http://dx.doi.org/10.17159/2519-0105/2022/v77no7a7

An evidence-based guide to occlusion and articulation.

Part 7: Guidelines for mechanical articulator use; conclusions and a note on complexity

SADJ August 2022, Vol. 77 No. 7 p430- p434

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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.

Guidelines for mechanical articulator use

First, despite all the evidence of instantaneous centres of rotation, the fact is that from a clinical point of view, we have to find a position that can be repeated, in the absence of a currently habitual intercuspal position. And even when that does exist, we have to have some means of relating the casts not only to each other but as far as is reasonably possible to at least some representation of the skull and hence to movements of the mandible in order to reduce as much as possible the final occlusal adjustments in the mouth. Hence the following suggested guidelines, based on all the evidence presented in the previous papers in this series.

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Mucosa-borne complete dentures (and removable partial dentures can be included here)

It is, perhaps, time to admit that the more complicated techniques offer no advantages, other than being impressive to the patient. Whilst the positive psychological effect of this is recognised, the same effect can – should! – be achieved by obtaining proper rapport with the patient without having to impress them with gadgets. Simplified techniques show no worse (and sometimes better) outcomes and there is ample evidence that this is the case. [1-4] In addition, there are guidelines for a minimum protocol which, although derived from expert opinion based on knowledge of the literature and experience, nevertheless condenses certain principles that are most likely to result in successful denture wearing, irrespective of the techniques used. [5] Therefore it makes sense to simplify procedures: an example is the CD4 technique.[6] In terms of articulation, there is no advantage to using anything more complicated than an average-value articulator, understanding that if changes such as vertical dimension are required, then new remounts may be required.

The occlusal goals would be bilateral centric contacts, and if possible, bilateral contacts in excursive movements as well. These are first achieved on the articulator, but then must be refined using the patient's own ability to chew, using for example, occlusal indicator wax. The evidence appears to be that it not necessary to reproduce the ideal contacts on every tooth, and so it is recommended to use an occlusal scheme such as lingualised occlusion, which makes such adjustments quick and easy to make clinically. [7] This scheme is very widely used now, and has the great advantage that it can be modified by adjustments only to mandibular teeth.

A note with respect to the elderly: whilst we can only use an observable hinge-like repeating movement of the mandible, usually guided by the clinician to a certain extent (because we need to keep hold of the mandibular denture), do not lose sight of the fact that the mandible is still held in a sling of muscles, tendons and ligaments. With age, sadly, changes occur in these structures and therefore elderly patients should be regularly recalled: those of us who have treated the elderly for conventional complete dentures know that the jaw relation you record in one year may well change when you record it, sometimes only one year later. So

Fig. 1. Examples of excessive reduction of surfaces involved in excursive movements. These have all been done in the clinics, with two having been returned to the laboratory, presumably for correction, which is unlikely to improve if the original cause – almost certainly the use of a hinge articulator – is not corrected.

a scheme like lingualised occlusion makes adjustments much easier (provided of course that you do not lose vertical dimension).

Implant- and tooth-supported overdentures

There seems no reason to change any of the principles used in mucosa-borne complete dentures except to concentrate more on achieving bilateral contacts in excursive movements. This is easier to achieve when assessing contacts in the mouth, because of the increased stability of the overdentures compared with that of mucosa-borne dentures. For example the use of occlusal indicator wax is much easier.

Fixed prosthodontics: Single restorations

I would, somewhat begrudgingly, agree that a single restoration that receives no contacts in excursive movements, may not need anything other than hand or simple hinge articulation. However, if there is any chance that there may be contacts in excursive movements, then it would make sense to use a semi-adjustable articulator, and if you can't let go of the facebow then by all means use it, but you should know that it will make no discernible difference. Adjustments will still be required in the mouth.

Fixed prosthodontics: multiple restorations, including anterior restorations

Hopefully by now this is obvious: use a semi-adjustable articulator, there is no indication for using a facebow, just mount the casts in the geometric centre of the articulator. It might be helpful to mount them with the occlusal plane at 14° to the horizontal as that is the average angle to Frankfort. The easiest way to do that is to grind the base of the model at a negative 14° to the occlusal plane. Then set the condylar guidance angles to traditionally-used average values (SCGA of 30° and MCGA to 15°).

However, it is strongly recommended to use the anterior and lateral (strictly latero-trusive) guidance as displayed by the casts, to make a custom incisal guidance table. This will make the movements of the articulator closer to those in the mouth and prevent an all too common sight such as the examples shown in Fig. 1.

These are not due to the opposing teeth producing wear through the palatal porcelain, but due to the clinician having to adjust the occlusion because the technician was not able to reproduce the anterior or lateral guidance curvatures. In all these cases, ceramo-metal crowns meant that the crowns could still remain (sort of) functional; now with the trend to all-ceramic crowns, such adjustments will most likely be fatal to the crown or the veneer or the core or both. The use of a custom-made incisal guide table will obviate or even eliminate this, and is not difficult or time-consuming to produce, as shown in Fig. 2.

