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Orthodontic Treatment Need: An Epidemiological Approach

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1. Introduction

The main aim of orthodontic treatment is to correct malocclusion, in order, whenever possible, to achieve functionally appropriate occlusion and optimum dental and facial aesthetics. To understand what malocclusion is, first we need to define its antonyms, in other words, what is meant by normal occlusion and ideal occlusion. Normal occlusion can be said to be that which meets certain predefined standards.

Edward Hartley Angle (1899) took the first permanent molars as the reference point and established the precise relations between the two dental arches that could be considered "norm-occlusion". "Normal occlusion" was thus defined as a concrete goal that the orthodontist should aim for in order to achieve a structural, functional and aesthetic norm (Canut, 1988). Since Angle's days, normal occlusion and ideal occlusion have been treated as synonyms in orthodontics, giving rise to both semantic and treatment difficulties. Nevertheless, from the statistical point of view the term "normal" implies a certain variation around the mean, while "ideal" implies a concept of perfection as the hypothetical aim (Bravo, 2003).

The occlusal norms that all orthodontists, over many years of professional practice, had borne in mind when deciding their clinical objectives were set out by Andrews (1972) in an article describing the six keys to normal occlusion. He later changed the adjective "normal" occlusion to "optimal" occlusion, arguing that he had used the word "normal" in the sense of optimal or ideal, as was often the case in the 1970s, and that normal occlusion was more correctly called "non-optimal occlusion".

"Orthodontic treatment need" can be defined as the degree to which a person needs orthodontic treatment because of certain features of his or her malocclusion, the functional, dental health or aesthetic impairment it occasions and the negative psychological and social repercussions to which it gives rise.

Throughout the history of orthodontics, there have been authors who have considered that malocclusion can lead to other problems, such as functional problems, temporomandibular dysfunction, and a greater propensity to trauma, caries, or periodontal disease. However, nowadays it is not so evident that these processes or diseases constitute indications for

orthodontic treatment. Generally speaking, the psychological and social implications of poor dentofacial aesthetics can be more serious than the biological problems, and in clinical trials, strong correlations have been found between dental aesthetics, treatment need and the severity of the malocclusion (Lewis et al., 1982). Hamdam (2004) concluded that 40% of the patients who underwent orthodontic treatment had been the butt of jokes because of their teeth. However, there was no association between the degree of orthodontic treatment need measured by an objective index (IOTN DHC) and the need perceived by the patients. Kiekens et al. (2006) concluded that what the patients hope for from orthodontic treatment is an improvement in their dentofacial aesthetics and, as a result, greater social acceptance and higher self-esteem. Because of this, in recent decades orthodontists have been increasingly directing their treatments towards improving facial aesthetics.

Strictly speaking, malocclusion is not an illness but an occlusal relationship that lies within the bounds of all the possible occlusal relationships. Deciding the exact point at which a specific malocclusion should be treated remains an open question among orthodontists and the subject of considerable debate in the literature, as owing to its nature, reaching a general consensus is proving really complicated.

The WHO (World Health Organization) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Consequently, a person cannot be considered completely healthy if a malocclusion prevents him or her from attaining this state of complete well-being, whether for physical (functional impairment) or psycho-social reasons (serious impairment of self-esteem or dentofacial aesthetics).

Disease does not always entail the absence of well-being, and even when well-being is absent this depends to a large extent on the patient's psychological state and personal and cultural principles and values. While clinical indices are concerned to measure the "disease", a purely biological concept, as objectively as possible, the indices that attempt to measure and determine "health" are very subjective, as health is a more psychological or sociological concept (Bernabé & Flores-Mir, 2006).

It should be emphasized that there is a lack of agreement on what is or is not considered malocclusion, and even greater disagreement when determining the orthodontic treatment need. However, enormous progress in this direction has been made in recent years, with important areas of consensus being reached among the specialists concerning specific situations in which orthodontic treatment should be recommended. The rapid development of indices to measure malocclusion and orthodontic treatment need have unquestionably contributed to these advances.

2. Using indices to measure malocclusion

2.1 Definition of "index"

Indices are quantitative assessment tools, employing continuous or numbered scales of malocclusion for epidemiological purposes and for a number of administrative applications.

An orthodontic treatment need index assigns a specific score to each malocclusion feature according to that feature's relative contribution to the overall severity of the malocclusion.

Each occlusal feature measured by a particular index is assigned a quantitative value or specific weight based on personal clinical concepts, consensus among specialists, reviews of the literature, social and administrative needs or scientific studies designed specifically for this purpose, hence the great variety of very different indices for recording malocclusion, which can have many uses.

Occlusal indices decide the need for treatment from the point of view of the orthodontist but tend to ignore the patients' own perceptions of their malocclusion and the repercussions it has in their daily lives, not only from a functional point of view but also on their looks, which undoubtedly have an effect on their social relationships. The traditional indices do not give any type of information on how the malocclusion affects the patients' lives from the psychosocial or functional point of view. These aspects seem to have become particularly important in recent years (Kok et al., 2004).

2.2 History, evolution, classification and properties of treatment need indices

Attempts to classify dentofacial disharmony date back to the beginning of the 19th century, to authors such as Joseph Fox (1776-1816), Christophe François Delabarre (1784-1862), Jean Nicolas Marjolin (1780-1850), Friedrich Christoph Kneisel (1797-1847) or Georg Carabelli (1787-1842). It was not until 1899, however, that Edward Hartley Angle (1855-1930) developed a clear, simple, practical classification that became universally accepted and used. Nonetheless, this index has evident limitations from the epidemiological point of view.

Angle's classification has been followed by many others. That of Lischer (1912) was similar but introduced the terms neutrocclusion (Angle Class I), mesiocclusion (Angle Class III) and distocclusion (Angle Class II). Simon (1922) proposed a classification that sets out the relation between the dental arches by reference to the three anatomical planes, based on different points on the skull. Dewey and Anderson (1942) published a book in which they extended Angle's classification to include five types of Class I malocclusion and three types of Class III malocclusion, known as the Dewey-Anderson Modification. The classification of Ackerman and Proffit (1969) was intended to overcome Angle's main weaknesses; however, it is more of a diagnostic procedure for listing the problems in each case of malocclusion in order to assist the clinician in drawing up a treatment plan.

