Three-dimensional analysis of simulated mandibular reconstruction using a segmental mirroring technique.

Otolaryngology – Head & Neck Surgery
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Background

- Primary goals of oromandibular reconstruction include:
  (1) Re-establish mandibular continuity
  (2) Restore oral function
- Adaptation of a reconstruction plate over distorted bone can result in malocclusion, temporomandibular joint dysfunction and an increased risk for plate extrusions
- Novel techniques permit 3D simulated resection and reconstruction of mandibular segments using a mirrored, or inverted, image of the unaffected contralateral mandible
- 3D sterelithographic models can be printed, using this technique, to fashion a reconstruction plate prior to surgery
- No study has examined the accuracy of this method using quantitative parameters based on the classification of defect using the Brown et al (2016) classification system (Fig. 1)

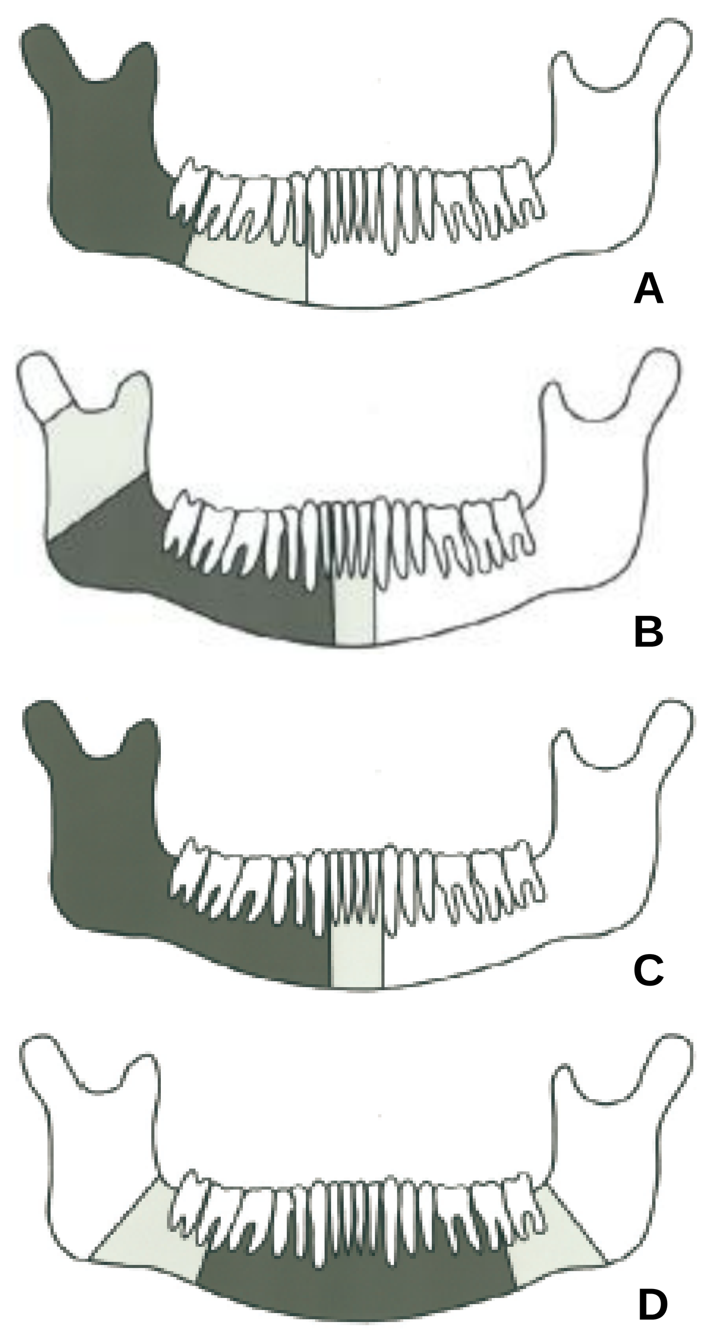

FIGURE 1. Classification of mandibular defects:
(A) Class Ic - Lateral defect including condyle
(B) Class II - Hemimandibulectomy including canine, not condyle
(C) Class IIc - Hemimandibulectomy including condyle.
(D) Class III - Anterior mandibulectomy, angles not included.
Adapted from Brown et al. (2016).

