Accuracy of Orthodontic Soft Tissue Prediction Software between Different Ethnicities

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Abstract:

Objective: The objective of this study was to assess the accuracy of the soft tissue prediction module of Dolphin Imaging Software (DIS) in patients requiring extractions as part of the orthodontic treatment plan and compare its accuracy between different ethnicities.

Materials and Methods: Initial and final records of 57 patients from three ethnic groups (African Americans, Caucasians, and Hispanics) who completed orthodontic treatment were included for assessment. The identified cases were managed non-surgically with dental extractions. A predictive profile was generated using DIS and compared to post-treatment lateral photographs. Actual and predictive profile photographs were compared using five designated parameters. The assessment parameters were evaluated using a manual protractor. ANOVA was used to compare differences between actual and predicted parameters between the specified groups and ICC was used to assess correlations between the data.

Results: Neither ethnicity nor gender had a significant effect on the difference between predicted and final values. No significant difference was noted between the predicted and final images for the nasolabial angle. Significant differences were observed for the mentolabial fold, upper lip to E-line, and lower lip to E-line between predicted and actual images. Additionally, soft tissue convexity was significantly different (p=0.019). Additionally, a clinically significant difference was found for the mentolabial fold.

Conclusion: Ethnicity and gender had no impact on the accuracy of predicted and actual image parameters. Overall, DIS demonstrated acceptable accuracy when simulating soft tissue changes after extraction therapy. Additional research on the accuracy of the software is warranted.

Keywords: soft tissue, accuracy, predictions, ethnicities

INTRODUCTION

Successful orthodontic treatment is not merely based on the correction of skeletal and dental abnormalities but also on achieving well-balanced an occlusion with optimum function and facial esthetics.[1-4] The principal motivating factor for patients to undergo orthodontic treatment is esthetics, which further highlights the importance of the soft tissue during treatment planning.[5] Additionally, profile improvement is one of the key measurements used by orthodontists to evaluate treatment results. Oftentimes, satisfactory profile improvements are a significant challenge to achieve.[6] To better achieve this treatment goal, the orthodontic profession has developed soft tissue prediction methodologies to anticipate the potential soft tissue changes associated with their suggested treatment.

There has been a progressive development of soft tissue predictions since the early 1970s. Early approaches utilized acetate tracing paper, which evolved into computer-based line drawings, and now many current technologies utilize computers that can alter a patient's photographs to predict the outcome.[7-11] The recent advancements in computerized treatment prediction programs have helped to significantly enhance diagnosis and treatment planning.[12-15] Apart from serving as a guide to achieve the desired result, visual treatment objective modules also function as a useful communication tool between the provider and patient, allowing the patient to preview the possible outcome.[7] Though prediction software can portray soft tissue treatment outcomes, it can if inaccurate, lead to dissatisfied patients when expectations are not achieved.[16]

Facial esthetics is highly dependent on the perioral profile of the lip form and quite often, the amount of lip change is predicted from the amount of maxillary and mandibular incisor retraction.[6] The position of the incisors is highly influenced by the anteroposterior goals of treatment, such as incisor flaring or retraction associated with extraction therapy.

Dolphin Imaging Software (DIS) has been increasingly used by orthodontists and previous studies have evaluated its prediction module for surgical cases.[1, 17] However, there are no studies that have assessed the accuracy of this software in patients having a malocclusion treated only with extractions. Moreover, there are no previous studies that have compared the accuracy of this soft tissue prediction software among different ethnic groups.

Therefore, the primary objectives of this study were to: 1) assess the accuracy of the DIS treatment simulation module in patients with malocclusions treated with extractions, and 2) compare the accuracy of the DIS treatment simulation module software among three ethnic groups.

MATERIALS AND METHODS

Population and Selection Criteria

The study utilized a retrospective case series study design. After receiving approval from the IUPUI IRB (#1810742579), the clinical data from the Indiana University School of Dentistry, Department of Orthodontics and local private practice offices were reviewed for suitable patient cases.
The inclusion criteria used for the study included:

- Self-reported African American, Caucasian, and/or Hispanic ethnicity
- Minimal growth potential (CVMS IV)[18]
- Angle Class I, II, or III malocclusions[19]
- Premolar extractions conducted as a part of orthodontic treatment
- Orthodontic records including pre- and post-treatment lateral cephalograms & profile photographs

Individuals were excluded from the study if they had the following criteria:

- Patients with a diagnosed or suspected craniofacial syndrome
- Patients with a history of facial soft tissue trauma
- Patients receiving orthognathic surgery during orthodontic treatment
- Patients suspected of receiving any form of cosmetic surgery between the pre-treatment and post-treatment orthodontic records

Data Collection and Measurements

Dolphin Imaging 11.9 software (Patterson Dental Supply, St. Paul, MN) was used for tracing the cephalometric landmarks of interest (Table 1). DIS was used to superimpose the pre-treatment profile photographs with the digitally traced pre-treatment soft tissue cephalometric landmarks (Figure 1). After digitally merging these images, a predicted post-treatment profile picture was generated. To aid in the accurate creation of a predicted post-treatment profile picture, the following values were taken from the patient's actual post-treatment records and incorporated into the prediction software: U1 – Apo (mm), L1 – Apo (mm), U1 – SN, L1 – MP (Figure 2). The prediction profile image (Figure 3A) was compared to the actual post-treatment outcome photograph (Figure 3B) to evaluate the accuracy of the soft tissue prediction. Five parameters were measured and calculated to assess the accuracy of the generated profile image against the actual post-treatment profile image:

- Nasiolabial angle (NLA)
- Mentolabial fold (MLF)
- Upper lip to E-line (ULE)
- Lower lip to E -line (LLE)
- Soft tissue convexity (G'-Sn'-Pg')

To ensure the image size (magnification) between the predicted and post-treatment photographs were similar, a transfer (fiduciary) line[20] was placed on the post-treatment photographs from the tragus of the ear to the antihelix (Figures 3A-B). The generated prediction photographs were then uploaded into a Microsoft Word version 16.0 (Microsoft, Redmond, WA) document and the same transfer line was added to the document. The magnitude of the predicted profile image was then resized to match the size of the actual post-treatment image, using the transfer line. Once properly sized, all images were printed in color and a protractor (3M Oral care, Monrovia, CA) was used to measure the linear and angular measurements of interest.
Prior to collecting the data for the study, intra- and inter-examiner repeatability and reproducibility was assessed. Five randomly selected patient images from the study population were chosen. The images were traced by two investigators (PP & KS) and then re-measured after a two week washout period. Intraclass correlation coefficients (ICCs) and Bland-Altman plots were used to evaluate the within-investigator repeatability and between-investigator reproducibility.

Differences between the predicted and actual post-treatment images were summarized with descriptive statistics (mean, standard deviation, range, and 95% confidence interval for the mean). Statistical significance of the differences between the predicted and final post-treatment outcomes were assessed using paired t-tests overall and within each ethnic group and for gender. Comparisons among the ethnic groups for differences between predicted and final were made using one-way ANOVA followed by pair-wise group comparisons using Fisher's Protected Least Significant Difference to control the overall significance level. The agreement between the predicted and final post-treatment outcomes was evaluated using ICCs and Bland-Altman plots. A 5% significance level was used for all tests. To help facilitate interpretation of the study's findings, the correlation scheme devised by Evans[21]was used to assess the observed associations (Table 2).

Along with the statistical level of significance established by the biostatistician, a level of clinical significance was established for the study as well. The investigators set the level of clinical significance using the following method. Predicted images were generated in increasing increments of 1mm or 1°, depending on whether the value being tested was a linear or angular measurement. Two blinded examiners then evaluated the images to determine the level at which the image change was visually perceptible. At the conclusion of this process, it was determined that a linear change of 2mm and an angular change of 5° was clinically significant. This effort was undertaken because a standard for clinically significant perceptible change has not been established in the literature.

RESULTS

Intra-repeatability and inter-reproducibility evaluation yielded highly acceptable results. The assessment of all parameters were found to have an ICC value of greater than 0.8.

Neither ethnicity ($p>0.15$) nor gender ($p>0.09$) had a significant effect on the difference between predicted and actual images (Table 3).

Moderate to strong ICC values were observed between predicted and final parameter values, illustrated in Table 4.

The nasolabial angle (NLA) was not significantly different ($p=0.560$) between the predicted and final images (Table 5). A moderate ICC correlation (0.55) was observed. The mean difference was -1.1°, which was within the clinically significant limits.

The mentolabial fold (MLF) was significantly different ($p=0.003$) between predicted and final images (Table 6), with the predicted values being lower than the final by 7.2° on average. A moderate ICC correlation (0.48) value was noted for this parameter. The mean difference of 7.2° was outside the clinically significant limits set for the study.

Significant differences ($p=0.019$) were observed for soft tissue convexity between predicted and final images (Table 7), with predicted higher than final by 1.8° on average. The correlation between the images was moderate with an observed ICC value of 0.59.The mean difference of 1.8° was within the clinically significant limits.

The upper lip to E-line (ULE) was significantly different (p=0.023) between predicted and actual images (Table 8), with the predicted lower than the final by 0.4mm on average. There was a strong ICC correlation (0.78) for this parameter. The mean difference was 0.4mm, which was within the clinically significant limits.

A significant difference (p<0.001) was noted between the predicted and final images (Table 9) for the lower lip to E-line (LLE), with the predicted values lower than the final by 0.9mm on average. A strong ICC correlation (0.73) was noted for this parameter. The mean value difference between the predicted and final was 0.9mm, which was within clinically acceptable range.

DISCUSSION

The goal of orthodontic treatment is to achieve a functional occlusion with harmonious facial esthetics. Therefore, diagnosis and treatment planning is a crucial step for the success of orthodontic treatment. With advancements in technology, many digital prediction software now exist on the market. These computerized prediction programs have enhanced the clinicians' ability to preview the post-treatment profile with possible surgical and non-surgical options through visual treatment objective (VTO) modules. Previous studies have evaluated the accuracy of such software in patients undergoing orthognathic surgeries. However, there is lack of literature assessing the accuracy of prediction software in patients undergoing comprehensive orthodontic treatment with only extractions.

