Quantitative Assessment Protocol for Facial Soft Tissue Volumetric Changes with Stereophotogrammetry

Ermina Lee[1], **Konstantinia Almpani**[1], **Marcus Crayton**[2], **Janice S. Lee**[1]

[1] Craniofacial Anomalies Bone Regeneration Section, National Institute of Dental and Craniofacial Research [2] Howard University Hospital, Oral and Maxillofacial Surgery Department, Howard University Hospital

Corresponding Author

Konstantinia Almpani
nadine.almpani@nih.gov

Citation

Lee, E., Almpani, K., Crayton, M., Lee, J.S. Quantitative Assessment Protocol for Facial Soft Tissue Volumetric Changes with Stereophotogrammetry. *J. Vis. Exp.* (), e69204, doi:10.3791/69204 (2025).

Date Published

September 25, 2025

DOI

10.3791/69204

URL

jove.com/t/69204

Abstract

The assessment of the impact of dental and orthodontic treatment, as well as of orthognathic surgery on facial soft tissue, is critically important because these types of treatment can significantly impact facial esthetics and, therefore, patient satisfaction. Accurate evaluation of the facial soft tissue response is essential for the achievement of optimum treatment results. Three-dimensional (3D) stereophotogrammetry is a reliable, radiation-free, non-invasive tool that can be used for quantitative assessments of the soft tissue surface, offering a highly accurate representation of the facial structures. The aim of this protocol is to demonstrate a methodology that can be used for the quantitative assessment of facial soft tissue changes with the use of stereophotogrammetry. For the video demonstration, we used a 3D image analysis software. The proposed protocol includes the steps of image preparation, spatial registration to a 3D axis, selection and superimposition of the areas of interest, and calculation of the volume of the area included between the two soft tissue surface images that are involved in the assessment. This protocol has been tested for its validity and reproducibility and can have variable applications for clinical as well as research purposes.

Introduction

The assessment of facial soft tissue changes is important in dentistry because facial soft tissues are an essential part of esthetics and function and are considered an integral part of treatment planning across dental disciplines. Soft tissue evaluation allows clinicians to predict the impact of therapeutic interventions-such as orthodontics, prosthodontics, and orthognathic surgery-on facial appearance and balance. Relying solely on skeletal or dental measurements can result in compromised treatment outcomes, as the achievement of ideal occlusion and/or skeletal relationships does not always translate to balanced or desired facial soft tissue changes[1,2].

Soft tissue analysis is essential for individualized treatment planning as it helps identify baseline facial characteristics, anticipate the effects of growth and aging, and predict how dental, orthodontic, or surgical interventions will alter facial contours and structural support[3,4]. Specifically, changes in lip support, facial convexity, and lower facial height are directly influenced by dental and skeletal modifications, and these changes can significantly affect patient satisfaction and the perceived aesthetic outcome[1,3]. Accurate assessment of soft tissue changes is crucial for achieving optimal results in esthetic zones, particularly in implant and restorative dentistry, where the preservation or augmentation of soft tissue volume is necessary to maintain a natural appearance and function[5]. Modern three-dimensional imaging and scanning technologies have improved the precision and reproducibility of soft tissue measurements, facilitating better diagnosis, treatment planning, and outcome evaluation[6,7].

The gold standard for assessment is serial 3D imaging to quantify soft tissue volume changes, supplemented by clinical examination and patient-reported symptoms[8]. The most accurate and reproducible approach is serial 3D stereophotogrammetry or laser surface scanning, which allows for precise measurement of soft tissue volume changes over time[8,9,10]. Previous publications have described quantitative methods for the assessment of facial soft tissue changes in the oral and maxillofacial literature, though reported outcomes remain highly variable[8,9,10,11,12,13,14,15]. However, in most of the previous studies, details regarding the steps involved are not included, and the reproducibility of the results is often not reported. Moreover, there is no video demonstration of the manual part of the process, which would be practically very valuable to clinicians and researchers who are interested in conducting soft tissue assessment. This video demonstration showcases in detail a methodology for conducting a semi-automated, high-accuracy, and highly reproducible 3D volumetric change assessment using facial surface imaging.

