

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/5566664>

# Dental occlusion: A critical reflection on past, present and future concepts

Article in *Journal of Oral Rehabilitation* · July 2008

DOI: 10.1111/j.0305-182X.2007.01820.x · Source: PubMed

CITATIONS

95

READS

3,828

3 authors:



**Jens Christoph Türp**

University Center for Dental Medicine Basel

339 PUBLICATIONS 2,898 CITATIONS

[SEE PROFILE](#)



**Charles S Greene**

University of Illinois at Chicago

125 PUBLICATIONS 3,139 CITATIONS

[SEE PROFILE](#)



**Joerg R Strub**

University of Freiburg

294 PUBLICATIONS 7,937 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Depth Psychology and Psychotherapy [View project](#)



Ethnological field studies [View project](#)

## Review Article

# Dental occlusion: a critical reflection on past, present and future concepts

J. C. TÜRP\*, C. S. GREENE<sup>†</sup> & J. R. STRUB<sup>‡</sup> \*Dental School, University of Basel, Switzerland, <sup>†</sup>College of Dentistry, University of Illinois, Chicago, IL, USA and <sup>‡</sup>School of Dentistry, University of Freiburg, Germany

---

**SUMMARY** For nearly a century, the diversity of concepts about ‘normal’ and ‘ideal’ dental occlusal relationships has led to confusion in trying to describe the occlusion of any individual patient. In addition, a similar controversy arises when trying to formulate treatment plans for patients who need extensive dental restorations or orthodontic treatment. And finally, the application of occlusal concepts to patients with temporomandibular pain and dysfunction has created a third area of debate. Over the past few decades, however, an appreciable part of the tenacious dogmatic heritage of this topic has

been challenged. As a result, the acceptance of morphological and functional variability of the stomatognathic system has gained increasing support, and this change has important consequences for modern dental practice. In this article, the past, present and future of the subject of occlusion will be considered.

**KEYWORDS:** dental occlusion, centric relation, centric occlusion, temporomandibular disorders, gnathology

Accepted for publication 16 April 2007

---

## Introduction

Since the emergence of modern dentistry, the study of dental occlusion has been a subject of major interest (1–4). This is not surprising because knowledge about occlusion-related issues is essential to good clinical practice in all dental disciplines (5). Indeed, after a long journey throughout the history of dental practice and science, occlusion has attained its current role as ‘the medium of dentistry’ (6).

In a narrow connotation, the term ‘occlusion’ relates to the arrangement of maxillary and mandibular teeth and to the way in which teeth contact. Thus, a simple definition of occlusion includes such terms as ‘the static relationship’ (7) or ‘any contact’ (8) ‘between the incising or masticating surfaces of the maxillary and mandibular teeth or tooth analogues’ (7). In a broader context, however, the definition of the term ‘occlusion’ is not limited to morphological tooth contact relationships. Rather, it embraces the dynamic morphological and functional

relationships between all components of the masticatory system – not just teeth and their supporting tissues but also the neuromuscular system, the temporomandibular joints (TMJs) and the craniofacial skeleton (8–10).

As most dentists are aware, debates and controversies about issues related to dental occlusion have been prevalent for more than a century. These controversies have affected dental practice at every level, beginning with orthodontic issues in childhood and progressing to occlusal evaluations of ordinary adults in the dental office. In addition, the need to perform complex restorative dentistry requires some organizing concepts for delivery of optimal results – yet, dentists cannot seem to agree on what those concepts should be, nor even on what constitutes a good outcome. Furthermore, for those patients who were unlucky enough to develop pain and dysfunction in the masticatory system (temporomandibular disorders, TMDs), there has been a high probability that their problems would be analysed and treated within some occlusal paradigm.

All three of these occlusion topics have been undergoing dynamic (and mostly positive) changes during the past few decades. The general thrust of these changes has been in the direction of broader definitions for acceptable natural and therapeutic occlusal relationships, based more firmly on biological principles. In addition, the recognition that occlusal variables are only infrequently significant in the development of TMDs (11–13) has led to a more medical model for the management of those disorders.

