REVIEW ARTICLE

Occlusion, malocclusion and method of measurements - an overview

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Abstract Epidemiological studies of occlusion and malocclusion not only help in orthodontic treatment planning and evaluation of dental health services but also offer a valid research tool for ascertaining the operation of distinct environmental and genetic factors in the aetiology of malocclusion. The objective of this article was to give an overview on occlusion, malocclusion and the various methods on measuring the occlusion. Each index and method of the assessment described was based on the opinion of an individual or a group of individuals. It had been widely agreed that no particular index or method available that are truly inclusive of all occlusal criteria. Therefore, different indices or method had been developed according to different requirements and it may be necessary to use more than one index in order to gather information to suit the objective of the particular study.

Introduction

Occlusion is defined a manner in which the upper and lower teeth intercuspate between each other in all mandibular positions and movements. It is a result of neuromuscular control of the components of the mastication systems namely: teeth, periodontal structures, maxilla and mandibular, temporomandibular joints and their associated muscles and ligaments (Ash & Ramfjord, 1982).

An individual's occlusal status is generally described by two major characteristics: intra-arch relationship, the relationship of the teeth within each arch to a smoothly curving line of occlusion and inter-arch relationship, the pattern of occlusal contacts between the upper and lower teeth (Proffit, 1986). A physiologic occlusion differs from a pathological occlusion in which the components function efficiently and without pain, and remain in a good state of health (Ross, 1970). It can be either normal occlusion or malocclusion. Specifically in this state the teeth remain firm, do not migrate or cause pain during and after contact. The temporomandibular joint and associated structures should function freely and without pain. In an epidemiological study, the terminology of occlusion encompassed all the occlusal variations ranged as ideal occlusion, normal occlusion and malocclusion.

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Ideal occlusion

An ideal occlusion is a hypothetical or theoretical concept based on the anatomy of the teeth and rarely found in nature. The concept is applied to a condition when the skeletal bases of maxilla and mandible are of the correct size relative to each other and the teeth should be in correct relationship in all three plane of space at rest (McDonald & Ireland, 1998). It can be precisely described and therefore used as a standard by which other occlusions can be judged. Houston *et al.* (1992) further suggested the following concepts of ideal occlusion in permanent dentition:

a) Each arch is regular with the teeth at ideal mesiodistal and buccolingual inclinations and the correct approximal relationship at each interdental contact area.

b) The arch relationships are such that each lower tooth (except the central incisor) contacts the corresponding upper tooth and the tooth anterior to it. The upper arch overlaps the lower anteriorly and laterally.

c) When the teeth are in maximum intercuspation, the mandible is in a position of centric relation, i.e. both mandibular condyles are in symmetrical retruded unstrained positions in the glenoid fossae.

d) During mandibular excursions, functional relationships are correct. In particular, during

lateral excursions there should be either group function or a cuspid rise on the working side with no occlusal contact on the contra lateral side and in protrusion the occlusion should be on incisor teeth but not on the molars.

Normal occlusion

Angle (1899) had provided the first clear definition of normal occlusion. The normal occlusion was when the upper and lower molars were in a relationship whereby the mesiobuccal cusp of the upper molar occluded in the buccal grove of the lower molar and the teeth were arranged in a smoothly curving line of occlusion. Normal occlusion and Class I malocclusion shared the same molar relationship but differed in the arrangement of the teeth relative to the line of occlusion. Class I might not have good alignment of teeth relative to the line of occlusion.

Normal occlusion according to Houston *et al.* (1992) was an occlusion within the accepted deviation of the ideal and did not constitute aesthetic or functional problems. It was not possible to specify precisely the limits of normal occlusion as long as there was no evidence that an irregularity could be disadvantageous to the patient.

