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The investigation of the changing facial appearance of identical twins employing a three-dimensional laser imaging system

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Structured Abstract
Authors – Kau CH, Zhurov A, Bibb R, Hunter L, Richmond S
Objective – An investigation to determine the changing facial appearance of identical twins.
Design – Clinical study.
Materials and Methods – Two Minolta Vivid 900 3D optical laser scanners were placed as a stereo pair to capture the soft tissues of a pair of identical twins. Each scan took approximately 2.5 s. The scanned whole faces were superimposed to determine changes in facial morphologies at different time intervals.
Outcome measures – The shell deviations between left and right scans of each patient were recorded and analysed for differences. Furthermore, final merged faces were overlaid to determine the changes in facial morphology over time.
Results – The results showed that changes in height and weight correlated with changes in facial morphology.
Conclusion – The 3D laser scanning device is a clinically useful tool in the study of facial growth and facial morphology in a pair of twins.

Key words: Facial growth; laser scanning; three-dimension; twins

Introduction

Three-dimensional images have previously been used to establish normative population databases, monitor facial growth (1), and assess clinical outcomes of surgical (2–4) and non-surgical treatments in the head and neck region (6–8). Laser scanning of soft tissue facial morphology is fast becoming a popular technique in three-dimensional imaging. A number of studies have reported on the validity and high accuracy of the Minolta 700 and 900 scanners and found them to be accurate to the level of 1.9 ± 0.8 mm (5) and

1.1 ± 0.3 mm (6). Independent studies by the authors show that the Minolta 900 is accurate to a level of 0.56 ± 0.25 mm and the error in computerized registration of left and right scans is 0.13 ± 0.18 mm (7). In addition, laser scanned data has been shown to be accurate even in children (8).

This clinical report aims to report on a technique to assess facial growth in a pair of twins and compares changes in facial appearance for a pair of identical twins over a 6-month period.

Subjects and methods

Identical female twins, RaJ and ReJ (Fig. 1), aged 11 years and 8 months, were recruited as part of a much larger growth study for which ethical approval had previously been granted (9). In the course of this study, height, weight and body mass indices (Table 1) were recorded and laser scanned images obtained at two time points (T1 and T2) 6 months apart.

Three-dimensional imaging system

The laser scanning system used in this study consisted of two high-resolution Minolta Vivid VI900™ 3D cameras operating as a stereo pair (Fig. 2). Each camera has a manufacturer's accuracy of 0.3 mm and emits an eye safe Class I (FDA) laser ($\lambda = 690$ nm at 30 mW) at an object to scanner distance of 600–2500 mm, employing a fast mode scan time of 0.3 s. The system uses a one-half-frame transfer charged couple device (CCD) and can acquire 307 000 data points. For soft tissue surface registration, a Minolta medium range lens with focal length of 14.5 mm was used and subjects were positioned at a distance of 1350 mm from the cameras. Information was transferred to a reverse modelling software package, Rapidform 2004 (INUS Technology Incorporated, Seoul, Korea), for analysis. This software provides nine different workbenches, which together allow high quality polygon, meshes, accurate free-form non-uniform rationale B-spline (NURBS) surfaces, and geometrically perfect solid

Fig. 1. (a, b) RaJ front 3/4 views, (c, d) ReJ front and 3/4 views, (e) the twins together at T1.

Table 1. **Height, weight and BMI of the twins**

	T1			T2		
Subject	Height	Weight	BMI	Height	Weight	BMI
RaJ	153	49	21	157	55	22
Rej	156	50	21	158	58	23

models to be created. RF4 generates data as absolute mean shell deviations, standard deviations of the errors during shell overlaps, maximum and minimum range maps, histogram plots and colour maps. All three-dimensional coordinate point measurements were made in mm.

Three-dimensional image capture technique

In this study, natural head posture (NHP) was used to position subjects for imaging. This clinically reproducible position (10,11) allows soft tissues to be scanned in a relaxed state. The subjects sat on a self-adjustable stool and were instructed to look into a mirror marked with standard horizontal and vertical lines in the form of a cross. Subjects were also instructed to swallow hard immediately before record taking to promote the adoption of a natural and reproducible lower jaw position. The total scan time was approximately 7.5 s. If it was perceived that the subject moved between scans, the procedure was repeated.

