Growth Prediction Using Artificial Intelligence

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BACKGROUND

- Treatment plans and visualizing treatment objectives are often based on an orthodontist's knowledge of growth and their assessment of growth predictions.
- Conventionally hand-wrist films, CVM, and serial cephalograms have often been used by clinicians in order to determine the level of skeletal maturation currently attained and to estimate future growth.
- Other growth prediction methods include growth charts, Rickett's visual treatment objective, other cephalometric templates and guides such as mesh diagrams and grids.
- Accurately predicting growth is difficult due to its complexity and individual variations.

Prediction accuracy of PLS vs. AI

1. Partial Least Squares (PLS): Superior predictive performance when compared to Ordinary Least Squares (OLS) method; can control significant correlations between soft tissue and skeletal variables of individual patients.

2. Artificial Intelligence (AI): A Deep learning method based on the deep neural network.

OBJECTIVES

This study aims to assess the accuracy of growth predictions via two growth prediction models: Partial Least Squares and Artificial Intelligence.

NULL HYPOTHESIS

No significant relationship can be found between independent and dependent variables when using PLS and AI.

MATERIALS AND METHODS

- Serial longitudinal lateral cephalograms were collected from 33 patients who had not undergone orthodontic treatment but had taken serial cephalograms. These were collected from Mathews Growth Study (AAOF, American Association of Orthodontists Foundation).
- On each image 46 skeletal and 32 soft tissue landmarks were identified by automated landmark identification software (Ceppro,DDH Inc.).
- Prediction models were built using multivariate Partial Least Squares regression method and a deep learning method based on Deep Neural Network consisting of 161 predictors and 156 responses.
- A statistical significance level of 0.0006 was set, considering multiple comparisons.

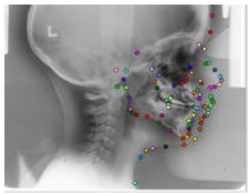

Figure 1. Automated landmark location with Ceppro. 78 anatomic landmarks, consisting of 46 skeletal and 32 soft-tissue landmarks, were identified.

RESULTS

Table. Mean and standard deviation of the prediction error distance (mm) for PLS and AI models. Checkmarks represent the more accurate model for each landmark.

	AI		PLS		More accurate		
Landmark	mean	sd	mean	sd	AI	PLS	*P*
Nasion	1.10	0.87	1.04	1.31			0.1352
Porion	2.14	1.20	1.56	1.04		v	<0.0001
Orbitale	1.62	1.14	1.33	1.16		v	<0.0001
ANS	1.72	1.04	2.00	1.60	v		<0.0001
PNS	1.78	1.20	1.62	1.14		v	<0.0001
A point	1.35	0.97	2.01	1.62	v		<0.0001
B point	1.39	0.88	2.94	2.03	v		<0.0001
Pogonion	1.53	1.05	3.23	2.29	v		<0.0001
Gnathion	1.52	1.08	3.35	2.31	v		<0.0001
Menton	1.51	1.04	3.33	2.30	v		<0.0001
Gonion (anatomic)	1.87	1.15	2.76	1.78	v		<0.0001
Condylion	1.81	1.00	1.37	0.79		v	<0.0001
Basion	2.09	1.16	1.48	0.95		v	<0.0001
Glabella	3.73	2.48	3.25	2.57		v	<0.0001
Pronasale	1.72	1.26	2.49	2.04	v		<0.0001
Soft tissue A point	1.37	0.89	2.33	1.88	v		<0.0001
Upper lip	1.44	1.04	2.73	2.08	v		<0.0001
Lower lip	1.47	1.14	2.94	2.20	v		<0.0001
Soft tissue B point	1.71	1.13	3.09	2.23	v		<0.0001
Soft tissue pogonion	1.93	1.26	3.39	2.35	v		<0.0001
Soft tissue menton	1.82	1.16	3.63	2.43	v		<0.0001

