inclination of the maxillary plane to the cranial base

The statistically significant predictors of the growth rotation of the maxilla were the S-N and S-Ar and gender (Table 6). The posterior rotation of maxilla, which is related to female gender, increased S-N and reduced S-Ar. The model accounted for 14.3% of variability and the most significant independent contribution gave S-Ar (7.1%).

Tablica 6. Model multiple linearne regresije za predikciju obrasca rasta maksile procijenjenu inklinacijom maksile na bazu lubanje
Table 6 Multivariate linear regression model for prediction of rotational growth pattern estimated by inclination of the maxilla in relation to the cranial base

	Nestandardizirani koeficijent B • Non-standardized coefficient B	Std. pogreška • Standard error	Standardizirani koeficijent Beta • Standardized coefficient Beta	Sig.	Korelacije • Correlations		
					Nultog reda • Zero order	Parcijalna • Partial	Semiparcijalna • Semipartial
(konstanta) • (Constant)	7.539	3.609		0.038			
s-n	0.207	0.086	0.290	0.017	-0.053	0.171	0.158
s-ar	-0.307	0.075	-0.340	<0.001	-0.337	-0.281	-0.266
co-a	-0.018	0.074	-0.035	0.803	-0.151	-0.018	-0.016
ar-go	-0.085	0.067	-0.144	0.210	-0.150	-0.090	-0.082
go-gn	-0.090	0.067	-0.215	0.183	-0.154	-0.096	-0.087
co-gn	0.052	0.063	0.170	0.405	-0.172	0.060	0.055
Spol • Gender	1.277	0.464	0.188	0.006	0.228	0.194	0.180

R=0.416; R^2=0.173; Prilagođeni • Adjusted R^2=0.143; p<0.001

Model multiple linearne regresije za predikciju obrasca rasta lica procijenjenu međučeljusnim kutom

Statistički značajni prediktori divergentnog obrasca rasta čeljusti su smanjenje Co – A-e, Ar –Go-a i Go – Gn-a te povećanje Co – Gn-a (tablica 7.). Cijeli regresijski model objašnjava 56,8 % varijabiliteta rotacijskog rasta lica.

Multiple linear regression model for prediction of facial rotation pattern estimated by intermaxillary plane angle

Significant predictors of hyperdivergent jaw growth pattern were decreased Co-A, decreased Ar-Go and Go-Gn and increased Co-Gn (Table 7). The entire regression model accounted for 56.8% of the rotational growth variability.

Tablica 7. Model multiple linearne regresije za predikciju međučeljusnog rotacijskog rasta procijenjenu međučeljusnim kutom
Table 7 Multivariate linear regression model for prediction of rotational growth pattern estimated by intermaxillary angle

	Nestandardizirani koeficijent B • Non-standardized coefficient B	Std. pogreška • Standard error	Standardizirani koeficijent Beta • Standardized coefficient Beta	Sig.	Korelacije • Correlations		
					Nultog reda • Zero order	Parcijalna • Partial	Semiparcijalna • Semipartial
(konstanta) • (Constant)	30.281	4.371		0.000			
s-n	0.133	0.104	0.109	0.203	-0.133	0.092	0.059
s-ar	-0.026	0.091	-0.017	0.775	-0.031	-0.021	-0.013
co-a	-0.599	0.089	-0.668	<0.001	-0.184	-0.435	-0.312
ar-go	-0.891	0.082	-0.888	<0.001	-0.104	-0.618	-0.508
go-gn	-0.756	0.081	-1.061	<0.001	-0.034	-0.557	-0.433
co-gn	1.147	0.076	2.179	<0.001	0.155	0.736	0.701
Spol • Gender	-0.826	0.562	-0.071	0.143	-0.115	-0.105	-0.068

R=0.764; R^2=0.584; Prilagođeni • Adjusted R^2=0.568; p<0.001

Rasprava

Anomalija klase III može biti rezultat mnogobrojnih kombinacija skeletnih i dentoalveolarnih komponenti. Sadržava morfološke značajke koje se razlikuju u različitim etničkim skupinama (23). Ortodonti bi trebali poznavati morfološke značajke lica tih različitih etničkih skupina kako bi u