The aim of the present article therefore was to reflect on the past, present and future of occlusal concepts. The authors hope that the clinical implications of these concepts for every practising dentist will become apparent.

### The importance of the occlusion

Besides knives and forks, teeth are the most important tools with which humans are cutting their food. Yet, the tasks associated with the dental occlusion reach far beyond masticatory tools (Table 1). The important biological and psychosocial role of the dental occlusion becomes most obvious when teeth are missing. Toothless, occlusion-free jaws are subject to a variety of functional, aesthetic, psychological and social impairments. However, in striking contrast to other mammals, where edentulousness is more or less equivalent to a death sentence, modern humans do not need teeth for survival.

**Table 1.** Various tasks of dental occlusion in modern *Homo sapiens*

Primary tasks
Food intake: biting/cutting (anterior teeth)
Mastication: food crushing (posterior teeth)
Ensuring the vertical dimension between upper and lower jaw
Ensuring the minimal distance between mandible and maxilla necessary for optimum functioning of the masseter and medial pterygoid muscles
Speech articulation: particularly anterior teeth: alveolar fricatives [s] and [z], interdental fricatives [θ] and [ð]
Jaw clenching and tooth grinding (as a consequence of stress and as part of sleep physiology or phenomenology)
Tool (teeth as 'third hand') and weapon (sharpness of anterior teeth)
Secondary tasks, shaped by socio-cultural influences
Aesthetics (anterior teeth; indirectly also posterior teeth)
Cosmetics ('white teeth'; dental adornment)
Erotic function

### Confusion in occlusion

In spite of its obvious clinical importance – or maybe because of it – the topic of occlusion has been characterized by a certain degree of confusion among dental students and practitioners. Among a variety of possible explanations, three main reasons may be identified for this phenomenon:

- 1 the growing diversity of concepts about occlusion;
- 2 shifts in the definition of important occlusion-related terms;
- 3 insufficient education about occlusal principles, as well as diversity within school faculties on these topics.

#### *The growing diversity of concepts about occlusion*

Over the years, a plethora of ideas, hypotheses, theories and practical concepts about occlusion-associated topics have been accumulated and propagated in the dental literature. Suggestions were proposed by a great variety of dentists, anatomists, anthropologists, dental technicians and others, often based on self-confident convictions and claims without scientific support. The remarkable diversity of occlusion-related clinical procedures and treatment approaches that were used over decades for the diagnosis and management of patients worldwide has left many clinicians – and patients – unsure about what the 'right' approach should be.

#### *Shifts in the definition of important occlusion-related terms*

Another source of confusion has been the change of the meaning of some long-established terms, such as *centric relation* and *centric occlusion*, for which different authors and clinicians have used various, sometimes contradictory definitions. These inconsistencies have not helped to clarify the study of occlusion. For example, the current version of the Glossary of Prosthodontic Terms (7) lists (partly for historical and educational reasons) seven different definitions of the term *centric relation* (CR). According to the Glossary, *centric relation* is currently defined as a condylar position that is located in an anterior–superior position against the slopes of the articular eminences. Conversely, some decades before, CR was described as the uppermost and rearmost position of the mandibular condyles, which implies a completely different location of the mandible, and some clinicians still use this latter definition today. Johnston (14), an orthodontist, once remarked that the

progressive modification in the definition of CR, i.e. from an extremely retruded to a more forward position, 'has done more to eliminate centric slides than 20 years of grudging acquiescence to the precepts of gnathology'. In other words, the mere change of the definition of CR brought about a significant reduction of the magnitude of centric slides.

Similar confusion exists regarding the term *centric occlusion*: once, it was a tooth-determined position, identical with maximum intercuspation of opposing teeth and irrespective of condylar position (3), and it is still defined in that way by some authors (15). Nowadays, however, the term *centric occlusion* is mostly used to characterize an occlusion of opposing teeth when the condyles are located anterosuperiorly (16), i.e. in centric relation as currently defined. This position, however, may or may not coincide with maximum intercuspation (7), so it is no surprise if many dentists are confused by this shifting terminology.

