

# Methodological Challenges in the Study of Dental Occlusion

**A Jokstad**

University of Toronto, Faculty of Dentistry, Ontario, Canada

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Correspondence and requests for reprints to:

Dr. Asbjørn Jokstad, DDS, Dr. Odont.

Prosthodontics, Faculty of Dentistry, University of Toronto,

124 Edward Street, Toronto ON M5G 1G6, Canada

Phone: +1-416-979-4930 ext 4427

Fax: +1-416-979-4769

email: [a.jokstad@dentistry.utoronto.ca](mailto:a.jokstad@dentistry.utoronto.ca)

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## Summary of review

This narrative review describes the methodological challenges in the study of dental occlusion. The reigning confusion about the scope of this topic is discussed, and a conceptual framework for understanding dental occlusion research is suggested. The characteristics of clinical studies used in the study of dental occlusion as well as their outcomes are presented within this proposed framework consisting of a triad comprising **the mandibular teeth alignments and - positions relative to the maxillary teeth**, the oral functions and oral appearance. Challenges in the preparation for a clinical study of dental occlusion are reviewed, which include a discourse on the objectives of a clinical study and appropriateness of different study designs. Guidelines are provided for the conduct of studies with a central focus on dental occlusion and diagnostic tests, prognosis, therapy and aetiology respectively. Summarizing chapters present methodological challenges in designing a clinical study of dental occlusion and threats to the proper conduct of a clinical study.

## Introduction

Few topics in dentistry can arise as much controversy as dental occlusion. On surface **it is** unclear why, since the term “occlusion” literary means “to close / bring together” and is commonly applied to describe the morphology of the contacting, i.e., occlusal, surfaces of opposing teeth in animals and humans. The Glossary of Prosthodontic Terms is considered one of the authoritative sources of definitions in dentistry and even though the glossary contains 152 definitions that include the term “occlusion” or “occlusal” the actual definition of occlusion is “*The static relationship between the incising/ masticating surfaces of the maxillary / mandibular teeth / tooth analogues*”<sup>1</sup>. Alas, one needs only to go to a few respected textbook on the subject. In the textbook on occlusion by Okeson<sup>2</sup> occlusion is defined simply as “*the static relationship of the teeth*” while Mohl et al.<sup>3</sup> argues that “...*occlusion encompasses all factors that serve to bring about, affect, influence, or result from mandibular position, function, parafunction, and dysfunction. It implies much more than the occlusal contact relationships of the dentition and includes reference to a dynamic biomechanical musculoskeletal system: the masticatory system*”. Multiple other definitions of occlusion can be found in the dental literature that range between these two diverging definitions. In some way, the latter extensive definition reflects the core idea of gnathology, which most today consider as outdated. In its days gnathology aimed to study “... *the biologics of the masticating mechanisms; that is, the morphology, anatomy, histology, physiology, pathology and the therapeutics of the oral organ, especially the jaws and teeth and the vital relations of the organ to the rest of the body*”<sup>4</sup>. The last textbooks in English containing “gnathology” in the title vanished from the market in the mid-1980s<sup>5,6,7,8,9</sup>. However, the lasting influence of gnathology on the clinical practice of dentistry and prosthodontics in particular is readily recognized <sup>10</sup>. **It is** also an interesting repetition of history that dentists captivated by dental occlusion and jaw movements since the 1930s have used mechanical instrumentations and label the practice as gnathology while some contemporary dentists today use “computerized electro-diagnostic instrumentation” and label the practice as neuromuscular dentistry, or, if using the absolute latest innovative label: “gneuromuscular dentistry”. There is lots of continuing education money to be made if the confusion about dental occlusion can continue to

prevail. Perhaps the fact contributes to why dental clinicians, researchers and educators cannot come to terms on how we should define, understand and emphasize or de-emphasize when considering the subject coined “dental occlusion”. As long as ill-defined terms and concepts are being used in prosthodontics<sup>11</sup> and dental occlusion, scientific discourses risk ending up in semantic confusion<sup>12,13,14</sup>.

