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Occlusal outcomes in combined orthodontic and orthognathic treatment

--Manuscript Draft--

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Abstract:	Objective: To investigate the treatment outcome in terms of the malocclusion features and the changes in the occlusion of patients undergoing orthodontic-orthognathic treatment using the Peer Assessment Rating (PAR) and the Index of Complexity, Outcome and Need (ICON) and to test the application of the Index of Orthognathic Functional Treatment Need (IOFTN) on this sample as a measure of orthognathic pre-treatment need. Design: Retrospective longitudinal cohort study. Setting: The orthodontic department at the Eastman Dental Hospital. Material and Methods: The study models of a sample of 100 orthodontic/orthognathic patients who were treated at the Eastman Dental Hospital were measured using the PAR index and ICON at three stages: pre-treatment, pre-surgery and at debond. Treatment need was assessed by measuring IOTN and IOFTN using start study models. Results: 99% of the sample showed an improvement in PAR score, with 82% of the sample being greatly improved. ICON showed that 95% of the sample had an improvement of different degrees with 5% being not improved or worse. The IOFTN qualified 97% of the patients for orthognathic treatment when used retrospectively on the sample while the DHC of IOTN qualified the whole sample for orthodontic treatment. Conclusions: Orthodontic/orthognathic treatment showed improved and acceptable overall results. The PAR index and ICON were valid measures to investigate the outcome of orthognathic treatment. IOFTN proved to be a useful tool in determining and prioritizing orthognathic treatment based purely on functional need.
Response to Reviewers:	Covering letter – Journal of Orthodontics JOR-652 Dear Mr Cobourne, I would like to submit a revised version of our original research article titled “Occlusal outcomes in orthognathic treatment”. 1- I am not currently happy with the general standard of English and the way this manuscript reads in general.

	The senior authors have revised the manuscript as requested. 2- The first paragraph relating to why IOFTN was put together needs to be changed because it is not academically accurate. This has been modified. 3- The introduction needs to be changed so that each paragraph does not being with a reference and then a 3 line description of what they did, before moving onto another reference and then what they did. This has been addressed concisely. Kind regards, Fawaz Almutairi
Funding Information:	

Occlusal outcomes in combined orthodontic and orthognathic treatment

Short title: Occlusal outcomes in orthognathic treatments

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Abstract:

Objective: To investigate the treatment outcome in terms of the malocclusion features and the changes in the occlusion of patients undergoing orthodontic-orthognathic treatment using the Peer Assessment Rating (PAR) and the Index of Complexity, Outcome and Need (ICON) and to test the application of the Index of Orthognathic Functional Treatment Need (IOFTN) on this sample as a measure of orthognathic pre-treatment need. **Design:** Retrospective longitudinal cohort study. **Setting:** The orthodontic department at the Eastman Dental Hospital. **Material and Methods:** The study models of a sample of 100 orthodontic/orthognathic patients who were treated at the Eastman Dental Hospital were measured using the PAR index and ICON at three stages: pre-treatment, pre-surgery and at debond. Treatment need was assessed by measuring IOTN and IOFTN using start study models. **Results:** 99% of the sample showed an improvement in PAR score, with 82% of the sample being greatly improved. ICON showed that 95% of the sample had an improvement of different degrees with 5% being not improved or worse. The IOFTN qualified 97% of the patients for orthognathic treatment when used retrospectively on the sample while the DHC of IOTN qualified the whole sample for orthodontic treatment. **Conclusions:** Orthodontic/orthognathic treatment showed improved and acceptable overall results. The PAR index and ICON were valid measures to investigate the outcome of orthognathic treatment. IOFTN proved to be a useful tool in determining and prioritizing orthognathic treatment based purely on functional need.

Keywords:

Occlusal indices
ICON
IOFTN
Orthognathic surgery
Treatment Outcome
PAR
IOTN

Introduction:

With an increased demand for combined orthodontic and orthognathic treatment and its increasing cost, commissioners and governing bodies have started to question the cost-effectiveness and overall benefit of such treatments, not only in terms of patient reported outcomes and improvement of the health related quality of life, but also with regards to actual occlusal outcome. Occlusal indices may be used to determine the need and outcome of orthodontic treatment and, more recently, indices to determine the complexity of treatment have been introduced.