The current study observed no impact of ethnicity or gender on the accuracy of predicted image parameters by DIS. This contradicts the work by Brock II et al.[22] who suggested that ethnic differences exist in the soft tissue response to hard tissue changes in the upper lip, at subnasale, and the superior labial sulcus. These response differences at the superior labial sulcus can be explained by the ethnic differences in initial lip thickness and incisor inclination. It is unclear whether DIS incorporates different ratios for different ethnicities. Almurtadha et al. showed that the significant retraction of the lips and an increase in NLA are associated with extraction protocols, but to what extent these changes are influential to the profile depends on different factors. [23] Therefore, predicting NLA changes after extraction is very challenging.

In the current study, the mean value difference for NLA was -1.1°, which was within clinically acceptable range. The NLA prediction with DIS was found to be accurate. No previous studies have investigated the accuracy of nasolabial angle prediction using DIS after dental extractions. Magro-Filho et al. compared DIS with the Dentofacial planner software and showed higher accuracy with Dentofacial planner in predicting NLA than DIS.[24] This study; however, was conducted using Class III cases, treated with double jaw orthognathic surgery and not dental extractions alone.

The DIS was least accurate when predicting the changes associated with the mentolabial fold. The mentolabial fold is comprised of the curvature of the lower lip and the curved superior portion of the soft tissue chin. One possible explanation for this observation could be that it is more difficult to measure the angle on two curved surfaces.[25] Andrade et al. showed that the nasolabial and mentolabial angles should be interpreted with caution due to variability in the measurements.[26] Based on the study findings, DIS failed to demonstrate acceptable accuracy for the MLF.

The mean value difference for soft tissue convexity was 1.8°, which was within the clinically acceptable range of 5°. Therefore, DIS prediction for soft tissue convexity seemed to be accurate. This finding is consistent with the work by de Lira et al., who showed that the facial convexity angle (G'-Sn-Pg') presented similar values between post-surgical and predicted profiles in Class II patients undergoing mandibular advancement.[1]

In the current study, the mean value difference was -0.4mm and -0.9mm for ULE and LLE respectively, which was within clinically acceptable range. Thus, DIS again appeared to possess acceptable accuracy when predicting ULE and LLE changes. Our results are similar to those found by Akhoundi et al., who assessed the accuracy of DIS in orthognathic surgical cases. Based on the frequency of errors in linear measurements, they concluded that predicted lips were in acceptable position.[27]

The predicted values were lower than the final outcome for ULE and LLE, suggesting less retraction of lips in the predicted profile generated by DIS than the actual final outcome. Previous studies have evaluated the ratio between lip change and incisor retraction. According to Lew et al., the ratio between lip change and incisor retraction was found to be 1:2.2 for the upper lip and from 1:1.4 for the lower lip.[28] For Caucasians, the ratios of maxillary incisor retraction to upper lip retraction range from 2.24:1 to 2.93:1 and for mandibular incisor retraction to lower lip retraction from 1.11:1 to 1.23:1. [29] For African Americans, the ratios of maxillary and mandibular incisor retraction to upper and lower lip retraction are

1.75:1 and 1.2:1, respectively.[30] However, the algorithmic ratio utilized in the DIS for lip change to incisor retraction is proprietary and not clearly known.

The authors acknowledge that the current study possessed a few minor limitations. First, the current study only utilized the prediction software from a single company. Additional prediction software were reviewed and considered for the study. Unfortunately, only the Dolphin imaging software allowed the user to specify exact post-treatment cephalometric values, which was a crucial component of the study design. Another minor limitation was the inability to correlate the method of space closure with the soft tissue changes. Given that this was a retrospective study using patient records from different clinics, it was impossible to gather the specific details associated with the method of space closure. Likewise, the authors were unable to quantify the exact amount of tooth change in the anteroposterior dimension. This shortcoming was addressed by measuring the actual post-treatment incisor changes and entering the values into the Dolphin imaging software.

CONCLUSIONS

- Ethnicity and gender had no impact on the accuracy of the DIS prediction module when forecasting soft tissue changes following orthodontic treatment with dental extractions.
- The Dolphin Imaging Software prediction module demonstrated acceptable overall accuracy when simulating soft tissue changes after extraction therapy.
- Adequate prediction levels were observed for all soft tissue parameters, except for the MLF.
- Additional research to assess the accurate prediction of the MLF using DIS after dental extractions is warranted.

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FIGURE LEGENDS

Figure 1: Step 1 of the prediction generation process. Superimpose the pre-treatment profile picture with digitally traced soft tissue landmarks of the pre-treatment cephalometric radiograph**.**

Figure 2: Step 2 of prediction generation process. Prediction profile photograph generated after dental extraction and application of treatment outcome values.

Figure 3A: Image of predicted profile, Figure 3B: Image of the actual final treatment outcome profile.