Of course it is still not going to perfectly reproduce the mouth, and will require adjustments when placed. This is fine for smaller-span prostheses, but when re-organising an entire occlusion (which should be in the realm of specialists) it is necessary to make provisional restorations, and adjust those over time. These then become the templates for a new custom incisal table and for the shape and form of the definitive restorations. This makes so much sense, and is routine when carried out by specialists, but seldom seen when carried out by general dental practitioners (who shouldn't be doing this anyway!).

Although this is about articulation, do not lose sight of the evidence of cusp angles, and, within the limitations of any existing excursive contacts, try not to exceed the recommended 25° cusp angles. And remember that the changing situation mentioned above for complete dentures in the elderly also applies to fixed prostheses, another reason for keeping cusp angles shallow and providing as much freedom in centric as possible.

Implant-supported fixed prostheses

The point has been made that it is not really the implants

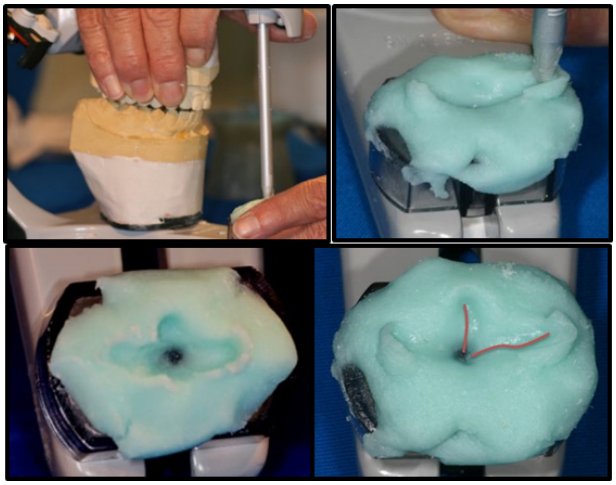

Fig. 2. The casts of the dentition before preparation are manipulated to produce a custom incisal guide from auto-polymerising resin. The red lines show the path taken in protrusive and right lateral excursive movements. Not that they are not straight because the palatal and occlusal surfaces are not straight. This will hopefully avoid the need for excessive adjustments in the mouth, as shown in Fig. 1.

that need protecting (once successfully osseointegrated of course) but the material of the superstructure, and so the concepts of distribution of forces, and freedom of movement during contact must prevail. For prostheses not involving the entire arch then ensure that the occlusal scheme is in harmony with that existing, and remember to reduce cusp angles and fissures. For full arch prostheses it makes no sense whatsoever to use a canine-guided disclusion if you approach this from a biological, functional and logical basis. It does makes sense to consider bilateral contacts in excursive movements. Therefore the logical choice of articulator is as for tooth-supported fixed prostheses, except that now you may not have the original teeth to guide the articulator by way of a custom incisal guide. In this case you must revert to the average incisal and lateral guidance angles of preferably no more than 10° and once again consider a period of provisional restorations prior to the definitive ones. Then the incisal guides can be created using casts of the (proven successful) provisionals.

CAD/CAM ceramics without any mechanical device

It has become necessary in this case to lament the lack of use of mechanical devices, contrary to all of the above. The next section will briefly deal with the virtual world of articulation, but as many specialist prosthodontists know, when patients end up in their chairs with cracked and chipped restorations, dull and lifeless looking crowns, there is far more to making a ceramic crown than just cutting a prep, taking an image, and sending it for milling. Of course, ideally, all restorations designed and created in the virtual world should be done with the use of a virtual articulator, but this may still be some way off. This is all the more reason to modify the digital library designs before milling, to reduce grooves and cusp angles. This will hopefully reduce the amount of adjustments once in the mouth, because these adjustments carry the danger of changing the height and thickness of the ceramic; this is dangerous because ceramics need to be of an even thickness, which gives them their strength. Altering the occlusal shape and form after milling is likely to create tensile forces instead of compressive ones, and it is these that initiate cracks. So only minor adjustments should be the aim, followed by polishing; and ceramics wear, whether they occlude with enamel, metal or other ceramic, so they should be polished on at least an annual basis.

But there is no doubt that the future does lie in the digital world and therefore it is necessary to use a virtual articulator, even with their current limitations (which are no worse than those of mechanical articulators), until a fully virtual patient can be created.

Virtual articulators

As I hope you will have gathered by now, there is much to learn from history, but the history of virtual articulators only goes back about 20 years, and the technological developments are so rapid that they are certainly faster than the publication of their use and efficacy. There is, though, already a fairly substantial body of work – at the time of writing, the words “virtual dental articulator” in PubMed yielded 103 useful results, dating back to the year 2000.

What is interesting, and somewhat dismaying, is that the basis for most of the current virtual articulators is the mechanical articulator, and the same reference points are still being used. So now we have virtual facebows, using either kinematic or, more commonly, arbitrary hinge axes, just as with a mechanical facebow. The idea of course, is to relate the maxillary cast to the skull, notably to Frankfort plane (although this seems to be variably defined), and then to relate the mandibular cast to the maxillary. Most current virtual articulators are mathematically derived and based on the mechanical articulator. They therefore are reproducing the same problems and false assumptions of the mechanical articulator.