The need for orthodontic treatment may be assessed using the Index of Orthodontic Treatment Need (IOTN) (Brook and Shaw, 1989). IOTN is widely used within primary and secondary care in the United Kingdom to determine which patients are eligible to have orthodontic treatment funded by the National Health Service. The IOTN is composed of a Dental Health Component (DHC), which assesses the functional need for treatment and the Aesthetic Component (AC), which assesses the psychosocial need. More recently, the Index of Orthognathic Functional Treatment Need (IOFTN) (Ireland *et al*., 2014) has been developed to aid the prioritization of severe malocclusions involving a skeletal discrepancy, not amenable to orthodontic-only treatment and to ensure equitable provision of care for those with the greatest functional need. IOFTN also addresses some of the limitations of IOTN when applied to orthognathic treatment, such as the lack of class III incisor relationships in the AC and functional elements, such as excessive incisor show in the DHC. IOFTN is based on the five categories of IOTN to allow familiarity for those using IOTN and has shown good inter- and moderate to good intra-operator reliability (Ireland *et al*., 2014). The Peer Assessment Rating index (PAR) (Richmond *et al*., 1992) is commonly used to assess the outcome of orthodontic treatment in terms of alignment and occlusion by measuring certain traits of the malocclusion on pre- and post-treatment study casts. The improvement in PAR score achieved during treatment may be expressed as a percentage, with a 30 per cent reduction in PAR score being required for a case to be considered as 'improved' and a change of 22 PAR points to bring about 'great improvement'.

The limitations of IOTN and PAR have been widely discussed. The need for treatment as identified by IOTN does not always correlate with the complexity of treatment and PAR scores may not identify poor occlusal results or limited objective treatments. The Index of Complexity, Outcome and Need (ICON) was developed as a

single index to assess treatment inputs and outcomes, specifically the complexity, need, outcome and acceptability of orthodontic treatment (Daniels and Richmond, 2000). ICON uses some of the features of IOTN and PAR and comprises five weighted measurements (AC of IOTN; presence of a crossbite, anterior vertical relationship measured by PAR; upper arch crowding/spacing; buccal segment antero-posterior relationship measured by PAR), the sum of which are interpreted with cut-off values to indicate treatment need, complexity, improvement and acceptability.

While there have been many studies using occlusal indices to assess the outcome of orthodontic only treatment, relatively few studies have been undertaken to test their use in combined orthodontic/orthognathic patients. Ponduri *et al.* (2011) found that the PAR index was a valid tool in assessing the outcome of orthodontic/orthognathic treatment when comparing a group of orthognathic patients with an orthodontic only group showing a similar degree of improvement in PAR scores. Templeton and co-workers (2006) compared the improvement in PAR and ICON with the subjective opinion of a panel of five experienced orthodontic consultants and found that the correlation was significant for treatment outcome and improvement. Jeremiah *et al.* (2012) also concluded that the combined orthodontic/orthognathic approach was effective in the correction of malocclusions when assessed using PAR by measuring the change in pre- and post-treatment PAR score of 118 patients from 10 orthodontic units in East England. In a prospective multicentre study, O`Brien *et al.* (2009) investigated orthodontic/orthognathic treatment effectiveness in 131 patients undergoing a combined treatment approach over 5 years. Seventy-one patients completed the study, showing a reduction in PAR score from a pre-treatment mean of 40.48 to a post-treatment mean of 10.58, a 72% reduction. They concluded that orthodontic/orthognathic treatment was effective in correcting dental and skeletal discrepancies. More recently, further retrospective evidence has shown that combined treatment is effective in correcting severe malocclusion (Cartwright *et al*. 2016).

The aim of this study was to investigate treatment outcome in terms of malocclusion features and changes in the occlusion of patients undergoing orthodontic/orthognathic treatment using PAR and ICON and to test the application of IOFTN on this sample as a measure of orthognathic pre-treatment need.

