Accuracy Assessment of a Three-Dimensional Virtual Soft Tissue Simulation System in Predicting Surgery Outcome for Class III Patients

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Abstract

Current orthodontic theory and practice are primarily based on improving facial esthetic appearance. Patients with exaggerated soft tissue features originating from severe skeletal discrepancies are appropriate candidates for surgical-orthodontic treatment. Three-dimensional simulation of soft tissue changes prior to actual operation is available as a prediction method to estimate possible treatment outcomes, although the accuracy of such methods remains ambiguous. The objective of this study was to assess the accuracy of virtual soft tissue simulation performed using a 3D system. Fifteen patients with skeletal class III relationship were included in the study. Pre-surgical records (CBCT, model scan, 3D face) were gathered within 1 month before surgery in order to set up the simulation model (T_1). Three months after surgery, post-surgical records (CBCT, 3D face) were collected to create the actual model (T_2). Distances and angular variables were measured on both models, and the differences between T_1 and T_2 were then analyzed. The results showed statistically significant differences ($P<0.05$) in terms of frontonasal angle, nose length, nasolabial angle, upper alar width, lip-chin-throat angle, lower lip length, soft tissue chin thickness, and throat length. The ability of Dolphin 3D software to simulate soft tissue features in class III surgery cases differed depending on the area of the face. Highly accurate areas were midface, upper lip, lower lip, and the lower part of the nose. Soft tissue chin thickness was found to be moderately accurate. However, simulations of the upper part of the nose should be considered with caution. The most inaccurate simulations were of the nasolabial angle, lip-chin-throat angle, and throat length.

Keywords: *Dolphin 3D software/ Soft tissue simulation/ Orthognathic surgery*

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Introduction

Current orthodontic theory and practice is primarily based on improving facial esthetic appearance. Patients with exaggerated soft tissue features originating from severe skeletal discrepancies are appropriate candidates for surgical-orthodontic treatment.[1-2] However, one limitation of orthognathic surgery is that soft tissue cannot be directly controlled. Surgeons are only able to move hard tissue. Soft tissue subsequently modifies itself following skeletal movement.[3] Soft tissue response is represented by movement of various bony landmarks rather than one skeletal reference point.[4] Therefore, predicting soft tissue profiles remains a challenge for orthodontists and surgeons.

Conventional methods for estimating treatment outcomes have evolved since the 1970s to estimate soft tissue change using specialized equipment combined with clinician's experience.[5] Previous methods were sensitive to error due to head positioning and geometric errors related to overlapping of the facial structures affecting landmark identification.[6] In 1985, Wolford et al. introduced the surgical treatment objective (STO), which involved manipulation of hard and soft tissue prediction ratios integrated with template methods used in different types of surgical procedures.[7] Development of computerized and three-dimensional software has since helped to overcome drawbacks of previous methods.

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3D simulation is performed by integrating digital data with the aid of computer software. The latest fusion method to be used is the voxel-based superimposition, introduced by Cevidanes et al.[8] Dolphin 3D software (Dolphin Imaging and Management Solutions Chatsworth, Calif) has become the most commonly used software.[9] Applying 3D facial soft tissue has become a new technique in virtual simulation. Three-dimensional simulation of soft tissue change is available as a prediction method to estimate possible treatment results prior to actual operation, although the accuracy of the system remains obscure. The objective of this study was to assess the accuracy of virtual soft tissue simulation by Dolphin 3D Software in cases of skeletal class III patients who undergone orthodontic treatment with two-jaw orthognathic surgery.

Materials and Methods

This study was carried out under the Division of Orthodontics, Department of Preventive Dentistry in partnership with the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Khon Kaen University, Thailand. The study population consisted of patients with skeletal class III relationship participating in surgical-orthodontic treatment and scheduled for double-jaw surgery between June 2020 and January 2021. Patients over 18 years of age and categorized under ASA Physical Status Class I were included in the study. Exclusion criteria eliminated patients categorized under ASA Physical Status Class II or higher, patients with craniofacial anomaly, intraoperative complications limiting surgical plan transfer, or postoperative complications affecting wound healing, those requiring additional intraoperative surgical procedures, and those having a history of physical trauma in the head or neck region or skeletal relapse from previous orthognathic surgery. The sample size was calculated according to precedent set by a 2017 study by Resnick et al. on the accuracy of 3D soft tissue prediction following LeFort I osteotomy.[10] It was determined that for the present study, 12 subjects would be required, anticipating a 20% drop-out rate. (Figure 1)

