Effectiveness of photographs of study models for IOTN scoring

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Aim: The aim of the present study was to investigate whether the same orthodontic information can be obtained from study models or photographs of study models in order to assess the Index of Orthodontic Treatment Need (IOTN). The study also aimed to assess inter- and intra-examiner reliability in the assessment of orthodontic treatment need.

Sample: Thirty sets of start and finish study models, demonstrating a range of malocclusions, were non-randomly obtained from patients treated at the University of Manchester Dental Hospital. The start models demonstrated a range of malocclusions (according to The British Standard Institute Incisor Classification 1983) of varying complexity.

Method: Six photographic views of each set of study models were taken against a dark background. Millimetric distances were determined by using dividers to measure photographic distances and actual distances in millimeters from a ruler embedded in the image. Four examiners assessed the study models and photographs of the models in a random order and the Aesthetic and Dental Health components of the IOTN were recorded.

Results: There were no statistically significant differences in the IOTN scores from photographs of study models compared with IOTN scores from study models of the same patient.

Conclusion: The IOTN scores derived from photographs of study models are valid and reliable measures of malocclusion.

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Introduction

Orthodontic study models have been used for many years as the standard method of orthodontic record keeping, diagnosis, and treatment planning. Normally, an impression is taken of the patient’s dentition, after which an orthodontic model is fabricated.1 In order to assess a malocclusion, the plaster models are used to take measurements such as overjet, overbite, and sagittal molar relationship. Moreover, several orthodontic treatment indices have been developed for use with orthodontic casts in order to prioritise a patient’s orthodontic treatment needs, as well as for the evaluation of treatment progress and results.

Although orthodontic study models are diagnostically useful, there is an associated significant storage cost to comply with medico-legal requirements. The Consumer Protection Act in the United Kingdom states that it is necessary to retain all patient records for a minimum of 10 years.2 This can prove to be expensive, especially where space is limited. Models are prone to loss and breakages during retrieval and use, highlighting the need for an alternative method of storage.3

A more convenient and cost-effective approach is to substitute study models with photographs of study models.4 Three-dimensional (3D) digital imaging is beginning to replace orthodontic study models.
The IOTN consists of two components: the Aesthetic Component (AC) and the Dental Health Component (DHC). The two components combined provide an indication of treatment need.

The DHC classifies occlusal traits into five categories according to their severity. Grade 1 indicates little or no need for treatment, ranging to Grade 5, which indicates an urgent need for treatment (Table I). The DHC was developed to guarantee validity and consistency in the evaluation of orthodontic treatment need between dental professionals.

The Aesthetic Component grades aesthetic impairment as a result of the malocclusion. It consists of 10 photographs, which depict different levels of dental attractiveness scored on a scale which indicates that 1 is the most attractive, and 10 is the least (Figure 1). The grading is determined by the orthodontist comparing 3D images to the photographs.

However, the practice is not yet widespread because 3D images are still expensive to acquire. Also, there is conflicting evidence regarding the accuracy of occlusal assessment using 3D imaging systems.5,6

There are a number of indices used to record treatment need, severity of malocclusion and health gain due to treatment. The Index of Orthodontic Treatment Need (IOTN) attempts to rank malocclusion by the significance of occlusal traits related to an individual’s dental health, and perceived aesthetic impairment.7

The IOTN was based on treatment need within the Swedish Health Service8 and its intention is to identify those individuals who would most benefit from orthodontic treatment. In the United Kingdom IOTN is used to assess the need and eligibility of children under 18 years of age for NHS orthodontic treatment on dental health grounds.

### Table I. IOTN Dental Health Component.

| Grade 5 | · Impeded eruption of teeth (except for third molars) due to crowding, displacement, the presence of supernumerary teeth, retained deciduous teeth, and any pathological causes.  
| Grade 4 | · Less extensive hypodontia, requiring pre-restorative orthodontics or orthodontic space closure to obviate the need for a prosthesis.  
| Grade 3 | · Increased overjet greater than 6 mm, but less than, or equal to, 9 mm.  
| Grade 2 | · Reverse overjet greater than 3.5 mm, with no masticatory or speech difficulties.  
| Grade 1 | · Reverse overjet greater than 3.5 mm, indicating an urgent need for treatment (Table I).  