Andrews (1972) reported of six significant characteristics consistently observed in 120 casts of non-orthodontics patients with normal occlusion. He had used the centre of the clinical crowns as reference points and measured the thickness, tip and torque of each tooth. These constants were referred to as the "six keys to normal occlusion". The significant features shared by all the patients were as follows:

a) *Molar relationship*: Corresponds with the mesiodistal relationship of upper first permanent molars of Angle (1899) with addition that the distal surface of the disto buccal cusp of the upper first permanent molar should made contact and occluded with the mesial surface of the mesio buccal cusp of the lower second molar.

b) *Correct crown angulation (mesodistal tip of the crown)*: The angulation of the facial axis of every clinical crown should be positive. The extent of angulation varies according to tooth type. (positive means: the gingival part of the long axis of each crown in the upper jaw is positioned distally to the occlusal part of this axis).

c) *Correct crown inclination (labiolingual or buccolingual torque)*: In upper incisors, the gingival portion of the crown's labial surface is lingual to the incisal portion. In all other crowns, including lower incisors, the gingival portion of the labial or buccal surface is labial or buccal to the incisal or occlusal portion. In upper posterior crowns (cuspids through molars), the lingual crown inclination of the buccal surfaces is slightly more pronounced in the molars than it is in cuspids and bicuspids. In lower posterior crowns (cuspids through molars), lingual inclination progressively increases.

d) *Absence of rotations*: Teeth should be free of undesirable rotations. If rotated, a molar or bicuspid occupies more space than it normally does. A rotated incisor may occupy less space.

e) *Tight proximal contacts*: In absence of abnormalities such as genuine tooth size discrepancies, contact point should be tight.

f) *Flat occlusal plane*: The curve of Spee should have no more than a slight arch with the deepest curve was 1.5 mm (plane drawn from incisors to second molars). The convex curve of Spee and mandibular core line bare excessive potions of the occlusal surfaces.

Works by Roth (1981) had then added some functional keys to the previous six keys to normal occlusion by Andrew:

a) Centric relationship and centric occlusion should be coincident.

b) In protrusion, the incisors should disclude the posterior teeth, with the guidance provided by the lower incisal edges passing along the palatal contour of the upper incisors.

c) In lateral excursions of the mandible, the canine should guide the working side whilst all other teeth on that and the other side are discluded.

d) When the teeth are in centric occlusion, there should be even bilateral contacts in the buccal segments.

Malocclusion

The term "irregularities of teeth" as applied to teeth that were twisted or unevenly arranged, did not express the full meaning of these deformities (Angle, 1899). The term "malocclusion" would be more expressive. The World Health Organization (1987), had included malocclusion under the heading of Handicapping Dento Facial Anomaly, defined as an anomaly which causes disfigurement or which impedes function, and requiring treatment "if the disfigurement or functional defect was likely to be an obstacle to the patient's physical or emotional well-being". Proffit (1986) elaborated that malocclusion might be associated with one or more of the following:

a) Malalignment of individual teeth in each arch: a tooth in an arch may occupy a position deviating from the smooth curve of line by being; tipped, displaced, rotated, in infra-occlusion, in supra-occlusion and transposed.

b) Malrelationship of the dental arches relative to the normal occlusion: may occur in any of the three planes of spaces: anteroposterior, vertical or transverse.

Today malocclusion occurs in the majority of the population. It is neither a normal or unhealthy condition (Proffit & Fields, 2000). Malocclusion is an appreciable deviation from the ideal occlusion that may be considered aesthetically unsatisfactory (Houston, et al., 1992) thus implying a condition of imbalance in the relative sizes and position of teeth, facial bones and soft tissues (lips, cheek, and tongue). It is important not to equate the possession of malocclusion with the need for a treatment instead it should be judged according to dental health, aesthetic or functional criteria namely: chewing, speech, breathing and swallowing (Sampson & Sims, 1992).

Classification of malocclusion

Different methods of classification of the malocclusion may be needed for different purposes. The requirements for clinical categorization differ from those of epidemiology (Houston et al., 1992). Several types of indices had been developed to describe:

a) *Epidemiological data collection*
The method of measuring the occlusal traits (Bjork et al., 1964; Baume & Marechaux, 1974; Bezroukov et al., 1979) were developed for epidemiological data collection and to standardize the method of measuring and describing every occlusal trait within a population.

b) *Occlusal classification*
Angle's classification (Angle, 1899) and the Incisor classification (British Standard Institution, 1983) provide a description of malocclusion, which allows communication between clinicians.

c) *Priority treatment need - dental health need*
Handicapping Labiolingual Deviation Index (Draker, 1960), Occlusal Index (Summers, 1971) and Index of Orthodontic Treatment Need: Dental health component (Brook and Shaw, 1989) were developed to assess the need for treatment according to dental health in a population so that priority can be assigned to selected cases when resources were limited.