Data processing of left and right facial scans

Extraneous data was removed by an in-house developed software subroutine, which took 30 s to complete (12). The left and right images were smoothed out (while preserving shape and volume) and registered and merged based on the overlap areas of the two facial scans, producing a whole face scan. The pre-merged scans were carefully checked individually and unwanted areas (hair and neck regions) that could not be automatically removed were done so manually.

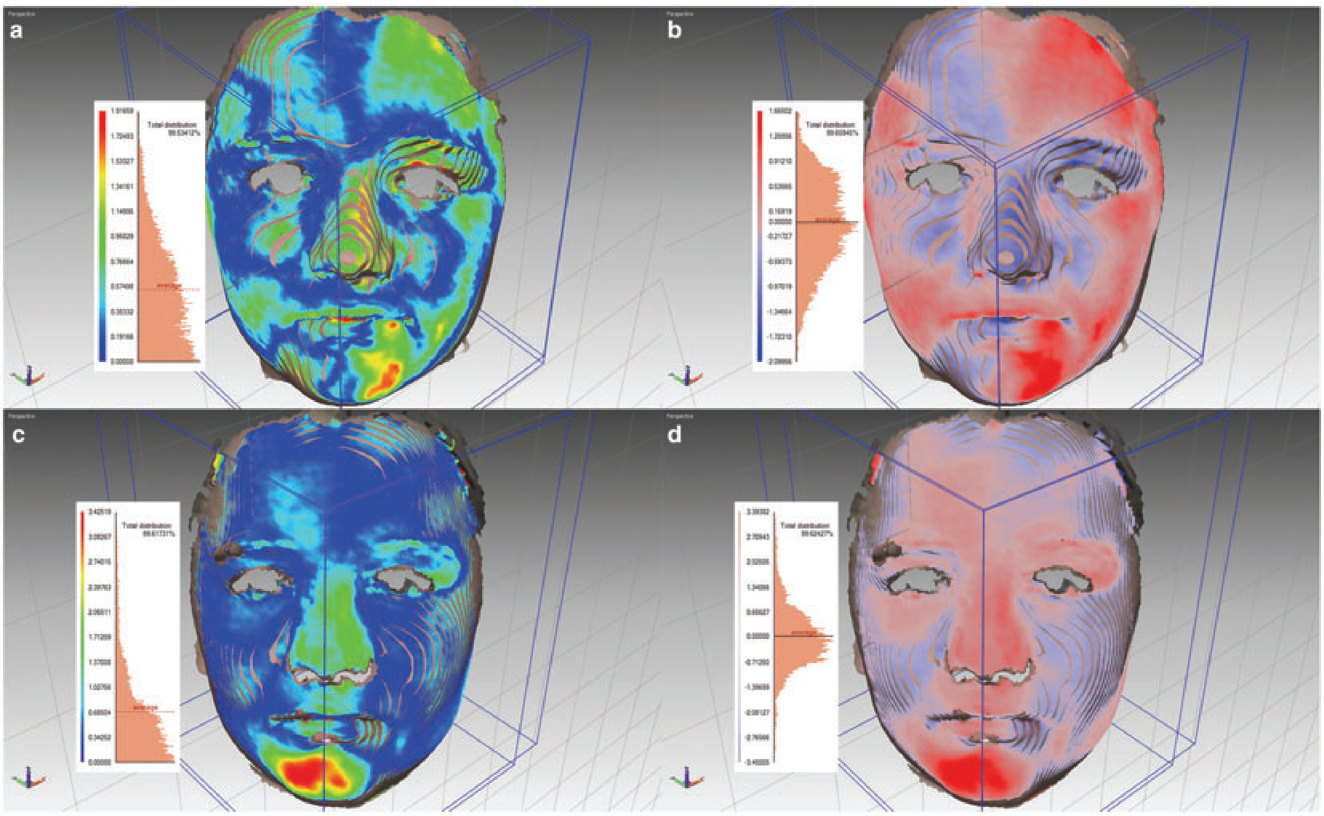

Fig. 2. Mean shell deviations in (a, c) absolute colour and (b, d) signed colour. Blue areas correspond to areas of 0–0.6 mm, green areas 0.6–1.5 mm and red corresponds to areas in the region of 1.5–1.9 mm. (a, b) Mean shell deviations of whole faces at T1, (c, d) mean shell deviations at T2.