Objective

To perform quantitative conformance analysis of simulated mandibular defects and their corresponding inverted contralateral mandibular segment using CT generated 3D computer models.

Materials and Methods

Image Acquisition & Virtual Segmentation:

- CT images (head/neck) were obtained, and retrospectively analyzed (n=10).
- Images were imported to a workstation and semiautomatic segmentation was performed (Mimics version 18.0 - Materialise, Leuven, Belgium).
- Bone and soft tissue were differentiated by intensity threshold and regions of bone specific to the mandible were isolated (Fig. 2).
- Areas of bone encompassing defect classes Ic, II, IIc and III were segmented, inverted and merged with the corresponding contralateral mandible (Fig. 2).

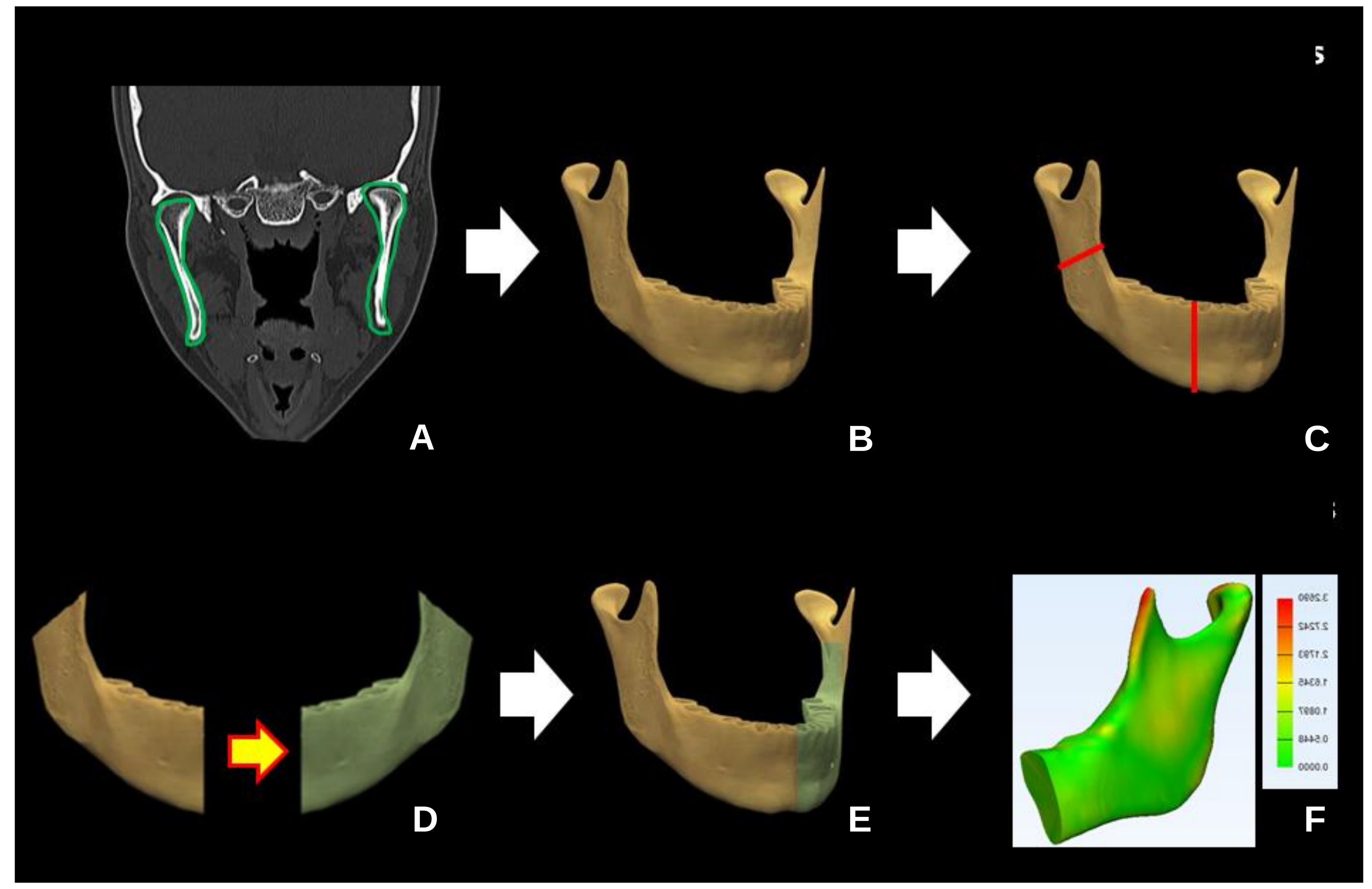

FIGURE 2. Method required for performing conformance analysis. **(A)** Segmentation, **(B)** 3D Modeling, **(C)** Virtual Osteotmies, **(D)** Segmental Inversion, **(E)** Co-registration and **(F)** Morphologic Analysis.

Volumetric/Conformance Analysis:

- Conformance distance (mm) was calculated between each vertex on the mandibular segment and the nearest three vertices on the corresponding contralateral inverted segment and displayed in colour coded maps (Fig. 3)
- The root-mean-square (RMS) conformance, a metric for morphologic similarity, was calculated for each comparison.
- Eight different reconstructive scenarios were analyzed for each patient: bilateral classes Ic, II, IIc and III.

Statistical Analysis:

- Paired t-tests were performed ($p<0.05$ deemed statistically significant)
- All descriptive statistics were calculated with SAS 9.3 (SAS Institute, Cary, NC, USA)

