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Original research

Diurnal variation in facial soft tissue profile: 3-Dimensional morphometry of facial soft tissue using laser scanner

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ABSTRACT

Purpose: The purpose of this study were to: (1) establish a facial soft tissue morphometric technique employing a 3-dimensional optical device; (2) evaluate its precision; and (3) determine the presence of diurnal variation in facial soft tissue morphology.
Materials and methods: Ten volunteers were enrolled using a 3-dimensional optical measuring device, SURFLACER VMH-300F. Measurements were conducted in the morning, during the daytime, and in the evening. Two analyses, reproducibility of measurement through comparison between the two measurements in each group (morning vs. morning, daytime vs. daytime, and evening vs. evening), and diurnal variation through inter-group comparison (morning vs. daytime, morning vs. evening, and daytime vs. evening) were carried out.
Results: The mean difference between two measurements in each group was 0.24 ± 0.06 mm in the morning group, 0.25 ± 0.08 mm in the daytime group, and 0.24 ± 0.06 mm in the evening group. As to diurnal variation, the difference was 0.38 ± 0.07 mm between the morning and daytime groups, 0.39 ± 0.03 mm between the morning and evening groups, and 0.40 ± 0.04 mm between the daytime and evening groups.
Conclusions: When facial morphology was measured at 3 different time points within a single day, the mean error was 0.24 ± 0.06 mm. Measurement at these 3 time points revealed no significant diurnal variation in facial soft tissue morphology. This technique and its results are anticipated to contribute to quantitative evaluation of facial soft tissue morphology.

1. Introduction

The two aims of surgical orthodontic treatment are: to alleviate dysfunction such as masticatory disturbance and dysarthria through restoration of the anatomical and occlusal relationships between the upper and lower jaws; and to improve facial appearance through such measures. Moreover, growing patient demand for esthetic improvement has made it essential to set treatment goals which will achieve the appropriate balance between "function" and "morphology". [1–3]

Recently, many advances have been made in measurement hardware and software for image processing and analysis. Computer programs are now being used in clinical practice to analyze 3-dimensional data obtained by X-ray computed tomography (CT) of the maxillofacial area, facilitating diagnoses, treatment planning, and surgery simulation. [4,5] However, this is still limited to simulations and has yet to replace conventional 2-dimensional analytical techniques. Therefore, prediction of changes in facial appearance (a matter of serious concern to the patient) still relies on 2-dimensional information such as that provided by radiographic cephalography and facial photographs taken at specific angles. [6–8] Three-dimensional assessment of the superficial morphology of facial soft tissue is needed to analyze preoperative facial appearance and predict postoperative changes. Such information would be useful in obtaining informed consent with respect to a proposed surgical procedure.

Three-dimensional information from X-ray CT scans is very useful but pertains primarily to evaluation of hard tissue. Therefore, X-ray CT is not an appropriate modality for obtaining information on the superficial morphology of facial soft tissue. Among the techniques that are available for obtaining such information, 3-dimensional optical measurement using a laser enables rapid, simple and highly precise information acquisition and can be repeated multiple times without causing excessive stress to the patient. This technique is, therefore, considered to be quite useful, and the number of reports regarding this technique has recently

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been increasing. [9–12] However, being new, there is as yet no standardized system for acquisition of facial soft tissue morphological information with this technique. Therefore, the reliability and reproducibility of facial soft tissue morphometry using this technique remains in question.

The living body changes continually and morphological change can occur over the course of a single day, one example of which being swelling of the facial tissues. Numerous studies have been carried out on these diverse morphological changes and the factors involved in them, with particular focus on measurement of circumference, volume, and surface area of the tissues involved. However, most such measurements have pertained to the crus, [13,14] and very few reports are available concerning morphological change in facial soft tissue, [15,16] that is, facial swelling. As yet, no absolute criteria have been established for facial soft tissue morphology. And to achieve more reliable and precise measurement and evaluation of facial soft tissue morphology, it is necessary to determine the optimal conditions under which such measurement might be carried out, as diurnal variation would have to be taken into account in determining timing of measurement, for example.

