ORIGINAL ARTICLE

Cephalometric variables as predictors of Class II treatment outcome

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Cephalometric analysis of skeletodental features is accepted as an integral part of orthodontic diagnosis and treatment planning. This assumes that diagnostic cephalometric variables affect prognosis and thus help reduce malocclusion severity, which is the aim of orthodontic treatment. The aim of this study was to assess the predictive value of 41 commonly used cephalometric parameters with regard to pretreatment severity and treatment outcomes. Pretreatment severity was assessed by using the Peer Assessment Rating (PAR) occlusal index, an instrument that has been shown to be valid and reliable. Treatment outcomes consisted of (1) posttreatment malocclusion severity (post-PAR), (2) relative improvement (percent PAR reduction), and (3) treatment duration. Complete records, including cephalograms, of 223 treated Class II cases were analyzed by means of separate multiple linear regression models. Each of the outcome variables and the pretreatment severity served as the respective dependent variables, and the cephalometric parameters served as the independent or predictor variables. The cephalometric parameters explained 39.2% of the pretreatment severity variance, 17.9% of posttreatment severity variance, 15.7% of relative treatment improvement variance, and 20.0% of treatment duration variance. (Am J Orthod Dentofacial Orthop 2000;118:636-40)

Social, economic, and political pressures are bringing about changes in all aspects of health care delivery. Changes are conditioned by a need to strive for evidence-based clinical practices, as formulated and recommended in the Institute of Medicine report.[1] A prerequisite for evidence-based care is that it be patient centered and that objective and measurable outcomes are specified.

Outcomes assessment has become the focus of systematic clinical studies, and the results show that considerable qualitative and quantitative variations characterize treatment outcomes.[2-4] The existence of substantial unexplained variations, both in the costs and in the benefits associated with treatment, calls into question the efficiency of treatments, the accuracy of diagnoses, and the choice of treatment protocols—and how these may be measured quantitatively. Orthodontic treatment is vulnerable to such questions because agreement does not exist on what constitutes effective orthodontic treatment and which outcome measures are of primary interest to consumers and providers. With a lack of valid and reliable outcome measures, it is difficult to make objective evaluations of the need for orthodontic treatment or the quality of existing treatment options. Orthodontic outcomes, short-term and long-term, have numerous attributes . For this reason it is necessary to limit outcomes assessment to the most important and generally accepted parameters of care, and to have a means of accurately quantifying these variables. Such variables should reflect the most salient features of treatment effects—those that either contribute to or detract from patient benefits.[5]

OUTCOME MEASURES IN ORTHODONTIC TREATMENT

Second-generation occlusion indices, such as the Peer Assessment Rating (PAR) index,[6-8] the Dental Aesthetic Index (DAI),[9] and the Index of Orthodontic Treatment Need (IOTN),[10,11] all quantify severity of malocclusion. The "quality" of treatment outcome is evaluated by quantitative changes in traits contributing to malocclusion, including overjet, overbite, midline deviation, alignment, and buccal occlusion. The PAR score, which includes these 5 traits of malocclusion, provides a reliable and valid measure of severity.[8] The difference in PAR scores between the pretreatment and posttreatment occlusion, calculated either in terms of the absolute differences or as a percentage PAR reduction,[12] measures the reduction in severity of malocclusion and therefore the amount of improvement, or "quality of care," produced by orthodontic treatment.[13]

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The duration of treatment in months is also an outcome variable that lends itself to accurate and unambiguous measurement.[14] Combining data on the percentage PAR reduction and duration of treatment yields estimates of treatment effectiveness and efficiency that enables comparisons to be made between alternative treatments, as well as malocclusion types, alternative delivery of care systems, patient demographics, and cost-related factors.

CEPHALOMETRIC VARIABLES

A concern sometimes raised is that indices of malocclusion describe only occlusal traits of the dentition, but orthodontists are also concerned with skeletal and soft tissue variations, both in diagnosis and treatment planning and in terms of the outcome of treatment. Such skeletodental measures of morphological variation are generally derived from cephalometric analysis.