Discussion

Class III malocclusion can contain many combinations of skeletal and dentoalveolar elements. All those morphological features differ from population to population (23). The knowledge of various morphological features is important to make the outcome of the therapy as complete and individual cijelosti postigli svrhu liječenja. Unatoč preporukama za rani početak terapije anomalije skeletne klase III, u kasnom pubertalnom rastu može se pojaviti recidiv koji zahtijeva kiruršku intervenciju. Terapija obraznom maskom za pacijente s anomalijom klase III rezultira pomakom gornje čeljusti prema naprijed i dolje te pomakom donje čeljusti prema straga (24 – 27). Rotacijske promjene čeljusti koje se pojavljuju uz translacijske pomake mogu potaknuti neželjene učinke kod ispitanika s prekomjernim rastom vertikalne dimenzije lica (28 – 30). To može pogoršati već postojeći hiperdivergentni profil. U slučaju pacijenata s maksilarnom retruzijom i malim gonijalnim kutom, terapija obraznom maskom povećava visinu lica i postižu se povoljni estetski rezultati (31). Zato je obrazac rasta vrlo važan u odluci o terapiji. Anomalije klase III povezane s vertikalnim obrascem rasta klinički se najteže liječe, ortodontski ili ortopedski. Svrha ovog istraživanja bila je utvrditi mogu li dužinske vrijednosti maksile, mandibule i kranijalne baze biti prediktori rotacijskog obrasca rasta lica među ispitanicima hrvatske populacije s anomalijom klase III, što bi bilo od velike pomoći u odlučivanju o vremenu liječenja i odabiru terapije (ortodontska, ortopedska, kirurška).

U tu svrhu korišteno je pet predikcijskih modela.

U prvom modelu najveći samostalni doprinos objašnjenju varijabiliteta rotacijskog rasta lica daje visina ramusa. Očekuje se da je povećana visina ramusa povezana s horizontalnim obrascem rasta lica, kao i u istraživanju Siriwata i Jarabaka (32). Drugi najveći doprinos daje efektivna dužina mandibule. Pretpostavlja se da je smanjenje efektivne dužine mandibule posljedica smanjenja gonijalnog kuta, odnosno rotacije mandibule oko točke gonion. Dužina prednje kranijalne baze i dužina maksile slabi su prediktori rotacijskog obrasca rasta lica. To može biti zbog varijabilnosti u položaju točke A– supraspinale i točke N – nasion tijekom rasta, što može dovesti do kontradiktornih nalaza.

U većini dosadašnjih istraživanja autori su procjenjivali prediktore ishoda ortodontskog liječenja anomalije klase III gdje su provedene diskriminantne funkcije ili regresijske analize kako bi se identificirali skupovi varijabli koji pokazuju najveću sklonost prema predviđanju (modeli predviđanja). Fudalej (33) je pripremio sustavni pregled u kojemu je 14 identificiranih članaka pokazalo da ne postoje studije koje dijele identičan skup prediktora ishoda terapije. Naprotiv, postojala je znatna raznolikost prediktora. Unatoč provedenim opsežnim kefalometrijskim analizama, samo dvije varijable koje imaju predikcijsku vrijednost istodobno su uspostavljene u više negoli jednom istraživanju, a to su dužina mandibularnog ramusa (34, 35) i ukupna, tj. efektivna dužina mandibule (35, 36). Slično je i u ovom istraživanju u kojemu najveći samostalni doprinos objašnjenju varijabilnosti rotacijskog rasta lica daju visina ramusa i efektivna dužina mandibule.

U drugom i trećem modelu, kao što se i očekivalo, povećana efektivna dužina mandibule najjači je prediktor vertikalnog obrasca rasta lica. No zanimljivo je napomenuti da su smanjenje ramusa i mandibularnog korpusa prediktori mandibularne postrotacije. Slično su pronašli Isaacson i suradnici (37) o visini ramusa. U svojem istraživanju zaključili su da je prosječna visina ramusa obrnuto proporcionalna kutu na-

as possible. Although some orthodontists recommend early treatment of skeletal Class III malocclusion, relapse can occur due to the postadolesent growth and therefore the case may become surgical. The therapy with facemask can displace maxilla forward and downward and the mandible backward (24-27). Those rotational and translational movements may lead to unwanted effects in high angle patients (28-30). It will worsen pre-existing hyperdivergent facial profile. In patients with maxillary retrognathism and small gonial angle, facemask therapy increases the vertical dimension and causes a favorable esthetic change (31). That is why the growth pattern is quite important in therapy decision. The patients with Class III malocclusion and vertical growth pattern are considered the most difficult to treat. The aim of this study was to determine whether the linear values of the maxilla, mandible and cranial base could be predictors of facal growth rotation in a Croatian population with Class III malocclusion which would be of great help when making a decison about the treatment timing and choice of therapy (orthodontic, orthopaedic, surgical).