### **Characteristics of Biomedical Research**

Researchers aim to find and determine facts, solve new or existing problems, prove new ideas, or develop new theories, usually using a scientific method. Research is traditionally labelled as basic or applied, but both with the essential components of formulating, testing, and modifying hypotheses through systematic observations, measurements, and experiments. Hence, the most common scientific method used today is termed the hypothetico-deductive model. In essence, probabilistic considerations determine whether hypotheses remain or are discarded, using the near-mythical “p-values” as virtual thresholds. Discussing elements of the philosophy of science is far beyond the intentions of this paper and the interested reader should study the recent outstanding textbooks on the subject by Rosenberg<sup>15</sup>, Goodman & Putnam<sup>16</sup> and Thompson<sup>17</sup>. Clinical research comes under the category of applied research and includes (i) animal studies, (ii) epidemiology and (iii) clinical studies on human subjects.

### **Characteristics of Clinical Studies**

At the core of a doctor and patient interaction is the need of the doctor to learn or know thoroughly (Greek: *Gnosis*) the condition’s probable cause (Greek: *Aitio*), to distinguish the signs and symptoms of the condition apart (Greek: *Dia*) and to know the likely outcome of the condition beforehand (Greek: *Pro*) with or without a cure (Greek: *Therapeia*). Today, clinical studies are categorized along these old Greek terms into the four domains Aetiology, Diagnosis, Prognosis or Therapy.

Clinical study terminology may sometimes remind one of the Bible story about the Tower of Babel. For a start, clinical studies are either experimental or observational and for the former the term “controlled trial” is preferred to “study”. A prudent approach is to recognize and adopt the six categories that the US National Library of Medicine currently use to describe clinical study designs in the Medline database, i.e., so-called

Medical Subject Headings or MESH terms. The six categories are two types of experimental study designs (1) Randomized controlled trial (RCT) and (2) Controlled clinical trial (CCT) and the difference lies within the names. The four remaining clinical study designs are observational, i.e., (3) Cohort study, (4) Case-control study, (5) Cross-sectional survey, and (6) Case–study or case–series. It should be noted that “cohort study” sometimes in the dental literature and elsewhere mean something else. Occasionally, the original meaning is correct, as in epidemiology to describe a population sample that has been exposed to some extrinsic or intrinsic risk or prognostic factor and followed for a set period of time (longitudinal study). Sometimes, however, the term “cohort” is improperly applied to reports on case-series and so-called two-cohort studies are sometimes a retrospective case-control study, a cross-sectional study, a CCT or simply a description of two case series.

### **A Conceptual Framework for Understanding Dental Occlusion**

Even though the difference of opinions about definitions and scope is acknowledged, addressing a topic such as “*Methodological challenges in the study of dental occlusion*” must necessarily have a structure. Designing laboratory experiments or animal studies according to good research principles, as well as challenges with epidemiological studies with regards to the study of dental occlusion will not be covered in this review and focus will be directed towards clinical studies.

Dental occlusion can conceptually be described within the framework of three dimensions, i.e., **the mandibular teeth alignments and -positions relative to the maxillary teeth** in context with oral functions and oral appearance or “look” (Fig. 1).

A possible avenue for the study of dental occlusion is to establish valid and reliable objective and subjective measurement tools as a basis for relating findings to, e.g., normative values. Many of these studies are purely descriptive of some morphology, function or phenomenon examined clinically or by the use of some more or less sophisticated imaging technique or recording device. A second category of studies explore the possible interactions between **the mandibular teeth alignments and -positions relative to the maxillary teeth** and oral functions and/or oral appearance. A

spectrum of hypotheses has been forwarded about possible associations between any of the items shown in Fig. 1. from analytical clinical studies exploring possible inferences of causal associations<sup>18,19,20,21,22</sup>. A third research avenue has been to establish epidemiological data of particular details of the dental occlusion in populations and subpopulations, including in patients. The possible research avenues for the study of dental occlusion described above are all associated with challenges with regard to study methodologies, covered in subsequent sections. Space does not allow for the citation of representative studies within all the research questions that will be identified in this review paper.

