

# An index of orthodontic treatment complexity

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**SUMMARY** The aim of the present study was to develop an index specifically for the measurement of treatment complexity. Input factors were directly related to complexity, and the output was a score measuring the degree of treatment complexity.

The sample comprised 120 sets of dental casts, 30 for each of the four main malocclusion classes. Sixteen orthodontists graded the study casts for perceived treatment complexity on a six-point scale and then listed, in order of importance, up to three occlusal features which they felt contributed to complexity from a pre-determined list. Multiple regression analysis was used to derive weightings for each occlusal feature, which would reflect the relevant treatment complexity. In order to obtain an overall treatment complexity score for each case, weightings were then multiplied by the corresponding occlusal feature scores and summed. The relationship between treatment complexity scores and perceived complexity was examined using Spearman's ranked correlation coefficient.

The regression equation explained 49.5 per cent of the variance in treatment complexity of the whole sample. Regression analysis on the basis of malocclusion produced  $R^2$  values of 90.7 per cent for Class I, 42.6 per cent for Class II division 1, 62.3 per cent for Class II division 2, and 79.5 per cent for Class III malocclusions. The index of orthodontic treatment complexity (IOTC) scores showed a moderate but highly significant association with the orthodontists' perceived complexity assessments ( $\rho = 0.42$ ,  $P = 0.000$ ).

The proposed IOTC shows sufficient promise to warrant further development.

## Introduction

Considerable effort has gone into the need to develop standardized, valid, and reliable measurement tools in orthodontics. The development of indices of treatment need, outcome, and complexity has been at the forefront of this research (Brook and Shaw 1989; Richmond *et al.*, 1992; DeGuzman *et al.*, 1995; Hamdan and Rock, 1999; Daniels and Richmond, 2000). Orthodontic treatment complexity has been defined as an entity that reduces post-treatment success (Richmond *et al.*, 1997), and treatment difficulty as the effort needed to establish correct (normal) tooth relationships (Bergström and Halling, 1997), or the probability of attaining an ideal occlusion when all treatment options are available (Pae *et al.*, 2001).

Rowe *et al.* (1990) studied assessments of treatment difficulty made by 30 orthodontists who examined pre-treatment records. Study casts were analysed using an objective measurement of malocclusion. The conclusion was that malocclusion severity and treatment difficulty were distinct but related entities. DeGuzman *et al.* (1995) also found close associations between perception of malocclusion severity and treatment difficulty. The premise that complexity or difficulty, although a parameter separate from severity, is related to it, was supported by Cassinelli *et al.* (2003). However, it has also been suggested that measurements of difficulty and severity either measure the same latent trait or that the difference between the two is small (Pae *et al.*, 2001). Richmond *et al.* (2001) suggested

that difficulty and complexity in orthodontics are synonymous and should be defined as a measurement of effort and skill, while severity is a measurement of how far a malocclusion deviates from normal.

There is general perception of treatment complexity among experienced orthodontists. Problems arise however when attempts are made to determine the factors that govern this perception. Cassinelli *et al.* (2003) suggested that difficulty in achieving an ideal or normal occlusion might arise from the pre-treatment occlusion, patient associated factors, and related treatment factors. Several authors have used the opinion of panels of orthodontists to evaluate pre-treatment study casts as a method for assessing factors associated with treatment complexity (DeGuzman *et al.*, 1995; Daniels and Richmond, 2000; Pae *et al.*, 2001; Cassinelli *et al.*, 2003). However, Richmond *et al.* (2001) found that pre-treatment factors were poor at predicting orthodontic treatment complexity and that only post-treatment factors mattered.