Protocol

This protocol was conducted in accordance with the ethical guidelines established by the Institutional Review Board of the National Institutes of Health (NIDCR IRB #16-D-0040). Informed consent was obtained from all subjects under an NIH IRB-approved protocol (NCT02639312), permitting the use of the3D facial photographs in research-related publications. All imaging was performed at the NIH Dental Clinic with the use of a 3D imaging system[16]. See the **Table of Materials** for details regarding the software used in this protocol. Explicit consent was obtained for the use of the 3D facial photographs used in this protocol.

1. Image preparation

1. The system captures three images: Right, Front, Left, and automatically processes these into a single 3D image. If auto-stitching fails, ensure the images were taken in the specified order and that positioning was correct (camera angle, open eyes, closed mouth). If the images appear to be properly captured, place manual landmarks as instructed by the software, and once satisfied, click **retry stitch**.

2. To manipulate the image without changing the spatial orientation, use the tools indicated with an **eye** icon in the left menu: **move, rotate, tilt, zoom**.

3. Remove unnecessary areas from the image using **Box Crop** to quickly eliminate everything outside the selected rectangular frame.

   NOTE: For more precise editing, use the **Paint Area Selection**, which allows for the manual selection of areas for removal, with the option to adjust brush size for detailed refinement.

4. Save the edited image using the **save** option from the **File** menu.

2. Baseline image registration to the 3D axis grid

NOTE: The baseline image is defined by the study design. This image is a reference from which the individual subject's subsequent images will be registered. Midline symmetry is established as follows:

1. Show **Axis Grids** in the viewport.
2. Click on **Snap View** to square the image to the nearest 90° frontal view.
3. From the left-side menu, select **Spin Active Surfaces** (cube icon) and rotate the image until it is evenly bisected by the vertical (Y) axis.
4. Using the **Paint Area Selection** tool, drag the brush across the frontal surface of the image by holding down the left mouse button and moving the cursor to highlight the face
5. Once selected, click **Find Symmetry** to automatically align the image along the vertical axis through its center
6. Use **Clear Area** to deselect the region after.
7. To correct image rotation and establish front-to-back orientation for registration, begin by displaying the image in two viewports.
8. Use the **Spin** tool (eye icon) and **Snap** function to obtain a lateral view. In the lateral viewport, use **Roll Active Surfaces** (cube icon) to adjust the image so that the head position is aligned vertically with the grid. Next, select **Pan Active Surfaces** (cube icon) and move the image within the lateral view until it is centered on the main vertical axis. Be sure to save the registered image.

3. Landmark annotations

NOTE: A soft tissue landmark-based registration was selected over a surface-based method to better account for variation in surface availability, which is limited by image quality and restricted to regions unaffected by surgery. The sequence of landmark annotations should be the same for each image. If possible, annotate a patient-specific landmark, such as a scar or mole, that lies outside of the region affected by surgery. The landmark selection should depend on the area of interest for each assessment.

1. To follow this protocol, use the following landmarks (see **Figure 1**):
   1. Medial canthus/Endocanthion (en): the inner commissure of each eye fissure. ~~Annotate the left first, then right.~~ Verify correct placement in the frontal view.
   2. Lateral canthus/Exocanthion (ex): the outer commissure of each eye fissure. ~~Annotate the left first, then right.~~ Verify correct placement in the frontal view.
   3. Glabella (g): most anterior midpoint on the fronto-orbital soft tissue contour. Identify the landmark placement on right and left profile views and then verify midline alignment in the frontal view.
2. Annotate the landmarks with the use of the **landmark** option from the left side menu
3. Save the landmarked image.

