A Comparison of Three Methods to Evaluate the Position of an Artificial Ear on the Deficient Side of the Face from a Three-Dimensional Surface Scan of Patients with Hemifacial Microsomia

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Purpose: Patients with hemifacial microsomia may have a missing ear on the deficient side of the face. The fabrication of an ear for such individuals usually has been accomplished by directly measuring the ear on the normal side to construct a prosthesis based on these dimensions, and the positioning has been, to a large extent, primarily operator-dependent. The aim of the present study was to compare three methods, developed from the identification of landmarks plotted on three-dimensional surface scans, to evaluate the position of an artificial ear on the deficient side of the face compared with the position of the natural ear on the normally developed side. ***Materials and Methods:*** Laser scans were undertaken of the faces of 14 subjects with hemifacial microsomia. Landmarks on the ear and face on the normal side were identified. Three methods of mirroring the normal ear on the deficient side of the face were investigated, which used either facial landmarks from the orbital area or a zero reference point generated from the intersection of three orthogonal planes on a frame of reference. To assess the methods, landmarks were identified on the ear situated on the normal side as well as on the face. These landmarks yielded paired dimensional measurements that could be compared between the normal and deficient sides. Mean differences and 95% confidence intervals were calculated. ***Results:*** It was possible to mirror the normal ear image on to the deficient side of the face using all three methods. Generally only small differences between the dimensional measurements on the normal and deficient sides were observed. However, two-way analysis of variance revealed statistically significant differences between the three methods (P = .005). ***Conclusions:*** The method of mirroring using the outer canthi was found to result in the smallest dimensional differences between the anthropometric points on the ear and face between the normally developed and deficient sides. However, the effects of the deformity can result in limitations in relation to achieving a precise alignment of the ear to the facial tissues. This requires further study. *Int J Prosthodont 2012;25:160–165.*

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Patients with congenital deformities (eg, hemifacial microsomia) may have an ear absent on the deficient side of the face. Traditionally, the fabrication of an ear for the deficient side has been accomplished by directly measuring the ear on the normal side and creating a prosthesis based on these dimensions. However, recently, techniques have been described to produce an ear using rapid-prototyping techniques. In these techniques, through use of scanned data from the ear on the normal side of the face, an ear can be produced for the deficient side that is similar in shape and dimensions.[1,2] This approach can be used effectively in planning the position of an ear for patients with normal facial symmetry where an ear has been lost as a result of trauma or surgical resection. However, predicting the position of an auricular prosthesis on the deficient side of the face for patients with congenital deformities (eg, hemifacial microsomia) poses considerable challenges. These patients often exhibit normal facial alignment on one side of the face while the other side is asymmetric where the external ear may be absent. Because of the deficiency of the hard and soft tissues, the asymmetric side of the face is often shorter since the mandible is underdeveloped both anteroposteriorly and vertically.

In previous work on patients with normal facial symmetry, the positions of the left and right ears have been assessed in relation to landmarks in the midline of the face (eg, nasion, subnasale). It was found that there were only very small dimensional differences between the left and right sides in relation to landmarks on the ears and those on the midline of the face.[3] This might suggest that in a patient with an absence of an external ear as a result of congenital deformity, one could simply record the dimensional measurements of the normal ear from the midline landmarks and transfer this information to determine the optimal position where the artificial ear could be situated on the abnormal side. However, this does not take into account that the contour of the face may be very different on the deficient side compared with the normal side.

Therefore, the aim of the present study was to compare three methods, developed from the identification of landmarks plotted on three-dimensional surface scans, to evaluate the position of an artificial ear on the deficient side of the face compared with the position of the natural ear on the normally developed side.

Materials and Methods

The main sequence of experiments used a technique in which an image of an ear on the normal side of the face was mirrored to the deficient side. In a preliminary experiment on a subject with normal facial form, it was confirmed that it was possible to mirror an image of the ear from one side to the other. In the definitive experiments, data were captured from the faces of 14 subjects with hemifacial microsomia by laser scanning. The method of laser scanning has been described previously.[3,4]