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and matching the patient with the photographs. The photographs were arranged in order by a panel of laypersons.9

Photographs are undoubtedly an essential part of clinical documentation, for case presentations, treatment progress and screening.10 As a result, photographs of study models form the focus of the present investigation as a cost-effective and viable method for IOTN scoring. The IOTN has been shown to be valid and reproducible with kappa scores ranging from 0.71 to 0.91 for both intra and inter-examiner agreement.11-14 The aim of this study was to investigate the inter- and intra-examiner reliability of using study models and photographs of study models as an alternative way of IOTN scoring.

The null hypothesis is that there was the same level of agreement in IOTN scores (DHC and AC) when assessed from study models or from photographs of the same models.

Materials and methods

Ethical approval was not deemed necessary by the University of Manchester Ethical Committee, because no identifiable patient information was used.

A sample of 30 study models from patients who had undergone orthodontic treatment was selected from the Orthodontic Department at the University of Manchester Dental Hospital. The sample comprised 23 start and 7 finished study models, all of which displayed a variety of malocclusions.

Using the British Standards Institution Incisor Classification Guide,15 the models were categorised into twelve Class I, eight Class II Division 1, four Class II Division 2, and six Class III groups. The sample study models were duplicated, and marked with numbers. Six photographs were taken of each set of study model using a Fujifilm FinePix S3 Pro digital camera (Fujifilm UK Limited, Bedford, UK) and a Nikon Macro Speed-light 60 mm/1:2.8 D lens (Nikon UK Limited, Kingston-upon-Thames, Surrey, UK) at a lens object distance of 30 cm. The photographs exposed the anterior, right and left buccal segments in occlusion (Figure 2 a, b, c) and upper and lower
occlusal views (Figure 3 a, b). An additional buccal view with a millimeter ruler was captured for the measurement of overjet (Figure 4).

The study models were securely stored in the University of Manchester Dental Hospital in a locked area and the photographs on the University of Manchester server on a password-protected site.

To aid visualisation, the study models were placed and viewed against a dark background. Also, to facilitate the assessment of IOTN occlusal traits, a millimetric ruler was placed at the edge of the photographs (Figures 2 – 4), and the millimetric distances were measured using a divider. The divider points were placed on the photographs to measure required distances, and transferred to the ruler to determine the distance in millimeters.

Four IOTN examiners randomly assessed all of the study models and the corresponding photographs for the Aesthetic and Dental Health Components. The examiners possessed a varying range of orthodontic experience. Two were orthodontic consultants, one was an orthodontic senior registrar and another was a third-year orthodontic postgraduate student.

To measure the intra-examiner and inter-examiner agreement, all four examiners scored the models for Aesthetic and Dental Health Components twice at intervals of three weeks and, one month later, all examiners scored the photographs of the study models twice at three-week intervals. Therefore, the results will show inter-examiner and intra-examiner agreement for the IOTN Aesthetic and Dental Health Components for each of the following:

1. Study models;
2. Photographs of the study models;
3. Photographs of the study models versus the actual study models.

The examiners were asked to score the Dental Health Component with the number only (1 to 5) without the prefix (a, b, c etc). It was intended to reveal whether the patient qualified for orthodontic treatment. A score of 1 above or below the actual value was accepted to be correct. The photographs were viewed using Windows Picture and Fax Viewer, and the examiners were given the option of being able to print any photograph needed in order to take measurements using a vernier caliper if they chose.
Statistical analysis

The data were recorded in printouts that were distributed to the examiners and then analysed using Stata (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX:StataCorp LP). Statistical analysis

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Table II. Intra-examiner agreement and Kappa of the IOTN-DHC for the study models.

<table>
<thead>
<tr>
<th>Examiner</th>
<th>Agreement (%)</th>
<th>Kappa</th>
<th>Std. err</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>99.37</td>
<td>0.9671</td>
<td>0.1818</td>
</tr>
<tr>
<td>B</td>
<td>99.58</td>
<td>0.9775</td>
<td>0.1823</td>
</tr>
<tr>
<td>C</td>
<td>99.38</td>
<td>0.9663</td>
<td>0.1825</td>
</tr>
<tr>
<td>D</td>
<td>99.58</td>
<td>0.9761</td>
<td>0.1824</td>
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Table III. Intra-examiner agreement and Kappa of the IOTN-AC for the study models.

