A Comparison Between Computerized Tomography, Magnetic Resonance Imaging, and Laser Scanning for Capturing 3-Dimensional Data from an Object of Standard Form

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Purpose: The study's aim was to compare dimensional measurements on computer images generated from data captured digitally by 3 different methods of the surfaces of a plastic cube of known form to those obtained directly from the cube itself.
Materials and Methods: Three-dimensional images were reconstructed of a plastic cube obtained by computerized tomography (CT), magnetic resonance imaging (MRI), and laser scanning. Digital calipers were used to record dimensional measurements between the opposing faces of the plastic cube. Similar dimensional measurements were recorded between the cube faces on each of the reconstructed images. The data were analyzed using a 2-way ANOVA to determine whether there were differences between dimensional measurements on the computer images generated from the digitization of the cube surfaces by the different techniques, and the direct measurement of the cube itself. ***Results:*** A significant effect of how the measurements were taken (ie, direct, CT, MRI, and laser scanning) on the overall variation of dimensional measurement ($P < .0005$) was observed. Post hoc tests (Bonferroni) revealed that these differences were due principally to differences between the laser-scanned images compared to other sources (ie, direct, CT, and MRI). The magnitude of these differences was very small, up to a maximum mean difference of 0.71 mm (CI ± 0.037 mm). ***Conclusion:*** All 3 methods of imaging would be of value in further studies, not only for the fabrication of complex shapes such as prosthetic ears, but also for other facial prostheses. *Int J Prosthodont 2005;18;405–413.*

Rehabilitation of a missing external ear may be considered for a patient wishing to disguise the loss of whole or part of an ear. This may arise because of trauma, surgical resection, or congenital malformation. The 2 types of treatment currently available are reconstructive surgery or prosthetic rehabilitation.[1,2] Whichever treatment is considered the more appropriate, dimensional measurements of the existing normal ear, its position, level, and prominence are used to plan the siting and shaping of a reconstructed ear or prosthesis.[3–6]

Traditionally, direct measurement (anthropometry) has been used to assess the dimensions, location, inclination, and level of an ear on the normal side, which is then used to fabricate a prosthetic ear for the abnormal side when there is unilateral loss of tissue. However there are problems with this approach. The dimensional measurements can be prone to inaccuracy, either because of distortion of the soft tissues of the natural ear or from difficulties in locating landmarks.[7] Furthermore, the fabrication of a prosthesis is depen-

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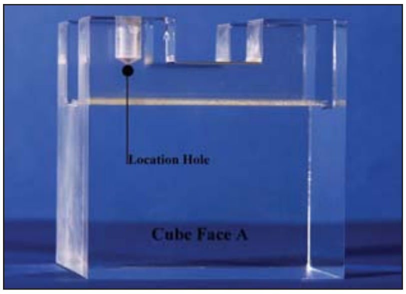

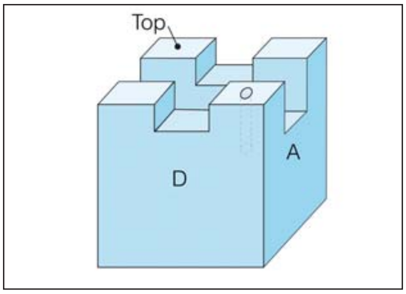

Fig 1a *(left)* A plastic cube with surfaces of approximately 60 mm in length. A location hole (as indicated) is used to identify the cube face A.

Fig 1b *(right)* A line diagram of the plastic cube. The opposite cube surface to that of face A is C, and the cube surface face D is opposed by cube face B.

dent on the artistry and skill of maxillofacial technicians and their ability to copy measurements and the shape of the normal ear.[8]

More recently there has been a particular focus on the use of non-contact techniques involving imaging of the ear as a means of producing an appropriately shaped and located prosthesis.[9–12] Wax ear models can be produced from computerized tomography (CT), magnetic resonance imaging (MRI), and laser scan data.[6,8,13,14] However, there have been no comparative studies to determine whether these techniques result in auricular prostheses of similar dimensional form. Although the production of the auricular prosthesis from digitized data will be identical, regardless of the type of imaging technique used, any variation in the final prosthesis will reflect the type of imaging process used.