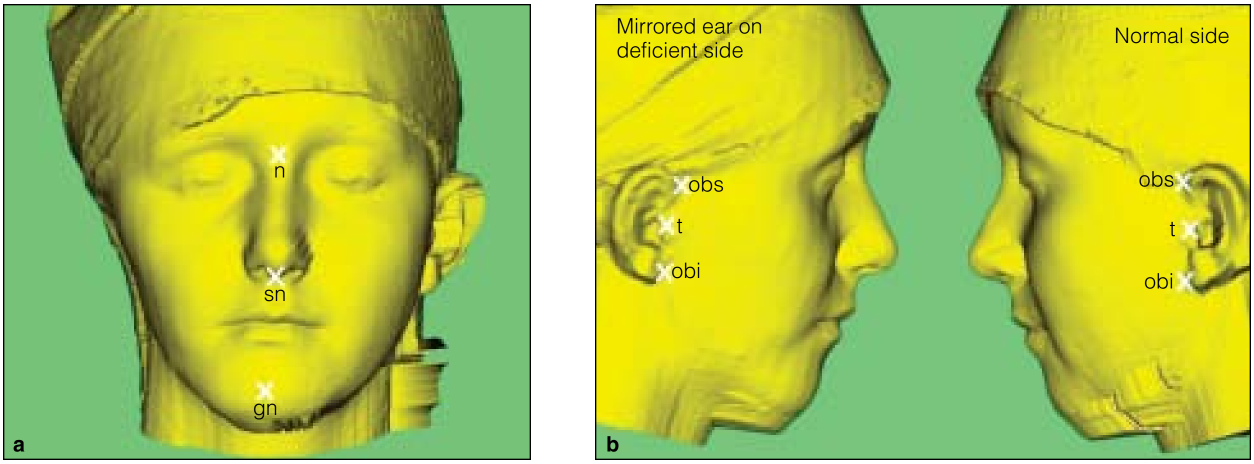
Three methods of mirroring the ear on the deficient side of the face in subjects with hemifacial microsomia were investigated to assess the method that achieved the most suitable position of the mirrored ear on the face. To permit a comparison between the methods, a number of landmarks were identified on the ear situated on the normal side as well as the face. The landmarks on the face were used to construct a series of planes from which dimensional measurements could be made.

In the first method (A), the outer canthi and nasion were identified. On the first image, the outer canthi were joined by a reference line that was made parallel and horizontal to the computer screen. The nasion was situated at the center of the screen.[5] The first image was then replicated into a second image. The second image was then edited to leave the image of the ear only (on the normal side). This image was then mirrored about the center of the screen (rotation about a vertical plane) thereby placing the ear image on the deficient side. Because of the lack of tissue on the deficient side, the mirrored ear image could be separate from the facial image. The two images were then combined so that the mirrored ear image was now located on the deficient side of the image of the full face. For some patients, depending on the magnitude of the deformity, it was necessary for the mirrored ear image to be manipulated on to the deficient side of the image of the face because of the asymmetry of the soft tissue. If this was necessary, the image was manipulated in a horizontal direction toward the midline until contact with the facial tissues on the first image was established. No movement was made either anteroposteriorly or vertically. The two images were combined and saved to a view file.

In the second method (B), the center of the screen was defined by a zero reference point constructed from a frame of reference. This zero reference point was formed by the intersection of three orthogonal planes (coronal, sagittal, and transaxial). The zero reference point would therefore not be a surface point as used in the other two methods. A full description of how the frame of reference is constructed and the calculation of the zero reference point has been described in previous work.[5] Once the zero reference point was defined and situated in the center of the screen, a similar method of replicating the facial image, editing and mirroring the second image, and finally, aligning the two images was carried out as described for method A.

In the third method (C), the inner canthi were identified. Again, on the first image, the inner canthi were joined by a reference line that was made parallel and horizontal to the computer screen. The nasion was situated at the center of the screen. This image was then replicated into a second image that was edited, leaving only the ear, as described in methods A and B. A similar method of mirroring and aligning the two images was carried out as described previously.

For each of the methods of mirroring the normal ear on the deficient side of the face, nine anthropometric



Figs 1a and 1b **(a)** Frontal image and **(b)** profile image of a subject with hemifacial microsomia on to which selected anthropometric landmarks are plotted. In Fig 1b, the image on the left illustrates how the mirrored ear would appear on the deficient side of the face. n = nasion; sn = subnasale; gn = gnathion; obs = upper insertion point of ear; obi = lower insertion point of ear; t = tragion.