Several investigators have found that complex cases had greater severity and treatment need before therapy and greater residual malocclusion after treatment (Stephens and Harradine, 1988; DeGuzman *et al.*, 1995; Bergström and Halling, 1997; Daniels and Richmond, 2000; Pae *et al.*, 2001; Richmond *et al.*, 2001; Cassinelli *et al.*, 2003). Complex cases were more likely to have required extractions, changes in treatment plan, more appointments, longer treatment duration, and the patients to have received

repeated warnings about compliance problems. Richmond *et al.* (1997) found that the treatment cost and the age of the patient at the start of treatment were significant factors in predicting perceptions of case complexity, whereas treatment duration and the pre-treatment index of orthodontic treatment need (IOTN) grade were not. In another study, Richmond *et al.* (2001) reported that perceived complexity was not associated with the number of changes in treatment plans, extraction patterns, or treatment length.

An index of orthodontic treatment complexity (IOTC) would have several potential uses, including identification of the level of expertise needed to treat a specific case, allocation of health care resources, appropriate recognition for professionals undertaking complex care, and provision for better patient information regarding the likely complexity of the treatment.

Daniels and Richmond (2000) developed an index of complexity, outcome, and need (ICON) to assess treatment inputs, outcomes, and case complexity. An international panel of 97 orthodontists from nine different countries gave subjective judgements on the need for treatment, treatment complexity, treatment improvement, and treatment acceptability. They assessed the degree of need for 240 sets of pre-treatment study casts and recorded treatment outcome using 98 paired pre- and post-treatment records. Using multiple regression analysis, traits were awarded different weightings according to their relative importance, and the sum of the weighted scores gave the final ICON score. Interpretation of ICON scores was carried out using cut-off values and score ranges derived from the subjective opinions of the 97 orthodontists.

The claimed advantages of ICON are that it is simple to use, requires no hierarchy, measures relatively few traits, and can be used on patients or study casts without modification. The index is valid for the assessments of treatment need, complexity, and outcome and avoids the need to use different indices to make different forms of assessment.

Unfortunately, clinical application of ICON revealed a number of limitations. The index is highly weighted for aesthetics (weighting of seven), an assessment which relies on subjective opinion and therefore reduces the objectivity of the index. Savastano *et al.* (2003) tested the validity of ICON for measuring orthodontic complexity, outcome, and treatment improvement. The results showed that intra-examiner agreement was moderate for complexity, slight for outcome, and poor for degree of improvement, while inter-examiner agreement was moderate for complexity and outcome and fair for degree of improvement. Koochek *et al.* (2001) tested the ICON for assessment of treatment need and found that, although it showed good sensitivity for detecting treatment need, its specificity was poor. Furthermore, ICON has a relatively lower predictive accuracy for treatment outcome than for treatment need, due to lower levels of inter-examiner agreement for decisions on treatment acceptability (Richmond and Daniels, 1998).

The aim of the present study was to develop an index specifically for the measurement of treatment complexity, with input factors directly related to complexity, and the output measurement being a score reflecting the degree of treatment complexity.

## Material and methods

### Sample selection

Study cast of 120 subjects equally divided into Class I, Class II division 1, Class II division 2, and Class III malocclusions were included in the study. The casts were collected from the Birmingham Dental Hospital and Walsall Manor Hospital, UK. Starting from a random site on the model box shelves, the casts were collected in sequential order until each malocclusion category was filled. The cases were grouped according to the classification of incisor relationship (British Standards Institute, 1983). The dental casts were part of treatment records from June 1996 to December 2003. Casts were made anonymous and numbered; from 1–30 for Class I, 31–60 for Class II division 1, 61–90 for Class II division 2, and 91–120 for Class III malocclusions. The order of presentation of study casts was randomized using random number tables, before they were seen by the examiners.

Selection criteria for inclusion were the availability of pre- and post-treatment study casts, availability of a pre-treatment dental pantomogram taken within 6 months prior to commencement of treatment, well-documented clinical records, and a successful completion.

Ethical approval was not needed for the present study since records were made anonymous to the examiners and were part of the standard orthodontic management at the two hospitals.