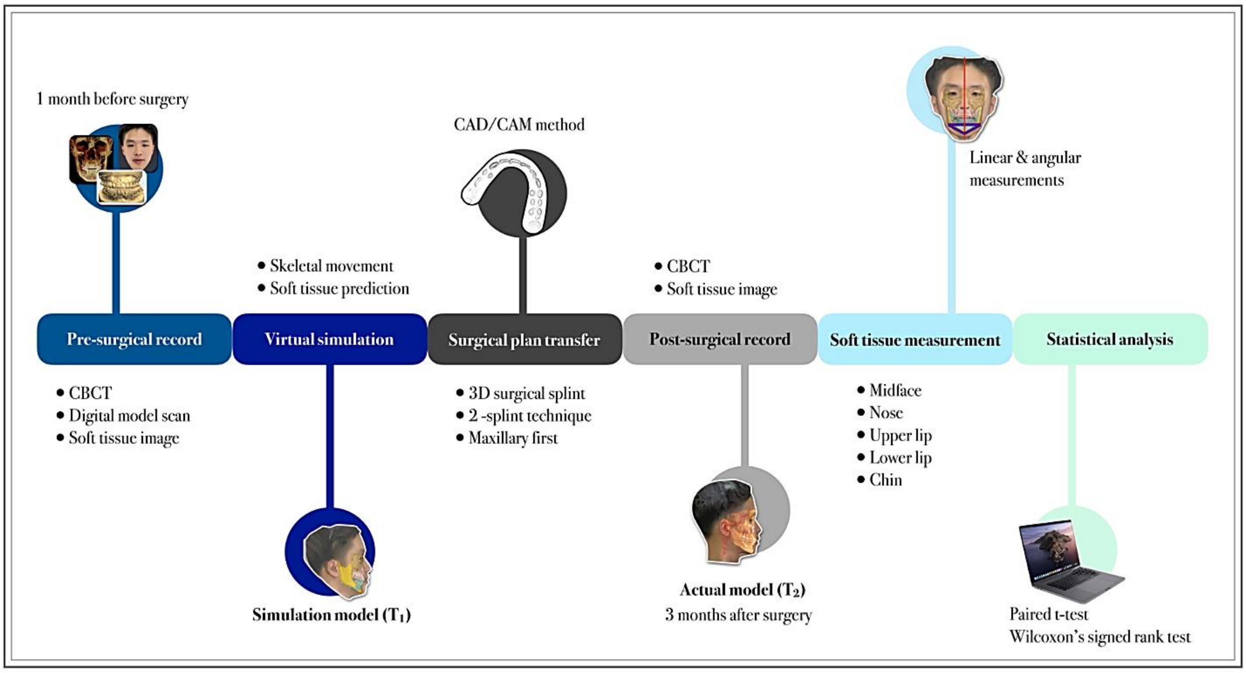

Figure 1 Overall workflow used in 3D protocol

Pre-surgical record: A set of 3D data was collected after completion of the pre-surgical orthodontic phase in order to carry out virtual planning using 3D software. The orthognathic triad consisted of skeletal, dental, and soft tissue components.[11] Data on skeletal structures were captured using CBCT (WhiteFox®, Ateon group, Merignac, France), digital arch models were scanned using a 3shape E2 scanner (3shape, Copenhagen, Denmark), and extraoral soft tissue features were scanned using a Bellus 3D Dental Pro application (Bellus 3D Inc, Campbell, CA), compatible with the TrueDepth camera embedded in an IPhone 11 Pro (Apple Inc, Cupertino, Calif). This step of the process was completed within 1 month prior to surgery.

Virtual simulation: Full 3D features were merged together in Dolphin 3D software (Dolphin Imaging and Management Solutions, Chatsworth, Calif). A surgical simulation was performed for each subject, and soft tissue modification was subsequently simulated after skeletal movement. The simulation model is referred to as T_1.

Surgical plan transfer: The virtual plan was transferred to the subject using maxillary first- and two-splint techniques with CAD/CAM surgical splint, which was designed within the software.

Post-surgical record: Three months after surgery, skeletal and soft tissue components were gathered using methods identical to those used in collecting pre-surgical records. Post-operative data were merged in Dolphin 3D software, and the actual model (T_2) was created.