A next level of describing the scope of research on dental occlusion defined within the proposed conceptual triad framework is how any of the possible associations listed above are influenced by: (i) general medical conditions such as bruxism, craniofacial anomalies, head or body posture, hormonal state, rheumatoid arthritis and temporomandibular disorders (TMDs) or temporomandibular joint (TMJ) disease, (ii) by general or local conditions such as pain, inflammation or xerostomia or (iii) by neuro-muscular response mechanisms that involve jaw proprioception and the observable individualized adaptive capacity to tolerate occlusal interference and/or changes of the vertical dimension of occlusion. The opposite of framing questions about potential influences of extrinsic and intrinsic factors on occlusion are investigations with objectives to examine to what extent occlusion affects activities of the muscles of the stomatognathic system individually and as a whole, the anatomical configurations of the different components within the TMJ, influence on obstructive sleep apnea or even on the cervical spine. Further extensions of these inquiries are the studies of the possibility, if any, of dental occlusion causing particular forms of headache, alternatively “trauma” to the periodontium or to the TMJs. Finally, several investigators have embarked on epidemiological study to establish possible association between dental occlusion and conditions such as cognitive function, mortality, nutrition, physical performance and quality of life. A wide range of basic and clinical research, including both experimental and observational clinical studies, have been attempted to elucidate the research questions, which falls within the categories aetiology, diagnosis, prognosis and therapy (Fig. 2).

Although the listed research topics are not particular to adults, very few studies involve children and adolescents. One explanation is probably the awareness of increased vulnerability of young participants. Within these two age groups the research avenues are possible extrinsic and intrinsic influences on jaw growth and development. E.g., studies on sucking habits, facial asymmetry and muscle thickness fall into this category of research and will not be dealt with in this paper. The same applies to the subject of genetic research involving genotype-phenotype distinctions to understand variations in tooth-jaw position, oral function and oral appearance.

A first category of clinical research pertaining to management of patients seeking treatment for dental occlusion issues revolve around issues such as subjective versus objective needs, patient expectations and communication (Fig. 3).

Moreover, research is directed towards conditions unrelated to tooth disease or as consequences of deteriorating dentition. In the first category are the questions on how to correctly diagnose, understand aetiology, establish prognosis and provide best therapy for patients within the “position”, oral functions” and “oral appearance” categories. Only one “illness” of the mandibular teeth alignments and -positions relative to the maxillary teeth has been recognized, which is coined “phantom bite” or “oral dysesthesia”. The diagnosis is not dental and is considered as a delusional disorder according the current ICD classifications. Dentists can actually make the condition worse by attempting to “cure” the disorder by providing dental therapy<sup>23</sup>. For the dentists, more relevant clinical-focused questions are whether particular features of the dental occlusion can be considered as a causal risk factor for diseases and conditions such as caries, periodontitis, tooth substance loss, TMD or TMJ problems or poor occlusal stability. “Dys-function” conditions where active research is done to elucidate hypothetical causal chains to the dental occlusion triad are dyskinesia, awake bruxism, sleep-behaviour-induced sleep bruxism, TMD and pain. Finally, several researchers have investigated relationships between patient smile, alternatively disfigurement, which both encompass dental occlusion, and asked individuals and professionals or even the patients themselves for their views on psychosocial value, quality of life and or societal determinants of acceptability.

A second category of clinical research is directed towards (i) the consequences for the patient if a deteriorating dentition remains non-restored and (ii) the alleged benefits to the patient if the dental occlusion is reconstructed using alternative technical solutions. The research has involved patients with restored teeth in a more or less intact dentition, patients with partially edentate jaws restored or not restored with tooth analogues, and patients with one or two edentate jaws restored with removable conventional prostheses or removable or fixed prostheses retained by dental implants (Fig 4).