Five prediction models were used.

In the first model, the largest contribution to the explanation of rotation pattern variability was the height of the ramus. It was expected that the longer ramus height is associated with the horizontal growth pattern, which is in agreement with the study of Siriwat and Jarabak (32). The second largest contribution was the effective length of the mandible. It is likely that the reduction in the effective length of the mandible is due to reduction of the gonial angle, that is because of the mandibular rotation around the point of the gonion. The anterior cranial base length and the length of maxilla were poor predictors of facial rotation pattern. This can be explained by the fact that there is variability in the position of point A-supraspinale and point N-nasion during growth, which can lead to contradictory findings.

The majority of authors of previous studies assessed predictors of the result of orthodontic treatment in Class III patients where discriminant function or regression analyses were used to identify the variables showing the highest prediction potential (prediction models). Fudalej (33) made a systematic review based on 14 selected scientific papers and found out that there were no studies having the same predictors of treatment outcome. Despite the extensive cephalometric analyses carried out, only the mandibular ramus length (34, 35) and total mandibular length (35,36) appeared in more than one research. These findings are in line with our study where the largest independent contribution to the explanation of rotation growth pattern variability is the height of the ramus and the effective i.e. total length of the mandible.

In the second and third model as expected, an increased effective length of the mandible was the strongest predictor of vertical rotation pattern. However, it should be pointed out that the reduction of ramus and mandibular corpus is a predictor of mandibular post-rotation. Isaacson et al. (37) obtained similar results regarding the height of the ramus. The mean height of the ramus was reversly related to the SN-MP angle i.e. ramus was shorter in the high and largest in the low angle group.

giba mandibularne ravnine prema kranijalnoj bazi (MP – SN kutu), tj. ramus je kraći što je MP – SN kut veći i obrnuto.

Smanjena dužina maksile također je prediktor vertikalnog obrasca rasta. To može biti zbog toga što je maksila smještena distalnije i uzrokuje postrotaciju mandibule kao posljedicu kompenzacijskog mehanizma. Slične podatke dobili su Ferrario i suradnici (38) koji su proučavali odnos između mandibularne veličine i oblika prema skeletnoj divergenciji (prema MP – SN kutu) i ustanovili da hiperdivergentni ispitanici općenito imaju manju maksilu i mandibulu.

U četvrtom modelu zanimljivo je da dužina maksile uopće nije prediktor rotacijskog rasta maksile, nego samo prednja i stražnja duljina kranijalne baze (povećan S – N i smanjen S – Ar povezani su sa stražnjom rotacijom maksile). To se može objasniti činjenicom da duljina Co – A utječe na anteroposteriorni položaj maksile, a rast kranijalne baze (prednji dio) uzrokuje translaciju nasomaksilarnog kompleksa (sekundarni pomak) i utječe i na vertikalnu dimenziju. Značajno veća srednja vrijednost kuta nagiba gornje čeljusti prema kranijalnoj bazi (ANS – PNS : S – N) kod žena negoli kod muškaraca znači da je maksila više usmjerena prema dolje u odnosu prema bazi lubanje; to se može odnositi na kaudalni rotacijski rast čeljusti kod žena.

U petom modelu statistički značajni prediktori divergentnog obrasca rasta čeljusti su smanjena dužina maksile, smanjenje visine ramusa i dužine korpusa mandibule te povećanje efektivne dužine mandibule. Bjork (39) je tvrdio da je otvoreni zagriz povezan s većom visinom ramusa mandibule, a Sassouni (40) i Schudy (17) isticali su da je otvoreni zagriz povezan sa smanjenom visinom ramusa mandibule. Hellman (41) je izvijestio da isključivo smanjena visina ramusa i smanjena dužina korpusa mandibule dovode do otvorenog zagriza prije negoli vertikalni razvoj nazomaksilarnog kompleksa.

U četiri od pet modela, vertikalni obrazac rasta je povezan sa smanjenom visinom ramusa, smanjenom duljinom mandibularnog korpusa i povećanom efektivnom dužinom mandibule. Slično su istaknuli u istraživanju Mangla i suradnici (42) o mandibularnoj morfologiji u različitim vrstama lica, naime, da se visina ramusa značajno povećava u hipodivergentnim i normodivergentnim skupinama u usporedbi s hiperdivergentnom skupinom. Ti su rezultati bili u skladu i sa zaključcima Sassounija (40, 43), Mullera (44) i Schudya (17) koji su uočili značajno smanjenje širine i visine ramusa u hiperdivergentnoj skupini. Taj se nalaz može objasniti vrlo značajnom negativnom korelacijom između visine ramusa i kutova mandibularne rotacije (SN – MP, PP – MP, Ar – Go – Me) koji kompenziraju učinak spuštanja mandibule s povećanjem visine ramusa i tako smanjuju njezin učinak na visinu prednjeg lica.