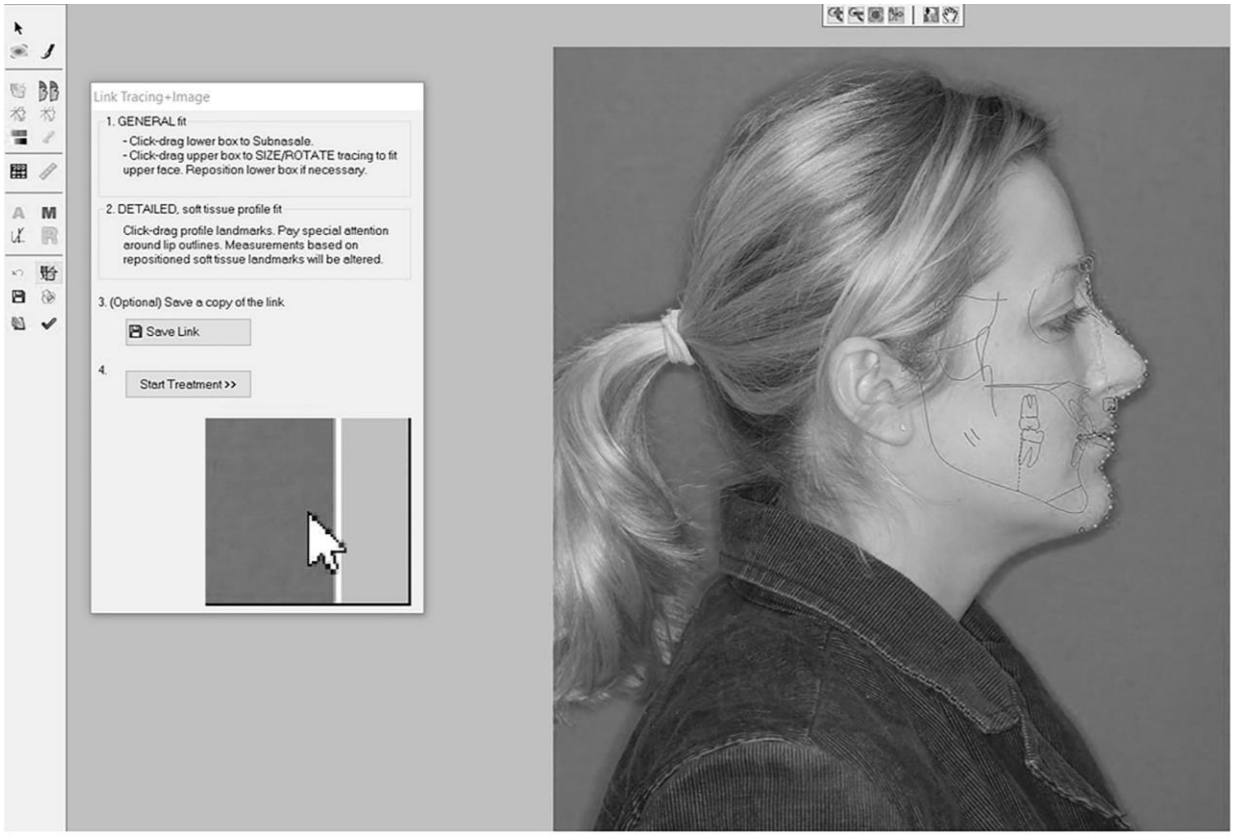

Figure 1: Step 1 of the prediction generation process. Superimpose the pre-treatment profile picture with digitally traced soft tissue landmarks of the pre-treatment cephalometric radiograph**.**