All the methods described so far are qualitative and serve to describe and classify a patient's malocclusion. However, countries that have health services which offer orthodontic treatment have developed and applied a series of quantitative methods (malocclusion indices) to detect the severity and treatment need of each case, in an attempt to define the priority of some cases over others objectively and thus rationalize their public expenditure.

Tang and Wei (1993) reviewed the literature and summarized the evolution of methods for recording malocclusion in recent decades. They concluded that the trend in both qualitative and quantitative methods has changed, as initially researchers did not define the signs of malocclusion before recording them, chose the variables arbitrarily and recorded the data according to a criterion of all or nothing. This has now changed and a study of the progress in occlusal recording methods shows that they are increasingly

accurate, reliable and scientifically-based, and consequently their detection of the problems possesses greater validity.

According to Richmond et al. (1997), an orthodontic index should consist of a numerical scale obtained by considering specific features of the malocclusion, making it possible to determine certain parameters such as treatment need or the severity of malocclusion in an objective way.

In 1966 the World Health Organization (WHO) defined the three characteristics that an index should possess: reliability, validity and validity over time.

There is wide agreement that an orthodontic treatment need index should possess the following characteristics:

- **Validity:** an index is said to be valid if it measures what it aims to measure. If a problem exists, it must detect it exactly and without error. In other words, it must identify the patients with the most detrimental malocclusions or those who would most benefit from treatment.
- **Objectivity:** the index design must attempt as far as possible to exclude examiner subjectivity.
- **Reliability (accuracy or reproducibility):** this is the degree of match between the results obtained when an index is applied to the same sample by different examiners or by the same examiner on different occasions.
- **Simplicity:** it must be able to be used by non-specialists. It must be capable of distinguishing between benign malocclusions that do not require treatment and more serious cases that need to be treated by a specialist.
- **Flexibility:** an index must be easily modified over time in the light of new research, discoveries or considerations.
- **Appropriate assessment of the aesthetic component of the malocclusion.**

Prahl-Andersen (1978) described the features that in his opinion an orthodontic treatment need index should possess. He emphasized that an index should not establish treatment priorities solely on the basis of the severity of the malocclusion and the functional problems that it could entail. It should also assess the degree to which the malocclusion occasions aesthetic impairment. In the medical field, a person's health should be judged on three criteria: objective signs (the orthodontist's diagnosis), subjective symptoms (the patient must recognize the problem) and social sufficiency (social attitudes).

Shaw et al. (1995) highlighted the following uses of the indices:

- Classifying, planning and promoting treatment standards.
- Assisting dentists and pediatric dentists to identify patients with orthodontic treatment need.
- Identifying patient prognoses and obtaining the patients' informed consent, informing them of the risks and treatment stability in both severe and borderline cases.
- Assessing the difficulty of the treatment that a particular patient must follow.
- Assessing the results of the treatment.

Throughout the history of orthodontics, indices have been developed to record malocclusions. Abdullah and Rock (2001) considered that most of them must have been developed with the following aims:

- To classify malocclusions in order to allow and facilitate communication between professionals.
- To compile a database to facilitate epidemiological studies.
- To classify cases according to the complexity of their treatment.
- To determine treatment needs and priorities.
- To identify the aesthetic aspects that affect treatment need.

It must not be forgotten that orthodontic treatment need indices, or at least most of them, are designed to determine treatment priority, in other words, to choose the potential patients who will most benefit from orthodontic treatment in a particular health service system.

In Europe, occlusal indices to estimate treatment need have been being used successfully since the end of the 1980s. The indices employed have generally been those developed by european authors but there has been no unanimity as regards which method to employ.

The controversy that surrounds orthodontic treatment need indices is such that in the United States, in 1969 the American Orthodontic Society adopted and recommended the *Salzmann Index* for estimating the treatment needs of the population but withdrew its recommendation in 1985 and currently does not recognize any index as more suitable than any other for this purpose (Parker, 1998).

Many very different indices have been developed to classify and group malocclusions according to severity or level of treatment need.

3. Principal treatment need indices

The *Malalignment Index* was developed by Van Kirk (1959) because he considered that there was no way of classifying patients objectively according to their tooth or bone malalignment. In this index, each tooth is given a score between 0 and 2 depending on its degree of rotation or displacement compared to the ideal position in the dental arch.

The state of New York started its Dental Rehabilitation Program in 1945 and one of the main problems was to select the patients who would receive orthodontic treatment. As a result, Draker (1960) developed and published *Handicapping Labio-lingual Deviation* (HLD) with the aim of determining orthodontic treatment need. This index assesses 7 criteria (displacement, crowding, overjet, increased overbite, open bite, anterior crossbite and ectopic eruptions) exclusively in the anterior sector, and also takes malformations into account. It can be applied both to models and to examinations of the mouth. When the scores for all the criteria total over 13, the subject is considered to present a physical malocclusion that needs treatment.

The *Treatment Priority Index* (TPI) was developed by Grainger (1967). This index is based on an assessment of ten occlusal features measured in a representative sample of 375 children of 12 years of age, of Anglo-Saxon origin, all without previous orthodontic treatment. The children were examined directly by orthodontic specialists. The patient is considered to need treatment when the scores for the ten occlusal features total over 4.5. A further eleventh feature is only considered in special cases (cleft palate or dysmorphism

caused by traumatic injury) in which treatment is a priority. TPI has been used in many studies and although the results have not always been regular, it has proved to give high intra-examiner and inter-examiner reproducibility and reasonably good validity. However, it requires a certain degree of knowledge and experience on the part of the examiner.

Howitt et al. (1967) developed one of the first indices to consider the aesthetic aspects of malocclusion: the *Eastman Esthetic Index* (EEI). In spite of its innovation in measuring the degree of aesthetic impact associated with the malocclusion, it has not achieved such widespread use as other indices.

