Functional Occlusion: I. A Review

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Abstract. *The features that constitute an 'ideal' functional occlusion have not been conclusively established. Orthodontic treatment has the capacity to change static and functional occlusal relationships fundamentally. In this article, we present the evidence on which features of the occlusion are reported to be detrimental to the teeth and masticatory system. Deficiencies in this research area are highlighted, together with the need for prospective longitudinal trials to clarify the requirements of an ideal functional occlusion. Based on the existing evidence this paper suggests which occlusal features may be significant in producing an 'ideal' functional occlusion. As no long-term studies exist to measure the impact of non-ideal occlusal relationships on the dentition, it is debatable whether orthodontic treatment should be prolonged in order to ensure that 'ideal' occlusal contacts are achieved. As the occlusion tends to 'settle' in the period following appliance removal, we propose that it may be more appropriate to examine the functional occlusal relationships after retention has ceased rather than prolong active orthodontic treatment to achieve 'ideal' functional occlusal goals.*

Index words: Canine Guidance, Functional Occlusion, Group function, Occlusal Interference, Occlusion.

Introduction

The 'ideal' occlusion described by orthodontists today, which is used as the basis upon which to judge outcome following orthodontic treatment, is derived from the work published by Angle (1900) and Andrews (1972, 1989), and focuses on specific anatomical relationships of the teeth and dental arches. It is generally assumed (Andrews, 1976; Roth, 1976) that an ideal static occlusal relationship is compatible with an ideal functional occlusion, but this is not necessarily so (Tipton and Rinchuse, 1991). The purpose of this article is to present the current evidence on the features that are thought to contribute to an ideal functional occlusion and those which are thought to be detrimental.

Terminology

There is considerable confusion in the literature on occlusion, and one of the reasons for this is the excessive number of definitions and their different interpretation. The terms used in this paper are defined here and represent the authors' interpretation of the literature:

Occlusion is each static contact between one or more lower teeth with one or more upper teeth.

Functional occlusion refers to the occlusal contacts of the maxillary and mandibular teeth during function, i.e. during speech, mastication, and swallowing.

Intercuspal position is the occlusal position with the teeth in maximum intercuspation. The term intercuspal position (ICP) is synonymous with many other terms, including centric occlusion, habitual occlusion, acquired occlusion, and habitual centric.

Retruded axis position is the position the condyle adopts during the terminal hinge movement of opening or closing. Synonyms for the retruded axis position (RAP) are centric relation, terminal hinge relation, and hinge axis position. Confusion arises from the lack of consensus on the exact location of the condyles in the glenoid fossa when they describe a pure hinge movement. Early definitions described the condyles as being in their most retruded position (Academy of Denture Prosthetics, 1956). More recently, the majority of authors describe the condyles as being located in the most superior-posterior position in the glenoid fossa (Academy of Denture Prosthetics, 1987). The exact position of the condyles when the mandible is in the retruded axis position is probably of little practical significance. The significance of the retruded axis position lies in the fact that it is a border position of the mandible, said to be highly reproducible for several subsequent jaw registrations and, therefore, an important reference point for occlusal diagnosis and rehabilitation.

Retruded contact position is the occlusal position when the first tooth contact occurs on the mandibular path of closure with the condyles in the retruded axis position.

Working side is the side that the mandible moves towards in a lateral excursion.

Non-working side is the side that the mandible moves away from during a lateral excursion.

Tooth Contact Patterns during Function

During mastication and swallowing, tooth contacts occur posterior, lateral, and anterior to the intercuspal position (Graf and Zander, 1963; Glickman *et al*., 1970; Pameijer *et al*., 1970)

The Retrusive Range (RCP–ICP)

The mandible can hinge about a horizontal axis through the condyles called the retruded axis. This permits an incisal opening of 20–25 mm with the condyles in the retruded axis position. When the mandible closes on the retruded axis, its position when the first tooth contact occurs is referred to as the retruded contact position.

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It is generally accepted that in most individuals with a natural dentition there is a short path of movement between the retruded contact position and the intercuspal position in an antero-posterior direction, and that both these occlusal positions are used frequently during function. Numerous studies have shown that a discrepancy of 0·5–1·5 mm exists between the retruded contact position and the intercuspal position as measured at the lower incisor point in adults (Hildebrand, 1931, cited in Bates *et al*., 1975; Heath, 1949; Posselt, 1952; Shefter and McFall, 1984; Agergberg and Sandstrom, 1988; Utt *et al*., 1995) and children (Ingervall, 1964; Kirveskari *et al*., 1986).