4. Selection of areas of interest in the baseline image and volume measurement

1. In the frontal view, select the **Pick Multiple Points for Closed Loop** tool and place points along the perimeter of the region of interest.
2. After completing the loop, select **Add to Area**.
3. Use the **Paint Area** tool to refine the selection by adding or erasing from the region of interest.
4. Perform the same procedure in the lateral and submental views to cover the region.
5. Once satisfied, use **Copy Area** to create a mask.
6. ~~Apply the **Closed Surface Volume** tool to measure the total volume within the region of interest. Be sure to save the image mask.~~
NOTE: In this protocol, the region of interest was defined as that affected by orthognathic surgery and delineated by the lateral and medial canthi, glabella, and cervico-mental angle.

5. Registration of subsequent images, superimposition of area of interest, and volume measurement

1. Open both the baseline image and image that will be registered to the baseline axis grid.
2. Select the **Side-by-Side** viewport with synchronization toggled off.
3. Use the **Spin** tool (eye icon) to manually rotate the image until its orientation closely matches that of the baseline image.
4. Once aligned visually, place the landmarks in the same sequence as described in step 3.
5. Select **Register Surfaces** and apply the following settings: move this surface "image" to fit this surface "baseline" and calculate alignment using "landmarks with corresponding names."
6. Switch to a single viewport and check the registration by performing **Color Surface by Distance** with the following selections: **color whole of**, this surface "baseline" by the distance to this surface "image".
NOTE: Unaffected or unaltered regions should show minimal color variation if registered well. Make sure to save the registered image.
7. Return to two viewports and use **Project Selected Area** to highlight the corresponding region from baseline onto the second image
8. Use **Copy Area** to create a mask isolating the region of interest.
9. ~~Use the **Closed Surface Volume** tool to measure the volume within the masked region.~~

Representative Results

This protocol describes in detail a standardized, reproducible approach for the 3D assessment of facial soft tissue changes. Stereophotogrammetry allows for the accurate quantification of facial swelling by capturing surface changes over time. Using a landmark-guided registration process, postoperative images are aligned to a stable baseline, enabling superimposition and comparison of areas affected by surgery. An area of interest is defined using reproducible anatomical boundaries, and the corresponding volume is calculated in cubic millimeters (cm^3). As each subject serves as their own internal control, absolute volumes are not directly comparable between subjects in this analysis.