Soft tissue measurement: External reference planes (Figure 2), including the coronal plane, horizontal plane, and midsagittal plane, were located on the stable structures of the 3D models (Table 1). The planes were perpendicular to each other and not altered by surgery.[12] Sixteen linear and five angular variables at midface, nose, upper lip, lower lip, and chin were measured twice on both T_1 and T_2 by the same observer. Localization of soft tissue landmarks was done by the researcher and the software automatically measured the variable. Soft tissue landmarks and measurements are reported in Tables 2 and 3. Figure 2 shows the 3D analysis carried out by this study.

Statistical analysis: The differences of the measurements between T_1 and T_2 were analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) version 20. Data distribution was evaluated using the Shapiro-Wilk test, and statistically significant values were determined using the parametric dependent paired t-test and the non-parametric Wilcoxon signed-rank test. A P-value of less than 0.05 was considered statistically significant.

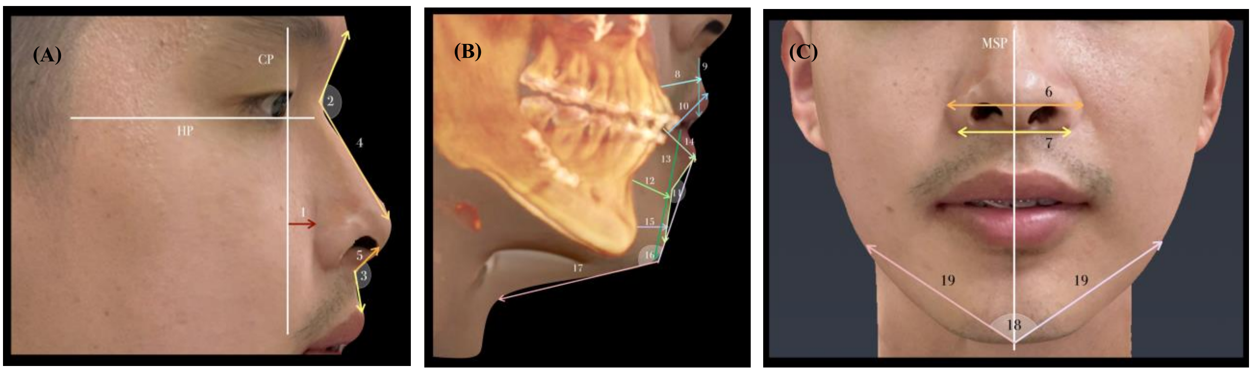

Figure 2 (A-C) 3D analysis. HP = Horizontal plane, CP = Coronal plane, MSP = Midsagittal plane.
1) Midface depth, 2) Frontonasal angle, 3) Nasolabial angle, 4) Nose length, 5) Columella length, 6) Upper alar width, 7) Outer alar width, 8) A–A' width, 9) Upper lip length, 10) Upper lip thickness, 11) Mentolabial angle, 12) B-B' width, 13) Lower lip length, 14) Lower lip thickness, 15) Soft tissue chin thickness, 16) Lip chin throat angle, 17) Throat length, 18) V angle, 19) V line distance

Table 1 External reference planes

Reference plane	Definition
Midsagittal plane (MSP)	A line drawn between G' and the philtrum
Horizontal plane (HP)	A line drawn between the most inferior point of each eyeball
Coronal plane (CP)	A vertical line passing through the most anterior point of the eyeball and perpendicular to the HP

Table 2 Soft tissue landmarks

Soft tissue landmark	Definition
G' (Soft tissue glabella)	The most anterior point of the superior orbital ridge
Ze (Zygomatic eminence)	The most anterior point of the convexity of the cheek
N' (Soft tissue nasion)	The deepest point of the concavity of the base of the nasal root at frontonasal suture
Cm (Columella point)	The most anterior, superior point of the columella
Prn (Pronasale)	The most anterior point of the nose
UAl (Upper alare)	The upper part of the most lateral point of the external nose
LAl (Lower alare)	The lower part of the most lateral point of the external nose at labial commissures
Sn (Subnasale)	The junction between the lower border of the nose and the upper lip
A' (Soft tissue point A)	The deepest point of the concavity between the subnasale and the labrale superious
Ls (Labrale superious)	The most anterior point of the upper membranous lip
Sts (Stomion superious)	The most inferior point of the upper lip
Sti (Stomion inferious)	The most superior point of the lower lip
Li (Labrale inferious)	The most anterior point of the lower lip
B' (Soft tissue point B)	The deepest point of the concavity between the labrale inferious and soft tissue pogonion
Pog' (Soft tissue pogonion)	The most anterior point of the soft-tissue chin
Soft tissue menton (Me')	The most inferior point of the soft-tissue chin
C (Cervical point)	The junction between the chin and neck
Go' (Soft tissue gonion)	The most lateral point on the soft-tissue contour of each mandibular angle