Data processing of the whole faces

The whole face scans of each twin were superimposed over one another to determine changes that occurred at T1 and T2. This systematic process started with the manual alignment of five points on the facial scans (four points at the corners of the eyes and one point on the nasal tip) and subsequently, by regional superimposition of the facial structures on the forehead of each individual twin.

Analysis of facial scans

Within RF4, a shell-to-shell deviation map showing differences between shells is automatically produced. The results include the maximum and minimum range of shell deviations, the average distance between the two shells and the standard deviation. This function was used to analyse the means shell deviations and standard deviations for left and right pre-merged scans and also the differences in whole face soft tissue morphology between the merged faces over the three time frames. In addition, the software produced coloured face maps to determine the patterns within the face where there were differences in the alignment of the shells.

Results

Time point 1 (T1)

The laser scans of the subjects were analysed independently to determine if the laser scans suffered from distortions or movements between scans. The mean ± SD shell deviations of left over right scans were 0.16 ± 0.16 and 0.25 ± 0.23 mm for RaJ and ReJ, respectively. These differences were not clinically significant, implying that the faces stayed fairly stable over time.

The mean ± SD shell deviation of the superimposed whole faces were 0.55 ± 0.41 mm. A closer look at the coloured deviation map however, shows the exact areas where these differences lie (Fig. 2). From the shell deviation map shown, it may be suggested that the greatest differences between these twins were in the nose and the chin area. In addition, ReJ also had a broader face.

Time interval (T2)

After 6 months, the twins were scanned and differences studied as part of a growth study protocol. The left and right scans were merged for each twin and the final scans were overlapped with a best-fit method and compared for differences. The pre-merged mean ± SD shell deviations for RaJ and ReJ were 0.31 ± 0.25 and 0.31 ± 0.31 mm, respectively. This result was not clinically significant, indicating that the subjects remained stable between scans.

The mean ± SD shell deviations of the whole faces of the twins was 0.68 ± 0.63 mm indicating a clinical difference between the faces. The majority of differences were again noted in the chin and nose areas (Fig. 2).

Individual growth changes

The changes in height and weight for RaJ and ReJ were 4 and 2 cm, and 6 and 8 kg, respectively. However, changes to the facial morphology were difficult to perceive with the naked eye.

There were significant differences between the mean shell deviations for each set of growth changes for the twins. By setting a tolerance level of 0.85 mm, representing the soft tissue reproducibility error (9), the coloured areas in green and red represented true growth in the different regions of the face. RaJ showed a large increase in the lower face (lower third of the maxilla and the majority of the mandible) and tip of the nose. This corresponded to her greater rate of growth in height as compared with ReJ (Fig. 3). This overall facial growth was in the order of 2–3 mm. The facial map of ReJ however, was largely unchanged except at the lateral extremes of the face and on the left body of the mandible. These changes may have a relationship to the increase in ReJ's weight.

Discussion

The growth of the face is complex, involving size and shape changes. Longitudinal facial soft tissue growth studies are rare and the majority of the information on growth changes is inferred from cephalometric measurements. In general, a downward and forward displacement of the facial complex relative to the cranial base is described although complex rotational growth