Salzmann (1967) was one of the first authors to be truly concerned about the patients' own perception of their malocclusion and about the impact and importance of orthodontics, and even of malocclusion, in society. As a result, he published the *Handicapping Malocclusion Assessment Record* (HMAR) index (Salzmann, 1968). The aim was to assess the patients' orthodontic treatment need, classifying the individuals examined according to the level of severity of the problem. This is considered an index with high reproducibility, as it does not use millimetrical measurements but concerns itself with determining functional problems that genuinely constitute an obstacle to the maintenance of oral health and interfere with the patients' proper development owing to their effect on dentofacial aesthetics, mandibular function or speech.

Summers (1971) published the *Occlusal Index* after observing the lack of consensus among orthodontic specialists. This index attempts to classify individuals as objectively as possible and presents clearly epidemiological characteristics. It measures nine occlusal features. Its main distinguishing feature is that it takes the patient's age into account.

Bjork et al. (1964) developed a method with clearly defined variables that can be recorded with good inter-examiner agreement. Based on this method, in 1969 a group of scientists from the World Dental Federation (FDI) Commission on Classification and Statistics of Oral Conditions-Measures of Occlusal Traits (COCSTC-MOT) analyzed the problem of determining occlusal status and developing recording systems for epidemiological purposes. The *Method for Measuring Occlusal Traits* was subsequently developed. This was adopted in 1972 by the FDI (1973) and modified by COCSTC-MOT in collaboration with the WHO, giving rise in 1979 to the final version of the "WHO/FDI Basic Method for Recording of Malocclusion", published in the Bulletin of the WHO (1979). The basic aims of this method, which follows clearly defined criteria, are to determine the prevalence of malocclusion and estimate the treatment needs of the population as a basis for planning orthodontic services.

The *Dental Aesthetic Index* (DAI) created by Cons et al. (1986), is unlike other indices in that the authors based it on the public's perception of dental aesthetics. This index has been used very successfully in numerous studies to assess the prevalence of malocclusion and the orthodontic treatment needs of different population groups. It will be discussed in greater detail in the next section.

The *Index of Orthodontic Treatment Need* (IOTN) described by Brook and Shaw (1989) has achieved widespread recognition both nationally and internationally as an objective method

for determining treatment need. This index classifies the patients according to both the degree to which the malocclusion affects their stomatognathic system and their aesthetic perception of their own malocclusion, with the aim of identifying which patients would benefit most from orthodontic treatment (Uçüncü & Ertugay, 2001). A more detailed description is given in section 5.

The *Peer Assessment Rating* (PAR) is a more recent index, developed in Europe in 1992 by Richmond et al. (1992). In their article, the authors explained that it would be very helpful for orthodontists to have an index which would enable them to assess the results on completing the treatment. They considered that the indices developed up to that point lacked sufficient reproducibility and validity. The PAR makes it possible to compare the success of orthodontic treatments and also to predict the severity of cases. To develop this rating, 10 orthodontic specialists assessed 200 models and assigned a value to each of the 11 occlusal features they considered indispensable for evaluating the severity of a malocclusion. The total PAR score is the sum of each of the values of the different occlusal features. The success of a treatment is tested by measuring the PAR index before and after treatment and calculating the difference between the scores. The validity of the study was confirmed by another in which 74 dentists examined 272 dental models and assessed their deviation from the ideal on a scale of 1 to 9. They also calculated the PAR score for each of the models. The correlation between the professionals' opinion and the PAR score was r=0.74, showing that this index is a good predictor of subjective clinical assessment. Subsequently, its validity has also been corroborated by other authors (McGorray et al., 1999).

The latest index reported in the literature is the *Index of Complexity, Outcome and Need* (ICON) developed in 2000 by Daniels and Richmond (2002). Its aim is to bring assessment of need and of the results of orthodontic treatment together in a single index. Its development drew on 97 orthodontists from different countries who gave their subjective opinion of the treatment need, complexity of the treatment and improvement following treatment of 240 initial models and 98 treated models. The criteria employed are the five occlusal features that predicted the expert group's opinion and the IOTN AC (IOTN aesthetic component). Cut-off points were analyzed to determine at what point the index gave an accurate prediction of the specialists' decisions. Good results were obtained for accuracy (85%), sensitivity (85.2%) and specificity (84.4%).

4. Dental Aesthetic Index (DAI)

Cons et al. (1986) described and explained the Dental Aesthetic Index (DAI). The distinctive feature of the DAI is that it is an orthodontic index which relates the clinical and aesthetic components mathematically to produce a single score. It is based on the SASOC (Social Acceptability Scale of Occlusal Conditions) developed earlier by the same authors (Jenny et al., 1980).

The authors wanted to achieve a different index that would be based on the public's perception of dental aesthetics. This was determined through an evaluation of 200 photographs of different occlusal configurations. The 200 cases were chosen, by a random process, from a larger sample of 1337 study models used in a previous study. The 1337 models represented a population of half a million schoolchildren aged between 15 and 18

years from the state of New York. The 200 photographs employed as stimuli for the assessment of dental aesthetics were chosen through a process that ensured that even the most extreme cases were represented. Approximately 2000 adolescents and adults took part in rating the aesthetics of the 200 photographs, each of which showed the models' occlusion in front and side views. The presence and measurement of 49 occlusal features selected by an international committee as being those it was important to consider when developing an orthodontic index were taken into account for each photograph.

Regression analysis was employed to relate the public's assessment of dental aesthetics to the anatomical measurements of the occlusal features that were present in each photograph. This led to the choice of ten occlusal features as the most important ones to take into account in an orthodontic index, insofar as each of them affected the structures of the mouth and influenced dental aesthetics.

This study provided a statistical basis for establishing the value of the regression coefficients used for the ten occlusal features finally chosen for the regression calculations.

All the variables were adjusted in a linear regression model and a predictive equation called the DAI equation was obtained. In the DAI equation, the score for each of the ten DAI components is multiplied by its respective regression coefficient (weighting), the values are added together and a constant, 13, is added to the total. The result of this operation is the DAI score. The DAI equation is as follows:

$$\sum (\text{DAI Component X Regression Coefficient}) + 13$$

In the DAI equation the regression coefficients are usually rounded off, making it less precise but easier to apply, especially in epidemiological studies. The actual and rounded regression coefficients and constant are shown in Table 1.