One of the difficulties in comparing imaging techniques on the ear is its complex shape and internal form. Differences between dimensional measurements on the computer image of the ear generated by each technique might be accounted for, not only by the type of scanning process, but also in the ability of the operator to consistently identify landmarks in order to make the dimensional measurements. For this reason, when comparing imaging techniques, it was felt in the first instance that it would be appropriate to assess these landmarks on a 3 dimensional object of a more precise and standardized form than an ear.

The aim of this study was to compare dimensional measurements on computer images generated from data captured digitally by CT, MRI, and laser scanning from the surfaces of a plastic cube of known form, to those obtained directly from the cube itself.

Methods and Materials

Construction of the Cube

A cube was constructed of plastic (polymethyl methacrylate), and was machined to give as near parallel form as possible for all surfaces of approximately 60 mm. Material was machined from the superior surface of the cube to leave 4 separate pillars at the corners from which some of the dimensional measurements were made. The cube was described by 4 side faces (A, B, C, D), and the top and bottom surfaces. The shape of the model is shown in Figs 1a and 1b.

Accuracy of Scanning Systems

The tolerance of the CT scanner was assessed with a phantom sphere filled with water, and was found to be within acceptable limits (Hounsfield value $\pm$ 4). For the MRI, the tolerance of a copper sulphate-filled sphere was also acceptable (less than 0.4 mm over the 18 cm distance). For the laser scanning system, calibration was performed using a technique previously reported and was within acceptable levels.[15] All methods of obtaining 3 dimensional data were within known reported acceptable levels below 0.5 mm.

Data Capture and Viewing

The digital computer images from CT were created by siting the plastic cube in the scanner with the pillars uppermost. The cube was positioned on the scanning table so as to produce transverse sections through the cube face B-D. A total of 76 contiguous slices were performed at 1 mm intervals with 1 mm collimation, and the image was reconstructed in 0.54 mm $\times$ 0.54 mm square pixels (Table 1, Fig 2a).

The volume of CT data consists of elements called voxels, with each voxel having a CT number (Hounsfield Unit [Hu]) ranging between –1,000 (air), 0 (water), and up to a maximum of 3,095.[16] The first stage in the process was to select a region of interest and isolate it from the total data volume. This process of segmentation is more commonly called thresholding. For the image of the cube captured from the CT data, the expected threshold value of the cube surface was defined as the middle value between air on the outside of the cube (–1,000) and the inside (233) providing a Hounsfield unit value of –387. This midpoint value was chosen to minimize errors in the surface position resulting from partial volume effects. The use of a lower threshold value would have resulted in a larger segmented object (in this case 100 Hu error would

Table 1 Details of Scanner and Data Acquisition for Each Method of Obtaining 3-Dimensional Data

CT scanning data
Siemens Somatron Plus 4 Scanner
(Siemens Medical, Siemens PLC, Siemens House, Oldberry Bracknell)
KV 120
MA 90
Matrix 512 × 512
Field of view 139
76 Slices
Slice width 1 mm
Collimation 1 mm
Soft tissue kernel
MRI scanning data
Siemens Magnetron Expert 1 Tesla
(Siemens Medical, Siemens PLC, Siemens House, Oldberry Bracknell)
MP rage sequence
TR 11.4
TE 4.4
Flip angle 12°
230 × 230 slices
Slice width 1 mm
160 × 256 matrix
Field of view 300 (*5/8) * 300
Pixel size 1.17 mm × 1.17 mm
Laser scanning data
Low power class 3 gallium/indium laser (1 mW)
(Bio-Engineering & Medical Physics Dept, University College London)
TV zoom lens (f ~12.7-75 mm) operating at 49 mm with a lens aperture of f2.8 mm.
250 vertical profiles
Each profile contains 140-222 points
At Increments of approx 1.44°

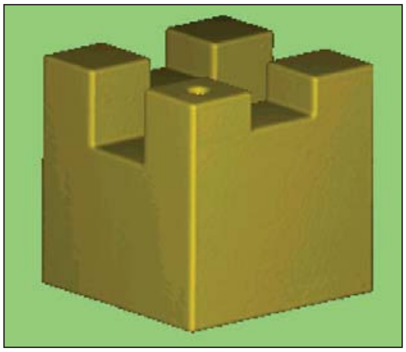

Fig 2a The reconstructed image from CT data.