## Where do we come from? The gnathological heritage

### *The authoritarian foundation*

Long before the foundation of the Gnathological Society of California in 1926 by Beverly B. McCollum and coworkers (17), important occlusion-related morphological and functional features had been observed by anatomists and dentists. From early on, however, authoritative beliefs dominated occlusion-related topics. Typical for this way of thinking was a subjective and biased view, a lack of clear evidence and a tendency to resort to black-and-white conclusions (18). Assumptions were taken for granted, despite the fact that they were often based on a mixture of personal conviction and plausibility, but without evidence from adequate research in support of the assertions made. For example, neither the well-known Bonwill triangle nor the equally recognized curve of Spee exists today in the way they were originally described and propagated for decades. Bonwill believed that the mandible comprised an equilateral triangle running from condyle to condyle and to a point between the lower central incisors. He saw in this equilaterality a proof of the existence of God (19). As early as 1921, however, Wilson (20) noted that 'Dr. Bonwill was obsessed with the idea of an equilateral triangle', but as he correctly pointed out 'an equilateral triangle was not nature's ideal, and that

the incorporation of the theory into dentistry only added mysticism and confusion (...)'. Regarding the curve of Spee, the anthropologist Brace (19) remarked that the ideal of 'spherical articulation' maintained its popularity far into the 1940s, particularly in prosthetic dentistry. 'Now as we look back we are struck by the fact that these (geometric; *added by the authors*) views were offered and accepted in the virtual absence of supporting evidence' (19).

Later, theory-driven gnathological authorities established mechanical views of and strong opinions about the masticatory system in general and occlusion in particular. Rigid occlusal standards based on pre-determined, predominantly morphological criteria were established (8); however, Walther (21) concluded that 'they were taught and applied without prior scientific investigation'. Thus, gnathology developed on rather weak scientific grounds (22). Later, neurophysiological and biomechanical aspects were considered, but many arguments were advanced in a simplistic way, as indicated by a comparison with current literature (23, 24).

### *On the search of the ideal occlusion*

Since the mid-1920s, many concepts of a 'perfect' or 'ideal' occlusion have been proposed (3, 25–28). Yet, an 'ideal' occlusion as described by various authorities is rarely found in real life (29), and it is by no means synonymous with a physiologically acceptable occlusion (30). Instead, theoretically 'ideal' concepts of occlusion are the result of human contemplation, and as such they are subject to personal interpretation (31). As pointed out by Huffman *et al.* (27), the word *ideal* implies 'something like *infinity* in that it can be approached but never actually reached'. Hence, it is worthwhile to recall the patient-friendly statement of Becker and Kaiser (32) that 'it is presumptuous to state nature's intent for an ideal occlusion, and therefore it is recommended to avoid occlusal therapy for individuals who appear to be functioning in health, even if their occlusal scheme does not fit a concept of optimum occlusion'.

### *Therapeutic occlusion: deviations from mother nature*

In order to attain the goal of a theoretically 'ideal' occlusion, numerous therapeutic occlusal schemes for doing major reconstructive dentistry have been intro-

duced into dental practice, for instance, by Peter K. Thomas, Harry Lundeen, Everitt Payne and Michael Polz. However, Mohl (33) noted that a therapeutic occlusion may include some structural modifications that are not necessarily found in nature, and he cautioned that such concepts should not be applied to functioning patients who do not need extensive dental work. Mechanically based views of the masticatory system often fostered rigid occlusal treatment concepts that were not always tolerated by patients – regardless of the astonishing adaptive potential of the human masticatory system. For example, some full-mouth reconstruction patients had locking intercuspation in centric relation ('point centric'), with no room for anterior or lateral 'freedom'.