<table>
<thead>
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<th>Examiner</th>
<th>Agreement (%)</th>
<th>Kappa</th>
<th>Std. err</th>
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</thead>
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<tr>
<td>A</td>
<td>99.01</td>
<td>0.9568</td>
<td>0.1810</td>
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<tr>
<td>B</td>
<td>99.32</td>
<td>0.9765</td>
<td>0.1816</td>
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<tr>
<td>C</td>
<td>99.05</td>
<td>0.9568</td>
<td>0.1789</td>
</tr>
<tr>
<td>D</td>
<td>99.67</td>
<td>0.9858</td>
<td>0.1823</td>
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Table IV. Inter-examiner agreement and Kappa of the IOTN-DHC for the study models.

<table>
<thead>
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<th>Examiners</th>
<th>Agreement (%)</th>
<th>Kappa</th>
<th>Std. err</th>
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<tbody>
<tr>
<td>A-B</td>
<td>98.75</td>
<td>0.9347</td>
<td>0.1814</td>
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<td>A-C</td>
<td>97.50</td>
<td>0.8701</td>
<td>0.1822</td>
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<tr>
<td>A-D</td>
<td>97.08</td>
<td>0.8399</td>
<td>0.1816</td>
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<tr>
<td>B-C</td>
<td>96.25</td>
<td>0.7973</td>
<td>0.1823</td>
</tr>
<tr>
<td>B-D</td>
<td>96.25</td>
<td>0.7881</td>
<td>0.1798</td>
</tr>
<tr>
<td>C-D</td>
<td>97.92</td>
<td>0.8826</td>
<td>0.1811</td>
</tr>
</tbody>
</table>

Table V. Inter-examiner agreement and Kappa of the IOTN-AC for the study models.

<table>
<thead>
<tr>
<th>Examiners</th>
<th>Agreement (%)</th>
<th>Kappa</th>
<th>Std. err</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>97.97</td>
<td>0.9311</td>
<td>0.1823</td>
</tr>
<tr>
<td>A-C</td>
<td>98.85</td>
<td>0.9525</td>
<td>0.1820</td>
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<td>A-D</td>
<td>97.90</td>
<td>0.9125</td>
<td>0.1769</td>
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<td>B-C</td>
<td>98.56</td>
<td>0.9430</td>
<td>0.1824</td>
</tr>
<tr>
<td>B-D</td>
<td>97.61</td>
<td>0.9053</td>
<td>0.1759</td>
</tr>
<tr>
<td>C-D</td>
<td>98.23</td>
<td>0.9319</td>
<td>0.1773</td>
</tr>
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</table>

For photographic and model comparison. Cohen’s Kappa (K) statistic was used to assess intra-rater and inter-rater reliabilities. Quadratic weighting was used to count for potential disagreement since some examiners did not use all the available ratings, and this was addressed using the absolute option in Stata. Interpretation was set at: ≤ 0.40 (poor); 0.40 – 0.60 (good); 0.60 – 0.80 (very good); 0.80 – 1.00 (excellent).

Results

Intra-examiner reliability in IOTN scoring of the plaster study models

Intra-examiner agreement of the IOTN-DHC for the study models (Table II) ranged from 99.37% to 99.58% and a K value from 0.97 to 0.98 (excellent). For IOTN-AC (Table III) the four examiners were found to have a K value from 0.96 to 0.98 (excellent) and percentage from 99.01% to 99.67%.

Inter-examiner reliability in IOTN scoring of the plaster study models

Inter-examiner agreement (Table IV) was slightly lower, with the K values ranging from 0.79 to 0.93 and percentages from 96.25% to 98.75%. For AC (Table V) it ranged from 97.61% to 98.85% with the K values from 0.91 to 0.95 (excellent).

Intra-examiner reliability in IOTN scoring of the photographs of plaster study models

Intra-examiner agreement of the IOTN-DHC for the photographs of the study models (Table VI) was 99.58% to 100%, with K values from 0.97 to 1.00 (excellent).

The IOTN-AC (Table VII) for the photographs ranged from 94.94% to 99.38%, with K values ranging from 0.78 to 0.98 (very good to excellent).
Inter-examiner reliability in IOTN scoring of the photographs of plaster study models

Inter-examiner agreement (Table VIII) ranged from 95.83% to 99.38% with the K values ranging from 0.77 to 0.97 (very good to excellent). The IOTN-AC scores (Table IX) ranged from 95.80% to 98.18% with the K values ranging from 0.80 to 0.94 (excellent).

Comparison between IOTN scores obtained from study models and their photographic counterpart

Intra-examiner agreement of the IOTN-DHC obtained from the photos of study models and the actual study models (Table X), measured using Kappa statistics, ranged from 0.95 to 0.98 (excellent). Agreement in percentage ranged from 99.17% to 99.58%. The intra-examiner agreement of IOTN-AC obtained from the photos of study models and the actual study models (Table XI) ranged from 97.65% to 99.64% and K values from 0.89 to 0.98 (excellent).