### Methods

The data collected from patient records included treatment length and number of visits, and missed and emergency appointments. The study casts were scored using the unweighted peer assessment rating (PAR) index by one author (SKL) who had been calibrated in the use of the index.

A panel of 16 examiners, nine consultant orthodontists, three specialist orthodontists, and four specialist registrars in their final year of orthodontic training, participated in the study. The mean age of the examiners was 42.7 years [standard deviation (SD) 12.0 years], 11 were males and five were females, and they presented with a wide range of experience in orthodontics (average length of time 14.4 years, SD 14.2 years).

The examiners were asked to assess the pre-treatment study casts in two ways: firstly, to grade their perception of orthodontic treatment complexity on a six-point scale (1 = easy to 5 = extremely complex and 6 = impossible without orthognathic surgery). The examiners were to assume that treatment outcome was not to be compromised and that a normal overjet and overbite would be established without

orthognathic surgery. They were also told to assume that all unerupted canines were to be aligned. Secondly, the examiners were asked to select up to three occlusal factors contributing to the complexity grade and list them in order of importance. A pre-determined list of 11 occlusal factors, presented in random order, was provided. This list was derived from components of the PAR index with the addition of 'missing teeth', 'teeth of poor prognosis', and 'degree of spacing' as supplementary factors.

The examiners were asked to record their assessments on a scoring sheet which contained patient information including age, gender, details of missing and unerupted teeth, and teeth of poor prognosis, but no patient identifiers (Table 1). The examiners were not briefed on how complexity was to be defined; however, an instruction sheet was provided as an aid (Table 2).

### Statistical analyses

Multiple regression analysis was used to study the relationship between the perceptions of treatment complexity grade (dependent variable) and the occlusal factors considered by the examiners to contribute to complexity (independent variables). Partial regression coefficients from the regression equation were used to derive weightings for each occlusal factor.

Orthodontic treatment complexity scores were then derived by multiplying each occlusal component score with its

corresponding weighting. Component scores were summed to provide an overall complexity score for each case.

Finally, Spearman's ranked correlation coefficients were used to study the relationship between calculated complexity scores on the one hand and perceived complexity grades and patient data on the other.

Statistical analysis was carried out using the Minitab statistical package (Minitab Inc., State College, Philadelphia, USA)

## Results

### Multiple regression analysis and derivation of weightings

Table 3 shows the distribution by age and gender of the subjects represented by the total sample of 120 study casts according to malocclusion Class. Occlusal factors contributing to the complexity score of each case were allocated rank values ranging from 3 for the most important factor to 1 for the least important. The average rankings for the 16 examiners were determined, followed by the calculation of mean rank values (MRVs) for each of the 11 occlusal factors across the 120 cases.

Multiple regression analysis was carried out using perceived complexity grades as the dependent variable, and MRVs for the 11 occlusal factors as the independent variables to produce the following regression equation:

Complexity score =  $-1.20$  (constant)  $+1.21$  overjet/reverse overjet  $-0.87$  centreline  $+0.64$  molar correction  $+1.13$

**Table 1** Scoring sheet

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**CASE NUMBER:** \_\_\_\_\_ **Examiner:** (please give your name) \_\_\_\_\_

Patient's age: \_\_\_\_\_ Patient's gender: \_\_\_\_\_

Missing teeth: \_\_\_\_\_

Unerupted teeth: \_\_\_\_\_

Teeth of poor prognosis: \_\_\_\_\_

**PART 1**

**Using the scale given below, please state how complex you believe the orthodontic treatment of this malocclusion would be.** Assume that the treatment outcome is not to be a compromise and that you are to achieve normal overjet and overbite, without orthognathic surgery. Assume that all unerupted canines are to be aligned. The ranking of 'impossible' should only be given to the case if you feel that it is untreatable without orthognathic surgery.

Please circle the appropriate number.

1	2	3	4	5	6
Easy				Extremely Complex	Impossible

**PART 2**

From the table below please list the numbers correlating to the three factors, which have lead to your decision as to the complexity of the orthodontic treatment of this case.