d) *Priority treatment need - aesthetic need*
Index of Orthodontic Treatment need (Brook and Shaw, 1989): Aesthetic component was developed in response to social science surveys that emphasized the importance of aesthetic impairment on a patient's psychological well-being.

e) *Treatment success*
PAR Index (Richmond, et al. 1992) was used to compare pre and post orthodontic treatment records and registered the quality of the outcome.

f) *Dental arch relationships*
GOSLON Yardstick (Great Ormond Street London and Oslo) is a methodology specifically developed for categorizing dental arch relationships in children with unilateral complete cleft lip and palate (UCCLP) examined in the late mixed or early permanent dentition (Mars et al., 1987). It has been verified as a reliable and reproducible evaluation to discriminate between the quality of dental arch relationships in cross-center studies (Mars et al., 1992), and during all stages of dental development (Noverraz et al., 1993). The GOSLON Yardstick can be used to predict surgical outcome as early as 5 years of age (Atack et al., 1997).

Aetiology of malocclusion

It is difficult to prove a single major cause of malocclusion as it develops slowly as a child grows and the development of occlusion is very vulnerable to many influences. Proffit (1986) reported that in the early part of the twentieth century it was generally believed by orthodontists that the environment (civilization) had a large effect on dental and facial development. However, in mid century, a combination of failures with the earlier treatment philosophy and increased knowledge of genetics resulted in genetically determined dental and facial proportions. The orthodontics' role at that time was limited to making the best of the situation. No growth modification, or indeed arch expansion was attempted in many instances as it was thought that these regimes would be futile.

As the 21st century begins, most researches proposed two broad set of theories to explain causes of occlusal variation based on genetics and the role of environment (Corrucini, 1984; Proffit, 1986; McDonald & Ireland, 1998). However no single, simple genetic or no single environmental cause could be blamed on the condition (Proffit 1986) and the aetiology of most malocclusion is usually multifactorial (McDonald & Ireland, 1998). The difficulty of separating these factors is obvious, since controlled human experimentation is not possible (Corrucini, 1984). Most orthodontists seem to believe that the genetic factor is most important thereby rendering any preventive measures impossible (Katz et al. 1965).

Proffit (1986) had suggested that crowding and malalignment were due primarily to inherited tendencies that determine facial proportions and soft tissue contour as well as teeth and jaw size. Mild and moderate degree of malalignment might be present even in the absence of habits or environmental factors, however extremely severe crowding probably has genetic component as well as environmental component. Aetiology of malocclusion (Proffit, 1986; McDonald & Ireland, 1998):

a) *Genetic factors*
i) Evolutionary reduction in jaw and tooth size causing jaw and tooth size discrepancies.
ii) Genetic syndromes
iii) Defect of embryologic development
iv) Admixture and breeding

a) *Environmental factors*
i) Any intermittent pressure or force exceeds 4-6 hours/day to the dentition e.g. pressure from surrounding soft tissue and habits as thumb sucking.
ii) Trauma
iii) Anomalies of postnatal development

Measurement of the occlusal traits

A good method of recording or measuring malocclusion is important for documentation of the prevalence and severity of malocclusion in different population. If the method is universally accepted and applied, data collection from different groups can be compared (Lavelle, 1976). It is well documented that many of the earlier result of epidemiological investigations are not comparable owing to subjective evaluation of the features registered. Occlusal traits can be assessed directly from the mouth or indirectly with a study cast or dry skull (Lavelle, 1976). The methods of recording and measuring occlusion can be broadly divided into two types: qualitative and quantitative.

Qualitative methods

Qualitative evaluation of malocclusion was attempted before quantitative methods. It is a descriptive classification and it does not provide any information of the treatment need and outcome. Studies on epidemiology of malocclusion in the earlier days did not define the method on measuring the variables, thus malocclusion symptoms were recorded in an all or none manner (Tang & Wei, 1993).

Quantitative methods

The development of quantitative methods of measuring malocclusion was made later than those for qualitative methods. Malocclusion indices have been used to categorize disorders for the purpose of epidemiology and research, in order to allocate patients into categories of treatment need and to compare the treatment success. It does not provide any information concerning the prevalence of given manifestation of malocclusion (Thilander *et al.*, 2001).

