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An evidence-based guide to occlusion and articulation. *Part 1: Occlusal terminology and a guide to jaw movement.*

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SUMMARY AND PREAMBLE TO THE SERIES

Although this is essentially a review, it has not been written in the passive, third-person style normally associated with scientific writing, as it is intended to be thought-provoking and, hopefully, educational. It has therefore been written in more of a conversational style, and is aimed at students, dentists and dental technicians who are receptive to a slightly different view of occlusion and articulation, based on evidence.

Occlusion is a topic that has become a kind of archaic minefield of conflicting ideas, propositions, and above all, solutions, most of which are based on a complete lack of understanding of the evolution and development of teeth, and by extension, of clinically objective evidence.

That in itself is a statement of conflict (and perhaps even heretical), but it is by way of warning that this guide is not going to be much like anything you will find in standard text-books of dentistry or dental technology. It is, rather, an attempt to help you navigate through what you will read elsewhere, in the hope that eventually you will find an understanding that you can live with. It will appear as a sequential series in 7 Parts.

Occlusal terminology and a guide to jaw movement.

The first thing to understand, is that no-one was really concerned about the term *occlusion* until the late 19th century, about 40 years after the industrial revolution (which was from about 1760 to 1840). Before 1880, occlusion meant, according to an online etymological dictionary:[1]

"act or fact of being stopped up," 1640s, from Medieval Latin occlusionem (nominative occlusio), noun of action from past-participle stem of Latin occludere (see occlude). Dentistry sense "position of the two sets of teeth relative to each other when the mouth is closed" is from 1880".

Quite how occlusion came to mean that, no-one seems to know. Coincidentally, toothpaste in a tube was invented at about the same time, and in the US the first national examining board was created. All of which are just coincidences. There were no apparent theories of occlusion until an American dentist, Edward Angle, described what he called different *mal*occlusions, in 1898. He also attempted to define "normal" occlusion.[2] In the next 40 years or so, all sorts of assumptions were made about the relationship of occlusion to all sorts of symptoms from muscle spasms to joint pain, ear ache and tinnitus and, even this: *"In the evaluation of this survey, there appears to be a close relation between malocclusion and insanity"* quoted in a 1956 paper![3-5]

In 1961 two much-quoted and still seemingly revered but now somewhat discredited papers (which were basically the same study published in two different places) reported the use of occlusal adjustments to relieve muscle and joint pain and bruxism.[6,7] There was no evidence for such adjustments and the author even stated *"Unavoidable resettling of the teeth after the first two or three adjustments occasionally resulted in new interferences that had to be eliminated".* There was no control group and no follow-up of the patients, merely a claim that their muscle pain and bruxism was relieved. Tons of enamel have since been destroyed on the altar of those scientifically flawed papers, quite unnecessarily.

There is a distinct lack of evidence in many of theories of occlusion and you will find it all over text-books of occlusion and very many people will continue to believe in the dogmas they want to believe in, without really questioning the evidence. Recent political events all over the world attest to the fact that facts often get in the way of beliefs. So what *are* the facts? The fact (sorry) is, there is no relationship between malocclusion, occlusion, and symptoms related to orofacial pain, the temporomandibular joint, ear ache or insanity.[2,8-10] Although to be fair, there is evidence of brain activity associated with chewing, and some neuroscientists believe that that the inability to chew may be linked to dementia; but once again a direct causal relationship has not been shown.[11]

All of which doesn't really help us when we need to replace the occlusal surface of some or all of the teeth, or to simply replace all of the teeth themselves. In order to do this, we do need to know something of how the jaw moves, and what happens when we do chew. So that is what this guide is going to try to do: explain as simply as possible just what the relationship is between jaw movements and the way teeth come together statically and, more importantly, functionally, so that we can understand how to replace

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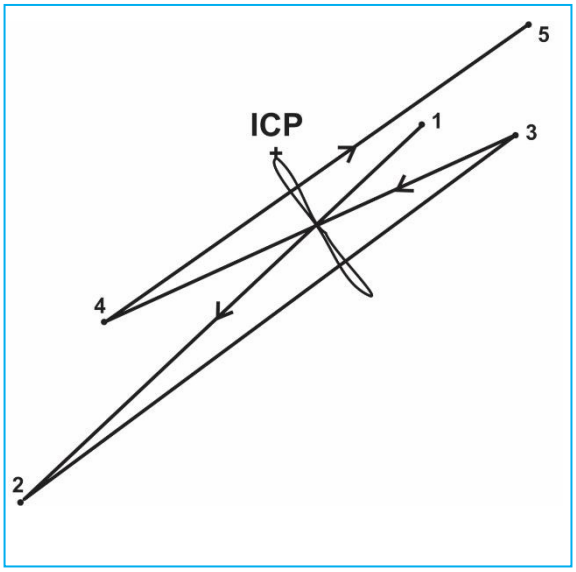
either the occluding surfaces of the teeth, or the teeth themselves. You will, without doubt, at both undergraduate level and post-graduation, have read and heard much on jaw movement and the TMJ, so I won't bore you with more of that here, but rather just make some points which I hope may clear up any confusion you may have and possibly help you sort out some of the many myths around this strange joint.