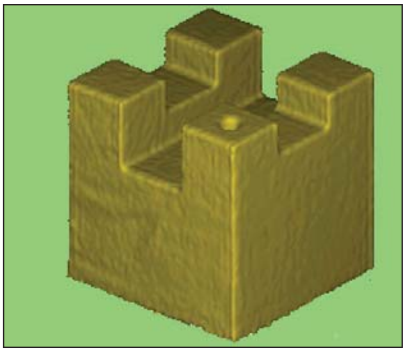

Fig 2b Reconstructed image from MRI data.

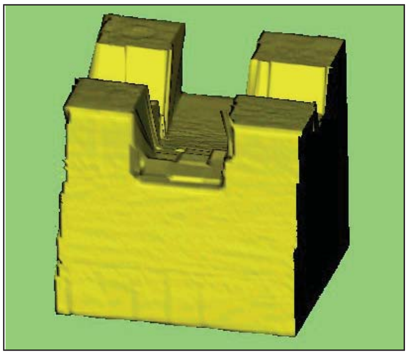

Fig 2c Reconstructed image from laser scanning (2nd scan top to bottom).

have given 0.15 mm surface difference). The MRI scan was performed using an MP Rage sequence. The plastic cube was immersed in a tank of water to obtain a negative image (ie, magnetic resonance signal is obtained from water around the plastic cube) with a layer of Agar-Agar to raise the bottom of the cube from the base of the tank in order to separate the tank from the cube in the reconstructed image. The cube was placed on the scanner table with the cube face B-D aligned in the z axis of the table. A total of 230 slices of 1 mm thickness were acquired, with a field of view of 300 mm and a matrix size of 160 × 256 mm providing a pixel size of 1.17 × 1.17 mm. The negative image was inverted to provide a positive reconstructed image of the cube (Table 1, Fig 2b).

MRI data does not use Hounsfield units but does have a numerical value (which approximates to the water content of an object). The segmentation process again involves choosing a value halfway between the values measured outside and inside the cube.

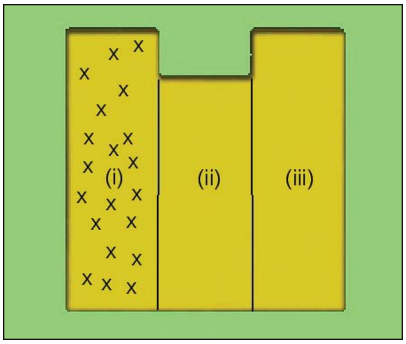

Fig 3a CT-reconstructed image of cube face A. Cube faces A-C and B-D were divided into 3 zones, and 20 points selected at random were plotted in each zone (60 points per cube face).

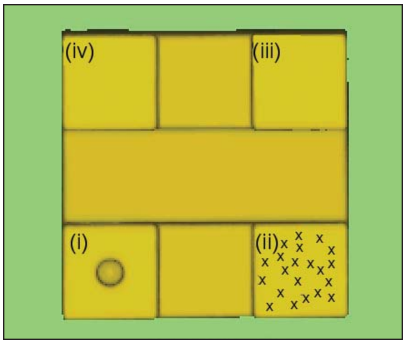

Fig 3b CT-reconstructed image of cube face top. Cube face top and bottom were divided into 4 zones and 20 points per zone were plotted at random (80 points per cube face).

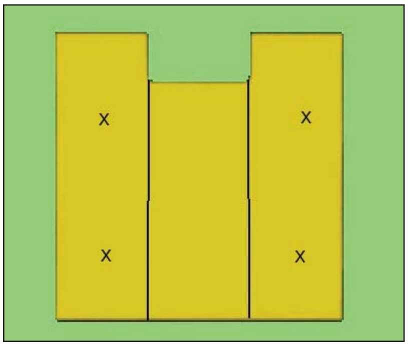

Fig 4 Four points were plotted on the cube face and on the computer-generated plane in the same order and at similar distances apart.

Therefore, the cube reconstructed from MRI data had a high value of 255 and a low value of 227 with a mid-value of 241.