1. **Table 1)** illustrates that AI method was more accurate than PLS in general, this difference was statistically significant except Nasion. Also, PLS was more accurate than AI in some landmarks, which were Porion, Orbitale, PNS, Articulare, Condylion, Pterygoid, Basion, and Glabella.
2. **Figure 2)** demonstrates the difference in error between PLS, AI 1, and AI 2 (the AI model after more training) when predicting Point A, Point B, upper lip, and lower lip. AI 2 appears to be the most accurate in regards to predicting growth. PLS performed better in predicting Point A, a landmark on the upper part of the face, compared to Point B, which is on the lower part of the face.
3. **Figure 3)** presents profile predictions, showing that the AI prediction profile (in red) more closely matches the actual profile (in yellow) in the lower face area than PLS prediction profile (in blue).

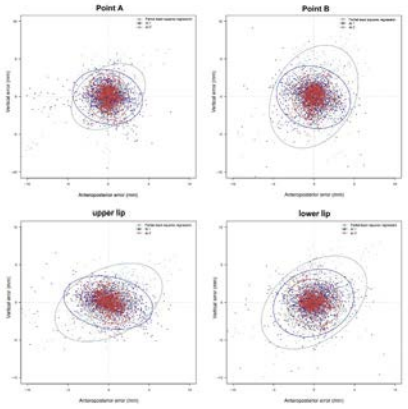

Figure 2. Scatter plots presenting errors and 95% confidence ellipses in anterior-posterior and vertical axes for the three prediction models. Green, PLS; Blue, AI 1; Red AI 2.

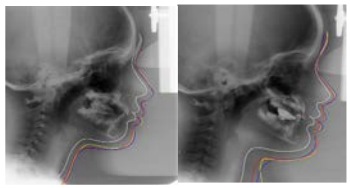

Figure 3. Example of profile predictions for patients included in the study. White, initial; Yellow, actual profile after growth; Blue, PLS prediction; Red, AI prediction

CONCLUSION

1. Both PLS and AI methods seemed to be valuable tools for predicting growth.
2. PLS accurately predicts landmarks with low variability in the cranial base.
3. In general, AI outperformed, particularly for those landmarks in the maxilla and mandible.
4. Applying AI for growth prediction might be more advantageous when uncertainty is considerable.

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Project Category: Research Awards

Abstract:
Objectives: To compare facial growth prediction models based on the partial least squares and artificial intelligence (AI)

Materials and Methods: Serial longitudinal lateral cephalograms from 33 patients who had not undergone orthodontic treatment but had taken serial cephalograms were collected from Mathews Growth Study located in the American Association of Orthodontists Foundation (AAOF) Growth Legacy Collection. On every image, 46 skeletal and 32 soft-tissue landmarks were identified using CEPPRO. Growth prediction models were built using multivariate Partial Least Squares regression (PLS) and a deep learning method based on the deep neural network incorporating 161 predictors, and 156 responses, variables. The prediction accuracy between the two methods was compared.

Results: On average, AI showed less prediction error than PLS. Among the 78 landmarks, AI was more accurate in 36 landmarks, whereas PLS was more accurate in 6 landmarks. The remaining 36 landmarks showed no statistical difference between the two methods. Overall, soft-tissue landmarks and landmarks in the mandible showed greater prediction errors than hard-tissue landmarks and landmarks in the maxilla, respectively.

Conclusions: PLS and AI methods seemed to be valuable tools for predicting growth. PLS accurately predicted landmarks with low variability in the cranial base. In general, however, AI outperformed, particularly for those landmarks in the maxilla and mandible. Applying AI for growth prediction might be more advantageous when uncertainty is considerable.

Acknowledgement: We appreciate Dr. Heesoo Oh and Dr. Heeyeon Suh for guiding and helping us with the research and poster. Thanks to your advice and mentorship, we could learn how to analyze and interpret the data and how to apply the results of comparison between AI and PLS when predicting growth for real patients.