Material and Methods:

The study models of 100 consecutively treated patients with complete records who had previously received combined orthodontic/orthognathic treatment at the Eastman Dental Hospital, London, were analyzed at three points of time: pre-treatment (T1), pre-surgical (T2) and at debond (T3). The orthognathic database was searched starting from January 2005 until 100 patients with full records were found. In all patients, the surgery involved either a mandibular, maxillary or bimaxillary procedure. All patients had completed treatment and were discharged and therefore ethical approval was not required.

Patients with craniofacial syndromes, cleft lip and palate or severe hypodontia were excluded. A previously calibrated examiner (FA) assessed the study models for IOTN (Aesthetic component (AC) and Dental Health Component (DHC)), PAR, and ICON at the three points. In addition, IOFTN was assessed at T1 supplemented by infortation in the clinical notes as, such as traumatic overbite or incompetent lips. Reproducibility was determined by reassessing the PAR and ICON values on 20 sets of study models at least 2 weeks following the original measurements.

Statistical analysis:

The data were analyzed using the Statistical Package for Social Science (version 16.0; SPSS, Chicago, IL, USA). Standard descriptive methods were used to summarize the data and Lin`s concordance correlation coefficient and the Bland and Altman scatter diagrams were used to test for repeatability.

Results

The study sample of 100 orthognathic patients included 67 females and 33 males (Table 1). The majority of the patients (52%) had a Class III malocclusion, 40% had a Class II Division 1 malocclusion, 4% had a Class II Division 2 and 4% had a Class I malocclusion. Skeletally, 50% had a Class III relationship while 44% had a Class II and 6% had a Class I relationship. (Table 1).

IOFTN

Based on the IOFTN, 57 patients were categorized as having a very great need for treatment, 22 patients having a great need while 16 were considered to have a

moderate need for treatment (Table 2). Two patients were categorized as having a mild need for treatment while only 3 patients were considered to have no treatment need. Therefore, ninety-seven per cent of the sample had an overall need for treatment.

IOTN

Applying the DHC of IOTN, the whole sample was considered in need of treatment with 6% in moderate need, 58% in great need and 36% in very great need.
Aesthetically, 94% were categorized as being an AC 6 or more, placing them in the need for treatment category, while 6% were categorized with no need for treatment.
A bimaxillary surgical procedure was performed in the majority of the patients (56%) while mandibular only surgery was undertaken in 30% and maxillary only surgery in 14% of the sample (Table 3).

PAR

PAR scores at the three time points measured are shown in Table 3. There was an improvement in PAR score in 99% of the sample with 82% of the sample being greatly improved (Figure 1). The mean start PAR score was 38.15 while the mean PAR score at the end of treatment was 7.38. There was a mean reduction of 31 points or 78.97%.

ICON

Applying ICON to the sample, the need for treatment, treatment complexity, improvement and post-treatment acceptability were recorded (Table 4). A total of 96% of patients were shown to be in need of treatment while only 4 were considered in no need of treatment. For treatment complexity, 7% were considered to need a treatment of mild complexity, 16% to need a moderately complex treatment and 22% to require difficult treatment. The majority of the patients (55%) were considered to require a very difficult treatment. Of the whole sample, 95% of the patients had an improvement of varying degrees while 5% were not improved or worse. 37% were greatly improved, 20% substantially improved, 25% moderately improved and 13% minimally improved. At debond, 28% of the end results were considered not acceptable while the end results of 72% of the sample were acceptable (Table 4).

Repeatability

The repeatability tests showed good agreement between the different measurements. The Lin's concordance correlation coefficients for the two PAR measurements were 0.985 and 0.994 respectively and for ICON 0.949 and 0.990. The paired *t*-test showed no significant *p*-value and the limit of agreement was reasonable although it was found to be wider initially for ICON due to the large weighting of the AC of IOTN and the subjectivity in this measurement.

Discussion

This retrospective study was undertaken to determine the occlusal outcome of combined orthodontic/orthognathic surgery on a sample of patients treated at the Eastman Dental Hospital, and to evaluate the use of IOFTN as a tool to assess patients' need for treatment. One hundred consecutive subjects with full records were chosen during a specific time frame when data collection for all orthognathic cases was undertaken.

