

# 3-dimensional facial soft tissue changes following orthopedic maxillary expansion

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*2023 Research Aid Awards (RAA)*

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# FollowUp Form

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## *Award Information*

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*In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:*

- Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
- Does this Final Report provide the level of detail, etc. that you would expect, if you were the reviewer?*

### **Title of Project:\***

3-dimensional facial soft tissue changes following orthopedic maxillary expansion

### **Award Type**

Research Aid Award (RAA)

### **Period of AAOF Support**

July 1, 2023 through June 30, 2024

### **Institution**

The Research Foundation of the State University of New York - Stony Brook

### **Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s)**

Heather Ercolano, DDS; Hechang Huang, DDS, MSD, MS, PhD; Richard Faber, DDS, MS;

### **Amount of Funding**

\$6,000.00

## Abstract

(add specific directions for each type here)

Transverse maxillary deficiency is the major cause of posterior lingual crossbite, the most prevalent transverse malocclusion, and may lead to esthetic and functional alterations to the stomatognathic system. Orthopedic maxillary expansion (OME) is the most common treatment modality employed to treat transverse maxillary deficiency. Facial soft tissue esthetics is a primary goal of orthodontic treatment and a major focus of diagnosis, treatment planning and outcome evaluation. In addition to its dentoalveolar and skeletal effects, OME may change facial esthetics. However, 2D photos lack the ability to record and measure 3D changes. Currently available studies with 3D cone-beam computed tomography (CBCT) images or stereophotogrammetry are inconsistent on the facial soft tissue changes following OME, chiefly due to less than ideal quality and accuracy of 3D facial soft tissue images. A few earlier studies using 3D facial images demonstrated that the nasal base and the mouth widened following OME. These changes induced by OME may impact facial esthetics. There is an urgent need to use more accurate 3D image analyses to assess facial soft tissue changes following OME. The Stony Brook University Center of Excellence for Wireless and Information Technology (CEWIT) developed a state-of-the-art system to capture 3D facial soft images with advanced digital technologies that has demonstrated superior accuracy. Our working hypothesis is that OME will change facial soft tissue esthetics.

The Overall Objectives of this study is to assess 3D facial soft tissue changes following OME.

The Specific Aims are:

- 1) Quantify 3D facial soft tissue changes following OME, including specific sites and amount in the middle and lower facial regions. Measurements in the transverse, vertical and anterior-posterior dimensions using facial landmarks will be collected and analyzed.
- 2) Visualize the pre- and post- OME facial soft tissue changes by superimposing 3D images.

The Long-term Objectives of the project is to construct a digital model of facial soft tissue changes induced by OME to improve orthodontic treatment planning.

Clinical implications and Significance: Understanding facial soft changes following orthodontic treatments is crucial for treatment planning by providing services leading to optimal esthetic outcomes according to the soft tissue paradigm. OME is the most common treatment for transverse maxillary deficiency. This study will obtain 3D measurements of facial soft tissues to accurately quantify and visualize changes induced by OME, and serve as the foundation to guide clinical practice to achieve desired treatment goals.

## *Respond to the following questions:*

### Detailed results and inferences:\*

If the work has been published, please attach a pdf of manuscript below by clicking "Upload a file".

OR

Use the text box below to describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should also be attached by clicking "Upload a file".

Tables and Figures.pdf

**Introduction:** Evaluating the changes in soft tissues is of the utmost importance for an orthodontist for treatment planning purposes and to inform the parents of patients. The purpose of this study is to use a 3D camera to evaluate the soft tissue changes in the frontal planes and lateral planes of the orofacial region in patients undergoing rapid palatal expansion (RPE) used to treat a skeletal or dental transverse discrepancy.

**Methods:** Our prospective sample comprised patients scheduled to undergo RPE. The inclusion criterion for the RPE was patients with a skeletal or dental crossbite. This assessment was completed clinically, as well as on digital study models in Class I relationships.

According to power and size calculations, a priori, the ideal minimum sample of patients was set at 26, with power at 80% and  $\alpha = 0.05$ . To ensure that the sample size met these requirements, 45 patients were recruited consecutively at the Department of Orthodontics and Dentofacial Orthopedics, Stony Brook University School of Dental Medicine. Participation in the study was voluntary. 18 patients were excluded from the study because their records were incomplete or of poor quality. The sample thus comprised 27 patients (9 male, 18 female). The mean age at treatment start was 12.1 years (range, 7-16 years).