The laser scan data were created from 2 separate scans: The first captured sides A and C of the plastic cube, and the second scan captured data of sides B and D and top and bottom of the cube (Fig 2c). Each scan consisted of 250 profiles (vertical direction) in increments of 1.44° with each profile containing approximately 140 to 222 points. The laser scanned images were recorded using a TV zoom lens. The 2 data sets were reconstructed on the computer screen using Gouraud shading techniques.[17]

Each digitized data set was reconstructed as a 3-dimensional image and viewed on the computer screen. The reconstructed cube images were orientated to the viewing position (Face A) determined by a location hole on the top left hand corner of the cube as seen on the computer screen.

Dimensional Measurements Between Cube Faces

In the first instance, a preliminary analysis of the cube itself was carried out using digital calipers (Mitutoyo Measurement Technology, SP10, UK). This showed that although the cube had been machined, there were, nevertheless, small imperfections across the surfaces, which meant that it could not be assumed that opposing surfaces were completely parallel to one another. This may have had a small, but possibly significant, effect upon the orientation of the computer-generated plane in relation to the surface of the cube. For this reason, in the definitive analysis, the surfaces of the cube were divided into zones from which the measurements were recorded. The 4 side faces of the cube (A,B,C,and D) were divided into 3 zones, and the top and bottom faces were divided into 4 zones. Each zone on the top surface was related to the pillar at each corner of the cube with a corresponding region on the bottom surface (Figs 3a and 3b).

Dimensional measurements were recorded between the cube faces opposing each other. The reconstructed images of each cube were assessed by examining the 6 cube faces (A,B,C,D, top and bottom). Dimensional measurements were recorded between the cube faces A to C, B to D, and top to bottom. A computer-generated plane was created on the surface of 2 of the side cube faces (A, B) and the bottom face. Four points were plotted, in the same order and similar distances apart, on the computer generated plane and in similar positions on the cube face (Fig 4). The computer software program used an established algorithm technique to calculate the least square fit of points to planes.[18] This allowed the computer-generated plane to be fitted as closely as possible to all of the points. The difference between the 2 surfaces was viewed as a color that was assigned a numerical value that could be set from 10.0 mm to 0.001 mm. A cursor could also be placed to confirm the difference between the surfaces.[19]

Point to computer-generated plane measurements were used on the reconstructed images of the cube to minimize errors of dimensional differences. To obtain the dimensional measurements, 20 points were selected at random and plotted in each zone at right angles from the computer-generated plane on cube faces C, D, and top (ie, 60 points in the 3 zones for the cube faces A to C to B to D, and 80 for cube face top to bottom). By aligning the X plotter over the corresponding point marker on the opposite cube faces (ie, cube faces A, B, and bottom to which the computer-generated plane was fitted), the difference between the point on the plane and the surface of the cube was obtained. By adding or subtracting this difference from the original point to plane measurement, the absolute value between the cube surfaces was obtained and used in the subsequent calculations.

Direct measurements were also recorded from the cube itself. Measurements between opposing faces (ie, A to C, B to D, top to bottom) were calculated using digital calipers aligned at right angles to the cube. The measurements were recorded across the opposing cube faces in the same zones as those recorded from the computer images.

The data were analyzed using a 2 way ANOVA to determine whether there were differences between dimensional measurements on the computer images generated from the digitization of the cube surfaces by different techniques and the direct measurement of the cube itself. Post hoc multiple comparison tests (Bonferroni) were performed to determine where the differences existed. Significance levels are expressed as exact *P* values with the exception of those where the value is less than .001 when they are expressed as $P < .0005$.

Results

Comparisons Between the Computer Generated Plane and the Cube Faces

The difference between the cube surface and the computer-generated plane was visually assessed by the color-coded technique, and the points confirmed by the curser for each method of scanning. An example of this is shown in Fig 5 in which the computer-generated plane has been superimposed onto cube face B to D created from magnetic resonance imaging generated data. The color-coded method showed small differences between the computer-generated plane and the cube faces for each of the imaging techniques (Table 2).