The potential negative effects of dental occlusions rehabilitation, sometimes according to a particular occlusal scheme, have been addressed relative to risk of periodontal breakdown, access to oral hygiene, removable prostheses instability, wear of the artificial teeth or the restorative material and consequences of possible interferences introduced by the operator. Some will also advocate that the study of dental occlusion should encompass investigations of minimum requirements of intra-tooth, full-coverage, partial and complete fixed or removable reconstructions to resist functional forces, mostly generated on the occlusal surface.

A major confounder contributing to the reigning confusion about the merits of rehabilitation with or without a particular dental occlusion scheme is the lack of consensus about which outcome to use for documenting treatment success. Patients with a deteriorating dentition may (still today!) be warned by some dentists about increased risks for potential adverse changes in the TMJs, development of TMDs, initiation of adverse bruxism, added wear of the remaining teeth and loss of the stability due to tooth tipping and/or extrusion causing possible interferences and ultimately a “bite collapse”. There are papers supporting any and all of these claims, although most of these were published in an era not reflecting today’s rigorous requirements for using meticulous study methodologies. The same applies to many of the papers reporting the alleged benefits to the patient if the dental occlusion is reconstructed, or reconstructed in some very particular way. What can clearly be stated is that several textbooks on oral rehabilitation are full of dogmas that have more or less all been based on deductive logic and not on inductive research. These dogmas include, but are not limited to, a pot-pourri of rules like “condyles should rest in their most supero-anterior position against



the posterior slopes of the articular eminence”; “articular disks must be properly interposed between the condyles and the fossae”, “the posterior teeth must have an even and simultaneous contact in centric relation”, “anterior teeth should contact and disclude the posterior teeth upon eccentric movement”, “in the upright head position the posterior teeth must contact more prominently than the anterior tooth contacts”, “provide the most shallow anterior guidance patterns that disclude posterior teeth”<sup>24,25</sup>. Several excellent reviews discuss the problems of interpreting the literature on whether occlusal features are of importance with regard to the outcomes following rehabilitation with conventional removable prostheses<sup>26</sup>, conventional and implant-retained removable prostheses<sup>27,28</sup> and implant-retained prostheses in general<sup>29</sup>.

## Outcomes

Outcomes, or sometimes more optimistically coined as “treatment success” following change of dental occlusion, fall within one of four categories: “surrogate”, “clinical”, “patient relevant” or “societal”. Surrogate outcomes are well known in the literature related to drug and medical devices trials and has been defined in the as “*a laboratory measurement or a physical sign used as a substitute for a clinically meaningful endpoint that measures directly how a patient feels, functions or survives. Changes induced by a therapy on a surrogate endpoint are expected to reflect changes in a clinically meaningful endpoint*”<sup>30</sup>. Pertaining to dental occlusion the most obvious surrogate outcomes are electromyography and 2- or 3-dimensional images of the TM-joint using an array of different imaging modalities. Also different oral functions have been appraised by using some method of objective measurements, e.g., chewing effectiveness, mandible trajectory tracked using a spectrum of different technologies, swallowing thresholds or even energy efficiency using particular type of hard/soft/brittle foods; speech clarity as well as maximum or habitual bite forces. There is little evidence to suggest that these measurements are predictive of patient-relevant outcomes. Finally, some investigators have made attempts to score facial or smile aesthetics objectively, again with uncertain correlations with patient-reported satisfaction. Patient-relevant outcomes are, e.g., self-reported pain or discomfort, acceptability of treatment, patient preference of alternative treatments, satisfaction with function (e.g., chewing,

dietary changes, speech), satisfaction with aesthetics, reported changes of social activity or perceived change of quality of life/health measures. Clinical outcomes that are meaningful for both care providers and patients are typically complications and treatment failures, e.g., need for re-treatment (re-operation and/or remake), failure of a newly made prosthesis, biological complications, mechanical complications and time to any retreatment. The last category, economic outcomes, includes: service utilisation or resource use, link between resource use and outcomes and enumeration of monetary and volume or other costs. The great majority of clinical studies have reported outcomes following interventions directed towards dental occlusion in the order as presented above<sup>31,32,33,34</sup>.