Table 3 Soft tissue measurements

Measurement	Reference points	Definition
Midface		
Midface depth	Ze - CP	Distance between right / left Ze and CP
Nose		
Frontonasal angle	G' - N' - Prn	Angle formed by the intersection of G' and Prn at N'
Nasolabial angle	Cm - Sn - Ls	Angle formed by the intersection of Cm and Ls at Sn
Nose length	N' - Prn	Distance from N' to Prn
Columella length	Prn - Sn	Distance from Prn to Sn
Upper alar width	UAl right - UAl left	Width of upper part of the most lateral point of external nose
Lower alar width	LAl right - LAl left	Width of lower part of the most lateral point of external nose
Upper lip		
A to A' width	A - A'	Distance from A to A'
Upper lip length	Sn - Sts	Distance from Sn to Sts
Upper lip thickness	Isi - Ls	Distance from Isi to Ls
Lower lip		
B to B' width	B - B'	Distance from B to B'
Lower lip length	Sti - Me'	Distance between Sti and Me'
Lower lip thickness	Ii - Li	Distance from incisal edge of lower central incisors to Li
Chin		
Chin thickness	Pog - Pog'	Distance from Pog to Pog'
Mentolabial angle	Li - ILS - Pog'	Angle formed by the intersection of Li and Pog' at inferior labial sulcus
Lip-chin-throat angle	Li - Pog' / Me' - C	Angle formed by the line drawn from Li to Pog', tangent to the line drawn from Me' to C
V angle (soft tissue)	Go'- Me' - Go'	Angle formed by the intersection of Go' and Me' on either side
V line distance	Me' - Go'	Distance from Me' to Go' on each side
Throat length	Me' - C	Distance from Me' to C

Results

This study was performed on 15 subjects, including 7 males (46.7%) and 8 females (53.3%). The age range prior to surgery was 18 to 37 years. The mean age of the subjects was 24.69. All subjects were diagnosed as skeletal class III. Bimaxillary surgery, including LeFort I osteotomy and bilateral sagittal split ramus osteotomy, was performed on every subject to advance the maxilla and achieve mandible setback. General characteristics and surgical details are presented in Table 4.

The examiner appraisement of the validity of landmark identification and variable measurements was done by allegorizing with the expert. 10% of the sample size were randomized. Measurements of all angular and linear value were done by both the examiner and the expert. The intra-examiner assessment of the repeatability of anatomical landmarks localization and variable measurements were done in every subject from the sample group. The measurement of all variables was done twice by single reviewer. The validity and repeatability assessment were done by using intraclass correlation coefficient. The results of ICC values were 0.92-1.00 which represented a high validity and reliability of the measurements.

Table 4 General characteristics and surgical correction performed on each subject

Subject	Gender	Age	Maxillary surgery	Mandibular surgery
1	Female	18	Advance 1.5 mm Impact 1 mm	Setback 3.5 mm
2	Female	22	Advance 1.5 mm Impact 1 mm	Setback 4 mm
3	Female	22	Advance 4.5 mm Impact 2 mm	Setback 5.5 mm
4	Female	22	Advance 2 mm Impact 2 mm	Setback 9.5 mm
5	Male	23	Advance 3 mm Impact 4 mm	Setback 7 mm
6	Male	27	Advance 2.5 mm Impact 2 mm	Setback 8 mm
7	Female	20	Advance 3 mm Impact 1 mm	Setback 6 mm
8	Female	26	Advance 2 mm Impact 2 mm	Setback 1.5 mm
9	Female	37	Advance 2 mm Down 0.5 mm	Setback 6 mm
10	Male	19	Advance 5 mm Impact 4 mm	Setback 11 mm
11	Female	23	Advance 4 mm	Setback 4.5 mm
12	Male	22	Advance 3 mm Impact 1 mm	Setback 12 mm
13	Male	30	Advance 2.5 mm Down 1.5 mm	Setback 13 mm
14	Male	27	Advance 3 mm Impact 2 mm	Setback 10.5 mm
15	Male	25	Advance 4.5 mm Impact 1 mm	Setback 10.5 mm

Findings from the statistical analyses are presented in Tables 5 and 6. The midface analysis showed no statistically significant differences between T_1 and T_2 for midface depth on either side; however, there were statistically significant differences in the nose area. The nasal analysis showed no statistically significant differences between T_1 and T_2 for columella length or lower alar width. On the other hand, statistically significant differences were found for nose length (P=0.01) and upper alar width (P=0.00). The upper lip analysis found no statistically significant differences for any of the measurements, whether upper lip length, upper lip thickness, or point A to soft tissue point A.