Table 1 Dimensions Assessed on Subjects' Images*

Anthropometric landmarks	Dimension from facial landmarks to ear landmarks on both normal and deficient sides
n–obs	Nasion to upper insertion point of ear
n–obi	Nasion to lower insertion point of ear
n–t	Nasion to tragion
sn–obs	Subnasale to upper insertion point of ear
sn–obi	Subnasale to lower insertion point of ear
sn–t	Subnasale to tragion
gn–obs	Gnathion to upper insertion point of ear
gn–obi	Gnathion to lower insertion point of ear
gn–t	Gnathion to tragion

*Dimensions were measured from the three facial points (nasion, subnasale, and gnathion) to the points located on the image of a normal ear (obs, obi, and tragion) that were mirrored on the deficient side.

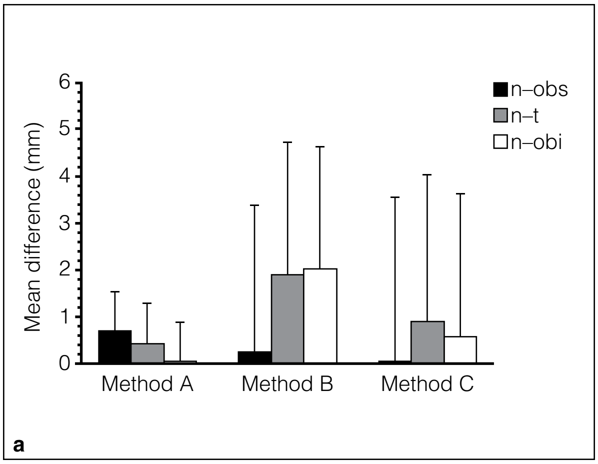
landmarks were plotted on the image saved as a view file for each of the 14 subjects. The anthropometric landmarks (Figs 1a and 1b) yielded nine paired dimensional measurements for each side (Table 1). Mean differences and 95% confidence intervals were calculated between the dimensional measurements recorded from the ear on the normal side and the midfacial landmarks compared with similar measurements on the deficient side. Two-way analysis of variance (ANOVA) was used to determine whether any statistical significance existed between the three different methods of mirroring a normal ear image on the deficient side of the face when compared to the position of the ear on the normal side to the midfacial landmarks. Post hoc Bonferroni tests were used to assess paired comparisons between the different methods.

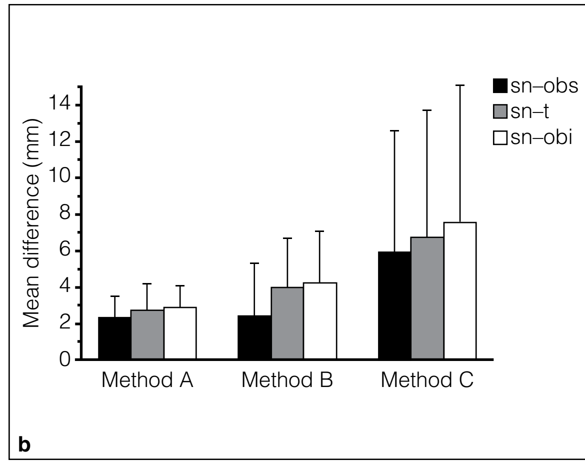
Results

It was possible to mirror the normal ear image on the deficient side of the face using all three methods for each of the 14 subjects with hemifacial microsomia. The dimensional differences between the different landmarks are shown in Figs 2a to 2c. Method A (outer canthi) generally presented the smallest mean differences and 95% confidence intervals between the anthropometric landmarks tragion and lower insertion point on the normal ear image and the mirrored ear image when compared to the midfacial points (nasion, subnasale, and gnathion). In relation to the upper insertion point of the ear, method B (frame of reference) showed smaller mean differences in relation to the midfacial points subnasale (Fig 2b) and gnathion (Fig 2c) than the other methods. Method C (inner canthi) showed the smallest difference for the upper insertion point in relation to the midfacial point nasion (Fig 2a).

The smallest mean differences between all three methods of mirroring the ear image were observed between the nasion to the upper and lower insertion points and the tragion (range: 0.05 to 2.03 mm). The largest differences were observed between the gnathion to the upper and lower insertion points as well as the tragion (range: 5.26 to 11.27 mm).

The two-way ANOVA revealed statistically significant differences between methods A, B, and C ($P = .005$). The analysis also showed a significant effect ($P < .0005$) arising from the dimensions used in determining the differences between methods. Multiple comparisons (Bonferroni post hoc tests) between the various methods revealed a significant difference between methods A (mirroring of ear





Figs 2a to 2c Mean differences and 95% confidence intervals between the normal ear position and mirrored ear position in relation to the **(a)** nasion, **(b)** subnasale, and **(c)** gnathion. Method A = outer canthi; method B = frames of reference; method C = inner canthi.