- It is a strange joint because it is the only joint which has no inherent anatomical limit (as anyone who has dislocated their jaw can verify). It is held like a sling by several muscles, and the limit to its movement is uniquely *outside* the joint: the teeth.
- The mandible as a result of being slung like this is never still unless the teeth are in occlusion (i.e. together in what is generally known as the *intercuspal* position or ICP). When not, it is constantly moving: even at rest with the teeth apart, it is making very small difficult to detect movements. We know all this from real-time functional MRI scans.
- The joint is the most slipperiest (if there is such a word) in the body. It has been estimated as being 5 times more slippery than ice on ice. Articulating cartilage surfaces lubricated by synovial fluid produce a coefficient of friction (μ) on the order of ~0.01 or less.[12,13] Ice on ice has a coefficient of 0.05. No wonder it is never still.
- You will have learnt about the border movements of the mandible known as Posselt diagrams, but I doubt you were told these are *not* normal movements. They are called border movements because they describe the *limit* of movements that can be made. Only in extreme nocturnal bruxism does anyone use those limits (we know this from watching people in sleep labs). In normal eating, speaking and chewing, they are not used in the manner shown in the original Posselt diagrams.[14]
- One of those movements, though, has long been considered useful. That is the *terminal hinge movement,* when the mandible supposedly makes a purely hinge-like movement, opening and closing on an arc. It was thought (and still is, by some) that the hinge is created by the condyles staying more or less in the same place in the joint fossa. However, it has been shown through the use of jaw tracking[15] and more recently by functional magnetic resonance imaging (MRI)[16] that the mandible does not make a pure hinge movement as there is always some translation involved.
- So if you believe in a pure hinge movement, then you will also believe in an axis of rotation, passing through the condyles. And this, as we shall see later, is the basis for an equal belief in the use of mechanical devices to reproduce jaw movement, i.e. articulators.

Figure 1. This depicts the major segments of the instantaneous centres of rotation from tracing the incisal point, with the trace shown sagittally. ICP = the intercuspal position from which movement was initiated (redrawn from McMillan *et al* 1989[15]).



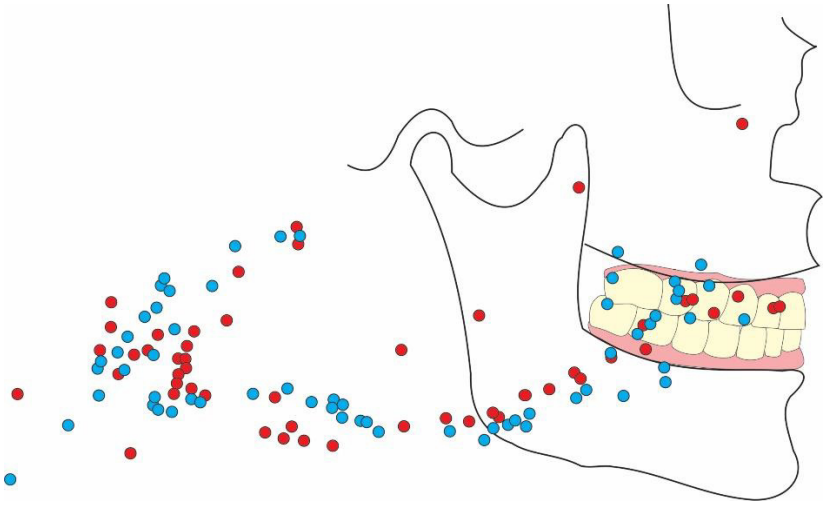


Figure 2. Mean ICR coordinates of all subjects during one full cycle of mouth opening (blue) and closing (red) (re-drawn after Krohn *et al* 2020).[16]