Class III patients represented the majority of the sample (52%) which was in agreement with the sample distribution of previous studies (Khan and Horrocks, 1997; Bailey *et al*., 2001) (Table 1).

IOFTN qualified 97% of the sample as being in need of treatment. The remaining 3 patients that were considered to have no need for treatment were perhaps controversial. These patients presented with a Class III malocclusion with compensated incisors and a well-aligned occlusion, with the majority of the labial segments just beyond an edge-to-edge incisor relationship. This led to classifying them as category 1 rather than category 3. In 2 of the 3 cases, there was only one incisor at almost an edge-to-edge relationship which would qualify them in the 3.3 category. However, pre-surgically one of the cases had a reverse overjet of 1 mm and another had 4 mm reverse overjet, while the third case stayed the same with an overjet of just below 1mm but had a lateral open bite.

The mean PAR score at the start of treatment (T1) was 38.15. Patients presenting for orthognathic treatment usually present with severe or complex malocclusions and hence a higher pre-treatment PAR score. For this reason, it should also be expected that orthognathic patients show a greater reduction in number and percentage of PAR points. The mean pre-treatment PAR score was comparable to the

mean PAR score at the start of treatment in other orthognathic studies, for example, 37.6 (Baker *et al.,* 1999), 38 (Ponduri *et al.,* 2011) 39.09 (Cartwright *et al.,* 2016) and 40.48 (O'Brien *et al.,* 2009). In comparison, the pre-treatment mean PAR score in patients undergoing orthodontic treatment has been shown to range from 28.7 (Birkeland *et al.,* 1997) and 29.8 (Baker *et al.,* 1999). In this study, the mean change in PAR score from the start of treatment to pre-surgery (T1 to T2) was a reduction of 8.86 points, which may reflect an improvement due to alignment. However, some cases showed an increase to a maximum of 20 PAR points as would be expected from decompensation and an increase in overjet or reverse overjet. The post-surgical PAR reduction from T2 to T3 showed a higher mean reduction of 22.37 points with a reduction in all cases.

In this study, the mean ICON score at T1 was 77.28. An ICON value greater than 43 indicates a pre-treatment need and this also indicates that treatment complexity is considered as very difficult (ICON > 77). The ICON score mean reduction from T1 to T3 was calculated according to the ICON improvement formula to be -23.48, which indicates substantial improvement (-25 to -1). The last part of the ICON score table is the result of treatment acceptability. If the score is less than 31, the result is considered acceptable. The mean ICON score in this study at T3 was 25.12 indicating an acceptable result of treatment for the whole sample. Researchers have investigated the validity and reliability of using ICON to look at the complexity, need and outcome of orthodontic treatments. Firestone *et al.* (2002) found that use of ICON is valid when applied by calibrated examiners on study models of orthodontic patients and that the cutoff point was closely represented by the treatment/no treatment decision taken by a panel of orthodontic specialists. Similarly, Savastano *et al.* (2003) found that ICON was valid as a measure of complexity and outcome but the improvement was not validated due to low inter-rater reliability. Others have investigated the applicability of ICON to different populations with different cutoff points. For example, Liao *et al.* (2012) attempted to validate the use of ICON on a sample of Chinese 12-13 year olds and concluded that whilst the inter-rater reliability was high, a lower cutoff point of 29 resulted in higher sensitivity and specificity of ICON in determining treatment need. However, there are few studies in the literature investigating the validity of ICON in measuring the complexity, need and outcome of orthodontic/orthognathic treatment.

In this sample, 7% of patients were considered to be of mild complexity according to ICON. On the other hand, the orthognathic treatment received by these patients was considered of high complexity. Complexity can sometimes be hard to define and the definition differs between clinicians. However, in ICON, the highest weighting is reserved for the Aesthetic Component (AC) of IOTN, which is considered a subjective measure. The consistency of the measure has been shown to be weak between scores 2 to 9, while the highest agreement was at scores 1 and 10 (Johansson and Follin, 2005). After introducing ICON, Daniels and Richmond (2000) suggested that in order to use the measure of complexity to predict treatment success, further validation of the complexity section should be undertaken. In this specific group of the sample the ICON score of complexity was low due to the compensation of the malocclusion. As the AC is weighted by 7 points, if it were to be recorded as one point higher, the total score would increase by 7 points. If the cutoff point of 31 was increased by 7 to 38, the post-treatment acceptance level would increase from 72% to 90%, leaving only 10% as unacceptable compared to 28% previously. The patients who finished with a high ICON score and considered to be an unacceptable treatment outcome may have finished with some of their malocclusion features not fully corrected or newly introduced features such as anterior open bites or crossbites. It was noted that some patients finished with an increased overjet which may be due to many factors such as insufficient surgical movements or where treatment aimed at a compromise outcome. It is not possible to account for these plans with occlusal indices.