The way to measure the ten DAI components correctly is as follows:

1. Number of missing visible teeth (incisors, canines, and premolars in the maxillary and mandibular arches). These are only taken into account if they affect the dental aesthetics, so if the space is closed, if eruption of the permanent tooth is expected or if the missing tooth has been replaced by a dental prosthesis, they should not be counted as missing visible teeth.
2. Assessment of crowding in the incisal segments. The aim is to calculate the existing crowding in the upper anterior and lower anterior sextants. The crowding discrepancy is not measured numerically but only as being present or absent. As a result the score will be 0 if there is no crowding, 1 if there is maxillary or mandibular crowding or 2 if the crowding affects both jaws.
3. Assessment of spacing in the incisal segments. In this case the space between the canines is greater than that required to accommodate the four incisors in a correct alignment. If one or more incisors has a proximal surface without interdental contact, the incisal segment is recorded as spaced. The score will be 0 if there is no spacing, 1 if there is maxillary or mandibular spacing or 2 if the spacing affects both jaws.
4. Measurement of any midline diastema in millimeters. Diastema is a very important occlusal feature from an aesthetic point of view. The midline diastema is defined as the space in millimeters between the two central permanent maxillary incisors when the points of contact are in their normal position.

5. Largest anterior irregularity on the maxilla in millimeters. The largest irregularity, again in millimeters, is measured according to the degree of vestibular-lingual displacement of each tooth in the anterior area of the maxillary arch. As the real crowding discrepancy cannot be measured in terms of millimeters of crowding without taking plaster models, which is not feasible in an epidemiological study, the largest irregularity encountered is recorded.
6. Largest anterior irregularity on the mandible in millimeters. The largest anterior irregularity is measured in millimeters, as for the maxilla.
7. Measurement of anterior maxillary overjet in millimeters. The distance from the labio-incisal edge of the upper incisor to the vestibular surface of the lower incisor. A WHO-type periodontal probe held parallel to the occlusal plane is employed for this measurement.
8. Measurement of anterior mandibular overjet in millimeters. The distance from the incisal edge of the most prominent lower incisor to the labial surface of the corresponding upper incisor.
9. Measurement of vertical anterior openbite. This measures the vertical space between the upper and lower incisors in millimeters.
10. Assessment of anteroposterior molar relation; largest deviation from normal either left or right. The score will be 0 if the occlusal relation is Angle Class I, 1 if the mesial or distal deviation is less than one full cusp and 2 if the mesial or distal deviation is one full cusp or more.

	Regression Coefficients	
DAI components	**Actual weights**	**Rounded weights**
1. Number of missing visible teeth (incisors, canines, and premolars in the maxillary and mandibular arches).	5.76	6
2. Assessment of crowding in the incisal segments: 0 = no segments crowded;1 = 1 segment crowded; 2 = 2 segments crowded.	1.15	1
3. Assessment of spacing in the incisal segments: 0 = no segments spaced;1 = 1 segment spaced; 2 = 2 segments spaced.	1.31	1
4. Measurement of any midline diastema in mm.	3.13	3
5. Largest anterior irregularity on the maxilla in mm.	1.34	1
6. Largest anterior irregularity on the mandible in mm.	0.75	1
7. Measurement of anterior maxillary overjet in mm.	1.62	2
8. Measurement of anterior mandibular overjet in mm.	3.68	4
9. Measurement of vertical anterior openbite in mm.	3.69	4
10. Assessment of anteroposterior molar relation; largest deviation from normal either left or right, 0 = normal, 1 = 1⁄2 cusp either mesial or distal, 2 = 1 full cusp or more either mesial or distal.	2.69	3
CONSTANT	13.36	13

Table 1. Components of the DAI regression equation and their actual and rounded regression coefficients (weights).

Although the DAI was developed for permanent teeth, it can easily be adapted for mixed dentition by simply ignoring missing permanent teeth if these are expected to erupt during the normal time range.

Once the patient's score has been calculated, it can be located on a scale in order to determine its position in relation to the dental aesthetics that are socially most acceptable and least acceptable. The higher the DAI score, the further the occlusal relation is from socially accepted dental aesthetics and the more easily it can be detrimental to the patient.

The DAI has ranges of scores to determine the severity of the malocclusion. A DAI score of 25 or less represents normal occlusion or slight malocclusion. Scores between 26 and 30 indicate moderate malocclusion with questionable treatment need. From 31 to 35, the malocclusion is more serious and treatment is recommended. Scores of 36 or more show severe malocclusion for which treatment is definitely needed.

As mentioned above, although the DAI scale offers these ranges to determine treatment need the scores can be placed on a continuous scale. The continuous scale makes the DAI sufficiently sensitive to differentiate between cases with a greater or lesser need within the same degree of severity. The cutoff points to decide which malocclusions should be treated by the public health services can be modified in view of the available resources.

One of the advantages of the DAI is that it can be obtained in barely 2 minutes, without X-rays, through an oral examination carried out by a trained dental assistant.

DAI components	Component x R. weight	Total
1. Number of missing visible teeth (incisors, canines, and premolars in the maxillary and mandibular arches).	1 missing tooth x 6	6
2. Assessment of crowding in the incisal segments: 0 = no segments crowded;1 = 1 segment crowded; 2 = 2 segments crowded.	1 segment x 1	1
3. Assessment of spacing in the incisal segments: 0 = no segments spaced;1 = 1 segment spaced; 2 = 2 segments spaced.	0 segments x 1	0
4. Measurement of any midline diastema in mm.	0 mm x 3	0
5. Largest anterior irregularity on the maxilla in mm.	3 mm x 1	3
6. Largest anterior irregularity on the mandible in mm.	2 mm x 1	2
7. Measurement of anterior maxillary overjet in mm.	5 mm x 2	10
8. Measurement of anterior mandibular overjet in mm.	0 mm x 4	0
9. Measurement of vertical anterior openbite in mm.	0 mm x 4	0
10. Assessment of anteroposterior molar relation; largest deviation from normal either left or right, 0 = normal, 1 = 1/2 cusp either mesial or distal, 2 = 1 full cusp or more either mesial or distal.	2 (full cusp) x 3	6
Constant		13
DAI score		41

Table 2. This hypothetical case illustrates how the DAI is calculated with the rounded coefficients.