Coincidence of the retruded contact position and the intercuspal position was found in 22 per cent of the sample examined by Shefter and McFall (1984) and one-third of the patients investigated by Solberg *et al*. (1979), but in only 12 per cent of the sample used by Posselt (1952) and 8 per cent of a group studied by Reynolds (1970).

Clinically, the difference between the two occlusal positions can usually be easily determined by closing the mandible in its rearmost (and uppermost) position by manual guidance until the first contact is established. This is the retruded contact position. If the patient is then asked to squeeze the teeth together, a protrusive movement, sometimes with a lateral component, allows the mandible to slide towards the intercuspal position. In some patients, however, location of the retruded axis position can prove more difficult. Habitual closing movements, because they are performed repeatedly, will tend to end in the intercuspal position, rather than the retruded contact position. The precision with which ICP can be located on each successive closure is the result of a conditioned reflex, generated by a 'memory' in the neuromuscular system, known as an engram. In some individuals, the conditioned reflex makes manipulation of the condyles into the retruded axis position very difficult to achieve. This 'memory' must be constantly reinforced by tooth contacts in the intercuspal position, and if tooth contact is prevented by using an anterior jig or bite plane for a short period of time (approximately 10 minutes is usually adequate; Lucia, 1964) the proprioceptive feedback leading to reflex closure in ICP is broken. The mandible can then be more easily guided into the retruded axis position.

Much of the orthodontic literature promotes the concept of an ideal treatment goal being coincidence of the retruded contact position and intercuspal position (Williams, 1971; Aubrey, 1978; Parker, 1978; Roth, 1981; Williamson, 1981). As epidemiological studies fail to find this type of occlusion in natural dentitions, the question arises as to why this should be the goal following orthodontic treatment? The argument put forward is that non-coincidence of the two positions (RCP and ICP) is associated with temporomandibular disorders (Solberg *et al*., 1979; Ingervall *et al*., 1980). However, the evidence is inconclusive. Early workers in this field examined electromyographic activity in the muscles of mastication in individuals with occlusal interferences (Ramfjord, 1961). The use of EMG was centred on the concept that muscle activity during function should be equal bilaterally. In Ramfjord's study (1961) an occlusal discrepancy between the retruded contact position and intercuspal position demonstrated asymmetrical, so-called unharmonious patterns of muscular contraction during swallowing. However, as no proper description of 'normal' EMG activity in masticatory muscles exists, the interpretation of data from such studies is of very limited value.

Cross-sectional population studies have been carried out by a number of authors to clarify the relationship between occlusal discrepancies in the RCP–ICP range and temporomandibular disorders (Geering, 1974; Solberg *et al*., 1979; Ingervall *et al*., 1980; Egermark-Eriksson et al., 1983; De Laat *et al*, 1986; Pullinger *et al*., 1988, 1993). Again, the evidence is inconclusive. Few of these studies have used control groups, and the signs and symptoms used to describe temporomandibular disorders (TMD) are inconsistent and diverse. Furthermore, the definition of and evaluation of occlusal discrepancies in these studies lack consensus agreement. Our interpretation of the currently available evidence leads us to suggest that an intercuspal position that does not exactly coincide with the retruded contact position can be considered normal. Conversely, there is no evidence that there is any disadvantage to the patient of having a retruded contact position that coincides with the intercuspal position, but treatment need not be unduly lengthened to achieve this goal.

Posterior Tooth Relationships during Lateral Excursion

Three different types of posterior tooth relationship can occur during lateral excursion of the mandible.

Balanced occlusion. During the entire lateral movement posterior teeth on both the working side and the non-working side are in contact. Early workers in the field of occlusion assumed that this type of occlusal construction was necessary to achieve the best results for both complete dentures and the natural dentition (Monson, 1932; Schuyler, 1935). Present day thinking has completely dismissed this concept for restoring the natural dentition, although it is still useful in complete denture construction.