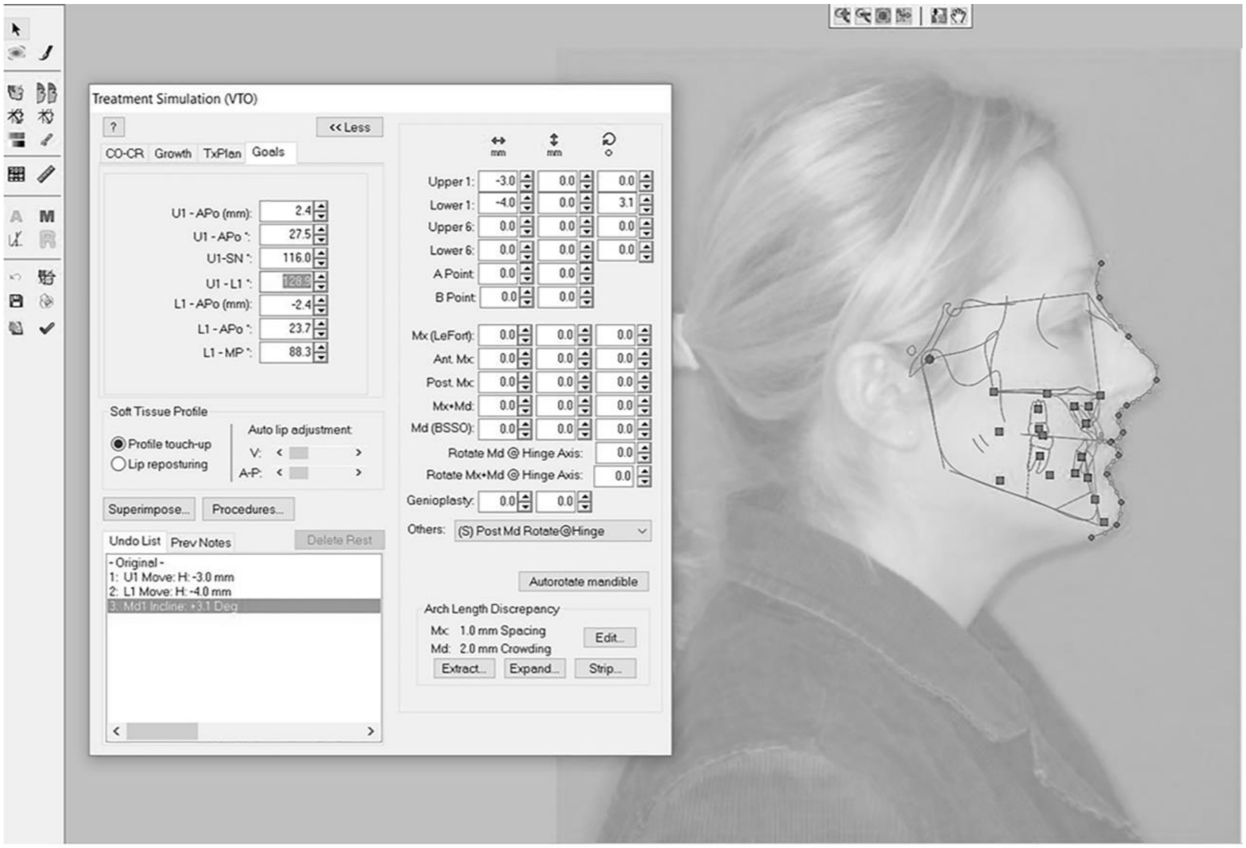

Figure 2: Step 2 of prediction generation process. Prediction profile photograph generated after dental extraction and application of treatment outcome values.

Figure 3A: Image of predicted profile, Figure 3B: Image of the actual final treatment outcome profile.

Table 1. Soft Tissue Landmark Descriptions

Soft tissue points	Descriptions
Glabella (G):	The anterior midpoint on the fronto-orbital soft tissue.
Tip of the nose (Pr):	The most anterior midpoint of the nasal tip.
Subnasale (Sn'):	The midpoint on the nasolabial soft tissue contour between the columella crest and the upper lip.
Soft tissue A point (A'):	The point of greatest concavity in the midline of the upper lip between subnasale and labrale superius.
Upper lip/labrale superius (Ls):	The midpoint of the vermilion line of the upper lip.
Lower lip/labrale inferius (Li):	The midpoint of the vermilion line of the lower lip.
Soft tissue B point (B'):	The point of greatest concavity in the midline of the lower lip between labrale inferius and soft tissue pogonion.
Soft tissue pogonion (Pg'):	The most anterior midpoint of the chin.
Soft tissue menton (Me'):	Lowest point on the contour of the soft tissue chin.
Soft tissue gnathion (Gn'):	Midpoint between the anterior and inferior points of the soft tissue chin.

Table 2. Correlation Interpretation Scheme

Correlation Range	Correlation Outcome
.0 - .19	Very weak
.2 - .39	Weak
.4 - .59	Moderate
.6 - .79	Strong
.8 - 1.0	Very strong

Table 3. Paired t-test evaluating differences predicted and final soft tissue parameters based on ethnicity and gender (*p values shown in the table*).

Parameters	Ethnicity	Gender
NLA	0.152	0.233
MLF	0.702	0.411
Convexity	0.410	0.099
ULE	0.280	0.931
LLE	0.883	0.978

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

Table 4. Intraclass correlation coefficient (ICC) between predicted and actual parameter values.