The score for the hypothetical case in Table 2 is 41, which would place the patient in the "orthodontic treatment needed" category.

4.1 Validity and reliability of the DAI

While developing the DAI and after their studies and subsequent publications, Jenny et al. (1993) considered that one of its characteristics was its high degree of validity.

The authors (Jenny & Cons, 1996) tested the reliability of the DAI when measured by trained assistants and found very high intra-class correlation. Although deep overbites that damage the soft tissues are not scored numerically in the DAI, these and other severe congenital conditions are easily recognized by trained personnel, who can refer such cases to orthodontic specialists.

The same authors found that while the acceptability of particular physical features of faces varied widely between different racial and cultural groups, that of dental characteristics remained far more constant among different cultures. This has made it possible to employ the DAI to assess malocclusions in different regions and countries, where it has shown itself to be a quick, simple, reliable index with a high level of validity.

A comparison of an evaluation of 1337 models by orthodontists with the results of the DAI found 88% agreement (Cons et al., 1986). In a prospective study conducted in Australia it was found that a DAI score that indicated treatment need was a good predictor of future orthodontic treatment (Lobb et al., 1994).

One important aspect of the DAI is that it can be measured by trained dental assistants, and this prior screening of the malocclusion severity levels from which patients can be treated reduces the number of first visits by orthodontists employed in public programs.

Numerous studies have suggested that the DAI can be applied universally without any need for modification or adaptation, allowing it to be used independently of the sample in which the study was conducted (Baca-Garcia et al., 2004).

Also, nowadays, the DAI has been included in the latest WHO oral health survey update (1997). The WHO's recommendation of this method for assessing dentofacial anomalies is a major step in its dissemination as a universal method for evaluating malocclusions.

5. IOTN (Index of Orthodontic Treatment Need)

Peter Brook and William Shaw (1989) developed the Orthodontic Treatment Priority (OTP) index, which they later called the IOTN. It was based on a combination of the SCAN or Standardized Continuum of Aesthetic Need (Evans & Shaw, 1987) and the index employed by the Swedish Dental Health Board. The IOTN was subsequently modified by Richmond et al. (1992) and Lunn et al. (1993).

The IOTN consists of two separate components, the aesthetic component (AC) and the dental health component (DHC). It is a method that attempts to determine the degree of malocclusion of a particular patient and that patient's perception of his or her own malocclusion. The novel feature of the IOTN compared to other indices was that it was the first to include a sociopsychological indicator of treatment need.

The two components are analyzed separately and while they cannot be unified to give a single score, they can be combined to classify the patient as needing or not needing orthodontic treatment.

From the start, the authors wanted their index to have two separate components, one to assess the aesthetic impact of the malocclusion and another for the present or potential dental health and functional indications. They also wanted each occlusal feature that contributes to the greater or lesser longevity of the stomatognathic system to be precisely defined, with easily detected and measured levels of severity and cutoff points between them.

Owing to the difficulty in determining the relative contribution of each feature to dental health, the index has to be flexible so that it can be adapted in the light of future research and discoveries.

5.1 The DHC (Dental Health Component) of the IOTN

The DHC (Dental Health Component) is the clinical or dental health component of the IOTN. It is the result of a modification of the index used by the Swedish Dental Health Board (Linder-Aronson, 1974).

The salient feature of this component of the IOTN is that it classifies patients into five distinct grades with clear cutoff points between each, defined according to the occlusal features of each patient and the contribution of each feature to the longevity of the stomatognathic system. In other words, it classifies the occlusal findings that represent the greatest threat to good oral health and function into different grades. Also, it can be obtained directly from examination of the patient or from study models.

One of the main features of this index is that it is not cumulative: it only takes into account the most severe occlusal feature and classifies the patient directly into the appropriate grade. In the same way, it largely ignores the cumulative effect of less severe occlusal features and, consequently, can undervalue certain malocclusions in some individuals.

The DHC has five grades, from Grade 1 (no need for treatment) to Grade 5 (very great need for treatment).

Index of Orthodontic Treatment Need Dental Health Component (IOTN DHC), (Brook & Shaw, 1989).

Grade 5 (Very great)

- Defects of cleft lip and palate and other craniofacial anomalies.
- Increased overjet greater than 9 mm.
- Reverse overjet greater than 3.5 mm with reported masticatory and speech difficulties.
- Impeded eruption of teeth (with exception of third molars) due to crowding displacement, the presence of supernumerary teeth, retained deciduous teeth, and any pathological cause.
- Extensive hypodontia with restorative implications (more than one tooth missing in any quadrant) requiring pre-restorative orthodontics.

Grade 4 (Great)

- Increased overjet greater than 6 mm but less than or equal to 9 mm.

- Reverse overjet greater than 3.5 mm with no reported masticatory or speech difficulties.
- Reverse overjet greater than 1 mm but less than or equal to 3.5 mm with reported masticatory or speech difficulties.
- Anterior or posterior crossbites with greater than 2 mm displacement between retruded contact position and intercuspal position.
- Posterior lingual crossbite with no functional occlusal contact in one or both buccal segments.
- Severe displacement of teeth greater than 4 mm.
- Extreme lateral or anterior open bite greater than 4 mm.
- Increased and complete overbite causing notable indentations on the palate or labial gingivae.
- Less extensive hypodontia requiring prerestorative orthodontics or orthodontic space closure to obviate the need for a prosthesis (not more than 1 tooth missing in any quadrant).