There is no argument about the fact that, in order to give clinicians and dental technicians a guide, certain recommendations for establishing a therapeutic occlusion are required. Interestingly, a concept of a functionally optimal occlusion as proposed 50 years ago by Beyron (34, 35) has recently been appreciated as a recommendable basis for the design of therapeutic occlusal schemes (36, 37). Instead of creating new and rigid definitions of ideal mandibular positions, tooth relationships or functional guideline patterns, these authors have adapted the empirical observations of Beyron about natural dentitions. After studying the occlusion in hundreds of successful subjects, he was able to characterize the essential features of those patients' occlusions as follows.

- 1** Maximum number of bilateral centric stops during closing in maximum intercuspation, regardless of any specific jaw relationship.
- 2** As far as possible, axial loading of posterior teeth for optimal force distribution within the alveolus.
- 3** Freedom in the retrusive range of occlusal contact (up to 1 mm), because this ensures that the mandible is not being forced into a border position as the teeth are meeting in centric occlusion.
- 4** Multidimensional freedom of occlusal contact movement, with group function during laterotrusion, and anterior tooth contacts during protrusion. This provides the most favourable force distribution for each type of functional movement.
- 5** Adequate vertical dimension of occlusion. (Note: No clear definitions for this term have ever been proposed, even by the gnathologists – but it has been discussed in terms of speaking, chewing, swallowing, freeway space, etc. As Beyron noted, the so-called 'loss

of vertical dimension' from occlusal dental wear is usually compensated to some degree by continuous eruption).

While clinicians should not necessarily regard Beyron's observations as being the final word on what a 'successful occlusion' should look like, it is pretty clear that the above parameters are fundamental elements of healthy functional occlusal relationships.

## Recent developments

### *The 'occlusion wave': new perspectives on occlusion*

The past two decades have seen a renaissance of the interest in occlusion-related topics. This is evidenced, for instance, by the publication of a variety of new textbooks (38–41) and by the fact that prestigious dental journals have devoted special issues to the topic of occlusion (42, 43). Obviously, talking about occlusion is *en vogue* again; however, this time more people are approaching this topic with a critical mind. Characteristic features of the new look have been:

- 1** a critique of the rigid traditional views that constricted the dental occlusion within narrow mechanistic concepts, instead of allowing for a multidimensional freedom of tooth contact in closure as well as in all jaw excursions;
- 2** a focus towards a biological understanding of mandibular function as well as dysfunction;
- 3** a recognition of the adaptive potentials of many components of the masticatory system – and especially the TMJs themselves.

As a result of this new awareness, a growing part of the dental community has been acknowledging that morphological and functional variation of the masticatory system is a normal biological principle rather than a sign of dysfunction or disease. Both animal and human research has shown that a 'physiological occlusion' develops through a natural process of growth and maturation, and as a result, intra- and interindividual variabilities are both normal and continuously changing. Although the occlusion of any individual patient may deviate from a pre-conceived ideal, it does not automatically require therapeutic intervention (9). Furthermore, because of local environmental factors and intra-individual biological processes (adaptations), the dental occlusion is changing constantly throughout life. For too long, this insight has not been recognized by many members of the dental profession. Instead, as

noted by Brace (19), 'since the dawn of modern dentistry, as it were, the idea of the perfect occlusion has shimmered in the imagination of the dental profession somewhat like the Holy Grail of Arthurian legend – the unattainable height of earthly aspiration'. According to Ross (44), the rare occurrence of a so-called 'perfect' or 'ideal' occlusion in natural dentitions indicates that 'nature does not require such perfection'. And finally, as we know today, occlusal variations and deviations are not necessarily associated with any specific health risks such as periodontal diseases or TMDs (45).

In this context, a few words on the term 'malocclusion' are warranted. Malocclusion is defined as 'a dental occlusion typified by variation from ideal form/morphology' (36). However, about 70% of North American youths have some form of malocclusion, mostly crowding of teeth within an Angle class I occlusion (36). Because of the large prevalence of "mal"occlusions, most of which are not bad at all, Palla (30) has recently suggested to erase the term 'malocclusion' from the dental literature. Obviously, both the biological understanding and the semantic labelling of various occlusal patterns need to be updated as new information emerges.