The goals of this study were to establish a facial soft tissue morphometric technique employing a 3-dimensional optical measuring device; evaluate its precision; and determine the presence/absence of diurnal variation in facial soft tissue morphology. To achieve these goals, we analyzed morphological change in facial soft tissue in the same subjects over the course of a single day.

Fig. 1. 3-dimensional optical measuring device SURFLACER VMH-300F.

2. Materials and methods

2.1. Subjects

Ten healthy adult volunteers comprising 3 men and 7 women with a mean age of 28.4 years (range, 26–37 years). All 10 subjects were dentists receiving training at the Department of Orthodontics, Tokyo Dental College. No restrictions were imposed regarding dentition or facial morphology, but individuals receiving orthodontic treatment or with a history of surgical orthodontic treatment were excluded from the study. In addition, individuals with illnesses (colds, etc.) at the time of measurement were also excluded from the study. This study was approved by the Tokyo Dental College IRB and all participants signed an informed consent agreement.

2.2. Facial soft tissue morphometry

A 3-dimensional optical measuring device, the SURFLACER VMH-300F (UNISN, Osaka, Japan; hereinafter referred to as "VMH-300F") was used for facial soft tissue morphometry (Fig. 1). The VMH-300F can measure facial morphology as a group of 3-dimensional coordinates in a contact-free manner. Using a semiconductor laser slit light, its measuring principle is light sectioning (reproducing the morphology of an object from scanned images). This device also allows morphological reproduction by spatial coding (coding of each point on an object's surface by means of the angle of light striking it from the light source). This device is fitted with an imaging unit composed of 4 CCD cameras and is capable of obtaining 3-dimensional coordinate data from approximately 50,000 points in one session. It has a scan pitch of 0.10–0.50 mm and one measurement session lasts approximately 4 s. It has a visual field of 300 mm in length, 250 mm in width and 250 mm in depth. The precision of measurement is 0.2% of the field of view. The spatial resolution is 0.50 mm in the vertical direction and 0.10 mm in the horizontal direction (depth of field resolution). Having the 4 cameras arranged so that they focus on the upper and lower left and right quadrants minimizes blind spots such as the submandibular region, for example. The VMH-300F has an ear rod and a guide beam for head positioning and fixation. The ear rod was designed specifically for this device, referring to the cephalostat conventionally used in radiographic cephalometric devices (Fig. 2). This rod determines horizontal positioning of the head during measurement. The guide beam is projected onto the face from 3 directions (from the right, left and medially). The head is positioned parallel to the Frankfurt horizontal plane as far as possible, with the projected beams providing guidance. In this way, the anteroposterior and superoinferior positions of the head (with the ear rod serving as the axis of rotation) are determined. The ear rod and guide beam allow bias in head position to be reduced when multiple measurements are conducted. The main unit of the device is controlled by a personal computer system (DELL PRECISION 380, Windows XP) mediated with the image processing board attached to the VMH-300F. The specific computer program constituting this system performs automated data synthesis from the right and left

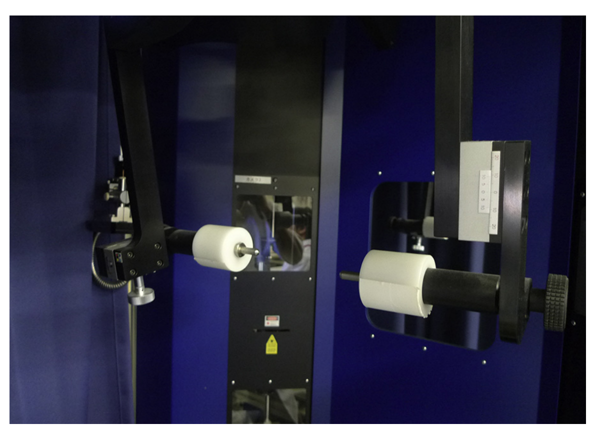

Fig. 2. Ear rod, designed with reference to the cephalostat used for radiographic cephalometric devices.