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Beyond the Predicted Profile: Clinical Validity of Artificial Intelligence Based Facial Outcomes in Orthodontics

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Abstract:

- ***Introduction and Background:***

Artificial intelligence is increasingly being explored to predict facial soft tissue outcomes following orthodontic treatment. AI systems may aid in treatment expectations and profile prediction in patients. However, it is important to determine that the predicted outcome is not simply visually accurate.

- ***Review:***

This narrative review discusses the differences between geometric accuracy, visual accuracy and clinical utility when using AI systems to predict post-orthodontic facial outcomes. Previous research has focused on using artificial neural networks, convolutional neural networks, deep neural networks and conditional generative adversarial networks. More recently, models have used machine learning with incisors and facial measurements, generative networks for lateral profile prediction and prediction from facial frontal photographs. Across all studies there has been varying success depending on the imaging type, region of interest, patient population and the type of measurement used. Difficulties were seen with predicting lower lip and chin areas. Additionally, even when there has been good success with numbers there has not been improved treatment decisions or outcomes.

- ***Conclusions:***

Using AI to predict facial outcomes is an emerging field which may be beneficial. However, the clinical validity of the outcomes should be investigated. Future research should ensure independent validation occurs, measurement of error within each anatomical region, patient and clinician evaluation, clear communication of uncertainty and evidence of clinical decision making. Until this evidence is present the outcomes should be used as support.

Keywords: *Artificial Intelligence, Orthodontics, Facial Profile, Soft Tissue Prediction, Deep Learning, Generative Artificial Intelligence, Treatment Planning.*

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I. INTRODUCTION AND BACKGROUND

When making a diagnosis and treatment plan for a patient, their appearance is an important factor. Patients often wish to understand how their teeth are moving and how the extractions and dentoalveolar relationships will change their facial profile. Using traditional visual goals and profile prediction software can help meet these expectations however soft tissue responses can be unpredictable and may not be able to be predicted by simple ratios of hard to soft tissues.

Artificial intelligence can be used to learn the relationships between pre-treatment patient characteristics and observed post-treatment outcomes. This has evolved to become more advanced using deep learning models, conditional generative adversarial networks and novel generative models [1-3]. This can be used to create individualised facial predictions based on cephalograms, 3D facial data and clinical measurements.

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➢ *However, a Key Question is;*

- *Is the Predicted Outcome Accurate?*

Three separate terms should be understood. Geometric accuracy is the difference between the predicted and actual anatomical landmarks or facial surface. Visual accuracy describes if the image created appears plausible. Clinical utility refers to whether this prediction helps make treatment decisions, informed consent or patient understanding.

A scoping review published in 2023 identified four original clinical studies using AI to predict facial changes. However, there were several issues with the evidence base [1]. More recently research has focussed on treatment outcome prediction, generative models and prediction using photographs. Therefore, this review aims to provide a clinical interpretation of the evidence. A new framework should be provided.

II. REVIEW

➢ *Evolution of AI Based Facial Prediction*

Initially AI based facial prediction has looked at using artificial neural networks to predict the changes in lip curves. More recently convolutional and deep learning networks have been used to predict facial landmarks and morphology. Tanikawa and Yamashiro developed AI systems to predict facial morphology following orthodontic treatment and orthognathic surgery using cephalometric and 3D facial data. Their findings have shown that using geometric morphometric techniques alongside deep learning is possible [2].

A study by Park et al investigated the use of deep learning models using a conditional generative adversarial network to predict 3D facial prediction following orthodontic treatment. They found a mean error of approximately 1.2mm and an overall accuracy of 80.8% based on the criteria defined in the study [3]. These findings highlight that further research could be useful. However, these findings should be interpreted with consideration to the dataset, design of the study and anatomical regions measured.

More recently models have been developed to predict incisor and facial profile changes based on pre-treatment clinical and cephalometric data [4]. Conditional generative networks have been investigated to predict lateral profile following treatment [5]. This has moved away from traditional proportional prediction to individualised statistical and image predictions.

➢ *Geometric Accuracy- Is the Anatomy Predicted Accurate?*

Understanding geometric accuracy is key. However, there are variations in how accuracy has been recorded. Studies have included Euclidean error, mean radial error, distance between surfaces and percentage of landmarks within a certain error. This means they cannot be assumed to be equivalent.

There may be a low mean error, however there may be large errors at key anatomical landmarks. There may also be a good mean surface distance but errors in certain areas such as the lower lip, mentolabial sulcus and chin.