Discussion

The IOTN is one of the most commonly used methods to assess the orthodontic treatment need of patients. In the present study, dental arch relationships were presented by six views of intra-oral photographs, which were subsequently used for determining the IOTN.

Technically progressive countries are favouring the use of 3D digital imaging rather than using conventional orthodontic study models. A high cost is incurred in producing 3D study models in many countries mainly because elastomeric impressions are required, which are sent for remote digitisation. This is a prohibitive factor for many global orthodontists as there is no objective means of evaluating orthodontic treatment results from a digital study model. To simulate a patient’s dentition, the use of photographs of study models is emerging as a possible substitute for clinical assessment (chair-side assessments) and other reproductions of a patient’s dentition. A photograph is an effective way of obtaining information and can be readily transmitted for consultations, referrals, presentations and for use in multiple studies. As digital technology improves, the expense involved in taking and storing photographs has reduced to such an extent that they are becoming frequently used,
even in developing countries. However, in generating and measuring two-dimensional images a consistent approach is essential.

IOTN scores taken from study models and the photographs of study models at an interval of three weeks were tested for their repeatability and reliability and it was evident that the IOTN scores were highly repeatable. There were no statistically significant differences in the IOTN scores from photographs of study models compared with IOTN scores from study models of the same patient.

The photographic method also showed good intra-examiner and inter-examiner reliability for the Dental and Aesthetic Components. The DHC values compared favourably with previously reported reliability scores when IOTN was applied to photographs of study models.\textsuperscript{19} Unlike in the present study, Mok et al.\textsuperscript{19} did not mention whether the examiners were IOTN calibrated, and this could be the reason why the current AC values were higher.

A predisposition to underscore photographs of the dentition when compared with the study cast ratings for the Aesthetic Component of the IOTN has previously been described.\textsuperscript{20} This bias was attributed to the photographs representing a two-dimensional depiction of a three-dimensional subject, which was expected to impair the assessment of anterior crowding as well as diminish the highlighting of overjet problems. Moreover, facial photographs generate a lower rating for orthodontic treatment need and a higher score of dental attractiveness compared with study casts.

A possible additional cause of disparity in assessment between study models and facial photographs or clinical examination could be a masking effect of the soft tissues on the full aesthetic or dental health impact of the malocclusion. The advantage of the IOTN assessment of the study model photographs was that there is no confounding factor generated by the soft tissues and all the traits of a malocclusion may be identified.

In circumstances in which a patient or dentist requests a second opinion, photographs of study models can be useful as they would relay the same information as the study model itself.

In regions of the United Kingdom, prior approval is required before the start of orthodontic treatment. A practitioner will be required to submit models, radiographs and photographs to the dental board for consideration. In these cases, photographs of the study models can prove useful for IOTN scoring, which saves on the cost of duplicating the models and postage.

The present study had limitations. While the sample contained a large range of malocclusions, particular traits were not observed or measured. There were no cases of cleft palate, lateral open bite and deciduous teeth, but all other measurable occlusal traits of the IOTN were noted.

The method used for study model photography is, however, not without flaws. The most common problem related to the image was incorrect placement of the ruler. The operator needs to be skilled and should have photographic experience. Although standardisation of intra-oral photographs is difficult due to technical problems, the results showed no significant differences between the IOTN scoring of study models and photographs. This may be explained by the subjective nature of the IOTN Aesthetic Component, the crudeness of the IOTN Dental Health Component and the accuracy of the ruler used in the photographs, particularly in the recording of overjet, which is the very important parameter in the IOTN classification.

In addition, the examiners sometimes experienced difficulties in assessing the overbite using the IOTN scoring. This problem would be overcome if virtual three-dimensional study models were used, allowing examiners to rotate the dental casts in various planes on the screen for verification. This method is expensive but, in contrast, the method used in this study was simple and inexpensive, allowing for easy inter-centre comparisons.

**Conclusions**

- Valid orthodontic information can be obtained from study models and photographs of study models for the assessment of the Index of Orthodontic Treatment Need (IOTN).
- Obtaining the Dental Health Component and the Aesthetic Component of the IOTN from the study models is reliable and reproducible.
- Obtaining the Dental Health Component and the Aesthetic Component of the IOTN from the photographs of the study models is reliable and reproducible and comparable to that obtained from the actual study models.
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References