The lower lip analysis revealed no statistically significant differences between T_1 and T_2 in terms of lower lip thickness or point B to soft tissue point B, whereas a marginal significance was found in terms of lower lip length. Soft tissue chin measurements exhibited no statistically significant differences between T_1 and T_2 for V angle or V line distance on either side. Differences in soft tissue chin thickness were found to be marginally significant with an average mean difference of 0.75 mm. Regarding throat length, statistically significant differences were found with a P=0.00.

This study measured linear and angular variables. Most of the differences in angular measurements of T_1 and T_2 were shown to be statistically significant, including the frontonasal angle (P=0.02), the nasolabial angle (P=0.00), and the lip-chin-throat angle (P=0.00).

Table 5 Differences between T1 and T2 revealing accuracy of middle face soft tissue simulation

Measurement (mm, degree)	T_1 Mean±SD	T_2 Mean±SD	$T_2 - T_1$ Mean difference±SD	95% CI		P-value
				Lower	Upper	
Midface						
Midface depth (Right)	7.83±2.73	6.55±2.65	-1.28±2.82	-2.78	0.22	0.09
Midface depth (Left)	7.01±2.30	6.08±2.66	-0.93±2.67	-2.35	0.49	0.18
Nose						
Frontonasal angle	139.90±6.91	138.27±7.90	-1.63±2.73	-3.08	-0.17	0.02*
Nasolabial angle	92.95±10.20	110.61±6.95	17.66±10.08	12.29	23.03	0.00*
Nose length	41.87±3.64	40.44±3.03	-1.43±1.67	-2.32	-0.54	0.01*
Upper alar width	39.74±3.99	42.12±3.51	2.39±2.36	1.13	3.64	0.00*
Columella length	9.29±1.57	9.39±1.45	0.10±1.05	-0.46	0.66	0.71
Lower alar width	31.73±3.50	31.13±4.27	-0.61±3.14	-2.28	1.06	0.91
Upper lip						
A to A' width	14.08±2.90	14.12±2.26	0.04±1.84	-0.94	1.02	0.93
Upper lip length	20.46±2.50	20.59±2.61	0.13±1.18	-0.50	0.76	0.67
Upper lip thickness	17.45±3.02	16.98±1.82	-0.47±1.97	-1.5	0.58	0.5

*Statistically significant at P<0.05. Differences tested using Paired T-test and Wilcoxon signed-rank test. T_1 = Simulation model, T_2 = Actual model

Table 6 Differences between T1 and T2 revealing accuracy of lower face soft tissue simulation

Measurement (mm, degree)	T_1 Mean±SD	T_2 Mean±SD	$T_2 - T_1$ Mean difference±SD	95% CI		P-value
				Lower	Upper	
Lower lip						
B to B' width	12.06±1.59	12.60±1.24	0.54±1.29	-0.15	1.23	0.12
Lower lip length	43.72±3.51	43.03±4.26	-0.69±1.14	-1.30	-0.08	0.04*
Lower lip thickness	16.25±2.86	16.16±2.48	-0.10±2.06	-1.19	1.00	0.60
Chin						
Soft tissue chin thickness	11.81±0.50	12.56±2.47	0.75±1.34	0.04	1.46	0.04*
Mentolabial angle	131.97±15.75	139.56±10.94	7.58±15.98	-0.93	16.10	0.08
V angle (soft tissue)	117.05±4.15	116.37±4.58	-0.67±1.52	-1.49	0.14	0.10
V line distance (Right)	66.83±5.57	66.31±5.48	-0.52±1.77	-1.46	0.42	0.70
V line distance (Left)	66.49±5.90	65.50±5.27	-0.99±1.26	-1.66	-0.32	0.42
Lip chin throat angle	102.95±15.21	121.17±10.40	18.22±14.06	10.73	25.71	0.00*
Throat length	34.70±10.21	46.56±8.73	11.87±10.74	6.15	17.59	0.00*

