*Short Communication*

# CAD Reconstruction Using Contralateral Mirrored Anterior Teeth: A 3-dimensional Metric and Visual Evaluation

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This study evaluated the concept of computer-aided design of anterior teeth by integrating morphologic information about the mirrored contralateral teeth. With the aid of a digital 3-dimensional tooth library, ipsilateral teeth were automatically mirrored, rotated, and translated to fit in the locations of the contralateral teeth. The reconstruction outcomes were evaluated via 3-dimensional similarity measures, measurements of approximal and antagonistic relationships, and visual ratings of experts. Metric and visual judgments indicate that integrating the shape of a symmetrically located contralateral anterior tooth seems to be a suitable base concept for computer-aided design of anterior restorations. *Int J Prosthodont 2008;21:521–523.*

Knowledge of basic morphometric regularities that allow fully automatic computer-aided design of anterior teeth is still inadequate. Nevertheless, there are already computer-aided approaches to design-suitable shapes for anterior rehabilitation. One of the recent techniques is the so-called replication mode,[1] which makes it possible for clinicians to design anterior teeth by integrating morphologic information of the patient's mirrored contralaterals. This technique is based on the premise that symmetrically located anteriors are significantly more similar to each other than nonsymmetric teeth. However, at present, only simple qualitative visual inspections and linear metric measurements are available to assess the similarity of anterior teeth.[2,3] This study presents a new method to 3-dimensionally quantify morphologic similarities and to demonstrate the high degree of similarity of symmetric anterior teeth. Furthermore, the study sought to quantify the esthetic and morphologic fit of the simulated reconstructions as demanded by experts.

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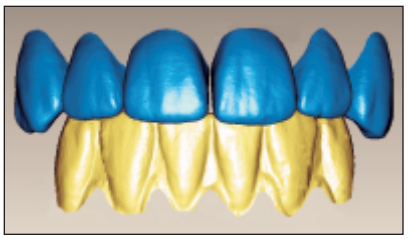
## Materials and Methods

### *Digital 3-dimensional Tooth Library*

Twenty persons between 18 and 25 years of age were randomly selected from a digital 3-dimensional (3-D) tooth library that consisted of 300 jaw models. These persons had no periodontal diseases and no severe orthodontic problems, and their maxillary anterior teeth were fully erupted and free of caries and restorations. Maxillary polyether impressions were obtained (Polyether Impregum Soft, 3M ESPE) and used to make stone casts (Fuji Superstone White, GC Corp). Complete surfaces of the anterior dentition as well as the impressions of a bite registration (Regisil, Dentsply) (Fig 1) were measured with a highly accurate 3-D scanner (es1, etkon) that uses the principles of optical triangulation.[4] Resolution of the measurement process was 30 µm × 30 µm in the x- and y-axes, with resolution in the z-axis (height) accurate to approximately 10 µm.

### *3-D Similarity Measure*

To assess the degree of similarity, complete anterior crowns were referenced to each other by using "best fit alignment" (Geomagic Qualify 7.0, Geomagic). Each point on the surface of a tooth was matched with the nearest point on the referenced tooth (3-D distance). Resulting difference images display areas of high or low correspondance in terms of color, according to the



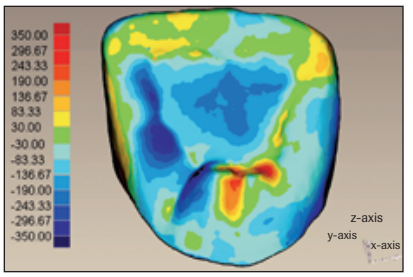



**Fig 1** *(left)* Antagonistic situation in an anterior set.

**Fig 2** *(right)* Palatal view of a central incisor: Difference image displaying local distances in terms of color. Red or blue = low correspondence; green = high correspondence.

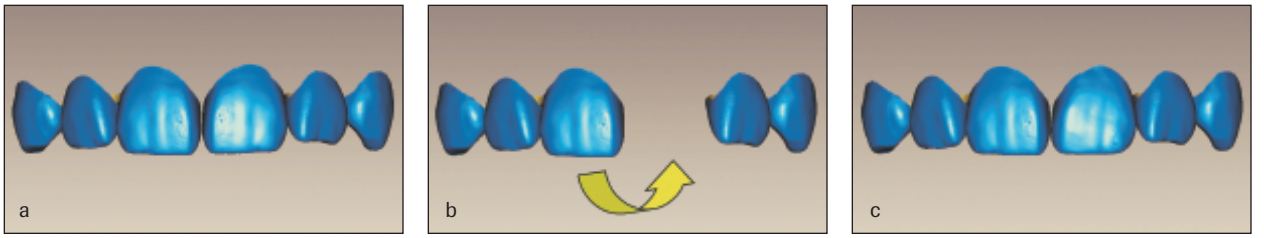



**Fig 3** Reconstruction process: Deletion of the left central incisor and transfer of the right central incisor into the vacant position. **(a)** Original situation. **(b)** Situation after deletion of left central incisor. **(c)** Situation after mirroring, rotation, and translation of right central incisor into vacant position.