Parameters	ICC values
NLA	0.55
MLF	0.48
Convexity	0.59
ULE	0.78
LLE	0.73

Table 5. Descriptive Statistics – Nasiolabial angle

Sex	Ethnicity	Type	N	Mean	SD	SE	95% CI - Mean		p-value	Min	Max
All	All	Predicted	57	93.5	14.6	1.9	89.7	97.4		57	124
		Final	57	94.6	13.6	1.8	91.0	98.2		48	125
		P-F	57	-1.1	14.0	1.9	-4.8	2.6	0.560	-31	52
	African-American	Predicted	19	83.9	14.4	3.3	77.0	90.9		57	115
		Final	19	84.9	15.3	3.5	77.6	92.3		48	114
		P-F	19	-1.0	16.6	3.8	-9.0	7.0	0.796	-31	52
	Caucasian	Predicted	19	103.3	9.4	2.2	98.7	107.8		90	124
		Final	19	99.3	10.5	2.4	94.3	104.4		82	125
		P-F	19	3.9	10.5	2.4	-1.1	9.0	0.120	-18	22
	Hispanic	Predicted	19	93.4	13.0	3.0	87.2	99.7		73	115
		Final	19	99.6	8.9	2.0	95.3	103.9		87	116
		P-F	19	-6.2	13.0	3.0	-12.5	0.1	0.052	-25	28
F	All	Predicted	40	90.9	13.9	2.2	86.5	95.4		57	115
		Final	40	94.0	12.9	2.0	89.9	98.1		48	116
		P-F	40	-3.1	12.9	2.0	-7.2	1.1	0.140	-31	28
	African-American	Predicted	15	80.9	11.7	3.0	74.4	87.4		57	97
		Final	15	85.0	13.4	3.5	77.6	92.4		48	102
		P-F	15	-4.1	11.7	3.0	-10.5	2.4	0.199	-31	12
	Caucasian	Predicted	10	101.6	7.9	2.5	95.9	107.3		90	112
		Final	10	97.7	9.1	2.9	91.2	104.2		82	109
		P-F	10	3.9	11.8	3.7	-4.6	12.4	0.325	-18	22
	Hispanic	Predicted	15	93.8	12.7	3.3	86.8	100.8		73	115
		Final	15	100.5	9.3	2.4	95.4	105.7		87	116
		P-F	15	-6.7	13.7	3.5	-14.3	0.9	0.078	-25	28
M	All	Predicted	17	99.7	14.8	3.6	92.1	107.3		72	124
		Final	17	96.1	15.4	3.7	88.2	104.0		56	125
		P-F	17	3.6	15.7	3.8	-4.5	11.7	0.360	-16	52
	African-American	Predicted	4	95.3	19.8	9.9	63.7	126.8		72	115
		Final	4	84.8	23.8	11.9	46.9	122.6		56	114
		P-F	4	10.5	28.1	14.0	-34.2	55.2	0.509	-10	52
	Caucasian	Predicted	9	105.1	11.1	3.7	96.6	113.6		90	124
		Final	9	101.1	12.1	4.0	91.8	110.4		86	125
		P-F	9	4.0	9.6	3.2	-3.4	11.4	0.247	-16	17
	Hispanic	Predicted	4	92.0	16.0	8.0	66.5	117.5		78	110
		Final	4	96.3	7.3	3.6	84.7	107.8		91	107
		P-F	4	-4.3	11.6	5.8	-22.6	14.1	0.515	-16	8

* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$

Table 6. Descriptive Statistics – Mentolabial fold

Sex	Ethnicity	Type	N	Mean	SD	SE	95% CI - Mean		p-value	Min	Max
All	All	Predicted	57	120.9	20.9	2.8	115.3	126.4		50	157
		Final	57	128.1	13.4	1.8	124.5	131.6		78	154
		P-F	57	-7.2	17.3	2.3	-11.8	-2.6	0.003**	-71	27
	African-American	Predicted	19	125.9	17.8	4.1	117.3	134.5		91	148
		Final	19	130.7	12.2	2.8	124.8	136.6		102	154
		P-F	19	-4.8	15.5	3.6	-12.3	2.7	0.191	-34	27
	Caucasian	Predicted	19	119.2	16.2	3.7	111.4	127.0		87	142
		Final	19	127.6	9.5	2.2	123.0	132.2		112	147
		P-F	19	-8.4	11.8	2.7	-14.1	-2.8	0.006**	-31	9
	Hispanic	Predicted	19	117.6	27.3	6.3	104.4	130.7		50	157
		Final	19	125.9	17.4	4.0	117.5	134.3		78	151
		P-F	19	-8.3	23.3	5.3	-19.5	2.9	0.137	-71	20
F	All	Predicted	40	121.1	21.1	3.3	114.3	127.9		50	147
		Final	40	129.4	11.3	1.8	125.7	133.0		110	154
		P-F	40	-8.3	18.0	2.8	-14.0	-2.5	0.006**	-71	17
	African-American	Predicted	15	126.3	16.0	4.1	117.5	135.2		91	143
		Final	15	134.1	10.3	2.7	128.4	139.8		110	154
		P-F	15	-7.8	13.4	3.5	-15.2	-0.4	0.041*	-34	9
	Caucasian	Predicted	10	120.9	14.2	4.5	110.8	131.0		87	140
		Final	10	125.0	8.3	2.6	119.0	131.0		112	141
		P-F	10	-4.1	11.4	3.6	-12.3	4.1	0.285	-31	9
	Hispanic	Predicted	15	116.0	28.3	7.3	100.3	131.7		50	147
		Final	15	127.5	12.9	3.3	120.3	134.6		111	147
		P-F	15	-11.5	24.7	6.4	-25.2	2.2	0.094*	-71	17
M	All	Predicted	17	120.4	21.2	5.1	109.5	131.2		89	157
		Final	17	125.1	17.2	4.2	116.2	133.9		78	151
		P-F	17	-4.7	15.8	3.8	-12.8	3.4	0.238	-29	27
	African-American	Predicted	4	124.3	26.5	13.3	82.0	166.5		97	148
		Final	4	118.0	11.5	5.7	99.8	136.2		102	129
		P-F	4	6.3	20.1	10.1	-25.8	38.3	0.578	-16	27
	Caucasian	Predicted	9	117.2	18.8	6.3	102.7	131.7		89	142
		Final	9	130.4	10.4	3.5	122.5	138.4		118	147
		P-F	9	-13.2	10.8	3.6	-21.5	-5.0	0.006**	-29	2
	Hispanic	Predicted	4	123.5	26.0	13.0	82.2	164.8		98	157
		Final	4	120.0	31.3	15.6	70.3	169.7		78	151
		P-F	4	3.5	12.5	6.2	-16.4	23.4	0.614	-8	20