Due to the nature of the study, there are some limitations to the findings. The sample was chosen from a database of orthognathic patients consecutively treated from 2005, until a sample of 100 patients with full records was identified. There may be a bias with respect to the patient sample as it is recognized that there is a high percentage of orthognathic patients who do not complete their treatment pathway for a variety of reasons. One of these may be that they have a less severe malocclusion than those who complete treatment and which they may be willing to accept when considering the invasive nature of surgical treatment. However, due to the relatively low numbers of the orthognathic population and the availability of complete records at three time points, it would be difficult to choose a truly random sample. This limitation can also be observed in the prospective study by O`Brien and co-workers (2009) where patients were excluded either due to missing records or cephalometric

analysis not carried out, which led to the exclusion of patients and the possible introduction of bias. Inter-examiner reliability was not compared due to the measurements being taken by one calibrated examiner. However, the intra-examiner reliability showed an acceptable result.

Conclusions:

1. The study has shown that, in general, orthodontic/orthognathic treatment in this sample resulted in a great degree of improvement as measured by PAR and ICON. An improvement in PAR score was seen in 99% of the sample, with a mean improvement of 79%. ICON scores demonstrated an improvement in 95% of the sample.

2. The application of a new index of need, IOFTN, on this sample was shown to be useful as only 3% of previously accepted and treated patients would not have qualified for treatment.

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Variable		**Percentage**
Total number of subjects	100	
Gender	Male Female	33 67
Dental relationship	Class I Class II Division 1 Class II Division 2 Class III	4 40 4 52
Skeletal relationship	Class I Class II Class III	6 44 50
Surgical procedure	Maxillary Mandibular Bimaxillary	14 30 56

Table 1: Demographics, malocclusion traits and surgery received

		IOFTN					
		1	2	3	4	5	Total
Skeletal	Class I	0	0	2	1	3	6
	Class II	0	2	0	13	29	44
	Class III	3	0	14	8	25	50
Total		3	2	16	22	57	100

Table 2: IOFTN and skeletal classification

	N	Minimum	Maximum	Mean	Std. Deviation
PAR T1	100	9	67	38.15	11.056
PAR T2	100	9	57	29.38	10.034
PAR T3	100	2	30	7.38	4.986
PAR reduction T1-T2	100	-42	20	-8.86	11.889
PAR reduction T2-T3	100	-72	-1	-22.37	11.787
PAR reduction T1-T3	100	-63	0	-31.00	11.891
PAR reduction % T1-T2	100	-77.78	177.70	-17.6272	35.955
PAR reduction % T2-T3	100	-95.24	68.97	-71.0919	23.684
PAR reduction % T1-T3	100	-97.74	0.00	-78.9793	15.971

