Objective method for evaluating orthodontic treatment from the lay perspective: An eye-tracking study

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Introduction: Currently, few methods are available to measure orthodontic treatment need and treatment outcome from the lay perspective. The objective of this study was to explore the function of an eye-tracking method to evaluate orthodontic treatment need and treatment outcome from the lay perspective as a novel and objective way when compared with traditional assessments. **Methods:** The scanpaths of 88 laypersons observing the repose and smiling photographs of normal subjects and pretreatment and posttreatment malocclusion patients were recorded by an eye-tracking device. The total fixation time and the first fixation time on the areas of interest (eyes, nose, and mouth) for each group of faces were compared and analyzed using mixed-effects linear regression and a support vector machine. The aesthetic component of the Index of Orthodontic Treatment Need was used to categorize treatment need and outcome levels to determine the accuracy of the support vector machine in identifying these variables. **Results:** Significant deviations in the scanpaths of laypersons viewing pretreatment smiling faces were noted, with less fixation time ($P < 0.05$) and later attention capture ($P < 0.05$) on the eyes, and more fixation time ($P < 0.05$) and earlier attention capture ($P < 0.05$) on the mouth than for the scanpaths of laypersons viewing normal smiling subjects. The same results were obtained when comparing posttreatment smiling patients, with less fixation time ($P < 0.05$) and later attention capture on the eyes ($P < 0.05$), and more fixation time ($P < 0.05$) and earlier attention capture on the mouth ($P < 0.05$). The pretreatment repose faces exhibited an earlier attention capture on the mouth than did the normal subjects ($P < 0.05$) and posttreatment patients ($P < 0.05$). Linear support vector machine classification showed accuracies of 97.2% and 93.4% in distinguishing pretreatment patients from normal subjects (treatment need), and pretreatment patients from posttreatment patients (treatment outcome), respectively. **Conclusions:** The eye-tracking device was able to objectively quantify the effect of malocclusion on facial perception and the impact of orthodontic treatment on malocclusion from the lay perspective. The support vector machine for classification of selected features achieved high accuracy of judging treatment need and treatment outcome. This approach may represent a new method for objectively evaluating orthodontic treatment need and treatment outcome from the perspective of laypersons. (Am J Orthod Dentofacial Orthop 2016;150:601-10)

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Treatment need for patients with malocclusion and the outcome of orthodontic treatment are typically evaluated by orthodontists or patients. Orthodontists use cephalometry, model analysis, and the Index of Complexity, Outcome and Need (ICON) in their evaluations.[1] Self-evaluation methods from the perspective of the patient include the Psychosocial Impact of Dental Aesthetics Questionnaire and the aesthetic component of the Index of Orthodontic Treatment Need.[2] Although these methods are effective at assessing treatment need, treatment outcome, and patient psychology, they do not evaluate the perspectives or opinions of a third party. Additionally, the available methods do not help clinicians to understand the origin of social deprivation among malocclusion patients and how casual observers view them. Because one motive for seeking treatment among malocclusion patients is to change how they are perceived by others,[3] and because treatment outcome is evaluated not only by patients and orthodontists but also by society, we propose an objective and sensitive method for evaluating the perspectives of laypersons as a supplement to current assessment tools to improve the evaluation of orthodontic treatment need and treatment outcome.

It is well established that eye movements are a surrogate of attention. The eye-tracking technique has been widely used in facial studies, such as studies of facial expression, sex, and race judgment. The major advantage of this technique is that it can record the movements of the eyeballs while multiple stimuli compete for attention. The changing hierarchy of attention is considered to reflect cognitive strategies for extracting facial information.[4] Previous eye-tracking research has characterized the scanpaths of casual observers when viewing normal faces.[5] The typical scanpath pattern for normal faces is triangular. Observers place most of their attention on the internal facial features, such as eyes, nose, and mouth, and converging evidence on the typical scanpath pattern has been obtained. In a study of the attention placed on the internal facial features, observers spent most of their time (43%) on the eyes and 13% of their time on the mouth.[6] A subsequent study examined the characteristics of the scanpaths of casual observers viewing the faces of dental patients. Hickman et al[7] concluded that patients with a perfect smile after orthodontic treatment received only approximately 10% of the attention of the observers. More of the initial fixations were on the mouth, and fixations on the mouth and nose regions were longer when observers were viewing patients with a cleft lip and palate than when they were viewing the control faces.[8,9] This finding indicates that faces with anomalies cause changes to the typical scanpath pattern. Additional studies have demonstrated that observers spent more time on the facial structure that they perceived to be abnormal when viewing pretreatment faces and that the scanpath was normalized when viewing posttreatment faces.[10-12] Researchers have proposed a novel method for objectively evaluating observer attention as an indicator of the success of surgical procedures to help minimize the appearance of facial deformities. Studies of the eye-tracking pattern of observers of faces with anomalies and how surgery can normalize the scanpath have provided insight into the evaluation of the effectiveness of facial reanimation surgery. By comparing pretreatment patients, posttreatment patients, and normal subjects, we can determine how orthodontic treatment can change the scanpath of observers, and the results of such studies maybe useful for the evaluation of orthodontic treatment.

Machine learning is a subfield of computer science that allows for predictions of data by building a model from given inputs. The support vector machine (SVM), a machine learning method in computer science, is efficient at generalizing to unseen data and making data-driven predictions. Therefore, SVMs are widely used in the early diagnosis and classification of diseases such as Alzheimer's[13,14] and colorectal tumors.[15] SVMs have also been used to manage eye-tracking data and boost diagnostic accuracy.[13,14,16,17] The principle of data prediction is that the machine can classify the data by identifying a hyperplane decision boundary with minimal errors by studying the innate features in each data type provided. In this study, the eye-tracking technique was used to quantify the attention bias on malocclusion patients and measure the effectiveness of orthodontic treatment at normalizing the scanpath of observers viewing malocclusion patients. The eye-tracking data of observers viewing normal subjects, pretreatment patients, and posttreatment patients were subsequently studied by SVM to improve the accuracy of assessing treatment need and treatment outcome of malocclusion by modeling eye movement characteristics.

The aims of this study were to (1) quantify attention bias toward malocclusion using the eye-tracking technique, (2) compare scanpath measurements among persons with normal occlusion (normal subjects) and pretreatment and posttreatment malocclusion patients when assessed by laypersons, (3) determine the accuracy of the assessment of orthodontic treatment need and outcome based on the SVM, and (4) explore the general ability of eye tracking in assessing orthodontic treatment need and outcome from the lay perspective. We explored

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