* P ≤ .05; ** P ≤ .01; *** P ≤ .001

Table 7. Descriptive Statistics – Soft Tissue Convexity

Sex	Ethnicity	Type	N	Mean	SD	SE	95% CI - Mean		p-value	Min	Max
All	All	Predicted	57	14.7	6.4	0.8	13.0	16.4		-4	28
		Final	57	12.9	6.5	0.9	11.1	14.6		-12	30
		P-F	57	1.8	5.7	0.8	0.3	3.3	0.019 *	-8	31
	African-American	Predicted	19	17.4	7.0	1.6	14.0	20.8		-4	28
		Final	19	14.0	9.3	2.1	9.5	18.5		-12	30
		P-F	19	3.4	8.2	1.9	-0.6	7.3	0.090	-8	31
	Caucasian	Predicted	19	11.4	5.5	1.3	8.8	14.1		3	23
		Final	19	10.1	4.3	1.0	8.0	12.1		2	18
		P-F	19	1.4	3.6	0.8	-0.4	3.1	0.116	-5	9
	Hispanic	Predicted	19	15.3	5.3	1.2	12.7	17.8		6	23
		Final	19	14.5	3.5	0.8	12.8	16.2		9	20
		P-F	19	0.7	4.2	1.0	-1.3	2.7	0.452	-7	8
F	All	Predicted	40	15.1	6.3	1.0	13.1	17.1		3	28
		Final	40	13.3	6.2	1.0	11.3	15.3		-12	25
		P-F	40	1.8	6.1	1.0	-0.2	3.8	0.071	-7	31
	African-American	Predicted	15	18.1	4.9	1.3	15.4	20.9		10	28
		Final	15	13.9	8.5	2.2	9.2	18.6		-12	25
		P-F	15	4.2	8.2	2.1	-0.4	8.8	0.068	-3	31
	Caucasian	Predicted	10	10.4	6.2	2.0	6.0	14.8		3	23
		Final	10	9.6	4.1	1.3	6.7	12.5		2	18
		P-F	10	0.8	3.4	1.1	-1.6	3.2	0.471	-5	7
	Hispanic	Predicted	15	15.2	6.0	1.5	11.9	18.5		6	23
		Final	15	15.1	3.5	0.9	13.2	17.1		10	20
		P-F	15	0.1	4.4	1.1	-2.4	2.5	0.954	-7	8
M	All	Predicted	17	13.7	6.8	1.6	10.2	17.2		-4	25
		Final	17	11.8	7.1	1.7	8.2	15.5		-3	30
		P-F	17	1.9	4.8	1.2	-0.6	4.3	0.124	-8	12
	African-American	Predicted	4	14.5	13.0	6.5	-6.2	35.2		-4	25
		Final	4	14.3	13.6	6.8	-7.4	35.9		-3	30
		P-F	4	0.3	8.4	4.2	-13.2	13.7	0.956	-8	12
	Caucasian	Predicted	9	12.6	4.8	1.6	8.9	16.2		7	22
		Final	9	10.6	4.8	1.6	6.9	14.2		3	18
		P-F	9	2.0	4.0	1.3	-1.1	5.1	0.169	-3	9
	Hispanic	Predicted	4	15.5	1.9	1.0	12.5	18.5		14	18
		Final	4	12.3	2.8	1.4	7.9	16.6		9	15
		P-F	4	3.3	1.7	0.9	0.5	6.0	0.032 *	1	5

* P ≤ .05; ** P ≤ .01; *** P ≤ .001

Table 8. Descriptive Statistics – Upper Lip to E-line

Sex	Ethnicity	Type	N	Mean	SD	SE	95% CI - Mean		p-value	Min	Max
All	All	Predicted	57	2.0	2.2	0.3	1.4	2.6		-5	7
		Final	57	2.5	2.3	0.3	1.9	3.1		-2	9
		P-F	57	-0.4	1.4	0.2	-0.8	-0.1	0.023*	-7	2
	African-American	Predicted	19	0.1	1.9	0.4	-0.8	1.0		-5	5
		Final	19	0.5	1.8	0.4	-0.3	1.4		-2	6
		P-F	19	-0.4	1.5	0.3	-1.2	0.3	0.204	-4	2
	Caucasian	Predicted	19	3.7	1.5	0.3	3.0	4.5		1	7
		Final	19	4.6	1.6	0.4	3.8	5.3		2	9
		P-F	19	-0.8	1.8	0.4	-1.7	0.0	0.057	-7	1
	Hispanic	Predicted	19	2.2	1.5	0.4	1.5	2.9		-1	5.5
		Final	19	2.3	1.3	0.3	1.6	2.9		0	5.5
		P-F	19	-0.1	0.8	0.2	-0.5	0.4	0.790	-2	1
F	All	Predicted	40	1.8	2.5	0.4	1.0	2.6		-5	7
		Final	40	2.2	2.4	0.4	1.4	2.9		-2	9
		P-F	40	-0.4	1.6	0.2	-0.9	0.1	0.127	-7	1
	African-American	Predicted	15	-0.4	1.6	0.4	-1.2	0.5		-5	2
		Final	15	0.1	1.0	0.3	-0.4	0.7		-2	2
		P-F	15	-0.5	1.5	0.4	-1.3	0.3	0.211	-4	1
	Caucasian	Predicted	10	4.3	1.8	0.6	3.0	5.6		1	7
		Final	10	4.9	2.0	0.6	3.5	6.3		2	9
		P-F	10	-0.6	2.4	0.8	-2.3	1.1	0.452	-7	1
	Hispanic	Predicted	15	2.2	1.6	0.4	1.3	3.1		-1	5.5
		Final	15	2.3	1.5	0.4	1.5	3.1		0	5.5
		P-F	15	-0.1	0.9	0.2	-0.6	0.4	0.582	-2	1
M	All	Predicted	17	2.6	1.4	0.3	1.9	3.3		0	5
		Final	17	3.2	1.9	0.5	2.2	4.2		-2	6
		P-F	17	-0.6	1.1	0.3	-1.2	0.0	0.046*	-2	2
	African-American	Predicted	4	1.8	2.4	1.2	-2.0	5.5		0	5
		Final	4	2.0	3.3	1.6	-3.2	7.2		-2	6
		P-F	4	-0.3	1.7	0.9	-3.0	2.5	0.789	-2	2
	Caucasian	Predicted	9	3.1	0.8	0.3	2.5	3.7		2	4
		Final	9	4.2	0.8	0.3	3.6	4.9		3	5
		P-F	9	-1.1	0.8	0.3	-1.7	-0.5	0.003**	-2	0
	Hispanic	Predicted	4	2.3	1.3	0.6	0.2	4.3		1	4
		Final	4	2.0	0.8	0.4	0.7	3.3		1	3
		P-F	4	0.3	0.5	0.3	-0.5	1.0	0.391	0	1