Table 3: PAR score and reduction

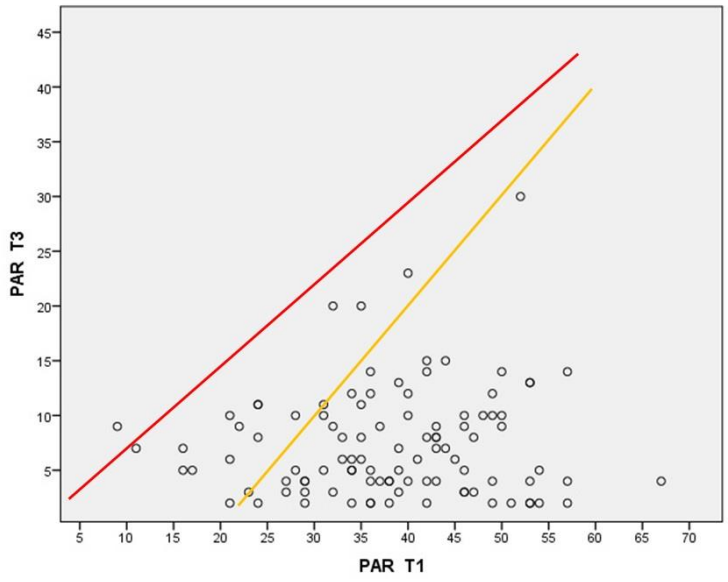

Figure 1: PAR Nomogram

	N	Minimum	Maximum	Mean	Std. Deviation
ICON T1	100	33	122	77.28	18.14
ICON T2	100	16	103	55.55	17.60
ICON T3	100	13	67	25.37	11.01
ICON T1-T2 Need	100	33	122	76.68	18.51
ICON T2-T3 Need	100	16	103	54.87	17.31
ICON T1-T3 Need	100	33	122	77.28	18.14
ICON T1-T2 Complexity	100	33	122	77.27	18.13
ICON T2-T3 Complexity	100	16	103	54.87	17.31
ICON T1-T3 Complexity	100	33	122	77.28	18.14
ICON T1-T2 Improvement	100	-309	95	-139.78	67.94
ICON T2-T3 Improvement	100	-192	20	-45.60	40.60
ICON T1-T3 Improvement	100	-187	56	-23.48	45.36
ICON T1-T2 Acceptability	100	-149	103	52.77	26.73
ICON T2-T3 Acceptability	100	13	67	25.12	10.46
ICON T1-T3 Acceptability	100	13	67	25.12	10.46

Table 4: ICON scores

Table 1: Demographics, malocclusion traits and surgery received

Variable		**Percentage**
Total number of subjects	100	
Gender	Male	33
	Female	67
Dental relationship	Class I	4
	Class II Division 1	40
	Class II Division 2	4
	Class III	52
Skeletal relationship	Class I	6
	Class II	44
	Class III	50
Surgical procedure	Maxillary	14
	Mandibular	30
	Bimaxillary	56

Table 2: IOFTN and skeletal classification

		IOFTN					Total
		1	2	3	4	5	
Skeletal	Class I	0	0	2	1	3	6
	Class II	0	2	0	13	29	44
	Class III	3	0	14	8	25	50
Total		3	2	16	22	57	100

Table 3: PAR score and reduction

	N	Minimum	Maximum	Mean	Std. Deviation
PAR T1	100	9	67	38.15	11.056
PAR T2	100	9	57	29.38	10.034
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PAR reduction T2-T3	100	-72	-1	-22.37	11.787
PAR reduction T1-T3	100	-63	0	-31	11.891
PAR reduction % T1-T2	100	-77.78	177.7	-17.6272	35.955
PAR reduction % T2-T3	100	-95.24	68.97	-71.0919	23.684
PAR reduction % T1-T3	100	-97.74	0	-78.9793	15.971

Table 4: ICON scores

	N	Minimum	Maximum	Mean	Std. Deviation
ICON T1	100	33	122	77.28	18.14
ICON T2	100	16	103	55.55	17.6
ICON T3	100	13	67	25.37	11.01
ICON T1-T2 Need	100	33	122	76.68	18.51
ICON T2-T3 Need	100	16	103	54.87	17.31
ICON T1-T3 Need	100	33	122	77.28	18.14
ICON T1-T2 Complexity	100	33	122	77.27	18.13
ICON T2-T3 Complexity	100	16	103	54.87	17.31
ICON T1-T3 Complexity	100	33	122	77.28	18.14
ICON T1-T2 Improvement	100	-309	95	-139.78	67.94
ICON T2-T3 Improvement	100	-192	20	-45.6	40.6
ICON T1-T3 Improvement	100	-187	56	-23.48	45.36
ICON T1-T2 Acceptability	100	-149	103	52.77	26.73
ICON T2-T3 Acceptability	100	13	67	25.12	10.46
ICON T1-T3 Acceptability	100	13	67	25.12	10.46

Figure 1

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