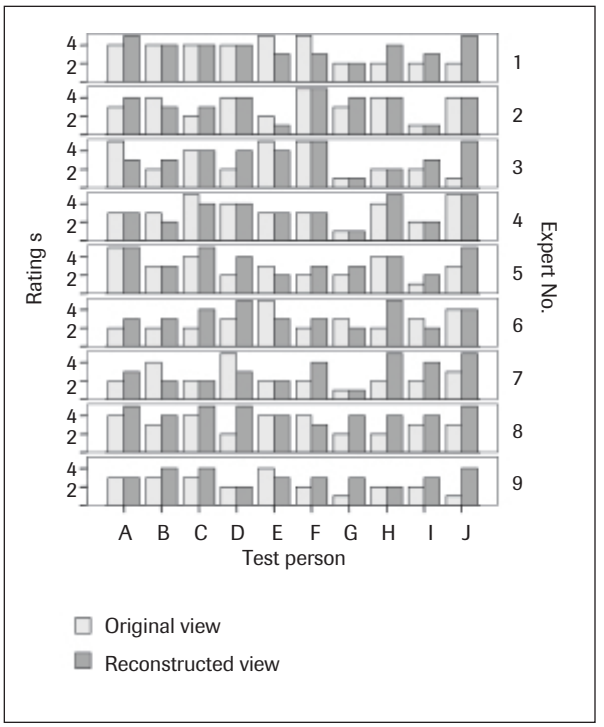



**Fig 4** Visual evaluations of the original and reconstructed views. 5 = very harmonious; 4 = harmonious; 3 = moderately harmonious; 2 = inharmonious; 1 = very inharmonious.

absolute values of local 3-D distances (Fig 2). As a similarity measure, the standard deviation of the 3-D distances (3-D Diff SD) was used. Mean values of symmetric and nonsymmetric pairs were compared by the Mann-Whitney *U* test ($P < .05$).

### *Simulation of Reconstruction Process and Evaluation*

In complete anterior sets, ipsilateral teeth were deleted and the previously referenced contralaterals were loaded into the set (Fig 3). The differences in the distances to neighboring teeth and to the antagonists (overlap = positive distance; space = negative distance) between the simulated tooth and the original tooth were calculated. In addition, 10 randomly chosen original frontal views and their corresponding views with reconstructed central incisors were evaluated concerning their attractiveness. In a random order, all 20 views were presented to 5 clinicians in private practice (each with more than 7 years' work experience) and 5 associate professors in the authors' institution. These dental experts were asked to rate the views (from very harmonious = 5 to very inharmonious = 1). Ratings of original views were compared to ratings of reconstructed views with the Wilcoxon test ($P < .05$).

## Results

The average similarity measure (3-D Diff SD) of symmetric and nonsymmetric teeth differed significantly ($P < .05$) by a factor of 3 (Table 1). The metric outcomes of the reconstruction process simulations are shown in

**Table 1** 3-D Diff SD as Similarity Measure for 3-D Comparisons of Complete Anterior Crown Shape

| | Symmetric | | | Nonsymmetric | | |
|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range |
| Central incisors (n = 20) | 85 | 18.37 | 53.18–125.38 | 255 | 43.79 | 167.28–360.56 |
| Lateral incisors (n = 20) | 111 | 23.37 | 68.39–166.52 | 329 | 47.88 | 220.75–405.29 |
| Canines (n = 20) | 100 | 25.18 | 46.28–171.53 | 298 | 52.31 | 195.47–420.39 |

**Table 2** Differences (Means and SDs) of the Relationships to Approximal Teeth and to Antagonists Between Original and Reconstructed Teeth

| | Mesial (µm) | Distal (µm) | Antagonistic (µm) |
|---|---|---|---|
| Central incisors (n = 20) | 29.80 (145.32) | –24.95 (151.08) | –3.55 (137.70) |
| Lateral incisors (n = 20) | –27.80 (152.52) | –40.95 (143.46) | –50.85 (158.70) |
| Canines (n = 20) | 69.25 (118.14) | * | –26.90 (119.02) |

*Distal differences were not evaluated for canines.

Table 2. In more than 95% of points, the newly positioned tooth differed by less than 250 µm from the replaced original tooth concerning its relation to antagonists and approximal teeth. With reference to visual aspects, the reconstructed anterior views were seen as significantly more harmonious than their original views ($P < .05$; Wilcoxon test) (Fig 4). In 46% of the comparisons the reconstructed situations were rated as more harmonious, and in 20% of the comparisons the original situations were considered more harmonious.

## Discussion

With a new 3-D similarity measure the high morphologic degree of similarity of symmetric anterior teeth was demonstrated, confirming current evidence.[5] The discrepancy with older studies,[2,3] which detected considerably larger differences, may be a result of the older studies' use of 1-dimensional parameters (eg, mesiodistal width). The determination of 1-dimensional metric parameters may result in substantial measurement errors, owing to unreliable settings of reference points, and seems to be inappropriate to describe complex 3-D structures such as teeth. The majority of the differences between the simulated and original teeth were moderate and rarely exceeded 0.25 mm. Because in the majority of cases, the mesial and distal differences almost compensated each other, the metric fitting can be interpreted as satisfactory. Although it is known that symmetry plays an important role in dental harmony,[6] it was surprising that the modified views were more often considered to be more attractive than the original ones.

## Conclusions

The use of the morphology of a symmetrically located contralateral anterior tooth is a suitable base concept for computer-aided design and for consecutive fabrication of anterior restorations. Limitations to this approach concern mainly functional aspects, which might easily be eliminated via minor modifications.

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