- However, if you understand that the mandible is held sling-like in a slippery joint, you will understand that any axis of rotation is likely to change and move as the mandible moves, and this is known as creating *instantaneous centres of rotation* (ICR). These are mostly nowhere near the condyles. Fig. 1 for example shows the result of tracking an incisal point by means of a kinesiograph, of a subject performing open/close movement patterns. For the movement shown (open from the intercuspal position to rest position and back again), there were 5 different instantaneous centres of rotation relative to the condyles. Fig. 2 shows the ICRs from calculations made using real-time MRI of subjects who were asked to open wide from the intercuspal position (ICP) and close again to ICP. The mean ICR pathways were *never* located within the condyle for both opening and closing movements.
- So if there is no pure hinge movement and no such thing as an intercondylar axis, is there any chance of reproducing jaw movements at all? This is important, and the answer is, not to the degree of perfection that studies revealing the ICRs would require (or at least, not yet). From a clinical point of view, we have to find as repeatable a position as we can, and we can actually observe what looks like a hinge movement, even if we know it is not really a hinge. It is most useful when a patient has no teeth, as it can be repeated (though with some difficulty in some patients) so at some point in its path you *can* decide where to put the teeth. This point in space is then referred to as the vertical dimension of occlusion.
- If the teeth are not together but the jaw is at rest, in space, this is called the vertical dimension of rest, or the rest position. As you can imagine, it varies a lot, but usually only in a small range of a millimetre or two.
- This 'hinge' movement of the mandible, useful as it is if we can repeat it, has also been responsible for a great deal of confusing terminology. And we can blame the invention of X-rays for that. Back in the day, when ethical research was, well, unethical, some patients were subjected to lots of X-rays of the TMJ and dentistry became obsessed with the position of the condyle in the glenoid fossa. Mostly of course, these were 2-dimensional images but now we have the magic of MRI and something called videofluoroscopy, which allows us to see everything whilst the jaw is moving (though it's not so easy to interpret).[17]
- But the early (and for some, still) obsession with condyle position has not helped. The American Academy of Prosthodontics has published fairly regularly, since 1956, a Glossary of Prosthodontic Terms (GPT) and is currently on its 9th edition, published in 2017.[18] In a recent history of this,[19] describing the latest revision, is stated: *"The most contentious term in the entire revision process was "centric relation"".*
- Here's the 1956 version: *"The most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movements can be made, at any given degree of jaw separation".*
- And here is the latest version: *"A maxillomandibular relationship, independent of tooth contact, in which the condyles articulate in the anterior-superior position against the posterior slopes of the articular eminences; in this position, the mandible is restricted to a purely rotary movement; from this unstrained, physiologic, maxillomandibular relationship, the patient can make vertical, lateral or protrusive movements; it is a clinically useful, repeatable reference position".*
- Phew! Does that make sense to you? No, nor to me. Unstrained? How do you tell? And of course you can make *"vertical, lateral or protrusive movements"* from any position, because of the anatomical nature of the joint itself, which the American Academy seems to have ignored. But what they have said, in line with what is in the previous bullets here, is that it is a position restricted to *"a purely rotary movement"* and therefore a *"repeatable reference position"*. Well, as we have seen, there is no such thing as a purely rotary movement.[15,16]
- And of course they don't define the *"reference position".* But does it really matter where the condyles are? Surely it is the observed movement that is important so it ought to called an *observed repeatable movement.* And you can then decide at what point during this movement to have the teeth come together. And you can call that centric relation occlusion if you want.
- No-one really knows where the condyles of the mandible are when the jaw is at rest but the teeth are not in contact. When the teeth are in contact, that is what has been referred to as centric occlusion rather than just being in occlusion. I have no idea why the word *"centric"* was used as it comes from the Greek kentrikos "*pertaining to a centre*". What centre? Same with centric relation.
- And the Glossary makes it worse. Centric occlusion is *"the occlusion of opposing teeth when the mandible is in centric relation; this may or may not coincide with the maximal intercuspal position".* Which is ridiculous, because it ignores their own definition of centric relation!
- This may be why centric occlusion is often confused with *maximum intercuspation*, or maximum *intercuspal position.* However, as we shall see later, what if you don't have cusps, or enough of them to intercuspate?
- So, the terminology around occlusion is really confusing. My advice is to use whatever helps you understand from a *functional* point of view, because it was the study of the static relationships of the teeth when for example, casts are put together, that gave rise to all sorts of dogmas for which there turned out to be no evidence.[20]
- Mandibular movement is complex, simply because it is held in a sling, and is influenced by the muscles carrying out whatever action you are doing, be it speaking, talking, chewing, doing nothing, or sleeping. The jaw never moves in a straight line, anywhere. That is why no mechanical instrument can ever reproduce jaw movement. It is also why the digital virtual world may hold great promise to reproduce jaw movements (some claim it does already, but we haven't got there, yet – see Part 7).
- This doesn't mean articulators have no use, because even an approximation is better than nothing. It just means you need to know what they are approximating, in other words, their limitations and why, for example, some types should never be used. This will be dealt with in Part 6.

Having written all this, I fear it may not seem so simple after all! But, if you think about all these points and try to contextualise them with what you may have been taught, and what you may have read, I am confident you will be able to sort the wheat from the chaff, and understand the terminology, and the nonsense around terms like centric relation. It's what happens when the teeth come together functionally that is important. And they don't come together that often, unless you are clenching your teeth all day. Teeth *'occlude'* when they come together but when chewing that is only fleeting, and they move across and over each other and need to be able to do that without interrupting the pattern of chewing. The teeth and the joint need to allow this to happen. That is what you need to know about occlusion!

Now, before we get to solutions, we need to look at how we as *Homo Sapiens Sapiens,* ended up with the teeth and the jaws and the joint we have. I am confident this will further help you to understand the functional aspects of occlusion and articulation. Part 2 will therefore look at the evolution of teeth and the temporomandibular joint.

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