The inclusion criteria of this study were as follows: ages 8 to 16, a transverse discrepancy requiring orthopedic maxillary expansion (OME), and willingness to comply with orthodontic treatment, which involved taking several 3D photographs. The exclusion criteria included prior orthodontic treatment, with or without palatal expander, and/ or presence of a craniofacial deformity or syndrome. All patient's parents were informed about the details of the study and signed an informed consent form before 3D images were captured. In addition, if patients were above 12 years of age, they signed an assent form.

#### 3D Camera System

The 3D camera system utilizes visible structured light to create 3D geometry from 2D images take of the patient's head. This technology avoids the use of radioactive rays, relying solely on visible light. The system records images and processes them to extract ambient, modulation, and phase variations. It has a depth accuracy down to 0.2 mm and can scan at a rate of 30 frames per second. The geometric processing algorithm is specifically tailored to this study's research goals, focusing on the comparison, registration, and analysis of geometric surfaces.

The initial 3D facial surface images were taken prior to the activation of the palatal expander (T0) with eyes closed, lips relaxed and in contact. The same protocol was followed for images acquired at T0 and at T1, the completion of the expansion phase. The 3D images were saved as .STL files.

Segmentation of the facial images was completed using a system called Meshlab, which is a 3D mesh processing system for processing and editing 3D triangular meshes. Thirteen soft tissue landmarks (Table 1) were chosen: soft tissue naision, right and left endocanthion, pronasale, right and left ala, subnasale, labrale superius, stomion, labrale inferius, right and left cheilion, and soft tissue pogonion. All landmarks were identified and chosen by one investigator. The software computed distances between selected points (Table 2). The lengths between points have been calculated using both the Geodesic distance and the Euclidean distance.

Participating patients had a traditional hyrax-type palatal expander (Leone America, CA, USA) cemented to teeth using Ultra Band Lok (Reliance Orthodontic Products, Itasca, IL, USA) or tooth-borne MARPE palatal expander (Great Lakes Dental Technologies, Tonawanda, New York, USA) that is fixed to the palatal bone with screws and cemented to teeth using Ultra Band Lok.

The activation of the jackscrew was 0.2 mm for each quarter turn and the parents were instructed to activate the screw 2 turns per day (0.4 mm) for the hyrax expander. The activation of the MARPE was 0.133 mm for each 1/6th of a turn and the parents were instructed to activate the screw 2 turns per day (0.27 mm). The patients were typically recalled on a weekly basis during the expansion period. Intermolar width measured from the mesiopalatal cusp tips as well as the interscrew distance were used to determine if expansion was completed. Once the required expansion was achieved, the hyrax expanders were tied off using either brass wire or by bonding composite on the jackscrew. The appliance was then kept in for the retention period that ranged from 3-6 months.

Statistical analyses were performed using the SPSS statistical software. Raw data was placed into Microsoft Excel spreadsheets for statistical analysis. Descriptive statistics were run for the 27 patients at all measured geodesic and Euclidean lengths at T0 and T1. Parametric analyses included paired T tests run across time points to compare T0 to T1 for each patient for the Euclidean measurement and the geodesic measurement. Chi-squared test was used for sex distribution comparisons. Then, the Pearson correlation coefficient was calculated to determine the correlation between the expansion amount and the facial soft

tissue changes. Results were considered significant at  $p < 0.05$ . The intra-measurer reliability for selecting landmark points was assessed to evaluate the reliability of the measurements in the same image and by the same investigator. It was evaluated using the 3D images of 3 randomly selected subjects, 3 months after original point selection. The Intraclass Correlation Coefficient of reliability (ICC) was used to determine the reliability of landmark point selection.