Whether patients derive any tangible benefits from the orthodontist's use of cephalometric features is controversial. Patients do not seek treatment to correct some cephalometric deviation but express concerns with facial and dental esthetics that may be attributable to craniofacial measures.[15] Consequently, whether outcome measures pertaining exclusively to cephalometric variables are valid remains to be demonstrated. Nevertheless, by incorporating cephalometric variables in addition to occlusal index for the purpose of understanding the relationships between process and outcome, predictive measures of morphology and associated variables may be reflected in patient benefits.[16]

The primary aim of this study was to assess the value of cephalometric variables in predicting orthodontic outcomes for patients with Class II malocclusions. A secondary aim was to identify those cephalometric variables that are most useful as predictors of pre-PAR, post-PAR, percent PAR reduction, and treatment duration.

MATERIALS AND METHODS

Orthodontic patients with Class II Division 1 malocclusions treated between 1977 and 1988 at the orthodontic graduate clinic of The Ohio State University's College of Dentistry were selected. Inclusion criteria identified patients with an overjet of more than 5 mm and complete pretreatment and posttreatment records that included lateral skull cephalometric films, study casts, and the treatment record. Surgical orthodontic patients and those with craniofacial anomalies were excluded. This process resulted in the selection of 223 Class II cases. Skeletal, dental, and soft tissue landmarks on the lateral cephalogram were digitized by a single examiner using the Dentofacial Planner system (Dentofacial Software, Toronto, Ontario) (Fig 1). Forty-one cephalometric variables from the initial pretreatment cephalogram were included in the analysis (Table I). Examiner reliability was assessed on 25 lateral cephalograms that were randomly selected and digitized twice at an interval of over 1 month to calculate the intra-examiner reliability. The pretreatment and posttreatment models were scored with the PAR occlusal index by a single examiner who had previously been calibrated in the use of the PAR the index. The duration of treatment (in months) was determined from the treatment records from the start of the treatment to debanding/discontinuing the active treatment appliance.

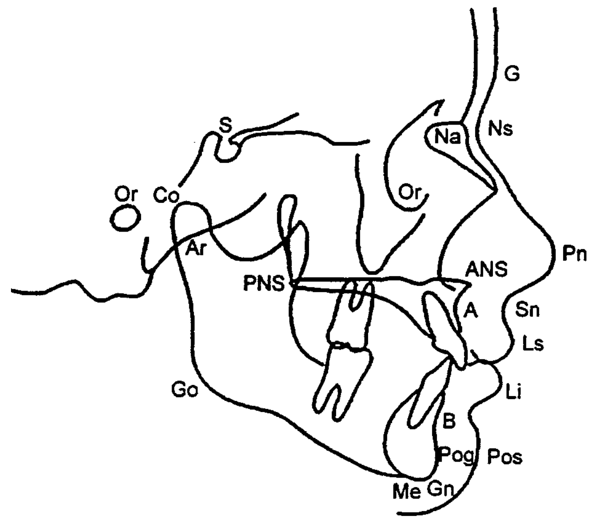

Fig 1. Cephalometric landmarks.

Data Analysis

For this study the PAR index weightings were derived from the American-based PAR validation study.[17] The pre-PAR and post-PAR scores and percent PAR reduction were then calculated. Intra-examiner reliability was estimated by the intraclass correlation coefficient for the lateral cephalometric variables and by the weighted κ statistic for the PAR index.

Computer-selected linear regression models were used to objectively estimate the amount of variance (R^2) of each of the 4 dependent variables (pre-PAR, post-PAR, percentage PAR reduction, and treatment duration) explained by the 41 cephalometric parameters (predictor variables). Because the sample consisted of 223 subjects, the maximum number of predictor variables allowed in any model was limited to 20. Predictor variables were selected by means of a protocol (SAS Institute Inc, 1989)[18] that maximizes the adjusted R^2 (R^2 adjusted for the number of predictor variables in the model), while keeping the number of predictor variables to 20 or less.