Moreover, several papers reporting on the alleged benefits of changes of dental occlusion on orofacial pain and TMDs/TMJ's include also more details beyond the prevalence or incidence of signs and symptoms pertaining to these conditions. Examples are patient-reported pain in the specific cranial areas, such as joints, muscles and/or head, TMJ sounds and sound character, particular details of jaw movement limitations, unassisted or clinician-induced tenderness upon palpation of TMJ or masticatory muscles or observations of movement limitations or sounds, x-rays, MRI, EMG, and jaw tracking while chewing is simulated. Truly, a bewildering group of treatment outcomes prone to bias upon use for a health condition that there is still no clear understanding of, nor consensus with regard to subcategories and the most appropriate criteria for diagnosing these<sup>35</sup>.

### **Characteristics of Clinical Studies used in the Study of Dental Occlusion**

As explained earlier, clinical research is commonly categorized into the four main categories: diagnosis, prognosis, therapy and aetiology. A cursory search in bibliographic databases will demonstrate that the majority of studies on dental occlusion are about aetiology. This is surprising, considering that **it is** far more difficult to falsify a hypothesis about aetiology compared to other research issues if one remains loyal to the hypothetico-deductive reasoning model in scientific research. An important premise is made in this statement, which is that a hypothesis must be falsifiable in order to

qualify as being scientific<sup>16</sup>. Within the realms of very vocal “gnathologists, equilibrists, neuromuscular dentists and gneurologists” it is understandable that the literature on dental occlusion abounds with ideas and theories that are not scientific and hence, refutable by research, however well undertaken.

### **Challenges in the Preparation for a Clinical Study of Dental Occlusion**

A clinical study is commonly initiated because (i) previous clinical studies have had conflicting results, been undersized or have demonstrated a difference, which needs clarification; (ii) findings in basic sciences or animal studies have been consistent and promising and the potential risks of adverse events in humans is considered low or (iii) clinical findings from studies having employed a methodologically weaker design, e.g., a case report or a case series, are promising. Whether the focus is on aetiology, diagnosis, prognosis or therapy, some study designs are preferable from a study methodological perspective (described in a following sections), but obviously will need to be considered in light of the local culture for clinical research, as described above; available resources and competencies; patient accrual availability, and time and money.

A very important element before proceeding with any clinical study is to conduct a systematic review (SR) on the topic, since exposing human subjects to interventions that have been shown to be inefficient or even harmful is unethical. For this reason, many medical granting organizations mandate a SR included in applications. If for nothing else, one learns from critically appraising previous studies which mistakes not to repeat in a new attempt.

At the core of clinical studies lies ethics, with focus on respecting the patient’s autonomy and adhere to the principles of non-maleficence, beneficence and justice<sup>36</sup>. Some countries mandate courses in research ethics before allowing potential investigators to proceed with the undertaking of clinical studies, e.g. online courses in the US<sup>37</sup> and Canada<sup>38</sup>. All ethics and regulations of clinical research worldwide are regulated by the Helsinki declaration, originally developed by the World Medical Federation in 1964 and now in its current 8<sup>th</sup> edition from 2008<sup>39</sup>. Before embarking on a clinical study it is important to consider how to interact with all potential stakeholders. First and foremost,

the relevant research ethics board (REB), also known as an institutional review board (IRB) in USA or (regional) ethics board in other countries must be involved and be consulted as much as possible prior to embarking on a study. Being a primary investigator entails also the undertaking of several central tasks:

- consider whether an external clinical research organization (CRO) should become involved in the project, either for designing the protocol, act as external monitoring body or for other involvements
- determine how many and which clinical centers should become involved. Sometimes this may become a necessity to accrue enough patients or enough patients within a defined time limit
- decide whether and how many face-to-face protocol development and/or calibration meetings need to be organized
- define the target patient population with specific inclusion and exclusion criteria
- identify possible threats to patient confidentiality, establish procedures to maintain confidentiality and protocols to follow to adhere to these procedures
- design proper case report forms (CRFs), which in some parts of the world, e.g., Europe, are mandatory and considered as legal documents

### **Views, Beliefs and Perceptions about Dental Occlusion and lack of Qualitative Research**

While many questions can be answered by the study design described in the previous sections, there are still a few others that remain (Table 1). Perhaps one area in the research on dental occlusion that has been neglected is a lacking of good qualitative research. Qualitative research aims to make sense of or interpret phenomena in terms of the meanings patients and/or clinicians bring to them. The research may define preliminary questions which can then be addressed in quantitative studies, e.g., patient's versus dentist's perception of smile aesthetics<sup>40</sup>. Qualitative research should address clinical problems through clearly formulated questions and use more than one research method (triangulation) and analyses of qualitative data can and should be done using explicit, systematic, and reproducible methods<sup>41,42</sup>.

## Threats to Proper Conduct of a Clinical Study

The final threats to undertake proper clinical research can be categorized into making errors in (i) study execution, (ii) data analysis, (iii) data interpretation, (iv) data omission, and (v) data presentation. Always use a checklist adapted for the study design when designing, executing and writing your research report. The current guidelines for correct reporting can at any time be found on the website of EQUATOR (Enhancing the Quality and Transparency of Health Research)<sup>43</sup>. Investigators and clinicians with ambitions to venture into designing and/or interpreting medical research methodology and statistics should study central textbooks on the subject for deeper understanding; e.g., authored by Altman<sup>44</sup>, Groten et al.<sup>45</sup>, Haynes et al.<sup>46</sup>, Gøtzsche<sup>47</sup> or Laake et al.<sup>48</sup>.

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**Table 1. Possible question pertaining to the study of dental occlusion**

<b>Question about</b>	<b>Example question:</b>
Diagnosis	What are the merits of using T-Scan to determine the extent and severity of occlusal interferences? <b>Expected study design: Cross-sectional / Cohort</b>
Therapy	Which restorative occlusion scheme / education strategy is the best on implant restorations? <b>Expected study design: RCT</b>
Prognosis	What will develop due to (or following introduction of) occlusal interferences? <b>Expected study design: Cohort</b>
Screening	How many patients have occlusal interferences upon mediotrusion? <b>Expected study design: Cross-sectional / Cohort</b>
Views/ Beliefs/ Perceptions	How do occlusal interferences impact on the patient's daily life? <b>Expected study design: Qualitative Research</b>
Prevalence / Hypothesis generation	How many patients have had a negative experience associated with their occlusion? <b>Expected study design: Cross-sectional / Qualitative Research</b>

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## Legends to Figures

Figure 1. Conceptual description of the subject “Dental occlusion” within the framework of the three dimensions: the mandibular teeth alignments and -positions relative to the maxillary teeth, oral functions and oral appearance.

Figure 2. Experimental basic and clinical research activities of the subject “Dental occlusion” within the framework of the three dimensions: the mandibular teeth alignments and -positions relative to the maxillary teeth, oral functions and oral appearance.

Figure 3. Clinical research activities with focus on clinical care and patient management of the subject “Dental occlusion” within the framework of the three dimensions: the mandibular teeth alignments and -positions relative to the maxillary teeth, oral functions and oral appearance.

Figure 4. Research issues linked to the study of the dental occlusion (red boxes) in patients with intact and restored dentate and partially edentate jaws and in patients with one or two restored edentate jaws (green boxes).