Zaključak

Efektivna dužina mandibule najznačajniji je prediktor rotacijskog rasta lica pri čemu povećana dužina u velikoj mjeri predisponira tendenciju vertikalnom obrascu rasta. Nije pronađena značajna spolna dihotomija, osim u četvrtom modelu gdje je stražnja rotacija maksile povezana sa ženskim spolom.

A decreased maxillary length was also a predictor of vertical rotation pattern. This may be because the maxilla is positioned more distally, thus causing the post-rotation of the mandible. Similar results was given by Ferrario et al. (38). The aim of theit study was to find the relationship between the mandibular size and the shape to skeletal divergency (according to MP-SN angle) and found that hyperdivergent subjects generally have a smaller maxilla and mandible.

In the fourth model is interesting that the length of the maxilla is not at all a predictor of the rotational growth of the maxilla, only anterior and posterior cranial base length (increased S-N and reduced S-Ar are related to the posterior rotation of the maxilla). It my be explained by the fact that the length Co-A affects anteroposterior position of maxilla whereas the growth of cranial base (anterior part) causes the translation of the nasomaxillary complex-secondary displacement and affects also a vertical dimension. Significantly higher mean value of ANS-PNS:S-N angle in females than males means that the maxillary plane is more downward positioned relative to the cranial base; this may relate to a caudal jaw growth rotation in females.

In the fifth model, the statistically significant predictors of divergent jaw growth pattern are a decreased maxillary length, decrease of ramus height and mandibular corpus length, and increase in effective mandibular length. Björk (39) demonstrated that an open bite is associated with a large ramus while Sassouni (40) and Schudy (17) reported that open bite usually goes with shorter ramus. Hellman (41) suggested that a short ramus and corpus, rather than vertical development in nasomaxillary complex, leads to the development of open bite.

In four out of five models, the vertical growth pattern is assocciated with decreased ramus height and mandibular corpus length and increased effective mandibular length. Mangla et al. (42) evaluated mandibular morphology in different facial types and found a significantly increased ramus height in hypodivergent and normodivergent groups when compared to hyperdivergent group. These results coincide with conclusions of a study by Sassouni (40, 43), Muller (44) and Schudy (17) who observed a significant reduction in the width and height of ramus in the hyperdivergent group. This finding may be explained by highly significant negative correlations between the ramus height and angles of mandibular rotations (SN-MP, PP-MP, Ar-Go-Me), which compensate the effect of downward mandibular movement with the increase in ramus heigh,t and hence decrease its effect on the anterior facial height.

Conclusion

The effective length of the mandible was the most important predictor of facial rotation pattern, with the increased length largerly predisposing the tendency to the vertical growth pattern. No significant dichotomy regarding gender was found except in the fourth model where the posterior rotation of the maxilla is related to female gender.

Kod pacijenata s maksilarnim retrognatizmom, zbog veće visine mandibularnog ramusa i kraće efektivne dužine mandibule, veća je vjerojatnost da će rana terapija obraznom maskom biti uspješna.

Sukob interesa

Nije bilo sukoba interesa.

A patient with maxillary retrognathism and greater height of mandibular ramus and shorter effective length of mandible is more likely to succeed in early treatment with facemask therapy.

Conflict of interest

None declared

Abstract

Objectives: The objective of this study was to determine whether the linear measures of the maxilla, mandible and cranial base were predictors of facial growth rotation in a Croatian population with Class III malocclusion by cephalometric radiographic methods. **Material and methods**: The examined sample consisted of pretreatment lateral cephalometric records of 201 (111 females and 90 males) untreated Class III patients of Caucasian Croatian ancestry from the Department of Orthodontics at Zagreb University. The measurements were divided into five categories for analysis: cranial base, skeletal maxillary and skeletal mandibular relationships, sagittal intermaxillary and vertical relationships. Five multiple linear regression models were used to identify predictors of facial rotation pattern. **Results:** The effective length of the mandible was the most important predictor of facial rotation pattern, with the increased length largerly predisposing the tendency to the vertical growth pattern. No significant dichotomy was found regarding gender apart from the fourth model in which the posterior rotation of maxilla is related to female gender. **Conclusion:** These predictors could help orthodontists determine timing and therapy for Croatian patients with Class III malocclusions.