Please list in order of **decreasing importance**.

1 Overjet/reverse overjet	7 Overbite/anterior open bite
2 Centreline discrepancy	8 Degree of crowding
3 Molar correction	9 Posterior crossbite
4 Lateral open bite	10 Teeth of poor prognosis
5 Impacted teeth	11 Missing teeth
6 Degree of spacing	

Factor 1 (most important) \_\_\_\_\_

Factor 2 \_\_\_\_\_

Factor 3 (least important) \_\_\_\_\_

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lateral open bite +1.03 impacted teeth +0.86 spacing +1.08 overbite/anterior open bite +0.76 crowding +0.93 posterior crossbite +1.11 poor prognosis teeth +0.89 missing teeth.

**Table 2** Instruction sheet

Please read the following instructions before completing the scoring sheets.

- This study aims to assess your perceptions on the complexity of orthodontic treatment and to elicit the reasons behind your perceptions.
- The table containing the patient's age, missing teeth etc. is for information purposes only and is not to be filled in by yourself.
- Each scoring sheet corresponds to a numbered set of study casts. Please complete parts 1 and 2 of each scoring sheet.
- For each case the treatment aim is to obtain a normal overbite and overjet, posterior crossbites are to be corrected. Molar correction refers to achieving molar intercuspation and not necessarily a Class I molar relationship.

With regards to the occlusal factors being selected: if you feel that only one or two factors are important and that no other factors listed are significant, then simply state these factors **i.e. select up to three factors.**

**Table 3** Distribution of age and gender among the sample

	Gender		Age (years)	
	Male	Female	Mean	Range
Class I	12	18	14.7	12–18
Class II division 1	17	13	14.1	11–28
Class II division 2	9	21	15.7	12–42
Class III	11	19	17	12–29
Total	49	71	15.4	11–42

**Table 4** Regression analysis for total sample, including analysis of variance

Predictor	Coefficient	SE coefficient	<i>T</i> value	<i>P</i> value	
Constant	−1.1967	0.8851	−1.35	0.179	
Overjet	1.2051	0.1686	7.15	0.000	
Centreline	0.8738	0.2099	4.16	0.000	
Molar correction	0.6426	0.1968	3.72	0.001	
Lateral open bite	1.1290	1.2730	0.89	0.377	
Impacted teeth	1.0288	0.1691	6.08	0.000	
Spacing	0.8565	0.4368	1.96	0.052	
Overbite/anterior open bite	1.0803	0.1593	6.78	0.000	
Crowding	0.7580	0.2017	3.76	0.000	
Posterior crossbite	0.9344	0.1969	4.74	0.000	
Teeth of poor prognosis	1.1072	0.4026	2.75	0.007	
Missing teeth	0.8924	0.2261	3.95	0.000	
<i>S</i> = 0.7320	<i>R</i> <sup>2</sup> = 49.5%	<i>R</i> <sup>2</sup> (adjusted) = 44.4%			
Analysis of variance					
Source	DF	SS	MS	<i>F</i> value	<i>P</i> value
Regression	11	56.7698	5.1609	9.63	0.000
Residual error	108	57.8781	0.5359		
Total	119	114.6479			

Table 4 illustrates the full statistical analyses (including analysis of variance) associated with the multiple regression modelling. The regression model explained 49.5 per cent of the variance in complexity for the sample ( $R^2$ ) and the adjusted  $R^2$  was 44.4 per cent. Best subset regression analysis was also attempted, in which different occlusal factors as independent variables are sequentially excluded from the regression model. This was undertaken in an attempt to improve the variance explained by the model. However omission of any factors from the model reduced  $R^2$  values, demonstrating that all 11 factors contributed to the overall regression formula.

