Development of artificial intelligence systems to predict facial morphology after orthodontic treatment

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Background

Conventional 2D software

Based on the premises that:
(1) the degree of movement of hard tissue is proportional to that of soft tissue, and
(2) a proportional constant number can be selected by orthodontists, due to which the results among different operators show significant variations.

Coefficient of determination R² (A measure of the global fit of the model)

- Low predictability

Objective

To develop artificial intelligence (AI) systems that predict the 3D facial topography after orthognathic surgery and fixed edgewise orthodontic treatment.

Methods

- Samples: A total of 137 patients, who underwent orthognathic surgery (n = 72, mean age = 23.5 years old) and orthodontic treatment with premolar extractions (n = 65, mean age = 15.6 years old) were enrolled. Three-dimensional facial images and lateral cephalograms were obtained before and after the treatment.
- Wire mesh fitting: For each patient at each time point, a wire mesh fitting on the face was conducted. This method generated 6,017 semi landmarks on the wire mesh (Figs. 2 and 3).
- AI systems: Based on the deep learning method, we developed two AI systems (S and E) to predict changes in the coordinate values of the semi landmarks due to orthognathic surgery and orthodontic treatment with premolar extractions, respectively. Cephalometric changes during treatment and coordinate values of semi landmarks on the faces before treatment were employed as predictor variables. The predicted post-treatment facial morphology was calculated as the sum of the coordinate value on the face before treatment and the predicted change for each semi landmark (Fig. 4).
- Evaluation: The system performance was evaluated using eleven-fold cross-validation for each AI system. The system error was determined as the difference between actual post- and predicted post-treatment coordinates of the semi landmarks in 2-D (Table 1). Furthermore, the total success rate was examined, wherein success cases were those with an average error of less than 1.1 mm or 2 mm.

Results

Soft- and hard- tissue changes after treatment were shown in Figs. 5-6. The system error was 0.89 ± 0.30 mm (S) and 0.69 ± 0.18 mm (E, Table 2). Maximum errors were observed in the nasal alar (S), the chin (S), the upper lip (S), and the lower lip (S and E; Figs. 7-8). The total success rate of 1 mm was 82% (74% [S] and 92% [E]), and the total success rate of 2mm was 100%. A system that recognizes the cephalometric landmarks was developed separately and a GUI was developed for the clinical application (Fig. 7).

Conclusions

The AI systems were confirmed to be accurate and reliable in predicting the 3D facial topography following orthognathic surgery and fixed edgewise orthodontic treatment.