Received: May 21, 2018
Accepted: July 15, 2018

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Key words
Malocclusion Angle Class III; Facial Bones; Cephalometry; Facial Asymmetry

References

1. Franchi L, Baccetti T, Tollaro I. Predictive variables for the outcome of early functional treatment of Class III malocclusion. Am J Orthod and Dentofacial Orthop. 1997 Jul;112(1):80-6.
2. Cruz RM, Krieger H, Ferreira R, Mah J, Hartsfield Jr J, Oliveira S. Major gene and multifactorial inheritance of mandibular prognathism. Am J Med Genet A. 2008 Jan 1;146A(1):71-7.
3. Yamaguchi T, Park SB, Narita A, Maki K, Inoue I. Genome-wide-linkage analysis of mandibular prognathism in Korean and Japanese patients. J Dent Res. 2005 Mar;84(3):255-9.
4. Frazier-Bowers S, Rincon-Rodriguez R, Zhou J, Alexander K, Lange E. Evidence of linkage in a Hispanic cohort with a class III dentofacial phenotype. J Dent Res. 2009 Jan;88(1):56-60.
5. Jang JY, Park EK, Ryoo HM, Shin HI, Kim TH, Jang JS et al. Polymorphism in the Matrilin-1 gene and risk of mandibular prognathism in Koreans. J Dent Res. 2010 Nov;89(11):1203-07.
6. Perillo L, Monsurro A, Bonci E, Torella A, Mutarelli M, Nigro V. Genetic Association of ARHGAP21 Gene Variant with Mandibular Prognathism. J Dent Res. 2015 Apr;94(4):569-76.
7. Da Fontoura CSG, Miller SF, Wehby GL, Amendt BA, Holton NE, Southard TE et al. Candidate gene analyses of skeletal variation in malocclusion. J Dent Res. 2015 Jul;94(7):913-20.
8. Tassopoulou-Fishell M, Deeley K, Harvey EM, Sciote J, Vieira AR. Genetic variation in myosin 1H contributes to mandibular prognathism. Am J Orthod Dentofacial Orthop. 2012 Jan;141(1):51-9.
9. HE S, Hartsfield Jr JK, Guo Y, Cao Y, Wang S, Chen S. Association between CYP19A1 genotype and pubertal sagittal jaw growth. Am J Orthod Dentofacial Orthop. 2012 Nov;142(5):662-70.
10. Garn SM, Lewis AB, Kerewsky RS. The meaning of bilateral asymmetry in the permanent dentition. Angle Orthod. 1966 Jan;36(1):55-62.
11. Harris EF, Bodford K. Bilateral asymmetry in the tooth relationships of orthodontic patients. Angle Orthod. 2007 Sep;77(5):779-86.
12. Baydaş B, Oktay H, Metin Dağsuyu I. The effect of heritability on Bolton tooth-size discrepancy. Eur J Orthod. 2005 Feb;27(1):98102.
13. Škrinjarić A, Šlaj M, Šlaj M. Fluctuating Dental Arch Asymmetry in Different Malocclusion Groups. Acta stomatol Croat. 2018;52(2):105-113.
14. Hardy DK, Cubas YP, Orellana MF. Prevalence of angle Class III malocclusion: A systematic review and meta-analysis. Open J Epidemiol. 2012 Nov;2(4):75-82.
15. Ngan P. Early treatment of Class III malocclusion. Semin Orthod. 2005 Sep;11(3):140-5.
16. Onyeaso CO. Prevalence of malocclusion among adolescents in Ibadan, Nigeria. Am J Orthod Dentofacial Orthop. 2004 Nov; 126(5):604-7.
17. Schudy FF. Vertical growth versus anteroposterior growth as related to function and treatment. Angle Orthod. 1964 Apr;34(2):75–93.
18. Jarabak, JR; Fizzell, JA – editors. Technique and treatment with light wire edgewise appliance. CV Mosby: St Louis; 1972.
19. Moon YM, Ahn SJ, Chang Y. Cephalometric predictors of long-term stability in the early treatment of Class III malocclusion. Angle Orthod. 2005 Sep;75(5):747-53.
20. Tahmina K, Tanaka E, Tanne K. Craniofacial morphology in orthodontically treated patients of Class III malocclusion with stable and unstable treatment outcomes. Am J Orthod Dentofac Orthop. 2000 Jun;117(6):681-90.
21. Muretić Z. Computer modification of radiographic cephalometric analysis „Zagreb 82“. Period Biolog. 1993; 95:137-40.
22. Bland JM, Altman DG. Statistics notes: measurement error. BMJ. 1996; 313:744.
23. Bui C, King T, Proffit W, Frazier-Bowers S. Phenotypic characterization of Class III patients. Angle Orthod. 2006 Jul;76(4):564-9.
24. Macdonald KE. Kapust AJ. Turley PK.Cephalometric changes after the correction of class III malocclusion with maxillary expansion/facemask therapy. Am J Orthod. Dentofacial Orthop. 1999 Jul;116(1):13–24.
25. Ngan P. Yiu C. Hu A. Hagg U. Wei SH. Gunel E.Cephalometric and occlusal changes following maxillary expansion and protraction. Eur J Orthod. 1998 Jun;20(3):237–54.
26. Turley PK.Treatment of the class III malocclusion with maxillary expansion and protraction. Semin Orthod. 2007 Sep;13(3):143–57.
27. Vaughn GA. Mason B. Moon HB. Turley PK.The effects of maxillary protraction therapy with or without rapid palatal expansion: a prospective, randomized clinical trial. Am J Orthod Dentofacial Orthop. 2005 Sep;128(3):299–309.
28. Deguchi T. Kanomi R. Ashizawa Y. Rosenstein SW.Very early face mask therapy in class III children. Angle Orthod. 1999 Aug;69(4):349–55.
29. Kajiyama K. Murakami T. Suzuki A. Comparison of orthodontic and orthopedic effects of a modified maxillary protractor between deciduous and early mixed dentitions. Am J Orthod Dentofacial Orthop. 2004 Jul;126(1):23–32.
30. Cordasco G. Matarese G. Rustico L.et al. Efficacy of orthopedic treatment with protraction facemask on skeletal class III malocclusion: a systematic review and meta-analysis. Orthod Craniofac Res. 2014 Aug;17(3):133–43.
31. Proffit, WR; Fields, HW Jr; Sarver, DM. Contemporary Orthodontics. 5th ed. St. Louis: Elsevier Health Sciences; 2014: p. 502–10.
32. Siriwat PP, Jarabak JR. Malocclusion and facial morphology is there a relationship? An epidemiologic study. Angle Orthod. 1985 Apr;55(2):127-38.