*Statistically significant at P<0.05. Differences tested using Paired T-test and Wilcoxon signed-rank test. T_1 = Simulation model, T_2 = Actual model

Discussion

This study aims to investigate the accuracy of prediction method performed in Dolphin 3D Software. The objective of virtual soft tissue simulation is to approximate post-operative soft tissue changes.[13] Patients' perceptions and satisfaction can be influenced by their soft tissue profile. While predicting final treatment outcomes is challenging, doing so accurately prevents patients from expecting too much.[14] In this study, CBCT scans were used to represent skeletal components. Skeletal movement during surgery plays an important role in altering soft tissue features. 3D simulation facilitates visualization of each treatment plan and evaluation of surgical effects upon soft tissue, including limitations of the treatment.[15] In our study, external reference planes used in 3D analysis were based on soft tissue structures. Various previous studies have used extraoral soft tissue images obtained from CBCT, but these were said to be untextured and unrealistic.[16-17] Therefore, additional facial scans merged with other components are crucial to performing accurate virtual simulation.

Maxillary advancement and impaction with mandibular setback were performed in all subjects. Moving maxillary downward was done in 2 subjects. According to Sun et al. the most problematic direction was vertical plane.[18] The accuracy of the vertical movement did not depend on digital splint. Therefore, the surgical procedure and surgeon's intraoperative decision played an important role to skeletal movement on vertical plane, which could affect soft tissue changes.[18] However, surgical operations were done by surgeons with more than 10 years of experience. Regarding to the operation notes of each subject, surgeons completed the surgery without any complications, and no different surgical procedures were observed. Moreover, orthodontic diagnosis was done under the same analysis, and pre-surgical orthodontic preparation was performed in all of the cases under the same principle.

In 2007, Kau et al. revealed that postoperative swelling reduced substantially within the following months after orthognathic surgery.[19] Approximately 60% of the swelling reduced after 1 month for both single and double jaw surgery, and facial morphology recovered to more than 83% within 3 months. Finally, soft tissue completely healed within 6 months. In our study, 3D facial soft tissue was scanned 3 months after surgery because greatest improvement of soft tissue healing was occurred, and to avoid soft tissue changes altered by post-surgical orthodontic tooth movement.

According to Bushchang et al. in 2005, soft tissue changes tend to differ according to ethnicity.[20] They also mentioned that soft tissue alteration as a result of surgical procedures vary across ethnic groups. Skeletal class III relationship prevalence has been shown to be highest among Asian populations.[21] Esthetic impairment in patients is primarily identified to be a result of skeletal class III malocclusion due to mandibular protrusion and midface deficiency. Among the different skeletal relationships, class III leads to the highest need for orthognathic surgery.[22-23] Therefore, this study specifically included skeletal class III patients to evaluate soft tissue features after mandibular setback and maxillary advancement.

According to Han and Lee, differences of soft tissue change larger than 2 mm affect the predicted profile and the patient's perceptions.[4] Hsu and Zhang et al. also found that different greater than 4 degrees would be considered clinically significant.[24-25] This indicates that prediction differences of linear measurement between 0-2 mm, and angular measurement between 0-4 degrees are clinically acceptable. Given this, prediction of nose length, lower lip length, soft tissue chin thickness, and frontonasal angle in the present study were found to be clinically acceptable, as their mean differences were less than 2 mm and 4 degrees accordingly.

