Artificial Neural Network Modeling for Treatment of Retained Es with no Permanent Successors

2023 Research Aid Awards (RAA)

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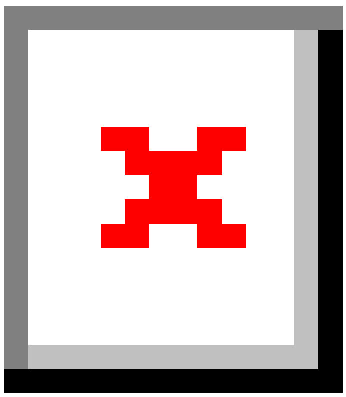
FollowUp Form

Award Information



In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:

- *Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
- *Does this Final Report provide the level of detail, etc. that you would expect, if you were the reviewer?*

Title of Project:*

Artificial Neural Network Modeling for Treatment of Retained Es with no Permanent Successors

Award Type

Research Aid Award (RAA)

Period of AAOF Support

July 1, 2023 through June 30, 2024

Institution

State University of New York (SUNY) at Buffalo - Orthodontic Department

Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s)

Dr Ozge Colak, Dr Thikriat Al-Jewair, Dr Mohammed Elnagar, William Tanberg, Dr Ryo Hamanaka

Amount of Funding

$6,000.00

Abstract

(add specific directions for each type here)

Artificial intelligence-assisted clinical decision model for managing retained primary second molars with no permanent successors

Colak O, Tanberg W, Hamanaka R, Elnagar M, Al-Jewair TS

Introduction: Retained primary second molars (Es) as a result of the congenital absence of mandibular second premolars are commonly seen in daily orthodontic practice. Managing these cases is challenging due to the complexity and variety in the case presentation and treatment options for each patient. Generally, orthodontists plan treatments based on their knowledge and clinical experience. Thus, the treatment plans made by experienced and less experienced orthodontists might differ. Therefore, a novel approach is needed to determine the optimal orthodontic treatment option for patients who have retained Es with no permanent successors. Artificial intelligence (AI)-assisted clinical decision-making tools could enhance the efficiency and accuracy of the treatment planning process and lead to improved treatment outcomes.

Study Objectives: The aim of this study is to develop and apply an AI algorithm to aid the clinical decision-making process for managing retained Es with no permanent successors using neural network machine learning.

Methods: The study will consist of patients who were diagnosed with at least one congenitally missing mandibular permanent second premolar with a retained E regardless of Angle's molar classification. Pretreatment clinical records from each patient will be collected from the University at Buffalo Orthodontic Clinic, University of Illinois Chicago Orthodontic Clinic and three private practices in multiple states. Three sets of input features including cephalometric, panoramic, and clinical variables will be identified from patient's records and used as input data. The sample will be categorized into three groups representing three different treatment decisions: 1) extraction of the E with space closure; 2) extraction of the E with space maintenance; and 3) retention of the E. The three treatment decision groups will be used as output data. The treatment decision will be based on majority treatment determination of three experienced clinicians. This data will then be randomly divided into training and test sets for building and evaluating all models. Two types of machine learning models will be constructed: multinomial logistic regression (MLR) and an artificial neural network (ANN). The MLR will serve two purposes. First to compare performance between it and the ANN. The second purpose will be to use information from it to identify significant predictor variables in potential efforts to reduce dimensionality. Principle component analysis (PCA) will also be used to examine dimensionality reduction. The comparison of different models will be evaluated using multiclass receiver

operating characteristic (ROC) methods such as averaging the areas under the curves (AUC) for the ROC's of each decision outcome.
Hypothesis: We hypothesized that our final machine learning model will be able to predict the correct treatment decision with an average AUC ROC of at least 0.8. Our final aim is to utilize this model as a decision support system in clinic and help the clinicians in the decision-making process in cases with retained primary second molars (Es) with no permanent successors.
Clinical implications or significance: The machine learning automated treatment planning method will accelerate the case review process in clinical setting and serve as a guiding tool to the clinicians.