Regression analyses were also carried out with the sample divided into the four different malocclusion Classes (30 cases in each group, Table 5). The regression model explained a considerable amount of the variance in complexity for Class I and Class III malocclusions ( $R^2 = 90.7$  and  $79.5$  per cent, respectively).  $R^2$  values were moderately high for Class II division 2 malocclusions (62.3 per cent) but lower for Class II division 1 (42.6 per cent).

Complexity weighting derived for the total sample was highest for overjet, followed by lateral open bite and teeth of poor prognosis (1.21, 1.13, and 1.11, respectively, Table 4). Lateral open bite had the highest complexity weighting for Class I and Class II division 1 malocclusions (3.06 and 2.41, respectively, Table 5), whereas spacing had the highest weighting for Class II division 2 and Class III malocclusions (6.70 and 2.29, respectively).

#### Derivation of complexity scores

Complexity scores were derived for each of the 120 cases as follows: firstly, unweighted pre-treatment PAR scores were



**Table 5** Regression analysis based on malocclusion class

	Regression Coefficients			
	Class I	Class II division 1	Class II division 2	Class III
Overjet/reverse overjet	1.64	1.00	1.46	0.92
Centreline discrepancy	1.23	0.86	0.99	0.58
Molar correction	1.35	0.74	1.55	0.40
Lateral open bite	3.06	2.41	0.24	1.03
Impacted teeth	1.43	0.72	1.60	0.43
Degree of spacing	1.42	1.47	6.66	2.29
Overbite/anterior open bite	0.89	1.07	1.54	0.64
Degree of crowding	1.27	0.78	1.58	0.25
Posterior crossbite	1.10	0.66	1.59	0.37
Teeth of poor prognosis	1.26	1.88	0.52	1.53
Missing teeth	1.08	0.78	0.33	0.58
R <sup>2</sup> (%)	90.7	42.6	62.3	79.5
P value	0.00	0.35	0.01	0.00

**Table 6** Example of the calculation of an index of orthodontic treatment complexity score

Factor	Grade	Regression coefficient	Component score
Overjet	4	1.2	4.8
Centreline	0	0.9	0
Molar correction	4	0.6	2.4
Lateral open bite	0	1.1	0
Impacted teeth	0	1.0	0
Spacing	0	0.9	0
Overbite/anterior open bite	2	1.1	2.2
Crowding	21	0.8	16.8
Posterior crossbite	6	0.9	5.4
Teeth of poor prognosis	0	1.1	0
Missing teeth	0	0.9	0
Total complexity score			31.6

recorded based on assessments of overjet, centreline, molar correction, lateral open bite, overbite/anterior open bite, and posterior crossbite. Unweighted PAR scores for crowding were also recorded but the presence of an impacted tooth or teeth in either or both the upper or lower jaws was only allocated a grade of 1. Spacing was graded according to the methods used in the ICON (Daniels and Richmond, 2000). Teeth with a poor long-term prognosis were allocated a score of 1, as were missing teeth in either or both arches (excluding third molars). Finally, unweighted scores for each occlusal feature were multiplied by their corresponding complexity weighting (Table 4) and summed to give a final IOTC score. Table 6 illustrates a worked example for the highest scoring case (case 113).

#### *The relationship between IOTC scores, perceived complexity, and patient data*

The relationship between IOTC scores and perceived complexity grades, as determined by the panel of 16 examiners, was studied using Spearman's ranked correlation

**Table 7** The relationship between index of orthodontic treatment complexity (IOTC) scores and other variables

Variables	Correlation coefficient	P value
IOTC versus perceived complexity	0.413	0.000
IOTC versus treatment length	0.191	0.037
IOTC versus number of visits	0.203	0.026
IOTC versus missed appointments	0.031	0.734
IOTC versus emergency appointments	0.007	0.944

coefficient. The correlation was 0.413 ( $P = 0.000$ ). The relationship between complexity scores and patient data was also studied; these included treatment length, number of visits, and missed and emergency appointments. Correlations are illustrated in Table 7.