Classifications used in various epidemiological studies

Various classifications had been used by different investigators to classify and quantify occlusal traits. A review of the classifications used in different population groups is showed in Table 1.

Angle's classification (Angle, 1899)

The earliest published method of recording malocclusion was Angle's classification of malocclusion (1899). He believed that all teeth are essential, yet in function and influence, some were of greater importance than others, the most important of all being the first permanent molars, especially the upper first molars, which were called the keys to occlusion;

a) They are the biggest teeth and their anchorage is strongest.

b) Their local position in the occlusal arch supports the main masticatory duty and operation.

c) They influence the vertical distance of upper and lower jaws, the occlusal height and aesthetic proportions.

d) As the permanent molars are the first erupting teeth of permanent dentition, they have "mighty" control on the teeth erupting later behind and in front of them, as they are forced to position to the already erupted and in occlusion functioning first molars.

Table 1 Classification used in occlusal studies in various populations

Author	Type of population	Sample n	Sample age	Classification
Lavelle (1976)	British caucasiod, Negroid and Mongoloid	1000	15–20	Bjork *et al.,* (1964)
Brunelle *et al* (1996)	NonHispanic white and blacks and Mexican American in United State	7000	8-50	Proffit(1986)
Garner & Butt (1985)	Black American and Nyeri Kenyans	445	13-15	Modified Angle
Wood (1971)	Alaskan Eskimo	100	11-20	Modified Angle
Ingervall *et al.* (1978)	Swedish	389	21-54	Bjork *et al.,* (1964)
Johnson *et al.* (1978)	Indonesian	184	7-13	Modified Angle
Otuyemi & Abidoye (1993)	Nigerian	574	12	Bjork *et al.,* (1964)
Tod & Taverne (1997)	Australian	216	18-64	Modified FDI (1979)
Tang (1994)	Chinese in Hong Kong	201	13-40	Occlusal index
Woon *et al.* (1989)	Malay, Chinese & Indian in Malaysia	347	15-19	Modified FDI (1969)
Adnan & Abdul Kadir (1988)	Temiar tribe of Orang Asli in Peninsular Malaysia	73	6-13	British Standard Institute (1983)
Thilander *et al.* (2001)	Bogota, Colombia	4724	5-17	Modified Bjork *et al.,* (1964)

e) The anomalies in dental positioning are mostly due to a more prominent dislocated position of the crowns of upper permanent molars to normal, less and minor due to a dislocation of their apex.

These findings lead Angle to postulate, that "the first upper permanent molar, more than any other tooth or anatomical point gives a precise scientific basis for defining occlusal disharmony and occlusal anomalies".

Houston *et al.* (1992) described Angle's classification as the only internationally recognized classification and widely used in epidemiological study of malocclusion. Despite such praises, the classification has been criticized by a number of authors. Graber (1972) pointed out that the Angle classification failed to distinguish between malocclusion and antero-posterior relationships. Rinchuse and Rinchuse (1988) proposed that the classification was not clear about the description and definition of different classes and Angle's writing was equivocal, leading to possibility of one class overlapping into another. In addition to the above, several investigations had provided data that question the reliability of Angle's classification. Gravely and Johnson (1974) for example, had demonstrated a poor intraexaminer and interexaminer reliability for Angle's classification, especially in categorizing Class II division 2 malocclusion.

A method for epidemiological registration of malocclusion (Bjork *et al.*, 1964)

Bjork *et al.* (1964) developed a method to record malocclusion with clearly defined items of the recorded symptoms. The registration of the malocclusion was divided into three parts:

a) Anomalies in the dentition; tooth anomalies, abnormal eruption and misalignment of individual teeth.

b) Occlusal anomalies; deviations in the positional relationship between the upper and the lower dental arches in the three planes.

c) Deviation in space conditions; spacing and crowding

This comprehensive system however was developed for epidemiological purpose with little emphasis upon treatment need. It was widely used in studies of the prevalence in malocclusion in various country of the world as shown in the Table 1. Developing from the principles of defining and recording individual traits of malocclusion in the above study, Working Group 2 (WG2) of Federation Dentaire International (FDI) had later developed a simplified method of measuring occlusal traits (Tang & Wei, 1993).