A study by Cho et al compared AI to traditional prediction methods. Overall, traditional methods (multivariate regression) had greater accuracy than the AI model however certain soft tissue landmarks showed greater accuracy with AI [6]. This shows that having a more complex algorithm does not necessarily mean better predictions.

Future studies should aim to provide results for individual anatomical regions, show the distribution of errors and compare the AI predictions to an appropriate traditional prediction method.

➢ *Visual Accuracy- Can the Clinician Differentiate the Predicted Face?*

Generative AI can produce facial images which look realistic. However, this does not mean that they are an accurate prediction for the individual.

A study by Park et al asked clinicians their views on the predicted 3D facial images as part of their validation [3]. This is useful as the aim of the predictions is to give patients an indication of what their outcome could be. However, just because someone could not tell the difference between the predicted and real doesn't mean all anatomical areas are accurate.

If a prediction looks good but is inaccurate this could lead to unrealistic expectations. It is important therefore to ensure that quantitative validation is provided alongside the image.

➢ *Prediction Using Photographs*

Models have been developed to predict outcomes using 2D facial photographs. These may be easier to obtain than 3D facial scans or CBCT datasets. However, it is important that the head positioning, facial expression, distance from camera, lighting and scaling are standardised.

A study published in 2024 compared AI and traditional methods to predict soft tissue and alveolar bone changes [6]. Other studies have looked at using AI to classify pre-treatment facial profiles for extraction cases and associated soft tissue changes [7].

A study published in 2026 looked at predicting soft tissue changes following treatment with premolar extractions using pre and post treatment photographs. They found an overall accuracy of 85.36%. However, the interlabial gap had poor accuracy [8]. This shows that even though there is a high accuracy, some areas relating to facial aesthetics may be difficult to predict.

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➢ *Generative Models*

Generative models may produce more accurate visualisations of facial morphology following treatment. A study published in 2025 looked at using conditional generative adversarial networks to predict orthodontic soft tissue profiles [5]. Another study published in 2026 looked at using deep neural networks with feature fusion to predict facial profiles for adult patients with Class III malocclusion following orthodontic treatment [9].

These may be useful to discuss potential changes in lip and convexity. However, it is important to understand that the prediction will be based on the treatment shown within the training data. If the model has been trained for a specific malocclusion or extraction protocol this may not be generalisable to patients with varying skeletal patterns, growth status, extraction plans or treatment mechanics.

If models have been trained on surgical and non-surgical data it is important to ensure they are not being applied for both. It would not be assumed that an outcome predicted for orthodontic camouflage would be the same as for orthognathic surgery.

➢ *Clinical Validity Framework*

To ensure a clinically meaningful evaluation of AI generated facial outcomes there are four areas to consider:

- Geometric Validity- Are the landmarks and surfaces predicted accurate enough? Consider error within each region, variability and clinically meaningful thresholds.
- Visual Validity- Do orthodontists and patients believe the image to be realistic? Ensure standardisation and differentiation between visually appealing and realistic.
- Decision Validity- Does having access to the prediction improve the clinical decision? This could be explaining different extraction plans or likely soft tissue changes. Simply agreeing with what the clinician was already thinking doesn't mean it has had a positive effect.
- Communication and Safety- Have the limitations, uncertainties and range of possible outcomes been explained to the patient? Images should not be assumed to be guaranteed outcomes.

This framework can be used to guide the clinical interpretation of studies. However, it is not a validated scoring system and needs to be prospectively validated.

III. LIMITATIONS AND FUTURE RESEARCH

A variety of patient populations, treatment types, imaging techniques, model types, outcomes and validation methods have been used. Some studies may have used internal validation or cross-validation so may not have shown that the model will perform well in other institutions or populations. A visually accurate outcome does not necessarily mean it will be clinically meaningful.

Future studies should focus on externally validating the models for a variety of patients such as Indian patients. Error should be standardised for landmarks and surfaces. Comparison should be made to traditional prediction methods and prospectively investigated to see if AI assisted visualisation improves patient understanding and treatment decisions.

It is important that the predicted outcome is consistent with what will happen with treatment. However, it should not be assumed that the outcome will be aesthetically pleasing. Clinicians should explain to patients that due to biological variation, soft tissue characteristics, growth, compliance and treatment factors this may influence the outcome.

IV. CONCLUSION

AI generated facial prediction is an emerging field which may be beneficial. However, geometric accuracy, visual accuracy and clinical utility should be considered individually. Current evidence suggests further research is needed.

The key next step is to determine if the AI generated predictions remain accurate for a variety of patient populations and treatments and that they improve clinical decision making. Until this is appropriately addressed AI generated facial prediction should be used as a visual aid under supervision of an orthodontist.

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