Previous findings on the accuracy of virtual simulation prediction of soft tissue changes have varied. Nadmni et al. (2013) concluded that the chin region was predicted inaccurately in their study,[26] a finding consistent with our research, in which throat length and lip-chin-throat angle were found to be inaccurate. Throat length simulation was regularly shorter than the actual length. The mean difference between predicted and actual throat length was approximately 18 mm, which was extremely high, indicating severe distortion of the simulation model. Prediction of soft tissue chin thickness versus actual thickness was shown to have marginally significant differences, but the mean difference was just 0.75 mm, having only minimal effects on the predicted profile's accuracy. However, transverse analysis of soft tissue in the chin, including V angle and V line distances, were simulated more precisely with mean differences of less than 1 degree and 1 mm, respectively. Meanwhile, in 2016, Peterman et al. found that the most inaccurate area was the lower lip. This is not in line with our study.[14] Although our statistical analysis showed marginally significant differences (p=0.04) between simulated and actual lower lip length, the difference of only 0.69 mm was clinically insignificant. A study by Resnick et al. reported nasolabial angle as the area that was most inaccurately predicted, which corresponded to our findings.[10] Nasolabial angle was consistently simulated to be more acute than the actual outcome. Recently in 2019, Elshebiny et al. discovered that upper lip and subalar area were estimated inaccurately.[17] Their results differed from ours. Upper lip measurements were found to be extremely accurate with a mean difference between simulated and actual distance of less than 0.5 mm. Nadmni et al., Peterman et al., and Resnick et al. studied about skeletal class III surgery in Caucasian population, whereas Elshebiny evaluate orthognathic surgery in skeletal class III Egyptian. Regarding the variance in the studies mentioned above, differences in race or ethnicity of the subjects could be one explanation. Another possibility is differences in the quality of soft tissue images used in each study. Surface soft tissue images from CBCT are untextured and less accurate.

As concluded by Han and Lee, horizontal soft tissue changes were more predictable relative to those in other directions.[4] The present study also found that most of the inaccurate variables were angular measurements taken in the vertical direction, including frontonasal angle, nasolabial angle, mentolabial angle, and lip-chin-throat angle. The mean differences of nasolabial and lip-chin-throat angle in particular were 17.5 and 18 degrees, respectively, causing soft tissue simulation to deviate significantly from actual soft tissue features. Linear measurements were revealed to be more accurate than angular measurements.

Facial soft tissue was classified into 5 categories: midface, nose, upper lip, lower lip, and chin. Midface analysis on both sides showed accurate simulation by the software, while analysis of the nose revealed less accurate prediction. Simulation of the upper nose (supra columella area) - including the frontonasal angle, nose length, and upper alar width - did not conform well with actual outcomes, whereas simulation of the lower nose (sub columella area) - columella length and lower alar width - were more correctly predicted. Upper lip measurements, including upper lip length, upper lip thickness, and A to A' width, were extremely accurate. Lower lip analysis, including lower lip thickness and B to B' width, was accurate, while lower lip length showed differences that were marginally significant. However, the mean difference was less than 1 mm, small enough not to affect clinical practice. Finally, every measurement of the chin region, apart from throat length, was shown to be accurately predicted. The capacity for Dolphin 3D software to predict surgical outcomes is summarized and shown in Figure 3. The high-accuracy areas consisted of the midface, lower nose, upper lip, and lower lip. Soft-tissue chin thickness was found to be moderately accurate. However, prediction for the upper part of the nose was found to be unacceptable.

When using virtual simulation methods, clinicians should be reminded that prediction is only an estimation for which precision cannot be guaranteed. Virtual mandibular setback is generally demonstrated to predict significantly shorter throat length than that which occurs in reality. It is possible for orthodontists and surgeons to plan for adjunctive genioplasty. However, throat length shown in the software is unreliable, and chin augmentation is not an appropriate procedure for this situation. On the other hand, in maxillary advancement procedures, simulation appears to present more acute nasolabial angles than actually result. This may lead to the surgeon deciding to reduce the amount of advancement of the maxilla to prevent excessive reduction of nasolabial angle. To avoid decisions based on inaccurate information, it is crucial for orthodontists and surgeons to know the accuracy and limitations of software used in predicting post-surgery soft tissue features. The limitations of this study were limit number of sample size, and also patients with craniofacial anomalies were not included. Study of different skeletal relationships, such as skeletal class I or skeletal class II, and different surgical procedures could be performed in further study. Although various 3D software packages are available, conventional clinical examinations should also be taken into account.

Figure 3 Color mapping of software's prediction capacity (A) Frontal view (B) Lateral view
Green mapping: High-accuracy area (80% non-significance of linear measurements, both statistically and clinically)
Blue mapping: Moderate-accuracy area (50-80% non-significance of linear measurements, both statistically and clinically)
Grey mapping: Poor-accuracy area (<50% non-significance of linear measurements, both statistically and clinically)
Red line: Unpredictable angulation

Conclusion

The potential for Dolphin 3D software to accurately simulate soft tissue features in class III surgery cases can be summarized as follows:

- Linear measurements are more accurate than angular measurements.
- The accuracy of virtual systems when simulating soft tissue is different for each area of the face.
- Capacity for accurate 3D simulation can be classified into 3 levels:
  - Highly accurate: Midface, Upper lip, Lower lip, Lower part of the nose (sub columella area)
  - Moderately accurate: Soft tissue chin thickness
  - Poorly accurate: Upper part of the nose (supra columella area)
- The most inaccurate simulations created by the software were those representing the nasolabial angle, mentolabial angle, lip-chin-throat angle, and throat length. These simulations should be considered unacceptable for clinical practice.