33. Fudalej P, Dragan M, Wedrychowska-Szulz B. Prediction of the outcome of orthodontic treatment of Class III malocclusions-a systematic review. Eur J Orthod. 2011 Apr;33(2):190-7.
34. Baccetti T, Franchi L, McNamara JA. Cephalometric variables predicting the long-term success or failure of combined rapid maxillary expansion and facial mask therapy. Am J Orthod Dentofacial Orthop. 2004 Jul;126(1):16-22.
35. Ghiz MA. Ngan P, Gunel E. Cephalometric variables to predict future success of early orthopedic Class III treatment. Am J Orthod Dentofacial Orthop. 2005 Mar;127(3):301-6.
36. Wells AP, Sarver DM, Proffit WR. Long-term efficacy of reverse pull headgear therapy. Angle Orthod. 2006 Nov;76(6):915-22.
37. Isaacson JR, Isaacson RJ, Spiedel TM, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthod. 1971 Jul; 41(3):219-29.
38. Ferrario VF, Sforza C, De Franco DJ. Mandibular shape and skeletal divergency. Eur J Orthod 1999;21:145-53.
39. Björk A. The face in profile: an anthropological x-ray investigation on Swedish children and conscripts. Svensk Tandl Tidskr. 1947:40(Suppl 5B).
40. Sassouni V, Nanda S. Analysis of dentofacial vertical proportions. Am J Orthod. 1964 Nov;50(11):801–23.
41. Hellman M. Open bite. Int J Orthodont 1931;17:421.
42. Mangla R, Singh N, Dua V, Padmanabhan P, Khanna M. Evaluation of mandibular morphology in different facial types. Contemp Clin Dent. 2011 Jul;2(3):200-6.
43. Sassouni V. Diagnosis and treatment planning via roentgenographic cephalometry. Am J Orthod. 1958 Jun;44(6):433–63.
44. Muller G. Growth and development of the middle face. J Dent Res. 1963;42:385–9.