Results: The ICC value for the inter-measurer reliability between the three sets of measurements were all above 0.90. The intra-measurer reliability was evaluated using a paired T test and were not significant. Of the 27 patients in the study, 18 participants were female (66.7%), and 9 participants were male (33.3%). The expansion amount ranged from 4mm to 10mm, with the mean being 7.07mm of expansion (Graph 1). When separating patients by expansion, patients were divided into 2 groups based on how much expansion completed was completed. There were 12 patients, 6 male and 6 female, who were expanded between 4-6mm. There were 15 patients, 3 male and 12 female, who were expanded greater than 6mm. The Pearson Chi-Square test was used to assess if there was an association between gender and expansion amount to reveal a p value of 0.1. Since the p value is greater than our significance of 0.05, this indicates that there is no association between gender and expansion amount (Table 3). The paired samples t test was used to compare the measures T0 and T1 for each pair. For the Euclidean measures, pairs 11, 12, and 13 were significant (Table 4). For the geodesic measures, pairs 4, 11, and 12 were significant (Table 5). We also separated the patients by expansion amount, 4-6 mm and 6+ mm, and ran the paired samples t test. This demonstrated that, within the Euclidean measures, the significant pairs were 12 and 13 for the 4-6 mm expansion group. For the 6+ mm expansion group, only pair 13 was significant (Table 6). For the geodesic measurements, within the 4-6 mm expansion group, the significant pairs were 11 and 12. For the 6+ mm expansion group, pairs 4 and 13 were significant (Table 7). The Pearson Correlation demonstrated several statistically significant correlations. Ones of particular interest within the geodesic measures include mouth width change and nasal base width change, right alar change and left alar change, right mouth width and right alar width, right mouth width and left alar width, left mouth with and right alar width, left mouth width and right mouth width (Table 8). In the vertical dimension, some statistically significant correlations include nasion to pogonion change and nasion to pronasale change, nasion to pogonion change and lower lip to pogonion change, and nasion to pronasale change and lower lip to pogonion change. For the Euclidean measures, the statistically significant correlations include, the right nasal base width change and left alar change, left nasal base width change and right nasal base width change, left mouth width change and left alar change, left mouth width and left alar change, change in mouth width and change in nasal base width, and the change in mouth width and change in nasal width at the alae. In the vertical dimension, there was statistically significant correlation between the nasion to pogonion change and nasion to pronasale change, the nasion to pogonion change and pronasale to subnasale change, and the nasion to pogonion change and lower lip to pogonion change (table 9).

Conclusion: The outcomes show that there are significant soft tissue changes in the vertical and transverse planes that occur from RPE in the orofacial region.

### **Were the original, specific aims of the proposal realized?\***

This study revealed significant orofacial soft tissue changes in both vertical and transverse dimensions that following RPE. The specific aims have been realized.

### **Were the results published?\***

No

**Have the results of this proposal been presented?\***

No

**To what extent have you used, or how do you intend to use, AAOF funding to further your career?\***

With the funding of the AAOF RAA, I was able to complete a project that will eventually get published, allowing me the catapult my career in research and academics.

**Accounting: Were there any leftover funds?**

\$1,000.00

***Not Published***

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**Are there plans to publish? If not, why not?\***

Yes, there are plans to begin the publishing process in July for the AJO-DO.

***Not Presented***

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**Are there plans to present? If not, why not?\***

There are plans to present the study in an AAO annual session.

***Internal Review***

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**Reviewer comments**

**Reviewer Status\***

## File Attachment Summary

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### *Applicant File Uploads*

- Tables and Figures.pdf

*Table 1: Soft tissue points with their corresponding anatomical name and definition.*

<b>Soft Tissue Point</b>	<b>Name of Point</b>	<b>Description</b>
0	Nasion	Most concave point in the midsagittal plane between the eyes
1	Right Endocanthion	Point where the upper and lower eyelids meet medially
2	Left Endocanthion	Point where the upper and lower eyelids meet medially
3	Pronasale	Most convex point in the midsagittal plane on the tip of the nose
4	Right Ala	Point where the nostril meets the cheek
5	Left Ala	Point where the nostril meets the cheek
6	Subnasale	Point in the midsagittal plane where the nasal septum meets the upper lip, point directly below the nasal septum
7	Labrale Superius	Point in the midsagittal plane at the top of the upper lip
8	Stomion	Point in the midsagittal plane where the upper and lower lips meet
9	Labrale Inferius	Point in the midsagittal plane at the bottom of the lower lip
10	Right Cheilion	Point at the lateralmost corner of the mouth
11	Left Cheilion	Point at the lateralmost corner of the mouth
12	Pogonion	Most anterior point on the convex portion of the chin in the midsagittal plane