Respond to the following questions:

Detailed results and inferences:*

If the work has been published, please attach a pdf of manuscript below by clicking "Upload a file".
<u>OR</u>
Use the text box below to describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should also be attached by clicking "Upload a file".

2 Tables COLAK.pdf
RESULTS:
A total 113 patients were included (50 males [44.2%] and 63 females [55.7%]). Among the total population, 52 patients received extraction of E and space closure, accounting for 46.0% of the total sample, and 38 received extraction of E and space maintenance, accounting for 33.6%, and 23 received retention of the Es, accounting for 20.3%. 60 of the total cases had bilateral retained Es (53%) and 53 of the cases had unilateral retained Es (38%).

The machine learning models produced overall accuracies with respective 95% confidence intervals as follows: MLR 85%, MLP 92%, RF 96% and DT 78%. RF classifier showed the highest accuracy in treatment planning. Backward elimination method was used to improve the success of the models. This technique was used until no further improvement was observed in a specific model. Elimination of the least contributing parameter after each iteration contributed to the accuracy of the models and improved it to 96% in RF model. Each machine learning model showed different results in the prediction of treatment plan when fed with the same input data. RF classifier achieved 100% sensitivity rate when predicting second and third treatment plans and 88% sensitivity rate when predicting the first treatment plan. In contrast, DT model showed the lowest sensitivity result (33%) when predicting the first treatment plan. All the four models were highly specific for the first and second treatment decisions, while the DT model showed the lowest specificity for the third treatment plan (%60).

Variable importance in the RF model was assessed using the mean accuracy decrease method. These results revealed that features such as amount of lower arch crowding, patient preference for restoration and ankylosis were the top three parameters which had the highest impact on the success of treatment prediction of the random forest model. The two parameters that showed the least correlation were upper lip to E plane distance and the depth of curve of Spee.

Were the original, specific aims of the proposal realized?*
Yes, in this study, we original aims of the proposal were investigated successfully and project is completed.

Were the results published?*
No

Have the results of this proposal been presented?*
Yes

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*
We have used the funding for data collection, and travel expenses to present the project at AAO meeting. We are currently writing the manuscript for publication and acknowledging the tremendous support received from AAOF.

Accounting: Were there any leftover funds?
$2,588.97

Not Published

Are there plans to publish? If not, why not?*
Yes, we are planning to publish it and currently working on our manuscript.

Presented

Please list titles, author or co-authors of these presentation/s, year and locations:*
Artificial intelligence-assisted clinical decision model for managing retained primary second molars with no permanent successors.

Colak O, Tanberg W, Elnagar M, Al-Jewair T

Presented at AAO Annual Session in May, 2024.

Comment: *The AAOF PARC commends you on completing this RAA project, and we look forward to your published results entering the public domain of academic orthodontics. We encourage you to continue with your interest in contributing to academics in your career.*

Was AAOF support acknowledged?

If so, please describe:

Yes, AAOF support was acknowledged in the poster presentation of the study as follows: ''This research project was generously funded by American Association of Orthodontists Foundation's Research Aid Award''.

Internal Review

Reviewer comments

Reviewer Status*

Approved

File Attachment Summary

Applicant File Uploads

- 2 Tables COLAK.pdf

Table 1: Description of the cephalometric indexes and algorithmic coding of nonquantitative data

Variable	Data Type	Units	Description
ANB	Continuous	°	Angle between A-point, nasion, and B-point
U1-SN	Continuous	°	Angle between the line through long axis of maxillary incisor and SN plane
U1-NA	Continuous	mm	Distance between labial surface of upper incisor and NA line.
L1-NB	Continuous	mm	Distance between labial surface of lower incisor and NB line
L1-NB	Continuous	°	Angle between line through long axis of mandibular incisor and NB plane
FMA	Continuous	°	Angle between line through mandibular plane and FH plane
IMPA	Continuous	°	The Angle between line through long axis of mandibular incisor and mandibular plane
FMIA	Continuous	°	Angle between line through long axis of mandibular incisor and FH plane
IIA	Continuous	°	Angle between line through long axis of maxillary incisor and mandibular incisor
SN-GoGn	Continuous	°	Angle between line through Sella-Nasion and Gonion-Gnathion
ANS-Me	Continuous	mm	Anterior facial height; distance between ANS and menton
Upper lip-E Plane	Continuous	mm	Distance from upper lip to esthetic line
Lower lip-E Plane	Continuous	mm	Distance from lower lip to esthetic line
CVMS stage	Discrete	-	Cervical vertebral maturation stage. Growing patients are 1 and nongrowing patients are 0