* P ≤ .05; ** P ≤ .01; *** P ≤ .001

Table 9. Descriptive Statistics – Lower Lip to E-line

Sex	Ethnicity	Type	N	Mean	SD	SE	95% CI - Mean		p-value	Min	Max
All	All	Predicted	57	0.1	2.5	0.3	-0.6	0.7		-7	4
		Final	57	1.0	2.5	0.3	0.3	1.7		-5	7
		P-F	57	-0.9	1.7	0.2	-1.4	-0.5	0.000***	-7	2
	African-American	Predicted	19	-2.1	2.2	0.5	-3.2	-1.1		-7	2
		Final	19	-1.0	2.2	0.5	-2.1	0.0		-5	5
		P-F	19	-1.1	2.1	0.5	-2.1	-0.1	0.031 *	-7	2
	Caucasian	Predicted	19	2.3	1.2	0.3	1.7	2.9		0	4
		Final	19	3.2	1.6	0.4	2.4	3.9		0	7
		P-F	19	-0.9	1.4	0.3	-1.6	-0.2	0.013**	-5	1
	Hispanic	Predicted	19	0.0	1.8	0.4	-0.8	0.9		-3	4
		Final	19	0.9	1.8	0.4	0.0	1.7		-4	4
		P-F	19	-0.8	1.6	0.4	-1.6	-0.1	0.032*	-4.5	1
F	All	Predicted	40	-0.4	2.6	0.4	-1.2	0.4		-7	4
		Final	40	0.6	2.6	0.4	-0.3	1.4		-5	7
		P-F	40	-1.0	1.4	0.2	-1.4	-0.5	0.000***	-5	1
	African-American	Predicted	15	-2.5	2.1	0.5	-3.7	-1.3		-7	0
		Final	15	-1.4	1.8	0.5	-2.4	-0.4		-5	2
		P-F	15	-1.1	1.4	0.4	-1.9	-0.3	0.009**	-4	1
	Caucasian	Predicted	10	2.4	1.0	0.3	1.7	3.1		0	3
		Final	10	3.2	1.9	0.6	1.9	4.5		0	7
		P-F	10	-0.8	1.7	0.5	-2.0	0.4	0.168	-5	1
	Hispanic	Predicted	15	-0.2	1.7	0.4	-1.1	0.8		-3	4
		Final	15	0.7	2.0	0.5	-0.4	1.8		-4	4
		P-F	15	-0.9	1.3	0.3	-1.6	-0.2	0.019*	-4	1
M	All	Predicted	17	1.1	2.0	0.5	0.1	2.1		-2	4
		Final	17	2.1	2.1	0.5	1.0	3.2		-2.5	5
		P-F	17	-0.9	2.2	0.5	-2.1	0.2	0.101	-7	2
	African-American	Predicted	4	-0.8	1.9	0.9	-3.8	2.3		-2	2
		Final	4	0.4	3.3	1.6	-4.8	5.5		-2.5	5
		P-F	4	-1.1	4.0	2.0	-7.5	5.3	0.614	-7	2
	Caucasian	Predicted	9	2.1	1.5	0.5	0.9	3.3		0	4
		Final	9	3.1	1.5	0.5	2.0	4.2		1	5
		P-F	9	-1.0	1.1	0.4	-1.9	-0.1	0.028*	-3	1
	Hispanic	Predicted	4	0.8	1.9	0.9	-2.3	3.8		-2	2
		Final	4	1.4	0.8	0.4	0.2	2.6		1	2.5
		P-F	4	-0.6	2.6	1.3	-4.8	3.6	0.667	-4.5	1

* P ≤ .05; ** P ≤ .01; *** P ≤ .001