## Discussion

The necessity for developing another IOTC may be questioned. Holmes and Willmot (1996) expressed concern regarding the need for such an index since only 19.7 per cent of consultants surveyed on their use of IOTN expressed a need for an index of complexity. This consideration is even more pertinent in view of the fact that ICON has already been developed. Reservations include the heavy weighting for aesthetics, which is highly subjective and may be a significant source of error. Savastano *et al.* (2003) showed variable levels of intra- and inter-examiner agreement when testing the validity of ICON as a measure of orthodontic complexity, outcome, and treatment improvement. Koochek *et al.* (2001) found that the specificity of ICON for detecting treatment need was poor.

Unlike PAR and IOTN, ICON has not gained widespread use. At first sight, the development of a further index would seem to add to the duplication of effort. However, the IOTC

builds on the principles underlying the PAR index by applying different weightings to each component to reflect treatment complexity. It could be used by anyone familiar with the PAR index without the need for further training or calibration.

Weighting was derived in a manner similar to that used to obtain PAR weightings. Multiple regression analysis was carried out using treatment complexity as perceived by the 16 examiners as the dependent variable and the MRVs of the 11 occlusal factors as independent variables. Regression coefficients for each factor were used as weightings. Overjet/reverse overjet, lateral open bite, and teeth of poor prognosis had the highest weightings (1.21, 1.13, and 1.11, respectively) and therefore were most important in the assessment of treatment complexity (Table 4).

The coefficient of determination ( $R^2$ ) gives an indication of how well the variance within the sample is explained by the regression model and it has been suggested that the  $R^2$  value has to be around 50–60 per cent before the equation is of genuine clinical use (Petrie *et al.*, 2002). The regression equation for IOTC had a  $R^2$  value of 49.5 per cent. This is only marginally below the level required for good prediction, and hence the index does show promise.

Attempts to exclude different independent variables on the basis of best subset analysis did not improve  $R^2$  values. This indicates that exclusion of any of the 11 occlusal factors from the model reduces its predictive power with regard to treatment complexity.

The sample was chosen to be representative of the different malocclusion classes according the classification of incisor relationship (BSI, 1983). When attempts were made to analyse complexity on the basis of malocclusion class (Table 5),  $R^2$  values were high for Class I and Class III malocclusions (90.7 and 79.5 per cent, respectively), moderately high for Class II division 2 malocclusions ( $R^2$  = 62.3 per cent) but low for Class II division 1 malocclusions ( $R^2$  = 42.6 per cent). Previous research has indicated that PAR performs better as a measurement of treatment outcome when different weightings are assigned to each of the malocclusion Classes (Hamdan and Rock, 1999). In the present study, correlations were improved for three of the four malocclusion Classes by subdividing assessments. This is particularly encouraging since sample size was reduced to a quarter of the overall sample size of 120 cases by the subdivision. Smaller samples might have been expected to increase the effect of the variance and thus reduce  $R^2$  values.

The validity of the IOTC was examined by correlating index scores with perceived complexity grades as assessed by the 16 examiners. Although the correlation coefficient was found to be somewhat disappointing (0.413), it was highly significant ( $P$  = 0.000, Table 7). Associations between patient factors and IOTC scores were also studied. Correlations between complexity scores and the number of missed and emergency appointments were not statistically

significant. Poor correlations were also found between complexity scores and total treatment time and total number of visits (Table 7). This suggests that cases predicted as being complex prior to starting treatment do not necessarily take the longest time to treat or require more appointments to achieve a good result.

## Conclusions

1. IOTC scores showed moderate but highly significant correlations with assessments of treatment complexity.
2. Overjet/reverse overjet, lateral open bite, and teeth of poor prognosis had the highest treatment complexity weightings; 1.21, 1.13, and 1.11, respectively.
3. Division of the sample into individual malocclusion classes to derive treatment complexity weightings considerably improved the performance of the regression model for Class I, Class II division 2, and Class III malocclusions.

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