Group function occlusion. During the entire lateral movement the buccal cusps of the posterior teeth on the working side are in contact. There is no tooth contact on the non-working side.

Canine protected occlusion. During the lateral excursion contact occurs only between the upper and lower canine, and first premolar on the working side. There is no contact between the teeth on the non-working side. The theory of canine protected occlusion is attributed to Nagao (1919), Shaw (1924) and D'Amico (1958), and is based on the impression that the canine tooth is the most appropriate tooth to guide the mandibular excursion. There are a number of reasons why this might be so:

(1) the canine has a good crown:root ratio, capable of tolerating high occlusal forces;
(2) the canine root has a greater surface area than adjacent teeth, providing greater proprioception;
(3) the shape of the palatal surface of the upper canine is concave and is suitable for guiding lateral movements.

In the specialty of restorative dentistry, where it is possible to introduce a specific occlusal scheme during occlusal rehabilitation, attempts have been made to establish a rational basis for choosing between canine guidance and

group function by examining epidemiological data and carrying out physiological studies. Epidemiological studies have attempted to discover which type of lateral occlusal scheme is found in untreated natural dentitions. Beyron's work (1964) was some of the earliest and showed quite conclusively that adult Australian aborigines had group function occlusion. Weinberg (1964) found that 81 per cent of his sample had group function, while only 5 per cent had canine guided occlusion. By contrast, Scaife and Holt (1969) examined 1200 individuals, and discovered that the majority had either unilateral or bilateral canine protected occlusion. Ingervall (1972) found that the majority of subjects had multiple tooth contacts on at least one of the working sides. However, the most striking finding in this study was the high frequency of non-working side contacts. A number of other studies involving natural populations also found occlusal relationships in which non-working side contacts were present (De Laat and van Steerberge, 1985; Droukas *et al*., 1985; Egermark-Eriksson *et al*., 1987; Yaffe and Ehrlich, 1987; Ingervall *et al*., 1991; Tipton and Rinchuse, 1991; Takai *et al*., 1993).

These studies on occlusal contact patterns during lateral excursions report contradictory results, but this may reflect the different methodologies. Ideally, such investigations should consider the tooth contacts from the intercuspal position through the entire range of functional lateral movement, but this is difficult to achieve clinically and tooth contact patterns have therefore been recorded at various static mandibular positions. Tipton and Rinchuse (1991) recorded the tooth contact pattern with the mandible in the lateral cusp tip to cusp tip position. Droukas *et al*. (1985) and Egermark-Eriksson *et al*., (1987) recorded tooth contacts at a distance 3 mm lateral to ICP, as measured at the incisors. Ingervall *et al*. (1991) stated that a lateral excursion of this magnitude is probably rarely used during natural function and a tooth contact pattern at a position closer to ICP would be more relevent. They, together with Yaffe and Ehrlich (1987) and Takai *et al*. (1993), recorded the tooth contact pattern at 1·5 and 3.0 mm of lateral excursion. As it is common to find lateral excursions that are initiated by group function, but terminate in canine contact only at the lateral edge-to-edge position, it is essential that investigators specify at which tooth position tooth contact recordings are made.

Inconsistent results of occlusal contact pattern may also be related to the influence of the materials used to register the contacts (Takai *et al*., 1993). Methods used to record the tooth contacts have included impression material, occlusal indicator wax, articulating paper, dental floss, and direct vision. Takai *et al*. (1993), using three of these techniques, demonstrated that the number of recorded tooth contacts varies with the material used to record registrations.

Berry and Singh (1983) revealed that the location and severity of occlusal contacts in a given individual change throughout the day and this added factor contributes to the inconsistencies seen in the studies of tooth contact patterns. Disappointingly, there are probably too many uncontrollable variables in these studies to draw meaningful conclusions.

As no one type of occlusal pattern has been shown to occur in natural dentitions, a number of physiological studies have been designed in an attempt to clarify whether one particular occlusal scheme is preferable to another. Williamson and Lundquist (1983) examined electromyographic activity of the temporalis and massester muscles during lateral excursions in individuals with canine guidance and group function. Considerably less activity was observed in those individuals with canine guidance. These findings were confirmed by MacDonald and Hannam (1984) and Shupe *et al*. (1984). Belser and Hannam (1985) conducted a similar study and concluded that canine protected occlusions do not significantly alter muscle activity during mastication, but do significantly reduce muscle activity during parafunctional clenching.