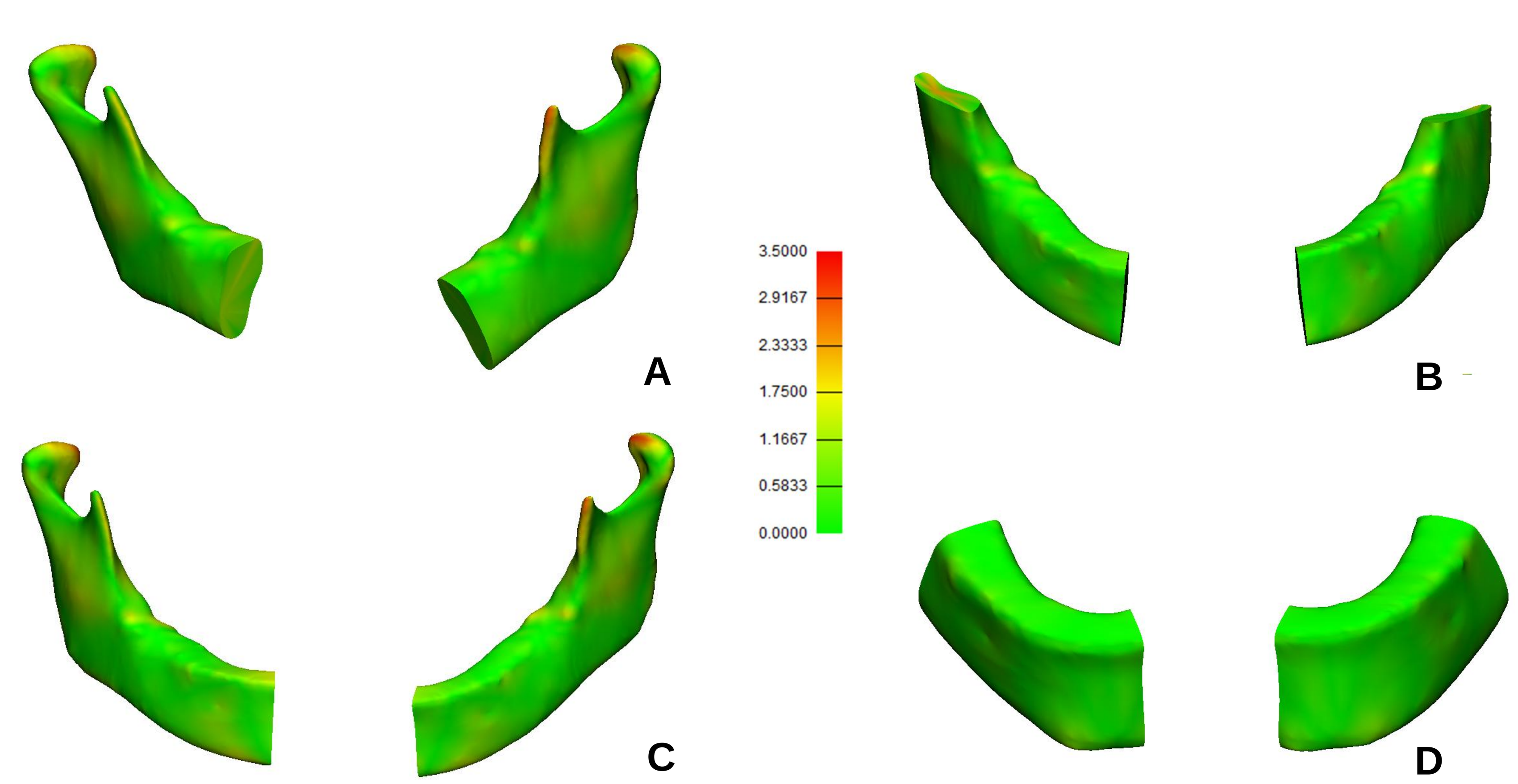

FIGURE 3. Conformance mapping and distance (mm) of segmented mandibular bone co-registered with the corresponding contralateral inverted segment: **(A)** Class Ic reconstruction **(B)** Class II reconstruction **(C)** Class IIc reconstruction and **(D)** Class III reconstruction. Colour-coding indicates areas of maximal conformance in green, moderate conformance in yellow, and poor conformance in red.

Results

- A high degree of overall conformance (<1mm), was observed when comparing all classes of simulated reconstruction (Table 1).
- There was no significant difference between RMS conformance distances when comparing side of simulated reconstruction for all classes (Ic: $p = 0.74$; II: $p = 0.90$; IIc: $p = 0.66$; III: $p = 0.59$).
- Closest mean RMS conformance was observed for class III simulated reconstructions (right: 0.4±0.3mm; left: 0.4†0.2mm), and were significantly improved in comparison to classes Ic ($p < 0.01$), II ($p < 0.01$) and IIc ($p < 0.01$).
- Inclusion of the condyle within the simulated reconstruction resulted in poorer mean RMS conformance in comparison to all other classes (class Ic – right: 0.7±0.4mm; left: 0.7±0.5mm; class IIc – right: 0.7±0.5mm; left: 0.7±0.5mm).

Table 1. Mean RMS conformance distances (mm) for simulated reconstructions of four mandibular defect classes† using contralateral inverted segments (n=10).

Right mandibular segment inverted				Left mandibular segment inverted			
Ic	II	IIc	III	Ic	II	IIc	III
0.7±0.4	0.6±0.4	0.7±0.5	0.4±0.3	0.7±0.5	0.6±0.4	0.7±0.5	0.4±0.2

†Brown et al (2016) classification of mandibular defects

Discussion

- The segmental mirroring technique provides a highly accurate method of reproducing the native contours of the most common mandibular defects
- While a high degree of conformance was observed for all defect classes (<1mm), class III (anterior defects) had the best conformance
- This technique would prove most useful in circumstances of significantly deforming bony tumors of the mandible.
- Reconstruction plates adapted to 3D stereolithographic models that have been printed using the segmental mirroring technique may enable reconstructive surgeons to better restore occlusion and limit plate related complications
- Further studies in patient populations are required to better evaluate the clinical benefits of using this technique

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