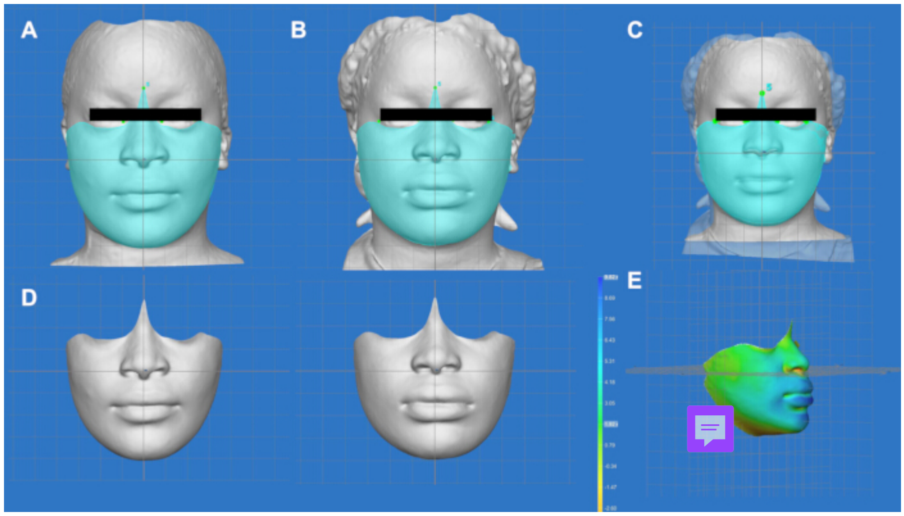

Figure 1: Demonstration of three-dimensional volumetric measurement. Demonstration of the use of this protocol for the quantitative assessment of the amount of facial swelling after orthognathic surgery. (**A**) Baseline image acquired one year after the surgery, when postoperative swelling was completely resolved. The image was registered to a 3D axis grid using the following anatomical landmarks: bilateral medial and lateral canthi, glabella. with definition of the ROI. (**B**) Postoperative image acquired 1 week after surgery, when most patients experience the most swelling. It was registered to the same axis grid, with projection of the baseline ROI onto the image.**(C**) Superimposition of baseline and postoperative images to confirm alignment accuracy.**(D**) Volumetric masks generated from the ROI at both time points, with resulting volumetric measurement in cubic millimeters (cm^3).**(E**) Heat map comparing volume differences between the masks; blue and green indicate increased volume, while yellow and orange indicate decreased volume as compared to the baseline image. A color-coded number index is included as a reference. The exact volumetric difference between the two masks is also provided as an output. Please click here to view a larger version of this figure.

Discussion

3D imaging has become the standard of care in the fields of dentistry and craniofacial surgery and offers quantitative soft tissue assessments of high precision[9]. The reproducibility and accuracy of the placement of anatomical landmarks on 3D images have also been validated in previous studies[17]. Therefore, stereophotogrammetry or 3D facial soft tissue images enables the acquisition of precise anthropometric measurements and the objective quantification of soft tissue changes through longitudinal image comparisons.

Prior literature on facial soft tissue assessment often describes methods that require extensive training in specialized image analysis software, the combination of different imaging modalities and types of software, or the annotation of multiple landmarks, which can necessitate substantial time and effort from users[9,11,12,18,19,20,21,22,23,24]. An area-based superimposition is also offered as an option by different software and has been implemented in previous studies[25]. This is an alternative superimposition tool that could be used instead of the manual landmark annotation. However, based on the practical experience of the authors after having tested both methods as part of a retrospective cohort study, landmark-based superimposition was an easier and more accurate option.

The main reason was that the area-based superimposition was more sensitive to small differences between the superimposed images, like, for example, the presence of even a single hair on the skin surface or the precise orientation of the head. This is an inherent problem in retrospective studies that could have been avoided with the use of a more standardized image acquisition protocol, as advised below. Nevertheless, previous publications using landmark-based superimposition do not include stepwise guidance of the process so that it can be easily replicated by other clinicians and/or researchers. We present here a standardized framework for the quantification of volumetric changes, which is already integrated into existing imaging software. This is a straightforward approach to volumetric soft tissue evaluations that does not require expertise in the field of image analysis to be completed.

Some of the technical challenges that are often encountered during the superimposition of facial surface images are related to the presence of facial hair. Depending on its length and thickness, facial hair can significantly compromise the accuracy of the scans because the skin surface is obscured. Consequently, the comparison between scans, which is a high-sensitivity, quantitative assessment, is going to be unreliable. Therefore, the existence of very minimal or, ideally, no facial hair is strongly recommended prior to the acquisition of the 3D facial scans. The subject's hair should also be placed away from the face, allowing for a clear view of the face, forehead, and ears.

In addition, patients with oral breathing patterns or lip incompetency due to underlying skeletal discrepancies often tend to posture with their lips apart. This can become a problem during the comparison of serial scans, especially when the position of the lips is not consistent. The position of the lips should be reproducible when two or more scans taken at different timepoints will be included in comparative volumetric evaluations. Finally, facial expressions should also be avoided during the acquisition of the scans for consistency and reproducibility reasons. It is recommended that all images be taken with the patient maintaining a neutral facial expression, with their lips closed, if possible, and keeping their teeth in contact in their habitual bite relationships. This position is considered the easiest to replicate over time.

Moreover, it is also important to instruct the subjects accordingly, so that they know exactly what they need to do and what the process of capturing the images includes. For the same reason, the personnel involved in the acquisition of the images should be trained and calibrated with each other, when more than one person is involved. This can significantly improve the quality of the scans and, subsequently, the accuracy of the quantitative evaluations.