Grade 3 (moderate)

- Increased overjet greater than 3.5 mm but less than or equal to 6 mm with incompetent lips at rest.
- Reverse overjet greater than 1 mm but less than or equal to 3.5 mm.
- Increased and complete overbite with gingival contact but without indentations or signs of trauma.
- Anterior or posterior crossbites with less than or equal to 2 mm but greater than 1 mm discrepancy between retruded contact position and intercuspal position.
- Moderate lateral or anterior open bite greater than 2 mm but less than or equal to 4 mm.
- Moderate displacement of teeth greater than 2 mm but less than or equal to 4 mm.

Grade 2 (little)

- Increased overjet greater than 3.5 mm but less than or equal to 6 mm with lips competent at rest.
- Reverse overjet greater than 0 mm but less than or equal to 1 mm.
- Increased overbite greater than 3.5 mm with no gingival contact.
- Anterior or posterior crossbite with less than or equal to 1 mm displacement between retruded contact position and intercuspal position.
- Small lateral or anterior open bites greater than 1 mm but less than or equal to 2 mm.
- Prenormal or postnormal occlusions with no other anomalies.
- Mild displacement oh teeth greater than 1 mm but less than or equal to 2 mm.

Grade 1 (None)

- Other variations in occlusion including displacement less than or equal to 1 mm**.**

Lunn et al. (1993) conducted a study to assess the use of the IOTN. They concluded that this index is a very valid tool for public administration purposes but suggested the need for certain modifications to make it quicker and easier to use.

Their suggestions included reducing the number of IOTN DHC grades to three in order to improve its reliability. These proposals were accepted by the Manchester team that had developed the IOTN.

- DHC 1-2 Little or no need for treatment
- DHC 3 Moderate need for treatment
- DHC 4-5 Great need for treatment

These modifications make it much easier to determine the treatment need of a population.

Burden et al. (2001) then proposed a further modification specifically for epidemiological studies, reducing the number of grades to two to make the IOTN DHC easier to use and to increase its validity and reliability.

- DHC 1-2-3 No need for treatment
- DHC 4-5 Need for treatment

They also decided to use the acronym MOCDO (Missing teeth, Overjet, Crossbites, Displacement of contact points, Overbite) to speed up the process and select the patients that need treatment.

This simplifies training and use. According to this modification, those with the following conditions need treatment:

- M (missing teeth): Hypodontia requiring prerestorative orthodontics or space closure. Impeded eruption of teeth. The presence of supernumerary teeth or retained deciduous teeth.
- O (overjet): Overjet greater than 6 millimeters. Reverse overjet greater than 3.5 millimeters without masticatory or speech difficulties. Reverse overjet greater than 1 millimeter but less than or equal to 3.5 millimeters with masticatory or speech difficulties.
- C (crossbites): Anterior or posterior crossbites with more than 2 millimeters displacement between retruded contact position and maximum intercuspal position.
- D (Displacement of contact points): Displacement of contact points greater than 4 millimeters.
- O (Overbite): Lateral or anterior open bite greater than 4 millimeters. Deep overbite causing gingival or palatal traumatic injury.

For the reasons mentioned above this modified IOTN is recommended for epidemiological studies, although it is not useful for administrative purposes because, having only two grades, the patients cannot be classified on a scale of malocclusion severity, so it is more difficult to adjust the resources to the needs.

5.2 The AC (Aesthetic Component) of the IOTN

Since one of the main reasons for undergoing orthodontic treatment is aesthetic, it was considered that the aesthetic component ought to be represented in a diagnostic tool or an index (Alkhatib et al., 2005) and that the patients' perception of their own malocclusion needed to be taken into account.

The aesthetic component (AC) employs the SCAN Index (Evans & Shaw, 1987). It consists of an illustrated scale showing ten grades of dental aesthetics and is employed to determine each patient's aesthetic perception of his or her own malocclusion. To design this index, 1000 intraoral photographs of 12-year-old children were collected and placed in order after a lengthy study (Brook & Shaw, 1989). The photographs were rated by six non-dental judges. The result was a scale of ten black and white photographs showing different levels of dental

attractiveness, ranging from photograph 1, the most aesthetic, to number 10, the least aesthetic (Uçüncü & Ertugay, 2001).

The patient has to look at his or her mouth in a mirror and identify it with one of the ten photographs in the scale. In this way, each patient's perception of his or her malocclusion can be observed.

To make the IOTN quicker and easier to use and improve its reliability, Lunn et al. (1993) proposed reducing the number of IOTN AC grades from 10 to 3. These proposals were accepted by the Manchester team that had developed the IOTN.

- AC 1-4 Little or no need for treatment
- AC 5-7 Moderate need for treatment
- AC 8-10 Great need for treatment

Nowadays, for practical and epidemiological purposes only two grades are considered: patients who identify with photographs 1 to 7 do not need treatment, while those who identify with photographs 8 to 10 do need treatment. It should be pointed out that in most cases, almost no patients identify their own teeth with the great orthodontic treatment need group (photographs 8-10). It is also considered to be no easy task for patients to decide which of the 10 photographs most resemble their own teeth, especially when they are very young.

In practice, the two components of the IOTN are determined separately and an individual is considered to need treatment if the IOTN DHC grade is 4 or 5 or the IOTN AC is in the grades 8-10 group. In either of these two situations the child needs orthodontic treatment for either dental health reasons (DHC) or for exclusively aesthetic reasons (AC). However, according to the modified IOTN developed by Burden et al. (2001), when this is employed in epidemiological studies both components are required, in other words, DHC grades 4-5 and AC grades 8-10.

5.3 Validity and reliability of the IOTN

When designing and testing the IOTN, Brook and Shaw (1989) observed that the reproducibility of this index was particularly good when measured under suitable conditions, and slightly less good when measured, for example, in schools.

Richmond et al. (1995) confirmed the validity and reliability of the IOTN in a study in which 74 dentists and orthodontists assessed the treatment need of a total of 256 models of orthodontic patients representing all types of malocclusion. The Spearman coefficient for the aesthetic component was 0.84 and that of the dental health component was 0.64.