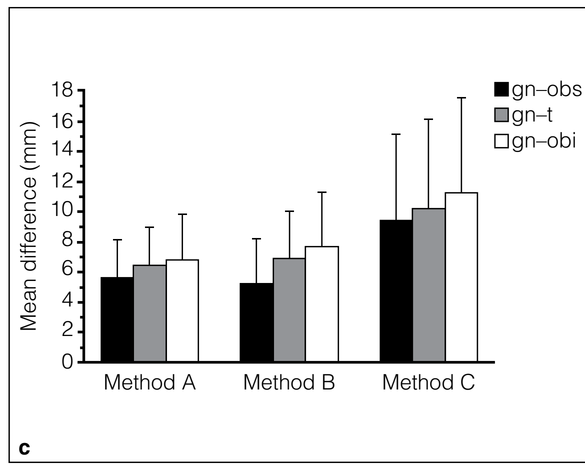


image using outer canthi) and C (mirroring of ear image using inner canthi) (P = .005). Statistical significance was not observed between any other method combinations. The smallest differences between the midfacial landmarks when compared to the normal ear on the laser scan image and the mirrored ear image were observed for method A. The largest differences observed were the lower insertion point to the gnathion (obi–gn). For method A, the differences were all less than 5.96% of the overall dimensional measurement (eg, obi–gn mean difference: 6.79 mm, compared to the overall dimensional difference of 113.97 mm); differences were 6.78% for method B (obi–gn mean difference: 7.63 mm, compared to the overall mean dimension of 112.61 mm) and 10.03% for method C (obi–gn mean difference: 11.27 mm, compared to the overall mean dimension of 112.31 mm).

Discussion

The concept of mirroring an ear from the normal side to the deficient side should result in the production of a prosthesis that is dimensionally similar to a natural ear. However, one of the issues that emerges using this approach in patients with hemifacial microsomia is that the contour of the face is likely to be different on the deficient side compared to the normal side. Therefore, even though it might be possible to mirror an ear with dimensions that are similar to the normal side, the difficulties in positioning the prosthesis may present significant challenges to producing an acceptable esthetic result.

In a preliminary experiment, mirroring of a normal ear image 180 degrees to the opposite side of the face of a subject with normal facial form revealed small differences in position. This is acceptable because even with subjects who have a "normal" facial form, it would not be expected that they would show absolute facial symmetry. Therefore, it was confirmed that it is possible to mirror an image from one side to the other, and it was therefore thought appropriate to investigate this technique on subjects with hemifacial microsomia.

To explore the three methods used to mirror the ear, differences between the normal and deficient sides were studied by a comparison of dimensional differences of anthropometric points with three different midfacial landmarks—nasion, subnasale, and gnathion. The nasion and subnasale are points that are routinely used in relation to positioning a prosthesis, and therefore it was important to see how the different methods of mirroring related to these points. The gnathion is a useful point in subjects with normal facial form. However, in patients with hemifacial microsomia, this point may be found at some distance from the center of the face resulting from distortion of the mandible. Therefore, it was of particular interest to determine whether there were differences between the normal and deficient sides in relation to the dimensional measurements between this point and the anthropometric points on the ear.

Although differences between methods were noted, it was interesting to see that the smallest differences between the normal and deficient sides were when the nasion was used as the reference position; the greatest differences arose when the gnathion was used as the reference position. The most likely explanation for this is that the gnathion is situated on the lowest portion of the face, which is where the distortion of the tissues is greatest because of the underdevelopment of the mandible on the deficient side. Therefore, since this point swings toward the deficient side (see Figs 1a and 1b), the differences between the two sides are greatest. The differences when the subnasale was used as the reference point generally appeared to be between those of the nasion (smallest) and gnathion (greatest). It may be that depending on the magnitude of the deformity, some deviation of the subnasale to the affected side might take place. This requires further study.

The creation of the reference lines and frames to mirror the ear image around its midpoint was found to be possible with all three methods. To determine the most appropriate method to use, a comparison of the mean differences between each dimension of the normal ear and the mirrored ear image when compared to the midfacial landmarks was carried out for all three methods. The smallest differences between the midfacial landmarks for the normal ear image and the mirrored ear image on the laser scan were observed for method A. It was expected that dimensional measurements to the gnathion would provide larger differences. As explained earlier, this is because of the deviation of the gnathion from the midline and is a characteristic of patients with hemifacial microsomia where underdevelopment of hard and soft tissues on one side of the face is prevalent.