Table I. Cephalometric variables

Skeletal AP	SNA, SNB, ANB, Wits appraisal, facial angle, A to Na-perpendicular, Pog to Na-perpendicular, mandibular unit length, maxillary unit length, Harvold unit difference
Skeletal vertical	Y-axis, mandibular plane angle (FH to GoGn), SN to GoGn, SN to OP, articular angle, gonial angle, upper facial height (mm), lower facial height (mm), percentage of lower facial height (%), posterior face height (mm), anterior face height (mm), PFH: AFH
Dental	Interincisal angle, overbite (mm), overjet (mm), upper 1 to NF (mm), lower 1 to MP (mm), upper 6 to NF (mm), lower 6 to MP (mm), upper 1 to SN, lower 1 to MP, upper 1 to NA (°), upper 1 to NA (mm), lower 1 to NB (°), lower 1 to NB (mm)
Soft tissue	Upper lip to E (mm), lower lip to E (mm), soft tissue upper facial height (mm), soft tissue lower facial height (mm), soft tissue facial ratio, nasolabial angle

Table II. Relationship of cephalometric parameters to outcome measures

			Predictor variables in model			
			Skeletal			
Predicted variable	*No. of predictor variables*	*Adjusted R^2 (%)**	*AP*	*VERT*	*Dental*	*Soft*
Pre-PAR	20	39.2	ANB, facial angle, Pg-Nperp, MandL	PFH, Na-ANS, ANS-Gn, %LFH, PFH: AFH, articular, gonial	L1 to MP, U6-NF, L6-P, interincisal, overjet, U1 to NA (mm), L1 to NB (mm)	UL to E, STFHrat
Post-PAR	19	17.9	SNB, A-Nperp, Pg-Nperp, MidfaceL	MP, SN-GoGn, %LFH, PFH	U1-NF, L1-MP, U6-NF, overbite, overjet, interincisal, U1-NA (°), L1-NB (°), U1-NA (mm), L1-NB (mm)	ST-LFH
%Δ PAR	20	15.7	ANB, A-Nperp, Wits, Pg-Nperp, MandL, MidfaceL, Max-Mand	SN-OP, %LFH, PFH	U1-NF, L1-MP, overbite, overjet, interincisal, U1-NA (°), L1-NB (°), U1 to NA (mm), L1-NB (mm)	ST-LFH
Duration	17	20.0	ANB, facial angle, Wits	MP angle, Sn-GoGn, ANS-Gn	U1-NF, L1-MP, U6-NF, L6-MP, overbite, overjet, U1 to NA (mm), L1 to NB (mm)	UL to E, LL to E, nasolabial angle

*All multiple regression models were significant ($P < .0001$).

RESULTS

Intra-examiner reliability for the PAR index was 0.935. The reliability of lateral cephalometric variables ranged from 0.982 for angular to 0.998 for linear measurements.

The amount of variance *(R^2)* explained by the linear regression models ranged from 15.7% to 39.2%. The highest adjusted R^2 was for pre-PAR, indicating that cephalometric variables are best at predicting pre-PAR scores. Table II reports the predictor variables that were entered into the models. Not all the predictor variables reported in Table II reached the $P = .05$ level of significance. Only 2 of the 41 variables were found to be statistically significant common predictors of the pre-PAR and the 3 outcome variables (post-PAR, percentage PAR reduction, and duration of treatment). These 2 variables were upper and lower incisors to nasion-A point and nasion-B point ($P < .05$).

DISCUSSION

The primary aim of this study was to assess the value of cephalometric variables in predicting orthodontic outcomes in Class II malocclusions; therefore, only pretreatment or initial cephalograms were used. Although we traced and digitized approximately 177 landmarks, only 41 of these cephalometric variables were selected for use in these analyses. These 41 cephalometric variables represent conventionally used vertical and sagittal skeletal and soft tissue components of currently accepted cephalometric analyses.

We recognize that in this study we have used the initial cephalogram, which primarily provides information on the *skeletal component* of the Class II malocclusion, whereas the PAR index score provides information on the *dental component* of the Class II malocclusion. However, previous studies have reported that patients' desire for treatment and satisfaction with the outcome of orthodontic treatment are centered on dental appearance and not on functional or occlusal results.[19,20]

A study by Han et al[21] has shown that the addition of cephalometric information, when provided incrementally as part of diagnostic records, does not predictably or significantly alter orthodontic treatment decisions. Vallera and Nelson[16] reported that orthodontists derive information from cephalometric analysis that facilitates their treatment decisions. In our study the skeletodental and soft tissue cephalometric variables predicted a relatively small proportion of the variance in the final occlusal result (17.9% for post-PAR) and the degree of improvement of the malocclusion (15.7% for percent PAR reduction). Interestingly, there was a stronger association with the pre-PAR score (39.2%).