#### *Therapeutic occlusal concepts*

Without doubt, for restorative purposes, some scientifically based recommendations are desirable for reaching an acceptable occlusion. Okeson (4) noted that the most favourable occlusal concept should 'be the least pathogenic for the greatest number of patients over the longest time', but he did not provide any specific recommendations for achieving that goal. Today, there is an increasing tendency for caring clinicians to choose simpler therapeutic occlusal concepts and procedures that are limited to what has traditionally been conceived to be necessary, e.g. the type of functional occlusion precepts advocated by Beyron (46). Those dentists who insist on utilizing complex occlusal concepts and protocols must be viewed with skepticism unless they can prove the superiority of their personal concepts.

#### *Occlusion and temporomandibular disorders*

The importance of occlusal features as aetiologic factors for the genesis of TMDs has been de-emphasized in

recent years, based on a large body of clinical studies. Thorough reviews of the literature as well as several epidemiological investigations were unable to show that naturally occurring features such as centric, balancing, working or protrusive occlusal 'interferences', various occlusal guidance patterns, missing teeth and oral/dental parafunctions are meaningfully associated with TMD signs and symptoms (47–49). However, it has been found that the presence of painful TMDs may influence mandibular positions and movements, thus possibly leading to occlusal disturbances (50). Similarly, degenerative changes in the TMJs can lead to changes in occlusal relationships (51). This means that many of the occlusal 'imperfections' observed in these patients may be consequences rather than causes of TMDs. As such, they should not be analysed or adjusted until symptoms abate (if at all). Furthermore, TMD patients who also require prosthodontic rehabilitation should have that treatment postponed until the pain condition has been resolved (52).

Other interesting relationships between TMDs and occlusion have come from the results of experimental studies. For example, in a double-blind randomized crossover study, Michelotti *et al.* (13) demonstrated that experimental occlusal interferences do not increase the habitual activity in the jaw muscles of asymptomatic volunteers and do not lead to TMD signs and/or symptoms. On the other hand, the results of a study by Le Bell *et al.* (53) indicate that subjects with no TMD history may respond differently to experimental interferences than individuals with a former TMD history: in a randomized double-blind clinical investigation, these clinicians found that subjects without a TMD history showed fairly good adaptation to artificial occlusal interferences, while individuals with a TMD history were characterized by a significant increase in clinical signs compared with the other groups. It should be noted that the increase related only to clinical signs of TMDs but not to symptoms. Based on these findings, it appears feasible that individuals with a history of TMDs may indeed have a greater risk of developing TMD signs in response to occlusal changes from dental work, so their dentists should be aware of that possibility.

#### **Where are we heading?**

Lately, prosthodontics has been appreciated as 'a biologically based discipline with variable but profoundly significant psychosocial, functional and

aesthetic implications for each patient' (54). As a consequence, dental education needs to shift its focus from predominantly technical aspects towards the biomedical sciences and molecular biology (30). The occlusion as 'the medium of dentistry' (6) is greatly affected by this paradigm shift.

The same is true for TMDs, which have lately been characterized as a 'genetic vulnerability disorder with strong involvement of the central nervous system' (55). According to this new view, which is mostly a conceptual framework at this point in time, TMD symptoms and signs are hypothesized as being related to three factors (55, 56):

- 1 genetically determined vulnerabilities because of (i) a deficiency within genes that are responsible for coding certain proteins or (ii) the presence of gene variants (57), which make the affected individual more vulnerable to temporomandibular pain;
- 2 behavioural risk-conferring factors, such as stress-related jaw clenching or tooth grinding (12, 58, 59);
- 3 environmental risk factors, i.e. psychosocial traits and states.

In such a construct, there is not much room left for occlusion to be considered as a significant aetiological factor of TMDs.