*Table 2: Soft tissue points pairs and their descriptive distances.*

<b>Pair</b>	<b>Lengths Measured</b>	<b>Description</b>
1	3-4	Right Alar Width
2	3-5	Left Alar Width
3	0-3	Nasion to Pronasale Length
4	0-1	Right Nasal Base Width
5	0-2	Left Nasal Base Width
6	3-6	Pronasale to Subnasale Length
7	6-7	Philtrum Height
8	7-8	Upper Lip Height
9	8-9	Lower Lip Height
10	9-12	Lower Lip to Pogonion Length
11	8-10	Right Mouth Width
12	8-11	Left Mouth Width
13	0-12	Nasion to Pogonion Height
14	1-2	Nasal Base Width
15	4-5	Alar Width
16	10-11	Mouth Width

Table 3: Chi-Square Tests for Euclidean and Geodesic Measure.

Chi-Square Tests

measure		Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2- sided)	Exact Sig. (1- sided)
Euclidean	Pearson Chi-Square	2.700 <sup>a</sup>	1	.100		
	Continuity Correction <sup>b</sup>	1.519	1	.218		
	Likelihood Ratio	2.724	1	.099		
	Fisher's Exact Test				.127	.109
	Linear-by- Linear Association	2.600	1	.107		
	N of Valid Cases	27				
Geodesic	Pearson Chi-Square	2.700 <sup>a</sup>	1	.100		
	Continuity Correction <sup>b</sup>	1.519	1	.218		
	Likelihood Ratio	2.724	1	.099		
	Fisher's Exact Test				.127	.109
	Linear-by- Linear Association	2.600	1	.107		
	N of Valid Cases	27				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 4.00.

b. Computed only for a 2x2 table

Table 4: Euclidean paired samples t test.

**Paired Samples Test**

measure	Paired Differences		t	df	Sig. (2-tailed)		
	Mean	Std. Deviation					
Euclidean	Pair 1	R_alar_width_T0 - R_alar_width_T1	.18925	1.51198	.650	26	.521
	Pair 2	L_alar_width_T0 - L_alar_width_T1	-.40990	1.24148	-1.716	26	.098
	Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	-.60267	2.85368	-1.077	25	.292
	Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-.64043	1.92809	-1.627	23	.117
	Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	.10396	1.86520	.290	26	.774
	Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	.19765	1.48625	.678	25	.504
	Pair 7	philtrium_height_T0 - philtrium_height_T1	-.33059	1.45531	-1.180	26	.249
	Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	-.26159	1.24869	-1.047	24	.305
	Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-.64375	2.51080	-1.332	26	.194
	Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-1.12642	3.29273	-1.676	23	.107
	Pair 11	R_mouth_width_T0 - R_mouth_width_T1	1.84391	4.27329	2.200	25	.037
	Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-2.57682	3.70182	-3.549	25	.002
	Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-1.30216	2.10335	-3.217	26	.003
	Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	.08872	2.59145	.175	25	.863
	Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	.30340	3.11538	.477	23	.638
	Pair 16	mouth_width_T0 - mouth_width_T1	.32125	3.19775	.482	22	.635

Table 5: Geodesic paired samples t test.

		Paired Differences					
measure		Mean	Std. Deviation	t	df	Sig. (2-tailed)	
Geodesic	Pair 1	R_alar_width_T0 - R_alar_width_T1	.13929	1.41227	.512	26	.613
	Pair 2	L_alar_width_T0 - L_alar_width_T1	-.21104	1.29697	-.830	25	.415
	Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	.49017	2.52423	.990	25	.332
	Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-1.22737	2.03070	-2.899	22	.008
	Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	.30827	3.00938	.512	24	.613
	Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	.31503	1.65955	.910	22	.372
	Pair 7	philtrium_height_T0 - philtrium_height_T1	-.23003	1.53434	-.703	21	.490
	Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	-.17807	1.39643	-.663	26	.513
	Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-.78031	2.39187	-1.695	26	.102
	Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-.40097	2.29648	-.855	23	.401
	Pair 11	R_mouth_width_T0 - R_mouth_width_T1	2.19623	4.40801	2.541	25	.018
	Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-2.33488	3.71934	-3.201	25	.004
	Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-.71350	1.92763	-1.887	25	.071
	Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	.00372	3.02123	.006	23	.995
	Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	.75154	3.26302	1.128	23	.271
	Pair 16	mouth_width_T0 - mouth_width_T1	.62275	4.58670	.692	25	.495

Table 6: Euclidean t test grouped by expansion.