In the first instance, the dimensions across all cube faces and all cube zones were calculated. Direct measurement of the cube itself showed a mean measurement of 60.11 mm (95% confidence intervals ± 0.02). The mean point to plane dimensional measurements for the reconstructed images were 60.08 mm for CT (CI ± 0.04), 60.09 mm for MRI (95% confidence intervals ± 0.04), and 59.40 mm for laser scanning (95% confidence intervals ± 0.05). These are shown in Fig 6.

Assessment of Dimensional Measurements Between Opposing Cube Faces

For the dimensional measurements between the top and bottom of the cube, only very small differences were observed across the zones, and this did not appear to be affected by the type of imaging technique.

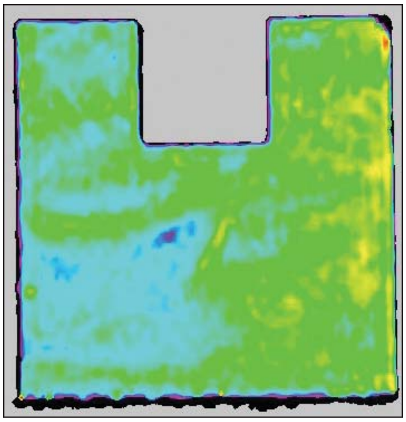

Fig 5 Computer-generated plane superimposed onto the surface of cube face (B to D) showing color coded differences. The blue color denotes a difference of –0.2 mm, the green +0.2 mm, the pink –0.6 mm, and the yellow +0.6 mm between the cube image and the computer-generated plane.

Table 2 Overall Mean Difference Between Each Reconstructed Cube Image by CT, MRI, Laser Scanning, and the Generated Plane

Method of scanning	Range (mm)	Mean difference (mm)	95% CI (mm)
CT	–0.08 to +0.11	0.01	±0.02
MRI	–0.39 to +0.39	0.05	±0.06
Laser	–0.33 to +0.66	–0.03	±0.08

A negative difference indicates that the point was below the computer-generated plane.

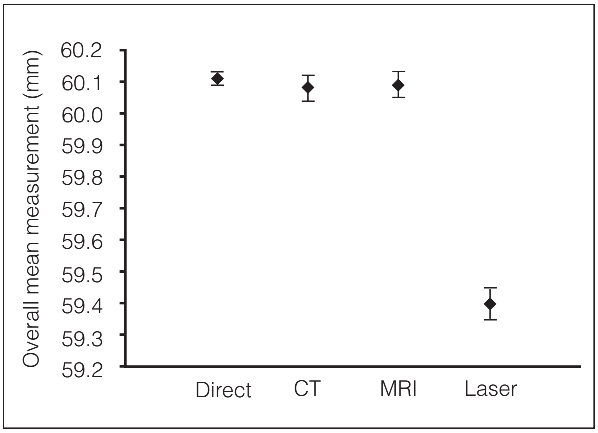

Fig 6 Overall mean dimensional measurements and 95% CI recorded directly from the plastic cube and from reconstructed images of the cube obtained from CT, MRI, and laser scanning.

The differences between the CT- and MRI-generated images were very small. For example, in zone 2, the mean dimensional measurement for the CT image was 60.27 mm, whereas for the MRI image it was 60.23 mm. Furthermore, these were very similar to dimensions recorded directly on the cube itself. The images gen-

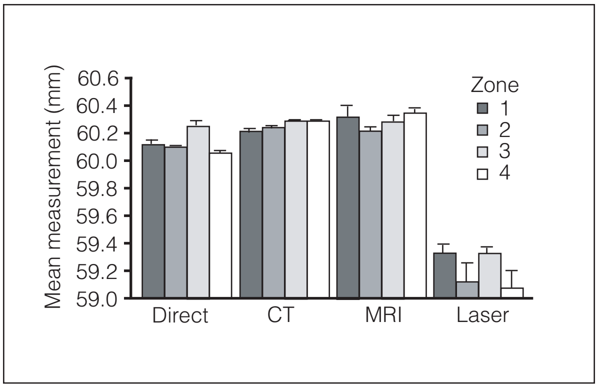

Fig 7a Mean dimensional measurements and 95% CI of each method of data collection between cube faces top and bottom.