Finally, from a clinical viewpoint, one of the most important objectives in providing any form of dental or medical therapy is patient safety (60). Patient-centred decision-making and informed partnership is gaining more and more importance. As a consequence, patient values, i.e. recognition of each patient's unique expectations, concerns and preferences, which constitute one of the three cornerstones of evidence-based dentistry (61, 62), are expected to be more deeply integrated into our clinical thinking than they have been in the past (54). One important outcome of the modern understanding of occlusion as discussed in this paper should be avoidance of occlusion-changing procedures in healthy functioning patients, while another should be the recognition that irreversible treatments are rarely required in the treatment of orofacial pain patients. With this in mind, occlusion will take its place within the biologically oriented and patient-centred dental sciences of the 21st century.

## References

1. Angle EH. Classification of malocclusion. *Dent Cosmos*. 1899;41:248–264, 350–357.

2. Washburn HB. History and evolution of the study of occlusion. *Dent Cosmos*. 1925;67:223–237,331–342.
3. Ramfjord SP, Ash MM. *Occlusion*. Philadelphia: Saunders; 1966:130.
4. Okeson JP. *Management of Temporomandibular Disorders and Occlusion*. 5th ed. St Louis: Mosby; 2003:109–126.
5. Wilson N. Foreword. In: Klineberg I, Jagger R, eds. *Occlusion and clinical practice – an evidence-based approach*. Edinburgh: Wright; 2004:v.
6. Ricketts RM. Occlusion – the medium of dentistry. *J Prosthet Dent*. 1969;21:39–59.
7. The Academy of Prosthodontics. The Glossary of Prosthodontic Terms, 8th Edition (GPT-8). *J Prosthet Dent*. 2005;94:10–92.
8. McNeill C. Fundamental treatment goals. In: McNeill C, ed. *Science and practice of occlusion*. Chicago, IL: Quintessence; 1997:306–322.
9. Mohl ND. Introduction to occlusion. In: Mohl N, Zarb GA, Carlsson GE, Rugh JD, eds. *A textbook of occlusion*. Chicago, IL: Quintessence; 1988:15–23.
10. Klineberg I, Jagger R. Preface and introduction. In: Klineberg I, Jagger R, eds. *Occlusion and clinical practice – an evidence-based approach*. Edinburgh: Wright; 2004: vii–viii.
11. Gesch D. Association of malocclusion and functional occlusion with signs of temporomandibular disorders in adults: results of the population-based study of health in Pomerania. *Angle Orthod*. 2004;74:512–520.
12. Gesch D, Bernhardt O, Mack F, John U, Kocher T, Alte D. Association of malocclusion and functional occlusion with subjective symptoms of TMD in adults: results of the Study of Health in Pomerania (SHIP). *Angle Orthod*. 2005;75:183–190.
13. Michelotti A, Farella M, Gallo LM, Veltri A, Palla S, Martina R. Effect of occlusal interference on habitual activity of human masseter. *J Dent Res*. 2005;84:644–648.
14. Johnston LE Jr. Fear and loathing in orthodontics. Notes on the death of theory. In: Carlson DS, ed. *Craniofacial growth theory and orthodontic treatment*. Craniofacial growth series, monograph 23. Ann Arbor, MI: Center for Human Growth and Development, University of Michigan; 1990:23.
15. Ash MM, Nelson SJ. *Wheeler's dental anatomy, physiology, and occlusion*. 8th ed. Philadelphia: Saunders; 2003:417.
16. Klineberg I. Interarch relationships of teeth. In: Klineberg I, Jagger R, eds. *Occlusion and clinical practice – an evidence-based approach*. Edinburgh: Wright; 2004:3–12.
17. Stuart CE, Golden IB. *The history of gnathology*. Ventura, CA: C.E. Stuart Gnathological Instruments; 1981.
18. Needleman I. Introduction to evidence based dentistry. In: Clarkson J, Harrison JE, Ismail AI, Needleman I, Worthington H, eds. *Evidence-based dentistry for effective practice*. London: Martin Dunitz; 2003:1–17.
19. Brace CL. Occlusion to the anthropological eye. In: McNamara JA Jr, ed. *The biology of occlusal development*. Ann Arbor, MI: Center for Human Growth and Development, The University of Michigan; 1978:179–209.
20. Wilson GH. The anatomy and physics of the temporomandibular joint. *J Nat Dent Assoc*. 1921;8:236–241.