Brook and Shaw claim good intra- and inter-examiner reproducibility when the IOTN AC is assessed by a dentist. However, according to Holmes (1992), the patients' perception tends to be more optimistic than that of the professionals. Nevertheless, the use of the IOTN AC has been the subject of some controversy in recent years. This is because of the lack of correlation between the dental health component (DHC) and the aesthetic component (AC), as found by Soh and Sandham (2004) in a study of an adult Asian population and by Hassan (2006) in a region of Saudi Arabia. Also, some authors such as Svedström-Oristo et al. (2009) have described certain problems when asking patients, both children and young adults, to identify their mouths with one of the 10 photographs employed as stimuli.

According to Alkhatib et al. (2005), the IOTN is not only valid and reliable but is also sensitive to the needs of patients and accepted both by the patients themselves and by the professionals who employ it. Hamdam (2004) confirmed the validity and reliability of the IOTN. Mandall et al. (2000) and Birkeland et al. (1996) concluded that it is a reproducible and reliable index.

A recent study by Johansson and Follin (2009) showed that the clinical criterion employed by 272 Swedish orthodontists was in good agreement with the results of the IOTN DHC. The main differences were found in IOTN grade 3, as the orthodontists considered most of the malocclusions in this grade to be in need of treatment.

However, O'Brien et al. (1993) found large differences in the choice of the different grades of need in both the DHC and the AC. Turbill et al. (1996) concluded that the IOTN is essentially an epidemiological index that has limitations when assessing the treatment needs of individual patients.

The IOTN is currently employed in the United Kingdom for prioritizing public orthodontic care services. Its reliability and validity have been extensively proved, it is simple and easy to use, and it is also one of the most-often cited indices in the literature.

6. The epidemiology of treatment need

Appropriate assessment and measurement of malocclusions is essential in epidemiological studies in order to ascertain the prevalence and incidence of occlusal alterations among the population. There are certainly many indices and measures for assessing malocclusion, but the DAI and the IOTN are the best known and most widely used owing to their manageability and proven validity.

Tables 3 and 4 show a number of malocclusion prevalence studies conducted since the year of publication of each of these indices up to the present.

On examining the main studies it will be seen that both the DAI and the IOTN have been used to a greater extent in cross-sectional studies with large samples, generally randomly selected, although it will be observed that they meet the requirements for epidemiological or prevalence studies. While the IOTN is used to a greater extent in Europe, The DAI is employed to a similar extent throughout the world, though least in Europe. However, whereas the IOTN is employed more in child/adolescent populations, the DAI is more often employed in adolescent/adult ones.

As noted above, comparison between the different studies is very complicated. The first reason is that they employ different methods and their data collection criteria are sometimes not sufficiently well explained. Examination of the studies shows that they use different indices, so although they measure the same condition (malocclusion prevalence or treatment need), they do not measure it in the same way or consider the same occlusal features. Obviously, also, the different studies were conducted in different populations, with differing sample sizes, ages and geographical origins. For all these reasons, it is posible to make comparisons but prudence is required when drawing conclusions. Epidemiological studies of malocclusion prevalence and orthodontic treatment need in large, representative samples continue to be necessary in order to effect more rigorous comparisons.

Authors (publication year)	Country	n	Age	DHC(4-5)	AC(8-10)
Brook and Shaw (1989)	United Kingdom	222	11-12	32.7%	5.4%
So and Tang (1993)	Hong Kong	100	19-20	53%	-
So and Tang (1993)	China	100	20	52%	-
Burden and Holmes (1994)	United Kingdom	874 955	11-12	31% 32%	12% 8.5%
Tuominen et al. (1995)	Finland	89	16-19	11.2%	-
Tang and So (1995)	Hong Kong	105	18-22	54.2%	-
Birkeland et al. (1996)	Norway	359	11	26.1%	9%
Otuyemi et al. (1997)	Nigeria	704	12-18	12.6%	-
Riedmann and Berg (1999)	Germany	88	20	60.2%	60%
Tickle et al. (1999)	United Kingdom	7888	14	26.2%	-
Cooper et al. (2000)	United Kingdom	142	19	21%	12.8%
Kerosuo et al. (2000)	Finland	281	18-19	15%	0%
Cooper et al. (2000)	United Kingdom	314	11	34%	4%
Johnson et al. (2000)	New Zealand	294	10	31.3%	3.8%
Mandall et al. (2000)	United Kingdom	434	14-15	18%	6%
Uçüncü y Ertugay (2001)	Turkey	250	11-14	38.8%	4.8%
Abdullah and Rock (2001)	Malaysia	5112	12-13	30%	-
Hamdam (2001)	Jordan	320	14-17	28	-
Hunt et al. (2002)	United Kingdom	215	17-43	-	2.8%
De Olivera and Sheiham (2003)	Brazil	1675	15-16	22%	-
Klages et al. (2004)	Germany	148	18-30	-	0%
Flores-Mir et al. (2004)	Canada	329	18-20	-	2%
Soh and Sandham (2004)	Singapore	339	17-22	50.1 %	29.2%
Kerosuo et al. (2004)	Kuwait	139	14-18	28.1%	1.4%
Abu Alhaija et al. (2004)	Jordan	1002	12-14	34%	-
Tausche et al. (2004)	Germany	1975	6-8	26.2%	21.5%
Mugonzibwa et al. (2004)	Tanzania	386	9-18	22%	11%
Hamdam (2004)	Jordan	103	15	71%	16.7%
Kerosuo et al. (2004)	Kuwait	139	14-18	28%	2%
Hlonga et al. (2004)	Tanzania	643	15-16	3-13%	-
Soh et al. (2005)	Singapore	339	17-22	50.1%	29.2%
Alkhatib et al. (2005)	United Kingdom	3500	12-14	15%	2.1%
Mandall et al. (2005)	United Kingdom	525	11-12	44.8%	2.7%
Klages et al. (2006)	Germany	194	18-30	-	8.8%