In summary, this protocol provides a practical guide for future clinical assessments and research studies seeking to evaluate the impact of different types of therapeutic interventions on facial esthetics, as well as the progression of healing processes, in the case of longitudinal assessments. This type of assessment could be very informative in various fields of dentistry, and particularly in the fields of fixed and removable prosthodontics, orthodontics, and orthognathic surgery[26,27,28,29,30,31,32]. Research studies focusing on soft-tissue response to dental and/or skeletal tissue interventions would provide valuable information about the effect of these various treatment modalities on the facial soft tissue contour, which is an essential component of the overall treatment result. In addition, longitudinal assessments of the soft tissue changes related to aging can be equally informative about the long-term effect that different types of treatment could have on the soft tissue profile. This information could be used in the future as part of customized treatment result simulation approaches, which could be an essential part of treatment planning and patient consultations.

Disclosures

The authors have no conflicts of interest to disclose.

Acknowledgments

This research was supported by the Intramural Research Program of the National Institute of Dental and Craniofacial Research (NIDCR) of the National Institutes of Health (NIH).

References

1. Bergman, R. T. Cephalometric soft tissue facial analysis. *Am J Orthod Dentofacial Orthop.* **116** (4), 373-389 (1999).
2. Mack, M. R. Perspective of facial esthetics in dental treatment planning. *J Prosthet Dent.* **75** (2), 169-176 (1996).
3. Arnett, G. W. et al. Soft tissue cephalometric analysis: Diagnosis and treatment planning of dentofacial deformity. *Am J Orthod Dentofacial Orthop.* **116** (3), 239-253 (1999).
4. Bishara, S. E., Jakobsen, J. R., Hession, T. J., Treder, J. E. Soft tissue profile changes from 5 to 45 years of age. *Am J Orthod Dentofacial Orthop.* **114** (6), 698-706 (1998).
5. Frese, C., Staehle, H. J., Wolff, D. The assessment of dentofacial esthetics in restorative dentistry: A review of the literature. *J Am Dent Assoc.* **143** (5), 461-466 (2012).
6. Gašparović, B. et al. Comparing direct measurements and three-dimensional scans for evaluating facial soft tissue. *Sensors (Basel).* **23** (5), 2412 (2023).
7. Cevidanes, L. H., Motta, A., Proffit, W. R., Ackerman, J. L., Styner, M. Cranial base superimposition for 3-dimensional evaluation of soft-tissue changes. *Am J Orthod Dentofacial Orthop.* **137** (4 Suppl), S120-129 (2010).
8. Van der Vlis, M., Dentino, K. M., Vervloet, B., Padwa, B. L. Postoperative swelling after orthognathic surgery: A prospective volumetric analysis. *J Oral Maxillofac Surg.* **72** (11), 2241-2247 (2014).
9. Yamamoto, S. et al. Intuitive facial imaging method for evaluation of postoperative swelling: A combination of 3-dimensional computed tomography and laser surface scanning in orthognathic surgery. *J Oral Maxillofac Surg.* **74** (12), 2506.e2501-2506.e2510 (2016).
10. Reategui, A. et al. Postoperative edema resolution post-orthognathic triple jaw surgery: A three-dimensional volumetric analysis. *J Craniofac Surg.* **33** (2), 512-516 (2022).
11. Ding, M., Li, C., Kang, Y., Shan, X., Cai, Z. Changes of the facial soft tissue after mandibular reconstruction using vascularized iliac flap. *Clin Oral Investig.* **27** (11), 6619-6625 (2023).