Table 2: Description and algorithmic coding of the panoramic indices for the retained E

Variable	Data Type	Units	Details
Ankylosis	Discrete	-	Uneven bone level between the retained E and the adjacent permanent first molar Present 1, Absent 0
Root resorption	Multipartite	-	Absent is 0 Mild is 0.25 (one-quarter resorbed) Moderate is 0.50 (half of the root resorbed) Severe is 0.75 (three-quarter resorbed) Complete root resorption is 1.
Caries	Quadripartite	-	Absent is 0 Initial is 0.25 (noncavitated, white spot lesions) Moderate is 0.50 (shallow cavitation or early cavitation) Advanced is 0.75 (deep cavitation, dentin is exposed)
Restoration	Multipartite	-	Absent is 0 Small is 0.25 (extension of less than half the intercuspal distance) Moderate is 0.50 (extension of 1/2 to 2/3 the intercuspal distance) Large is 0.75 (extension of greater than 2/3 the intercuspal distance) Cusp replacement is 1 (to or beyond the cusp tip)
Infraocclusion	Discrete	-	Presence of occlusal surface below the adjacent teeth. Present is 1, Absent is 0
Periapical and interradicular pathology	Discrete	-	Present is 1, Absent is 0

Table 3: Description and algorithmic coding of clinical indices

Variable	Data Type	Units	Details
Sex	Discrete	-	Females are 0 and males are 1.
Age	Integral	year	12 years of age or older
Patient preference for restoration	Discrete		‘’I do not want to have restoration ‘’ is labeled as 0 ‘’I want to have restoration’’ is labeled as 1
Type of agenesis	Discrete		Unilateral is 0, Bilateral is 1
Presence of other missing teeth	Discrete		Yes is 1, No is 0
Profile	Tripartite	-	Straight profiles are 0, convex profiles are 1 and concave profile are -1.
Crowding, Upper arch	Continuous	mm	The discrepancy between space required and space available in the upper arch.
Crowding, Lower arch	Continuous	mm	The discrepancy between space required and space available in the lower arch.
Molar Relationship, Left/Right	Discrete	-	Class I, II, III molar relationships will be labeled as 0, 1 and -1, respectively. The first number indicates molar relationship on the left side, the second number indicates the right side. E.g. (0, -1) means that molar relationships are Class I on the left side and Class III on the right side.
Overbite	Continuous	mm	Superior-inferior overlap of the maxillary incisors over the mandibular incisor
Overjet	Continuous	mm	Anterior-posterior overlap of the maxillary incisors over the mandibular incisor
Curve of Spee	Continuous	mm	The anatomic curvature of the mandibular occlusal plane.

Table 4: Statistics of four learning models from classification tests

AI Model	Group*	Sensitivity	Specificity	Accuracy (%)
Multinomial Logistic Regression	Txt-1 Txt-2 Txt-3	0.77 0.83 0.92	0.94 1.00 0.80	85
Multilayer Perceptron	Txt-1 Txt-2 Txt-3	0.88 0.83 1.00	1.00 1.00 0.86	92
Decision Tree	Txt-1 Txt-2 Txt-3	0.33 1.00 1.00	1.00 1.00 0.60	78
Random Forest	Txt-1 Txt-2 Txt-3	0.88 1.00 1.00	1.00 1.00 0.93	96

* Treatment-1: Extraction of the E with space closure; Treatment-2: Extraction of the E with space maintenance; Treatment-3: Retention of the E.