			Paired Samples Test					
measure	expansion.condensed		Paired Differences		t	df	Sig. (2-tailed)	
			Mean	Std. Deviation				
Euclidean	4-6	Pair 1	R_alar_width_T0 - R_alar_width_T1	.76043	1.59216	1.654	11	.126
		Pair 2	L_alar_width_T0 - L_alar_width_T1	-.51080	1.21057	-1.462	11	.172
		Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	.04173	1.10602	.131	11	.898
		Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-.67905	2.54492	-.885	10	.397
		Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	.61213	1.90069	1.116	11	.288
		Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	-.22095	1.45034	-.528	11	.608
		Pair 7	philtrium_height_T0 - philtrium_height_T1	-.54094	1.65802	-1.130	11	.282
		Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	.08958	1.47349	.202	10	.844
		Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-1.06671	2.05228	-1.801	11	.099
		Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-.87419	1.84557	-1.641	11	.129
		Pair 11	R_mouth_width_T0 - R_mouth_width_T1	3.14528	5.30884	1.965	10	.078
		Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-3.40219	3.60909	-3.266	11	.008
		Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-.99539	1.39242	-2.476	11	.031
		Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	-.54715	3.20133	-.567	10	.583
		Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	1.39095	3.83239	1.204	10	.256
		Pair 16	mouth_width_T0 - mouth_width_T1	1.38084	2.62484	1.578	8	.153
	6+	Pair 1	R_alar_width_T0 - R_alar_width_T1	-.26769	1.32305	-.784	14	.446
		Pair 2	L_alar_width_T0 - L_alar_width_T1	-.32918	1.30200	-.979	14	.344
		Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	-1.15501	3.73010	-1.159	13	.267
		Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-.60775	1.31361	-1.668	12	.121
		Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	-.30257	1.79557	-.653	14	.525
		Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	.55645	1.47232	1.414	13	.181
		Pair 7	philtrium_height_T0 - philtrium_height_T1	-.16231	1.30579	-.481	14	.638
		Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	-.53751	1.01099	-1.989	13	.068
		Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-.30538	2.84997	-.415	14	.684
		Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-1.37866	4.37319	-1.092	11	.298
		Pair 11	R_mouth_width_T0 - R_mouth_width_T1	.88957	3.18923	1.080	14	.298
		Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-1.86936	3.76342	-1.859	13	.086
		Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-1.54758	2.55883	-2.342	14	.034
		Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	.55502	2.03007	1.059	14	.308
		Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	-.61683	2.08842	-1.065	12	.308
		Pair 16	mouth_width_T0 - mouth_width_T1	-.35991	3.43338	-.392	13	.701

Table 7: Geodesic t test grouped by expansion.