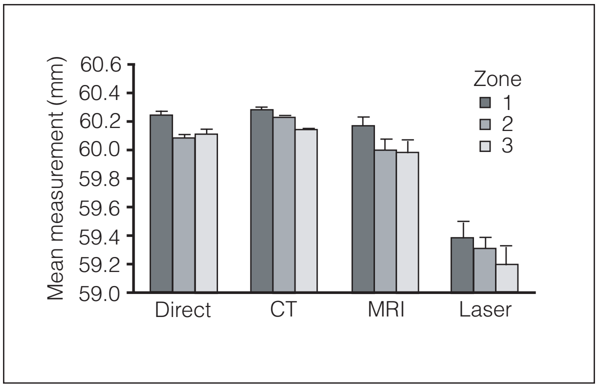

Fig 7b Mean dimensional measurements and 95% CI of each method of data collection between cube faces B and D.

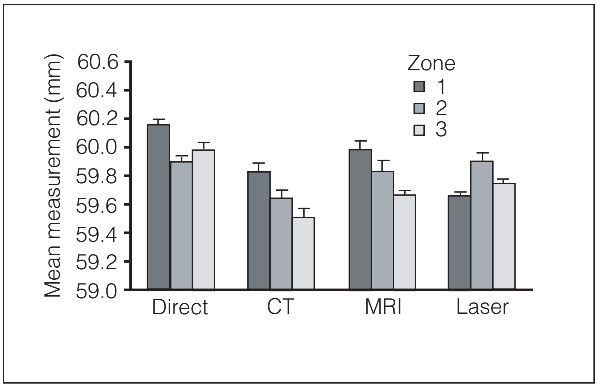

Fig 7c Mean dimensional measurements and 95% CI of each method of data collection between cube faces A and C.

erated by laser scanning appeared to have dimensions that were less than those generated by the other imaging techniques, as well as the direct measurement of the cube. These occurred across all zones (Fig 7a).

Similar observations were made on cube faces B to D. There appeared to be a small influence of the zone from which the measurements were taken. The dimensions from zone 1 appeared to be generally a little higher than those obtained from the other zones. The differences between the direct measurements of the cube and the images generated by CT and MRI were very small and of a maximum mean magnitude of approximately 0.2 mm. The images generated by laser scanning had dimensions that were less than those generated by other imaging techniques and the direct measurement of the cube. These ranged up to a 1 mm mean difference (zone 3 laser scanned versus zone 3 CT), and occurred across all zones (Fig 7b).

For the dimensional measurements on cube faces A to C, there were no clear effects of the zones from which the measurements were made. The dimensional differences between the images generated by all scanning techniques were very small and did not differ greatly from those obtained from direct measurements of the cube (Fig 7c).

The ANOVA showed that there was a significant effect on the overall variation of dimensional measurement ($P < .0005$) depending on the way in which the measurements were made (ie, direct, CT, MRI, laser scanning). Post hoc tests (Bonferroni) revealed that these differences could be accounted for principally by differences from the laser-scanned images to other sites (laser scan versus direct—$P < .0005$, laser scan versus CT—$P < .0005$, laser scan versus MRI—$P < .0005$). There were no significant differences between any of the other combinations (ie, CT versus MRI, etc). The ANOVA also showed a significant effect from the zone in which the measurements were made on the overall variation ($P < .0005$), and there were significant effects from the interactions between the way in which the measurements were made (ie, direct, CT, MRI, laser scanning) and the zones themselves ($P < .0005$).

Discussion

The study has shown that it is possible to capture data reliably using all imaging techniques from an object with a known form and calculate dimensional measurements on images displayed on a computer. However, there were some small dimensional differences between the techniques in relation to particular surfaces of the cube. The image generated from CT and laser scanning was taken directly from the cube itself. This was not possible using MRI, as the signal is obtained from spinning protons. For this reason, the cube was immersed in water to obtain the necessary image. Despite this additional step, the images obtained were very similar dimensionally to the CT-generated images and the direct measurements of the cube itself.

As there was some initial evidence that the machined cube had surfaces that were not exactly parallel, it was judged that a point to computer-generated plane measurement would provide a more consistent method of recording dimensional measurements between the cube faces, than using a point-to-point measurement. This was achieved by ensuring that dimensional measurements on the reconstructed images obtained by the 3 methods of scanning were recorded orthogonal to the computer-generated plane. There were no major differences between the computer-generated plane and the images of the cube surface for each technique. This meant that there were no particular difficulties in aligning the images on the computer to make appropriate measurements between cube faces.

