Three-dimensional imaging in craniofacial surgery

A review of the role of mirror image production

As long as craniofacial 3-D imaging has been around, mirror imaging has been applied to copy the unaffected side onto the affected one [2, 4]. However, so far, mirror imaging has been a 2-D procedure, since the mirror operation was always carried out in the scan plane and for each scan separately.

Fukuta et al. have now brought mirror imaging to the level where it belongs – a 3-D tool irrespective of the orientation of the scan plane.

Reslicing

Although it is always advantageous to position the patient as symmetrically as possible, it may be that a part of the patient, such as the mandible, remains in an oblique position (Fig. 14). Therefore, the technique of reslicing the original data volume to obtain images in planes perpendicular to the plane of symmetry is a prerequisite for the proper use of mirror imaging. Reslicing at a small angle with respect to the original slice orientation may produce artifacts if the interpolation technique applied is not sophisticated enough. Of this, however, no mention is made in this paper.

Mirror imaging

The authors have demonstrated the mirror image technique in four cases, thus, producing images of the ideal postoperative patient (Figs. 4d, c, 10c, 14c, 18e, 19e, 20b, e). The term “mirror imaging” is described as a process involving mirroring of the normal side onto the affected side followed by a “subtraction”, which is confusing. The reason is that subtracting Fig. 1c from 1d does, in practice, not yield Fig. 1f because the symmetry of the nonaffected side is not exact and, therefore, manual editing is required where bone remains present and “negative” bone must be interpreted as being air. This shows that the procedure is not as straightforward as the authors would have us believe.

Repositioning

The authors introduced the technique of modifying the position of an isolated bony structure and moving it to the correct position, such as was done with the mandible in case 3 (Fig. 14b, d, e). This technique has been described by others [1, 3] and has been referred to as “surgical simulation” or “electronic scalpelining.” It is obviously a vital step in the process towards proper implant design, but the reader is left in the dark as to exactly how the user tells the computer where to move the bone. These techniques are usually so computing-intensive that they cannot be carried out interactively in real time. It is also unclear whether there is a possibility of allowing the computer to determine the best fit between the mirrored right ramus and the rotated left ramus, which would mean that placing the left ramus in the correct position could be done automatically.

Implant or graft design

The authors introduce a technique using the mirrored missing bone; simplifying it to obtain an implant or graft design (Case 1–Fig. 6, Case 2–Fig. 11c, Case 3–Fig. 14c). This opens the road toward computer-aided manufacturing of artificial implants and the selection of donor sites for an appropriate bone graft. This process of simplification, however, is not simple since parts of the mirrored bone have to be trimmed and other parts have to be added. How does the user tell the computer where to take away material and where to add it? The orbital floor in the mirrored part is very thin (Fig. 4d, e) while the implant design is relatively thick (Fig. 5a).

The selection of a donor site is a three-dimensional problem while the authors present it as a two-dimensional one (Figs. 5e, 11f, 14f). Is the computer used to check the required bone thickness at the selected donor site, and can it automatically select a site with a required surface curvature?
Verification of the plan during actual surgery

In three out of the four cases presented, corrective surgery was carried out. In only one of these three cases (Case 1) the authors present a postop CT scan (Fig. 6). In comparing the surgical result with the plan, we notice that the implant is not in the planned position (Figs. 5a, 6a), as the medial side is much lower, and that the bone graft was not removed from the planned site but more posteriorly (Figs. 5b, 6b). The question arises why these differences are present and whether they are relevant. What tools are available to the surgeon to verify that the planned implant position is actually obtained at surgery. Because, if this verification is not possible, the 3-D planning procedure becomes an expensive technique. In Case 2, the surgical result is spectacular (Fig. 12), but again it is difficult to assess how it was obtained. There is no postop CT, it is not clear where the hydroxyapatite was placed. We know from other post-enucleation socket syndrome patients that this can be very critical [5].

Conclusions

We may, therefore, conclude that Fukuta et al. have introduced a number of techniques which, potentially, can be of great value to surgeon and patient. It is a pity, however, that in many instances no description of the procedure and verification during surgery was given. I feel that the next step after this pilot project should be initial analysis of the value of the described planning procedure including a description of what the most probable surgical result would have been if the mirror imaging planning technique had not been available. The cost effectiveness of the technique should be evaluated and compared to alternative techniques such as computer-controlled milling of patient models.

References


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Authors’ response

We are most grateful for Dr. Zonneveld's perceptive comments. There is no doubt that everyday usage of these imaging techniques breeds a familiarity which in writing about them gives an impression of simplicity – we would agree that this is far from the truth.

Reslicing techniques have frequently been used to reformat a coronal or parasagittal image from the original axial data, especially in evaluation of orbital deformities. This technique involves the use of interpolation which produces artifacts. Theoretically, the discrepancy of each point on the reformatted slice from the actual point should be within one voxel size, i.e. 1 mm, thus errors are minimal.

Figure 1 in the paper illustrates the steps of mirror imaging and clearly shows that mirror imaging is two dimensional processing of three dimensional data. With the slice image in Fig. 1, the subtraction of the affected side from the unaffected side results in the image of the surgical defect. However, subtraction may result in an image which includes asymmetry, which is in addition to that resulting from the disease process. As described in the discussion, this natural asymmetry must be trimmed out by the surgeon using a hand trace editing program from slice-to-slice. This maneuver emphasizes that the surgeon's involvement in the creation of mirror image is of value. We would wholeheartedly agree that mirror imaging is not simple and straightforward, but would rather say that mirror imaging contains quite a few sources of potential error and requires the adjustment by a knowledgeable surgeon.

The computerized automatic repositioning of an isolated anatomical segment into an optimal position is