		Paired Samples Test						
measure	expansion.condensed	Pair	condensed	Paired Differences			Sig. (2-tailed)	
				Mean	Std. Deviation	t		df
Geodesic	4-6	Pair 1	R_alar_width_T0 - R_alar_width_T1	.57308	1.52637	1.301	11	.220
		Pair 2	L_alar_width_T0 - L_alar_width_T1	-.47615	1.35574	-1.165	10	.271
		Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	.31641	.99936	1.097	11	.296
		Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-1.48306	2.47827	-1.795	8	.110
		Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	1.23778	4.18174	.936	9	.374
		Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	-.04939	1.42863	-.115	10	.911
		Pair 7	philtrium_height_T0 - philtrium_height_T1	-.52802	1.84991	-.903	9	.390
		Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	.22618	1.48413	.528	11	.608
		Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-1.07792	2.11177	-1.768	11	.105
		Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-.51599	1.76254	-.971	10	.354
		Pair 11	R_mouth_width_T0 - R_mouth_width_T1	3.82519	5.29876	2.394	10	.038
		Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-3.19915	3.64903	-3.037	11	.011
		Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-.29163	2.12519	-.475	11	.644
		Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	-.41755	3.88135	-.357	10	.729
		Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	1.44982	3.80851	1.319	11	.214
		Pair 16	mouth_width_T0 - mouth_width_T1	1.05644	3.97875	.920	11	.377
	6+	Pair 1	R_alar_width_T0 - R_alar_width_T1	-.20774	1.25826	-.639	14	.533
		Pair 2	L_alar_width_T0 - L_alar_width_T1	-.01663	1.26301	-.051	14	.960
		Pair 3	nasion_pronasale_T0 - nasion_pronasale_T1	.63911	3.36994	.710	13	.490
		Pair 4	R_Nasal_base_width_T0 - R_Nasal_base_width_T1	-1.06300	1.76769	-2.250	13	.042
		Pair 5	Left_Nasal_base_width_T0 - Left_Nasal_base_width_T1	-.31140	1.80417	-.668	14	.515
		Pair 6	pronasale_subnasale_T0 - pronasale_subnasale_T1	.64907	1.84343	1.220	11	.248
		Pair 7	philtrium_height_T0 - philtrium_height_T1	.01830	1.24357	.051	11	.960
		Pair 8	upper_lip_ht_T0 - upper_lip_ht_T1	-.50147	1.28010	-1.517	14	.151
		Pair 9	lower_lip_ht_T0 - lower_lip_ht_T1	-.54222	2.64276	-.795	14	.440
		Pair 10	lower_lip_pogonion_T0 - lower_lip_pogonion_T1	-.30365	2.73807	-.400	12	.696
		Pair 11	R_mouth_width_T0 - R_mouth_width_T1	1.00166	3.32094	1.168	14	.262
		Pair 12	L_mouth_width_T0 - L_mouth_width_T1	-1.59407	3.74907	-1.591	13	.136
		Pair 13	Nasion_pogonion_T0 - Nasion_Pogonion_T1	-1.07510	1.73752	-2.315	13	.038
		Pair 14	Nasal_base_width_T0 - Nasal_base_width_T1	.36019	2.15419	.603	12	.558
		Pair 15	Nasal_width_at_alae_T0 - Nasal_width_at_alae_T1	.05326	2.58727	.071	11	.944
		Pair 16	mouth_width_T0 - mouth_width_T1	.25101	5.17106	.182	13	.859

**Table 8: Pearson Correlation using Geodesic measure of change.**

**Correlations**

Pearson Correlation  
measure: Geodesic

	change.r.alar	change.l.alar	change.nasion.to.pronasale	change.R.nasal.base.width	change.left.nasal.base.width	change.pronasale.subnasale	change.philtrium.height	change.upper.lip.height	change.lower.lip.height	change.lower.lip.pogonion	change.L.mouth.width	change.nasion.pogonion	change.nasal.base.width	change.nasal.width.at.alae	change.nasal.width	change.mouth.width
change.r.alar	1	-.436*	.290	-.278	-.060	-.118	.067	.034	.049	-.332	.660**	-.311	-.002	-.375	-.289	
change.l.alar	-.436*	1	.042	-.413*	.187	-.083	-.110	.194	-.151	-.143	-.556**	.160	.075	-.006	.057	
change.nasion.to.pronasale	.290	.042	1	.095	-.028	-.176	.021	-.033	-.184	-.520**	-.100	-.653**	-.130	-.276	-.452*	
change.R.nasal.base.width	-.278	-.413*	.095	1	-.483*	.287	.058	-.245	-.135	.147	-.110	-.223	.024	.213	.132	
change.left.nasal.base.width	-.060	.187	-.028	-.483*	1	-.441*	-.180	.273	-.030	.002	-.010	.282	-.271	-.296	-.387*	
change.pronasale.subnasale	-.118	-.083	-.176	.287	-.441*	1	.066	-.026	-.266	.113	.114	-.095	.095	.122	.210	
change.philtrium.height	.067	-.110	.021	.058	-.180	.066	1	-.018	-.132	.315	.125	.021	.365	-.167	.204	
change.upper.lip.height	.034	.194	-.033	-.245	.273	-.026	-.018	1	-.226	.318	.020	.339	.414*	-.374	.054	
change.lower.lip.height	.049	-.151	-.184	-.135	-.030	-.266	.132	-.226	1	.485*	.157	.253	.157	.353	.381*	
change.lower.lip.pogonion	-.332	-.143	-.520**	.147	.002	.113	.315	.318	.485*	1	.080	.611**	.332	.321	.600**	
change.L.mouth.width	.660**	-.556**	-.100	-.110	-.010	.114	.125	.020	.157	.080	1	-.047	-.093	-.248	-.179	
change.nasion.pogonion	-.311	.160	-.653**	-.223	.282	-.095	.021	.339	.253	.611**	-.047	1	.289	.030	.338	
change.nasal.base.width	-.002	.075	-.130	.024	-.130	.095	.365	.414*	.157	.332	-.093	.289	1	-.080	.645**	
change.nasal.width.at.alae	-.375	-.006	-.276	.213	-.296	.122	-.167	-.374	.353	.321	-.248	.030	-.080	1	.675**	
change.mouth.width	-.289	.057	-.452*	.132	-.387*	.210	.304	.054	.381*	.600**	-.179	.338	.645**	.675**	1	