Authors (publication year)	Country	n	Age	DHC(4-5)	AC(8-10)
Bernabé and Flores-Mir (2006b)	Peru	281	16-25	29.9%	1.8%
Hassan (2006)	Saudi Arabia	743	17-24	71.6%	16.1%
Souames et al. (2006)	France	511	9-12	21.3%	7%
Chestnutt et al. (2006)	United Kingdom	2595 2142	12 15	35% 21%	- -
Nobile et al. (2007)	Italy	1000	11-15	59.5%	3.2%
Ngom et al. (2007)	Senegal	665	12-13	42.6%	3.3%
Manzanera et al. (2009)	Spain	665	12 15-16	21.8% 17.1%	4.4% 2.4%
Svedström-Oristo et al. (2009)	Finland	434	16-25	-	2%
Puertes-Fernández et al. (2010)	Algeria	248	12	18.1%	13.7%
Hassan and Amin (2010)	Saudi Arabia	366	21-25	29.2%	-

Table 3. Studies of different populations using the IOTN (DHC/AC)

Authors (publication year)	Country	n	Age	Treatment Need (≥31)
Estioko et al. (1994)	Australia	268	12-16	24.1%
Katoh et al. (1998)	Japan Taiwan	1029 176	15-29 18-24	30.1% 25.9%
Otuyemi et al. (1999)	Nigeria	703	12-18	9.2%
Johnson et al. (2000)	New Zealand	294	10	55.4%
Chi et al. (2000)	New Zealand	150	10	47%
Abdullah and Rock (2001)	Malaysia	5112	12-13	24.1%
Esa et al. (2001)	Malaysia	1519	12-13	24.1%
Onyeaso et al. (2003)	Nigeria	64	16-45	48.4%
Baca-García et al. (2004)	Spain	744	14-20	21.1%
Onyeaso (2004)	Nigeria	136	6-18	50%
Onyeaso (2005)	Nigeria	577	12-17	22.7%
van Wyk and Drummond (2005)	South Africa	6142	12	31%
Frazão and Narvai (2006)	Brazil	13801	12-18	18%
Bernabé and Flores-Mir (2006a)	Peru	267	16-25	32.6%
Marques et al. (2007)	Brazil	600	13-15	53.3%
Hamamci et al. (2009)	Turkey	841	17-26	21.5%
Manzanera et al. (2010)	Spain	655	12 15-16	21.2% 16.1%
Puertes-Fernández et al. (2010)	Algeria	248	12	13.2%

Table 4. Studies of different populations using the DAI

7. Conclusions

Many very different indices have been developed for classifying malocclusions according to their severity or level of treatment need. Although a certain consensus has been reached on the features that the ideal index should possess, controversy continues over which should be used for this purpose.

Evidently, patients often seek orthodontic treatment but present considerable variations in malocclusion. The wide range of situations between ideal occlusion and very severe malocclusion make it very difficult to establish the precise limits of what should and should not be considered treatment need. Consequently, ascertaining the real malocclusion prevalence and establishing reliable comparisons concerning their frequency in different populations is by no means simple. Also, as there is also no unanimous criterion for deciding what to consider malocclusion, its real frequency cannot be established.

In this chapter we have presented a large number of orthodontic treatment need indices. However, the two indices that are currently most often used for epidemiological studies are the DAI and the IOTN. Hlonga et al. (2004) and Liu et al. (2011) have observed a significant correlation between the two indices. Nevertheless, high correlation does not necessarily imply high agreement (Manzanera et al., 2010). In epidemiological studies this is not a particularly important problem because both are valid methods for determining the orthodontic treatment need of a population, but when they are applied in individual cases, the choice of DAI or IOTN will lead to the appearance of both false negatives and false positives.

Comparison of these two indices finds similarities and differences. Both comprise two components, one anatomical and the other aesthetic, both measure occlusion features proposed by experts and both attempt to identify the individuals with the greatest treatment need in public programs. Although most of the features they measure are identical, each feature is rated differently in the two indices. The advantage of the DAI is that the aesthetic perception is linked to the anatomical assessment through regression analysis to produce a single score, whereas the IOTN has two components that cannot be unified. Also, the DAI offers a continuous scoring system, so it can classify different degrees of malocclusion within each of the pre-established levels. The IOTN cannot establish a continuous order within each grade, so it is more complicated to use for public health programs. In the DAI, unlike the IOTN, the occlusal features examined are different according to whether it is the primary dentition, mixed dentition or permanent dentition that is being measured, and since its design is more suitable for permanent teeth, it leads to the use of more than one epidemiological index.

It would appear, agreeing with some other authors, that DAI is more useful for administrative purposes, in other words, when the budget is limited and the patients must be placed in strict order of severity in order to give priority to those in most need of treatment. This is possible because the DAI scale is continuous, whereas the IOTN makes not distinctions within grades. The IOTN, however, being easily and quickly obtained, is more effective in epidemiological studies, to determine the percentage of the population in need of treatment without establishing priorities.

The great value that society sets on aesthetics nowadays, the importance that patients themselves ascribe to their malocclusions and the extent to which their condition affects their quality of life must not be forgotten. In recent years particular attention has been paid to surveys that attempt to measure the way in which malocclusion affects a person's quality of life; these include studies by De Baets et al. (2011), Liu et al. (2011) and Agou et al. (2011). Such surveys should be employed in decision-making as complementary tools to the different orthodontic treatment need indices.

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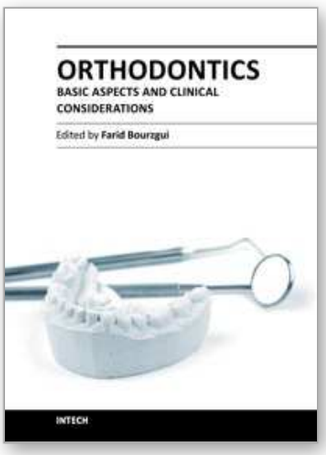

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The book reflects the ideas of nineteen academic and research experts from different countries. The different sections of this book deal with epidemiological and preventive concepts, a demystification of cranio-mandibular dysfunction, clinical considerations and risk assessment of orthodontic treatment. It provides an overview of the state-of-the-art, outlines the experts' knowledge and their efforts to provide readers with quality content explaining new directions and emerging trends in Orthodontics. The book should be of great value to both orthodontic practitioners and to students in orthodontics, who will find learning resources in connection with their fields of study. This will help them acquire valid knowledge and excellent clinical skills.

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