Since it became clear that the surface of the machined cube had small imperfections (which meant that it could not be assumed that opposing surfaces were totally parallel to one another), a decision was made to sample measurements in individual zones rather than sample measurements randomly across the whole surface of the cube. Statistical analysis of the dimensional measurements showed that the zone from which the measurements were taken did account for some of the variation observed between the dimensional measurements. However, these dimensions were still very small across the cube faces.

The overall mean dimensional measurements revealed that there was little difference between the dimensional measurements recorded directly from the plastic cube and the reconstructed images of CT and MRI. However, differences between the techniques became apparent when looking at the cube faces individually. Generally, there were no significant differences between dimensions measured on images generated from CT and magnetic resonance. Furthermore, these did not differ from direct measurements on the cube itself. These results appear to be at least as good as those in a previous study[20] done on cadaver knee joints that found a 99.2% (mean error 0.68 mm) measurement accuracy from CT, reconstructed images, and a 97.6% (mean error 1.64 mm) measurement accuracy from MRI-reconstructed images.

However, dimensions of the laser-scanned images differed significantly from the CT-images and MRI, as well as the direct measurement on the cube itself. It appeared (Figs 6a and 6b) that the dimensions were less than those from CT, MRI, and direct measurements for cube faces B to D and top to bottom. These differences might be explained by the limitations of the laser scanning system that was used; it is not possible for the laser beam to be projected as an orthogonal line to the top and bottom of the cube at the same time as that being projected onto the sides of the cube. For this reason, the surfaces of the cube had to be scanned in 2 stages. This is supported by the observations that the scan in which faces A to C were captured (very small differences compared to the other methods), was different to the scan in which faces B to D and top to bottom were captured (larger differences compared to other methods).

One explanation of the slightly different results with the laser scanner compared with the other methods, may be that the cube dimensions do not allow the scan to be carried out within an optimal calibrated range. This particular laser scanner is calibrated for optimum accuracy in the radial range of 50 mm to 140 mm, since this is the range of radii found when scanning the human face. Since the cube has an overall dimension of only 60 mm and the center of rotation of the scanner lies within it, this may have placed some limitations on the system. However, despite some evidence of the laser scanning technique resulting in slightly smaller dimensional measurements of the cube than the other techniques, the differences in relation to the overall magnitude of the cube are in fact minimal. It would appear that the differences would be no greater than approximately 1.67% of the overall dimensions of the cube (ie, a maximum 1 mm difference compared with the 60 mm cube dimension). These figures are of a similar magnitude to previous work.[21,22] Hildebolt et al[21] looked at the difference between standard dimensional measurements on the skull using a direct measurement technique and a CT image. A 2% measurement difference was found. In relation to the results obtained in the present study, the cube has dimensional measurements that are broadly similar to the length of a normal ear. A 2% difference in this would be unlikely to have any clinical relevance when constructing an artificial ear.

A study by Dahlmo et al[22] measured the magnitude of the variation between a computer aided design (CAD) object created on a computer screen and the subsequent model produced by computer-aided manufacture (CAM). A square and a cone were mechanically scanned with a contact probe. The data from the scans were used to mill a piece of titanium, and selected dimensions were measured. It was observed that approximately 95% of all measurement differences were less than 15μm (SD 7.7 μm), and that the observed values were greater than the true values. However, it was concluded that there were no differences in measurement derived from the CAD data to that of the actual measurement recorded directly from the object created by the CAD program. Although Dahlmo et al[22] reported a greater accuracy than the present study, any dimensional differences that were seen are unlikely to have any clinical relevance.

Although not studied in detail, it seems possible that there may be interactions between the type of imaging technique and the zone on the cube from which it has been taken. However, the differences observed are also very small in relation to the overall size of the cube.