\*\* Correlation is significant at the 0.01 level (2-tailed).  
\* Correlation is significant at the 0.05 level (2-tailed).

**Table 9: Pearson Correlation using Euclidean measure of change.**

**Correlations**

Pearson Correlation  
measure: Euclidean

	change.r.alar	change.l.alar	change.nasion.to.pronasale	change.R.nasal.base.width	change.left.nasal.base.width	change.pronasale.subnasale	change.philtrium.height	change.upper.lip.height	change.lower.lip.height	change.lower.lip.pogonion	change.L.mouth.width	change.nasion.pogonion	change.nasal.base.width	change.nasal.width.at.alae	change.nasal.width	change.mouth.width
change.r.alar	1	-.248	.338	-.357	-.128	.032	.147	.056	-.023	-.361	.690**	-.157	-.098	-.265	-.234	
change.l.alar	-.248	1	.234	-.443*	.124	-.028	-.042	.139	-.128	-.369	-.539**	-.180	.182	-.111	.035	
change.nasion.to.pronasale	.338	.234	1	.129	-.502**	.381	.085	-.078	-.354	-.617**	.001	-.853**	.063	-.214	-.181	
change.R.nasal.base.width	-.357	-.443*	.129	1	-.550**	.291	-.037	-.246	-.199	.189	-.087	-.187	.029	.190	.111	
change.left.nasal.base.width	-.128	.124	-.502**	-.550**	1	-.675**	-.201	.275	.204	.299	-.026	.461*	-.161	-.169	-.219	
change.pronasale.subnasale	.032	-.028	.381	.291	-.675**	1	.107	-.105	-.229	-.104	.080	-.430*	.045	.091	.106	
change.philtrium.height	.147	-.042	.085	-.037	-.201	.107	1	.016	.200	.211	.165	-.006	.352	-.211	.163	
change.upper.lip.height	.056	.139	-.078	-.246	.275	-.105	.016	1	-.313	-.041	-.015	.302	.387*	-.510**	-.151	
change.lower.lip.height	-.023	-.128	-.354	-.199	.204	-.229	.200	-.313	1	.648**	.072	.329	.150	.341	.411*	
change.lower.lip.pogonion	-.361	-.369	-.617**	.189	.299	-.104	.211	-.041	.648**	1	.001	.541**	.064	.328	.326	
change.L.mouth.width	.690**	-.539**	.001	-.087	-.026	.080	.165	-.015	.072	.001	1	.084	-.230	-.166	-.238	
change.nasion.pogonion	-.157	-.190	-.853**	-.187	.461*	-.430*	-.006	.302	.329	.541**	.084	1	.101	-.034	.098	
change.nasal.base.width	-.098	.182	.063	.029	-.161	.045	.352	.387*	.150	.064	-.230	.101	1	-.087	.640**	
change.nasal.width.at.alae	-.265	-.111	-.214	.190	-.169	.091	-.211	-.510**	.341	.328	-.166	-.034	-.087	1	.685**	
change.mouth.width	-.234	.035	-.181	.111	-.219	.106	.163	-.151	.411*	.326	-.238	.088	.640**	.685**	1	

\*\* Correlation is significant at the 0.01 level (2-tailed).  
\* Correlation is significant at the 0.05 level (2-tailed).