A method for measuring occlusal traits developed by the Federation Dentaire International (FDI) Commission on

Classification and Statistics for Oral Conditions (COCSTOC) (Baume *et al.*, 1973)

During Federation Dentaire International (FDI) Conferences (1969) held in New York, a variety of methods were presented for recording occlusal features. During the period of 1969 to 1972, the above method was modified and simplified by the Working Group 2 (WG 2) of the FDI Commission on Classification and Statistics for Oral Conditions (COCSTOC), in collaboration with the World Health Organization (WHO), after being field tested.

The aim of the method was to study the problem of assessing the occlusal status and to develop a system of measuring occlusion which could be applied widely and the result could be compared. It was not developed as an index of treatment need, since it was difficult to establish meaningful cut off points (Baume *et al.*, 1973). Assessment was made on the permanent dentition in three parts;

a) Dental examination: anomalies of development, congenitally missing teeth, supernumerary teeth, malformed teeth, impacted, missing due to trauma or extraction and retained desiduous teeth.

b) Intra-arch examination: crowding, spacing, anterior irregularities and upper midline diastema.

c) Inter-arch examination: molar relationship, posterior openbite, posterior crossbite, overjet, overbite, midline deviation, anterior openbite and soft tissue impingement.

The socio-phychological effects of occlusal features on an individual, their family and peers were not taken into consideration since an objective method of measuring these factors had not been established (Baume *et al.* 1973).

Irregularity index (Little, 1975)

This index was based on measurement of mandibular irregularity and could be used by public health and insurance programme to establish malocclusion severity and determine treatment priorities. Five linear displacements of adjacent contact points starting from the mesial of right lower canine to mesial of left lower canine was recorded. The sum of five displacements represented the irregularity value. This method is a simple, valid and reliable method for measuring dental irregularity quantitatively. However it tended to exaggerate cases with severe labiolingual displacements with shortage of arch length (Abdullah & Rock 2001).

Basic method for recording occlusal trait (Bezroukov *et al.*, 1979)

The main objective of this method is to provide a common morphological basis for studies of the prevalence of malocclusion and dental irregularity.

This method was developed from the Method of Measuring the Malocclusion Traits by Working Group 2 (WG 2) of the FDI Commission which had been published in the International dental Journal in 1972. The previous version had been field tested in the period of 1973-76. It was then submitted to COCSTOC at the 64th annual session of the FDI in Athens in 1976 and further field trial was carried out. Final modifications based on these trials were subsequently made by some members of WG2. In 1979 the World Health Organization (WHO) issued the detailed methodology for recording malocclusion which would permit more objective epidemiological comparisons between sample groups.

The examination was only carried out on the subject with a permanent dentition as the author pointed out that occlusion in the stage of mixed dentition is not stable and self correcting. This new version divided the examination into dentition, space condition and occlusion. The critical severity levels, for example maxillary overjet, overbite and anterior openbite were modified. However the detailed recording only included dento-alveolar characteristics and leave great subjectivity regarding facial pattern and the need for treatment (Sampson & Sims, 1992). This index later influenced the development of Dental Aesthetic Index (Abdullah, 2000).

British Standards Institute Classification (1983)

British Incisor Classification System was introduced by Ballard and Wayman (1965) of Angle classification, including Angle's categories. The reliability of the system was considered superior to Angle's classification because the posterior teeth did not influence and in conflict with the incisor occlusion type (Du *et al.*, 1998). Williams and Stephens (1992) had carried out a study to measure the reproducibility of British Standard Incisor Classification. The findings indicated that the most disagreement was related to border line Class I and Class III and the causes were due to failure to appreciate that it was the cingulum plateau rather than the middle third of the visible palatal surface of the maxillary central incisor which was the crucial aspect of the classification.

Conclusion

Each index and method of the assessment described earlier was based on the opinion of an individual or a group of individuals. There are bound to be disagreement amongst other professionals as to the validity of a particular method (Abdullah & Rock, 2001). It had been widely agreed that no particular index or method available that are truly inclusive of all recommended criteria (Gray & Demirjian, 1977). Therefore, different indices or method had been developed according to different requirements (Tang & Wei, 1993; Abdullah & Rock, 2001).Given the above, it may be necessary to use more than one index in order to gather information to suit the objective of the particular study.

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