21. Walther W. Determinants of a healthy aging dentition: maximum number of bilateral centric stops and optimum vertical dimension of occlusion. *Int J Prosthodont.* 2003;16 (Suppl.):77–79; discussion 89–90.
22. Woda A. A step toward setting norms: comments on the occlusal interface. *Int J Prosthodont.* 2005;18:313–315.
23. van Eijden TM. Biomechanics of the mandible. *Crit Rev Oral Biol Med.* 2000;11:123–136.
24. Türker KS. Reflex control of human jaw muscles. *Crit Rev Oral Biol Med.* 2002;13:85–104.
25. Friel S. Occlusion: observation on its development from infancy to old age. *Int J Orthod.* 1927;13:323–342.
26. Stuart CE. Good occlusion for natural teeth. *J Prosthet Dent.* 1964;14:716–724.
27. Huffman RW, Regenos JW, Taylor RR. Principles of occlusion. Laboratory and clinical teaching manual. Ohio State University. Department of Operative Dentistry. Columbus, OH: H & R Press; 1969:I-A-12.
28. Andrews LF. The six keys to normal occlusion. *Am J Orthod.* 1972;62:296–309.
29. Woda A, Vigneron P, Kay D. Nonfunctional and functional occlusal contacts: a review of the literature. *J Prosthet Dent.* 1979;42:335–341.
30. Palla S. The interface of occlusion as a reflection of conflicts within prosthodontics. *Int J Prosthodont.* 2005;18:304–306.
31. Carlsson GE, Haraldson T, Mohl ND. The dentition. In: Mohl N, Zarb GA, Carlsson GE, Rugh JD, eds. A textbook of occlusion. Chicago, IL: Quintessence; 1988:57–69.
32. Becker CM, Kaiser DA. Evolution of occlusion and occlusal instruments. *J Prosthodont.* 1993;2:33–43.
33. Mohl ND. Diagnostic rationale: an overview. In: Mohl N, Zarb GA, Carlsson GE, Rugh JD, eds. A textbook of occlusion. Chicago, IL: Quintessence; 1988:179–184.
34. Beyron H. Characteristics of functionally optimal occlusion and principles of occlusal rehabilitation. *J Am Dent Assoc.* 1954;48:648–656.
35. Beyron H. Occlusion: point of significance in planning restorative procedures. *J Prosthet Dent.* 1973;30:641–652.
36. Bryant SR. The rationale for management of morphologic variations and nonphysiologic occlusion in the young dentition. *Int J Prosthodont.* 2003;16 (Suppl.):75–77; discussion 89–90.
37. Klineberg I, Stohler CS. Study group report and discussion. *Int J Prosthodont.* 2003;16(Suppl.):89–90.
38. Mohl N, Zarb GA, Carlsson GE, Rugh JD, eds. A textbook of occlusion. Chicago, IL: Quintessence; 1988.
39. McNeill C. Science and practice of occlusion. Chicago, IL: Quintessence; 1997.
40. Klineberg I, Jagger R, eds. Occlusion and clinical practice – an evidence-based approach. Edinburgh: Wright; 2004.
41. Laskin DM, Greene CS, Hylander WL. TMDs. An evidence-based approach to diagnosis and treatment. Chicago, IL: Quintessence; 2006.
42. Nelson SJ, Nowlin TP. Occlusion. *Dent Clin North Am.* 1995;39:233–477.
43. Klineberg I, Stohler. Interface of Occlusion. *Int J Prosthodont.* 2005;18:277–315.
44. Ross B. Satisfactory occlusal relations for the individual with a craniofacial anomaly. *Int J Prosthodont.* 2003;16(Suppl.):74–75; discussion 89–90.
45. Mohlin B, Kurol J. To what extent do deviations from an ideal occlusion constitute a health risk? *Swed Dent J.* 2003;27: 1–10.