12. Huang, L., Li, Z., Yan, J., Chen, L., Piao, Z. G. Evaluation of facial soft tissue thickness in asymmetric mandibular deformities after orthognathic surgery. *Maxillofac Plast Reconstr Surg.* **43** (1), 37 (2021).
13. Sakane, K. et al. Factors affecting progressive facial swelling immediately after orthognathic surgery: A retrospective cohort study. *J Craniomaxillofac Surg.* **51** (11), 692-695 (2023).
14. Dann, J. J. 3rd, Fonseca, R. J., Bell, W. H. Soft tissue changes associated with total maxillary advancement: A preliminary study. *J Oral Surg.* **34** (1), 19-23 (1976).
15. Betts, N. J., Dowd, K. F. Soft tissue changes associated with orthognathic surgery. *Atlas Oral Maxillofac Surg Clin North Am.* **8** (2), 13-38 (2000).
16. Camison, L. et al. Validation of the Vectra H1 portable three-dimensional photogrammetry system for facial imaging. *Int J Oral Maxillofac Surg.* **47** (3), 403-410 (2018).
17. Metzler, P. et al. Validity of the 3D Vectra photogrammetric surface imaging system for cranio-maxillofacial anthropometric measurements. *Oral Maxillofac Surg.* **18** (3), 297-304 (2014).
18. Rana, M., Gellrich, N. C., Joos, U., Piffkó, J., Kater, W. Three-dimensional evaluation of postoperative swelling using two different cooling methods following orthognathic surgery: A randomised observer blind prospective pilot study. *Int J Oral Maxillofac Surg.* **40** (7), 690-696 (2011).
19. Kwon, S. H. et al. Three-dimensional photogrammetric study on age-related facial characteristics in Korean females. *Ann Dermatol.* **33** (1), 52-60 (2021).
20. Kim, Y. S. et al. Regional thickness of facial skin and superficial fat: Application to the minimally invasive procedures. *Clin Anat.* **32** (8), 1008-1018 (2019).
21. Piombino, P. et al. Facial soft tissue thickness measurement method and relationship with BMI, age and sex. *J Stomatol Oral Maxillofac Surg.* **124** (4), 101420 (2023).
22. Kamak, H., Celikoglu, M. Facial soft tissue thickness among skeletal malocclusions: Is there a difference? *Korean J Orthod.* **42** (1), 23-31 (2012).
23. Buitenhuis, M. B., Klijn, R. J., Rosenberg, A., Speksnijder, C. M. Reliability of 3D stereophotogrammetry for measuring postoperative facial swelling. *J Clin Med.* **11** (23), 7137 (2022).
24. Mailey, B. et al. Evaluation of facial volume changes after rejuvenation surgery using a three-dimensional camera. *Aesthet Surg J.* **36** (4), 379-387 (2016).
25. Stucki, S., Gkantidis, N. Assessment of techniques used for superimposition of maxillary and mandibular 3D surface models to evaluate tooth movement: A systematic review. *Eur J Orthod.* **42** (5), 559-570 (2020).
26. Hernández, E. L., Alvarez, A., Abou-Ayash, S., Att, W. Effect of complete dentures on facial soft tissue volume: A 3D comparative study. *Int J Prosthodont.* **35** (2), 208-218 (2022).
27. Güler, Ö. Malkoç, S. Comparison of facial soft tissue changes after treatment with three different functional appliances. *Am J Orthod Dentofacial Orthop.* **158** (4), 518-526 (2020).
28. Susarla, S. M., Berli, J. U., Kumar, A. Midfacial volumetric and upper lip soft tissue changes after Le Fort I

advancement of the cleft maxilla. *J Oral Maxillofac Surg.* **73** (4), 708-718 (2015).

29. Maal, T. J. et al. One-year postoperative hard and soft tissue volumetric changes after a BSSO mandibular advancement. *Int J Oral Maxillofac Surg.* **41** (9), 1137-1145 (2012).
30. Yazaki, M. et al. Comparison of three-dimensional soft tissue changes according to the split pattern after sagittal split osteotomy in patients with skeletal class III malocclusion. *Clin Oral Investig.* **28** (1), 34 (2023).
31. Salloum, E., Millett, D. T., Kelly, N., McIntyre, G. T., Cronin, M. S. Soft tissue changes: A comparison between changes caused by the construction bite and by successful treatment with a modified twin-block appliance. *Eur J Orthod.* **40** (5), 512-518 (2018).
32. Choi, T. H., Kim, S. H., Yun, P. Y., Kim, Y. K., Lee, N. K. Soft tissue changes after clockwise rotation of maxillo-mandibular complex in class III patients: Three-dimensional stereophotogrammetric evaluation. *J Craniofac Surg.* **32** (2), 612-615 (2021).