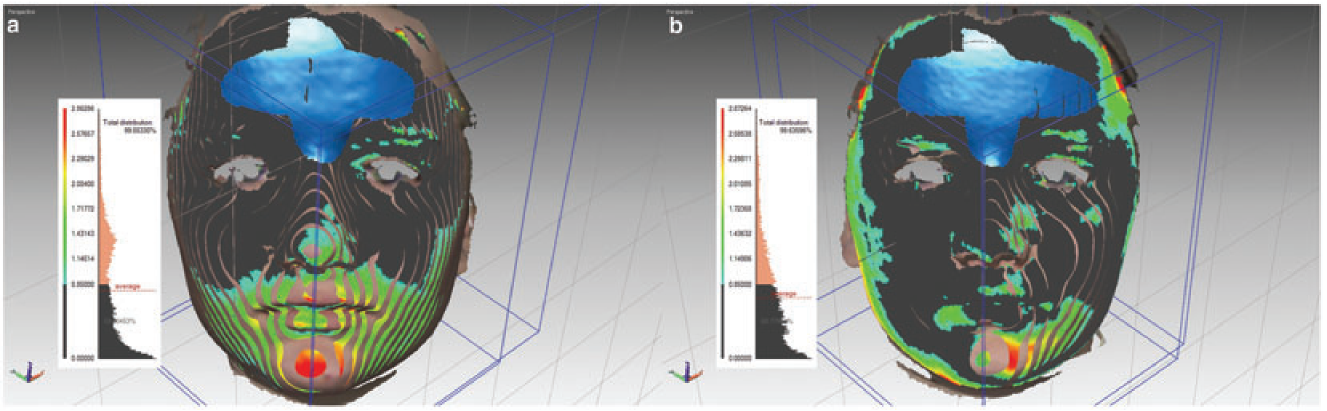

Fig. 3. Comparisons of faces by regional superimposition. (a) Subject ReJ. Black areas indicate no changes to a level of 0.85 mm. Green areas correspond to changes of 1.0–2.0 mm and red 2.0–3.0 mm. (b) Subject RaJ. Black areas indicate no changes to a level of 0.85 mm. Green areas correspond to changes of 1.0–2.0 mm and red 2.0–3.0 mm.

patterns are often observed (13). Many of the landmarks chosen do not represent true anatomical structures and soft tissue measurements are difficult due to the 'burn out' effects at the extremes. The errors associated with cephalometric analysis are significant (14–16). In addition, the technique is invasive, involving the exposure of growing children to X-rays which increases the risk of cancer to this group of patients by a multiplication factor of 3 (17).

Laser scanning however, is non-invasive. Several studies that have employed laser scans to measure facial changes, have determined the validity of the technique by measuring the distances between chosen anthropometrics points on the three-dimensionally generated images against corresponding points on lives subjects (18–21). One such study used cross-sectional data of subjects between the ages 5 and 10 years old. It found that there was considerable growth in the lower jaw (1–5 mm), with greater growth in males compared with females (1). Both male and female face heights increased annually in the order of 3–4 mm on average whilst there were little alterations to the mid-facial prominence. These results had to be based on averaging the facial scans of each age cohort, therefore limiting the inferences that could be drawn from the results.

Other non-growth-related studies have employed complex mathematics to derive and analyse shapes (22,23). More recently, attempts have been made to analyse the dynamic face by linear measurement between points (24) and the geometric construction of facial polygons (25).

This pilot study attempts to move away from conventional linear point measurements in the understanding of cranio-facial changes. The use of facial maps and coordinate point recognition is relatively new but has allowed an insight into the understanding of the dynamics of facial growth.

Growth studies on twins have been carried out using conventional anthropometrics and stereophotogrammetry. A study on a group of 52 liked sex twins observed annually between the ages of 9 and 16 years found that vertical rather than lateral dimensions of the face dominated during growth (26). In addition, the alar of the nose and angle of the mouth changed proportionally in relation to the inter-cantal line. However, measurements were made only in two planes of space. Volumetric and surface area changes were not recorded. To date, no studies have been carried out using a three-dimensional laser scanning system.

This study has been able to show areas of change and to quantify those changes in the faces of twins. Furthermore, interesting correlations to changes in facial morphology can be made to general somatic growth.

Conclusion

The following conclusions may be drawn from this study:

1. The three-dimensional laser scanning technique described provides an efficient, valid and reproducible method of recording similar facial morphology.

2. The technique is non-invasive.
3. The three-dimensional data obtained allows the magnitude and direction of facial growth to be better appreciated.

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