The evidence in favour of one type of occlusal scheme over another is therefore scarce. Pragmatically, however, it is worth considering that a canine protected occlusion is far less likely to be associated with occlusal interferences on the non-working side than a group function occlusion due to the steeply inclined palatal surface of the canine.

Occlusal Interferences

The term occlusal interference has been defined in a number of ways. Posselt (1968) described an occlusal interference as a cuspal contact forcing the mandible to deviate from a normal pattern of movement. The sixth edition of the glossary of prosthodontic terms (VanBlarcom, 1994) defines an occlusal interference as any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts. Ash and Ramfjord (1996) wrote 'the term occlusal interference refers to an occlusal contact relationship that interferes in a meaningful way with function or parafunction'. None of these definitions is precise, but early workers in this field reached on a consensus on which features of the occlusion were likely to 'interfere' with function or parafunction by giving rise to signs or symptoms of TMD. These features were:

1. Occlusal contacts on the non-working side (Geering, 1974; Ingervall *et al*., 1980; DeBoever and Adriaens, 1983; Mohlin and Thilander, 1984; De Laat *et al*., 1986; Nilner, 1986).
2. Unilateral contacts in the retruded contact position (Ingervall *et al*., 1980; Egermark-Eriksson *et al*., 1983; Nilner, 1986; Seligman and Pullinger, 1991).
3. Long slides (greater than 1 mm) between the retruded contact position and the intercuspal position (De Laat *et al*., 1986; Pullinger *et al*., 1988, 1993).
4. Asymmetry in the slide between the retruded contact position and the intercuspal position (Solberg *et al*., 1979; De Laat *et al*., 1986; Pullinger *et al*., 1988; Seligman and Pullinger, 1991).

The limitations of these studies include the lack of agreement among authors on which features constitute TMD, lack of consistency in diagnosing occlusal interferences, and lack of any control groups. Undoubtedly, research in this area is fraught with practical difficulties, but future studies must address these issues. Until such time as prospective, longitudinal data is available it will be impossible to verify the claims made by these authors regarding the relationship between occlusal interferences and TMD.

Epidemiological studies have shown that the presence of occlusal interferences is widespread in all population groups, and that there are more people with non-ideal functional

occlusal relationships than people with signs or symptoms of functional disorders (Agerberg and Sandstrom, 1988; Heikinheimo *et al*., 1990; Ingervall *et al*., 1991). Should this evidence lead to a practice of disregarding basic functional principles during orthodontic treatment? Our reservation against adopting this approach is that the gradual adaptation of muscles and joints, which occurs during the slow development of a specific occlusion during growth, is less likely to occur following the much quicker change related to orthodontic treatment. Other possible consequences of occlusal interferences, such as bruxism and tooth wear (Faulkner, 1990), and relapse of tooth position (Sved, 1960; Storey, 1993; Weiland, 1994) may only occur some time after completion of orthodontic treatment, but may nevertheless be triggered by interferences introduced during appliance therapy.

Conclusions

The criteria that denote an 'ideal' functional occlusion have not been conclusively established. The currently available evidence is drawn from research that has a number of serious limitations. Until such time as further work in this area clarifies the issues, the following features must be assumed to be compatible with an 'ideal' functional occlusion:

1. Bilateral occlusal contacts in the retruded contact position.
2. Coincidence in the position of the retruded contact position and the intercuspal position or a short slide between the two positions (<1 mm).
3. Contact between opposing teeth on the working side during lateral jaw movements. Contact may be limited to the canines (canine protection) or extend posteriorly to include one or more pairs of adjacent posterior teeth (group function).
4. No contact between teeth on the non-working side during lateral excursions.

As there are no prospective controlled trials that conclusively establish the consequences of 'non-ideal' occlusal relationships on the dentition, it is impossible to gauge whether active orthodontic treatment should be prolonged to ensure that the objectives of an 'ideal' functional occlusion are achieved. Orthodontists are familiar with the occlusal changes which occur following the removal of appliances (a process described as occlusal 'settling') and a final assessment of functional occlusal contacts following orthodontic treatment can only be made after retention has ceased.

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