Two-way ANOVA revealed that a significant difference existed between the three methods. In addition, a significant effect was noted for the dimensions used in determining the differences between methods. This is expected since the dimensions themselves are different from each other (ie, nasion–upper insertion point of ear, tragus–gnathion). The multiple comparison tests between the methods revealed a significant difference between methods A (outer canthi) and C (inner canthi). Taken together, the data suggest that the choice of the outer canthi is probably the least likely to result in large differences between the anteroposterior position of the mirrored ear when compared to the anthropometric landmarks on the midline of the face with that of the normal ear.

One limitation of a study such as this is that it has only looked at differences between methods of flipping the ear from one side of the face to the other. It has not in itself made any attempt to evaluate the positioning of such an artificial ear that could be constructed from the data with one that could have been constructed more traditionally by an operator measuring the natural ear and positioning the constructed artificial ear to the best of his or her judgment. Although it might initially be considered to be a straightforward process to make such a comparison, in reality, there may be significant limitations to achieving this objective. Both the traditional techniques and the digital approaches described in the present study have to overcome a fundamental problem in most patients with hemifacial microsomia: There may be no clear facial midline because of the alignment of the tissues toward the deficient side, as shown in Fig 1a. For artificial ears made by traditional techniques, the operator has to determine the position largely based on experience and the form of the tissues on the defect side. In the present study, the techniques described have explored a linear process of flipping the ear from the normal to the deficient side, but the resulting position may still not be aligned to the tissues of the face without further manipulation of the image, as described. It might be possible to address this problem by using a more sophisticated approach[6,7] of morphing. This is a novel three-dimensional surface-processing technique that involves the manipulation of two separate images by means of a scaled process to produce a morphed image (normal image deficient to landmarks on the deficient side). This requires further study.

Conclusions

All three methods were found to be useful in relation to mirroring the normal ear image on the deficient side of the face in patients with hemifacial microsomia. These methods were used with data from laser scanning of the face, but can also be used with data from other three-dimensional surface-scanning systems. As the differences between methods were generally of a small magnitude, even though statistically significant differences were found, they may not necessarily have significant clinical implications. Nevertheless, the use of the outer canthi was found to result in the smallest dimensional differences between the anthropometric points on the ear and the midline on the normal and deficient sides. The nature of the facial deformity will vary between different individuals, and this can result in limitations in relation to achieving a precise alignment of the ear to the facial tissues to create a harmonious esthetic result. This requires further study.

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Literature Abstract

Investigation of indoor air volatile organic compound concentration levels in dental settings and some related methodologic issues

This study investigated the levels of volatile organic compounds (VOCs) in a particular dental setting and identified methodologic problems faced in such studies. On reviewing two similar studies on VOC levels in a dental setting, the authors found that differences in sampling methods, clinical layouts, ventilation designs, and procedures performed account for differences in their outcomes. A pilot investigation was undertaken to determine the levels of indoor VOCs in an emergency ward of a dental hospital in Italy, the Ospedale Odontoiatrico George Eastman of Rome. Passive sampling of indoor and outdoor air was performed for 1 week in July, August, and September to measure concentrations of BTEX (bezene, toluene, ethylbenzene and m-o-p-xylenes), methyl methacrylate, and aldehydes. Results showed an increased mean total indoor concentration of these VOCs, which was somewhat linked to the number of dental procedures performed, thus indicating an indoor source of VOCs. Though the currently calculated concentrations cannot represent VOC concentration levels in all dental settings, this method of analysis allows for an unbiased estimate of VOC concentration. A systematic survey of involving a greater number of samples would potentially allow for correlation between the relative frequency of different dental procedures and the concentration of contaminants.

Santarsiero A, Fuselli S, Piermattei A, et al. *Ann Ist Super Sanita* 2009;45:87–98. **References:** 27. **Reprints:** Anna Santarsiero, Dipartimento di Ambiente e Connessa Prevenzione Primaria, Istituto Superiore di Sanitá, Viale Regina Elena 299, 00161, Rome, Italy. Email: anna.santarsiero@iss.it—*Teo Juin Wei, Singapore*