This study was designed to answer 2 specific questions relating to the value of cephalometric variables in predicting the outcome of orthodontic treatment in patients with Class II Division 1 malocclusions with an overjet of greater than 5 mm. Intuitively, it would seem that the skeletal contribution to the Class II malocclusion should have an effect on the outcome of the orthodontic result. A severe Class II skeletal pattern with upright rather than proclined maxillary incisors is more difficult to treat by camouflaging the skeletal pattern, and it would be expected that this be reflected in the final occlusal result. Likewise, in the vertical dimension the overbite should reflect a hypodivergent skeletal facial pattern. Interestingly, cephalometric variables explained almost 40% of the variation in the pre-PAR score, confirming that the cephalogram may be important in diagnostic decision making; this needs to be explored further. However, this study did not confirm that the cephalogram provides useful information for predicting the occlusal result, as only 18% of the variance was explained in the post-PAR score and thus the occlusal outcome of treatment. This was unexpected, as the skeletal pattern was not necessarily corrected with treatment. By camouflaging the skeletal discrepancy, the dentoalveolar component might be expected to result in more upright maxillary incisors and proclined mandibular incisors, affecting overbite, overjet, and the interdigitation of the buccal occlusion. These are all components included in the post-PAR score and thus the outcome of orthodontic treatment.

Given that cephalometric radiographs contain a potentially infinite number of variables and that there is no uniformly accepted analysis throughout the orthodontic specialty, the secondary aim in this study was to identify cephalometric variables that are predictors of occlusal outcome and length of orthodontic treatment. Only 2 of the 41 cephalometric variables were statistically significant common predictors of pre-PAR, post-PAR, percent PAR reduction, and duration of treatment. Because the incisal relationship (overjet of > 5 mm) was an inclusion criterion defining Class II Division 1 malocclusion in this study, the significance of upper and lower incisal angulation to NA and NB was not surprising.

A potential limitation of this study was the linear regression protocol used for selecting predictor variables by maximizing the adjusted R^2. While this was useful for estimating the amount of variance explained by the predictor variables, it did not ensure a stable model to make predictions and it did not consider potential nonlinear relationships or the effects of interactions among the predictor variables. Another limitation was the use of retrospective archival records, which may introduce bias in a study. We attempted to reduce this bias by including only patients with complete records. A previous report indicated that the initial severity of malocclusions in patients with complete records did not differ from that of patients with incomplete records.[22]

CONCLUSIONS

This study evaluated selected cephalometric variables with the intention of identifying predictors of the occlusal outcome of orthodontic treatment in patients with Class II malocclusions.

1. Cephalometric variables explained 39.2% of the variation in the pre-PAR scores; this suggests that cephalometrics may be more valuable as a diagnostic tool than a prognostic tool.
2. The selected cephalometric variables explained only 18% of the variance of the posttreatment occlusal result (post-PAR).
3. Sixteen percent of the variance in improvement of the malocclusion (percent PAR reduction) could be explained by cephalometric variables.
4. Twenty percent of the variance in treatment duration could be explained by commonly used cephalometric variables.

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COMMENTARY

The authors of the article above are to be commended for their effort to add more data regarding the quantification of the results of orthodontic treatment. Our specialty has been slow to measure the outcome of treatment efforts, and we are definitely in a period when evidence-based care is the goal.

The PAR index is known and accepted worldwide, and it has been shown to be a valid and reliable measure of the severity of malocclusion. The specific goal of this study was to evaluate some cephalometric variables as they relate to pretreatment and post-treatment PAR scores and treatment duration. Not surprisingly, little correlation was found. Although most orthodontists rely on cephalometrics in treatment planning and evaluation, few cephalometric measurements are closely related to the occlusion and alignment of teeth, which is what PAR looks at. In addition, while the PAR index is very reproducible for the original malocclusion, it is much less so for the more subtle differences in occlusion after treatment. This makes the process of looking for treatment differences even less likely.

Researchers at several universities are working on related projects, and each one can bring us closer to being able to quantify the benefits of orthodontic care.

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