46. Wiskott HW, Belser UC. A rationale for a simplified occlusal design in restorative dentistry: historical review and clinical guidelines. *J Prosthet Dent.* 1995;73:169–183.
47. Stohler CS. Clinical decision-making in occlusion: a paradigm shift. In: McNeill C, ed. Science and practice of occlusion. Chicago, IL: Quintessence; 1997:294–305.
48. Gesch D, Bernhardt O, Kirbschus A. Association of malocclusion and functional occlusion with temporomandibular disorders (TMD) in adults: a systematic review of population-based studies. *Quintessence Int.* 2004;35:211–221.
49. Gesch D, Bernhardt O, Alte D, Kocher T, John U, Hensel E. Malocclusions and clinical signs or subjective symptoms of temporomandibular disorders (TMD) in adults. Results of the population-based Study of Health in Pomerania (SHIP). *J Orofac Orthop.* 2004;65:88–103.
50. Obrez A, Türp JC. The effect of musculoskeletal facial pain on registration of maxillomandibular relationships and treatment planning: a synthesis of the literature. *J Prosthet Dent.* 1998;79:439–445.
51. Plesh O, Stohler CS. Prosthetic rehabilitation in temporomandibular disorder and orofacial pain patients. Clinical problem solving. *Dent Clin North Am.* 1992;36:581–589.
52. Türp JC, Strub JR. Prosthetic rehabilitation in patients with temporomandibular disorders. *J Prosthet Dent.* 1996;76:418–423.
53. Le Bell Y, Jämsä T, Korri S, Niemi PM, Alanen P. Effect of artificial occlusal interferences depends on previous experience of temporomandibular disorders. *Acta Odontol Scand.* 2002;60:219–222.
54. Klineberg I, Stohler CS. Introduction to study group reports. *Int J Prosthodont.* 2005;18:277–279.
55. Stohler CS. TMJD 3: A genetic vulnerability disorder with strong CNS involvement. *J Evid Based Dent Pract.* 2006;6: 53–57.
56. Stohler CS. Taking stock: from chasing occlusal contacts to vulnerability alleles. *Orthod Craniofac Res.* 2004;7:157–161.
57. Zubieta JK, Heitzeg MM, Smith YR, Bueller JA, Xu K, Xu Y *et al.* COMT val158met genotype affects mu-opioid neurotransmitter responses to a pain stressor. *Science.* 2003;299: 1240–1243.
58. Huang GJ, LeResche L, Critchlow CW, Martin MD, Drangsholt MT. Risk factors for diagnostic subgroups of painful temporomandibular disorders (TMD). *J Dent Res.* 2002;81:284–288.
59. Velly AM, Gornitsky M, Philippe P. Contributing factors to chronic myofascial pain: a case-control study. *Pain.* 2003;104:491–499.
60. Zarb G. The interface of occlusion revisited. *Int J Prosthodont.* 2005;18:270–271.

61. Clarkson J, Harrison JE, Ismail AI, Needleman I, Worthington H, eds. Evidence-based dentistry for effective practice. London: Martin Dunitz; 2003.
62. Straus SE, Richardson WS, Glasziou P, Haynes RB. Evidence-based medicine. How to practice and teach EBM. 3rd ed. Edinburgh: Churchill Livingstone; 2005.

Correspondence: Prof. Dr Jens C. Türp, Klinik für Rekonstruktive Zahnmedizin und Myoarthropathien, Universitätskliniken für Zahnmedizin, Hebelstrasse 3, CH-4056 Basel, Switzerland.  
E-mail: jens.tuerp@unibas.ch