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การทำนายเนื้อเยื่ออ่อนด้วยวิธีสามมิติ เพื่อวางแผนผ่าตัดกระดูกขากรรไกร ในผู้ป่วยที่มีความผิดปกติของกระดูกขากรรไกรประเภทที่ 3

ธนานนท์ เหล่ากุลดิลก พูนศักดิ์ ภิเศก** เสาวลักษณ์ ลิ้มมณฑล*** อารยา ภิเศก**** ภัทรมน รัตนาพันธุ์****

บทคัดย่อ

การรักษาทางทันตกรรมจัดฟันในปัจจุบัน มีจุดมุ่งหมายหลักในการปรับความสวยงามของใบหน้าของผู้ป่วยให้ดีขึ้น ผู้ป่วยที่มีความไม่สมดุลของลักษณะเนื้อเยื่ออ่อนที่มีสาเหตุจากความผิดปกติของโครงสร้างกระดูกขากรรไกรระดับรุนแรง ควรได้รับการรักษาด้วยการจัดฟันร่วมกับการผ่าตัดกระดูกขากรรไกร ซึ่งขั้นตอนการทำนายผลก่อนเริ่มการรักษาด้วยวิธีทำนายเสมือนจริงแบบสามมิติได้เข้ามามีบทบาทสำคัญ แต่อย่างไรก็ตาม ความเที่ยงตรงของวิธีข้างต้นยังไม่มีความชัดเจน ดังนั้นวัตถุประสงค์ของงานวิจัยนี้คือ เพื่อประเมินความเที่ยงตรงของการทำนายเนื้อเยื่ออ่อนด้วยวิธีสามมิติ ประชากรที่ใช้ในการศึกษาได้แก่ ผู้ป่วยที่มีความผิดปกติของโครงสร้างกระดูกขากรรไกรประเภทที่ 3 จำนวน 15 ราย โดยเก็บข้อมูลก่อนผ่าตัด 1 เดือน ประกอบด้วย ภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟ แบบจำลองฟันสามมิติ และภาพถ่ายใบหน้าสามมิติ เพื่อสร้างแบบจำลองทำนายผล (T_1) และเก็บข้อมูล 3 เดือนหลังผ่าตัด ประกอบด้วย ภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟ และภาพถ่ายใบหน้าสามมิติ เพื่อสร้างแบบจำลองแท้จริง (T_2) แบบจำลองทั้งสองจะถูกวัดมุม และระยะ ทำการวิเคราะห์ความแตกต่างทางสถิติ จากผลการศึกษา พบความแตกต่างอย่างมีนัยสำคัญทางสถิติในตัวแปรได้แก่ มุมระหว่างหน้าผากและจมูก ความยาวของจมูก มุมระหว่างจมูกและริมฝีปากบน ความกว้างของปีกจมูกส่วนบน มุมระหว่างริมฝีปาก คาง และคอ ความยาวของริมฝีปากล่าง ความหนาของคาง และความยาวของคอ ซึ่งสามารถสรุปได้ว่า การทำนายการเปลี่ยนแปลงของเนื้อเยื่ออ่อนของซอฟท์แวร์ดอลฟินสามมิติ ในผู้ป่วยที่มีความผิดปกติของโครงสร้างกระดูกขากรรไกรประเภทที่ 3 มีความเที่ยงตรงแตกต่างกันในแต่ละบริเวณบนใบหน้า โดยบริเวณที่สามารถทำนายได้เที่ยงตรงมากได้แก่ ใบหน้าส่วนกลาง ริมฝีปากบน ริมฝีปากล่าง และส่วนล่างของจมูก อย่างไรก็ตามควรมีความระมัดระวังในการประเมินส่วนบนของจมูก บริเวณที่สามารถทำนายได้เที่ยงตรงปานกลางได้แก่ ความหนาของคาง บริเวณที่ทำนายได้ไม่เที่ยงตรงมากที่สุดได้แก่ มุมระหว่างจมูกและริมฝีปากบน มุมระหว่างริมฝีปาก คาง และคอ และความยาวของคอ

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