The techniques used in this study would have the potential to be used in a variety of clinical applications, as well as the construction of prosthetic ears, which has already been described.[8] One of the limitations of the laser scanning technique is that it cannot allow the capture of undercuts. This might place some restrictions on its use, but it would be of value for prostheses in which the issue of undercuts does not arise. For example, laser scanning has been used for the fabrication of nasal prostheses.[23] Furthermore, all 3 techniques of obtaining 3 dimensional data permit the reconstructed image from the area of investigation to be reversed and transposed to the defect site. CT scanning has been used for cranioplasties[24] and maxillary obturators[25] where undercut areas need to be recorded precisely. MRI can be used in a similar way, but to our knowledge this has not been used in the fabrication of any other facial prostheses except for the ear.[8] Although MRI scanning may be more costly than CT, the advantage is that it is a non-invasive procedure that does not expose the subject to radiation. However, it cannot be used in subjects who have foreign objects in the body such as pacemakers, surgical clips, and metal implants.[26,27] Whatever system of scanning is used, all techniques can be used for the production of the prostheses themselves, as the format of the images can be converted by software into a common format for modeling.

Conclusion

The results have shown that all 3 methods of imaging offer potential use in relation to the construction of prosthetic ears for patients who have unilateral absence of a natural ear. CT and MRI of the cube resulted in very similar dimensional measurements that were obtained by directly measuring the cube itself. Laser-scanned images showed slightly smaller dimensional measurements than the other techniques, including the direct measurements. This would be unlikely to have adverse clinical consequences in relation to ear dimensions, as differences this small are unlikely to be detected, even by trained observers.[4] Furthermore, laser scanning offers the potential to capture the image in a very small period of time (15 to 30 seconds) compared to the other imaging techniques which require the subjects to be immobile for longer periods of time. This requirement might be more difficult for scanning younger patients. These imaging techniques may be of use not only for the fabrication of complex shapes such as prosthetic ears, but also for other facial prostheses, and therefore offers opportunity for further study.

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Literature Abstract

Mandibular overdentures supported by 2 or 4 endosseous implants

The aim of this 5-year prospective comparative study was to evaluate the treatment outcome (survival rate, condition of hard and soft peri-implant tissues, patient satisfaction, and prosthetic and surgical aftercare) of mandibular overdentures supported by 2 or 4 implants. Sixty edentulous patients (39 women, 21 men; mean age 54.9 years; median 52 years; range 38-81 years) with a mandibular height between 12 mm and 18 mm (Cawood Classification V-VI) participated and were randomly assigned to 2 groups. Thirty patients were treated with overdentures supported by 2 IMZ implants (group A) and 30 patients were treated with an overdentures supported by 4 IMZ implants (group B). Standardized clinical (presence of plaque, calculus, and bleeding) and radiographic (mesial and distal bone level using reproducible radiograph with a beam direction device) parameters were evaluated 6 weeks after completion of the prosthetic treatment, and after 1, 2, 3, 4, and 5 years of functional loading. Prosthetic and surgical aftercare was scored during the evaluation period. The patient satisfaction questionnaires consisted of 54 items divided into 6 scales: *A)* 9 items concerning functional problems of the mandibular dentures; *B)* 9 items concerning functional problems of the maxillary dentures; *C)* 18 items concerning functional problems and complaints in general; *D)* 3 items concerning facial esthetics; *E)* 3 items concerning accidental lip, cheek, and tongue biting; *F)* 12 items concerning esthetics of the dentures. One implant was lost (group A) during the healing period, giving a success rate of 99%. There were no significant differences regarding any of the studied clinical or radiographic parameters of the peri-implant tissues between the groups. None of the patients reported sensory disturbances in the lip or chin region. No differences in satisfaction were observed between the groups. With regard to aftercare, there was a tendency of a greater need of prosthetic interventions in group A, while correction of soft-tissue problems was restricted to patients in group B. There is no difference in the clinical and radiographical state of patients treated with an overdenture on 2 or 4 implants during a 5-year evaluation period. Patients of both groups were equally satisfied with their overdentures.

Visser A, Raghoebar GM, Meijer HJA, Batenburg RHK, Vissink, *A. Clinic Oral Impl Res* 2005;16:19–25. **References:** 29. **Reprints:** A Visser, Dept of Oral and Maxillofacial Surgery and Maxillofacial Prosthodontics, University Hospital Groningen, PO Box 30.001, NL-9700 RB Groningen, The Netherlands. E-mail: a.visser@kchir.azg.nl—*Tee-Khin Neo, Singapore*