But the future is brighter than that, and not far off. Already publications are reporting on success with a truly virtual patient, with a reproduction of the facial expressions, the teeth and most importantly and crucially if they are to make any sense, reproduction of the actual mandibular movements of the patient.

In summary, this is, more or less, how it all works: the first step is clearly to reproduce the teeth and this is done by scanning the entire arches. There remains, though, some controversy as to whether this can or should be done using an intra-oral scanner. A recent review felt they were not sufficiently accurate for full-arch digital implant impressions, [8] and a study purely on accuracy [9] found that precision values varied from 35 µm to 97 µm and recommended them for “single crowns, small bridges, and separate quadrant prostheses” and concluded that “Scanners based on triangulation are hardly appropriate for full-arch prostheses”. Nevertheless, many case studies have reported the successful use of full-arch scanners [10] and they are considered sufficiently accurate for removable prosthodontics. [11]

Once a digital file has been obtained, from an impression, a cast or an intra-oral scanner, then the maxillary and mandibular arches must be related to each by some means of recording the actual or desired occlusion.

Several different methods have been described recently and they won't all be described here; they range from the use of leaf gauges and anterior stops [12] to the use of interocclusal records [13] and the patient's own current habitual occlusal position using model scanners [14] or intra-oral scanners to record the buccal relationships. [8]

Then the maxillary arch must be related to the skull, and for this a virtual facebow is required when using the mathematically simulated articulator, or, preferably a CT or CBCT scan when a jaw-motion recording device is also used for a more completely adjustable virtual articulator. Once again, several techniques have been described for creating a virtual facebow, based again on the assumption that there is a hinge axis, and determining this kinematically or arbitrarily, just as with a mechanical facebow. And this can be done either completely digitally by using CT or CBCT scans to create a 3D image of the skull, [15] or using a combination of extra-oral images of the arbitrary points to locate Frankfort plane and the hinge axis [16] and even by the use of smart-phones to take a 3D scan of the face. [17] Whatever the method, the virtual articulator is then set to average values for whatever that particular software will allow: usually at least the sagittal and medial condylar guidance angles. None of which makes any sense, because of the false assumptions inherent in digitising mechanistically unsound concepts.

But far better of course would be to reproduce the patient's actual mandibular movements in all planes, and for that you need something called a jaw motion analyser. Some recent studies have described these techniques [18,19] but all of these still need to be tested using multiple clinical studies and preferably randomised clinical trials (RCTs), though these are extremely difficult and time consuming and challenging for the patients – imagine having to have different sets of full-mouth rehabilitations, using them, and then replacing them with another set made from a different articulator. No wonder RCTs are rare in Prosthodontics. However, from a functional understanding of occlusion, if the digital world can reproduce the patient's own movements then we will have a real virtual representation and this is really exciting to contemplate! I would even go so far as to say that it will have as much impact on prosthodontics as did the advent of successful titanium implants.

Conclusions to the series and a note on complexity

This series of articles has been written in the hope that some of the more arcane aspects of occlusion may be located in clinicians' and technicians' minds in a more bio-functional context. The bathwater of history is full of attempts to try to understand complex mandibular movements and is littered with wondrous mechanical devices and many misplaced 'eureka!' moments. This is not to say that mechanical devices have not played and may still play a part in treatment, but it has to be said that the purely mechanistic view of occlusion as exemplified by the gnathological schools, has ignored the fundamental purposes of what the stomatognathic system was set up for, or rather has evolved into. I hope the brief journey into the rest of the mammalian animal kingdom has helped with this understanding of why we have a hard inert substance over a soft but living substance with reparative powers ideal for a purpose that is (except under pathological conditions) now no longer required. That of course is because of the huge change to our diets, and now that we are having to deal with replacing lost anatomy, this surely has to be rooted in a functional understanding of the whole system. I hope too, that the definitions so beloved by the American Academy make a little more sense and that you can separate the nonsense from the sense. A recently published consensus review of the literature [20] is still hung up on 'centric occlusion' and 'maximum intercuspal position' and ignored the fact that there is no point. Sorry, I'll put that another way: there is no point contact but there must be freedom, so find a starting position that is repeatable and call it whatever you want, and know that the patient will function around an area, albeit a small one.

Jaw movements are amazingly complicated, and although it is necessary to simplify them, within reason, the adaptability of the system allows us to do this. I hope too, that you will now also have a different view of the joint, from it's amazing evolution during the development of the middle ear (which defines us as mammals) to its form related to the function required for the physiology of the particular animal, from joints that allow only hinge movements to joints that allow wide circular movements, to joints that can combine all necessary movements.

It is, though, the digital world that is most likely to give us the most help, but I fear that many of the pioneers in this world may have been too rooted in their mechanistic past. Virtual articulators of the mathematically derived type are merely the equivalent of a semi-adjustable articulator set to average values. What is most exciting is that we are close to having a virtual articulator that simulates the patient's own jaw movements, because after all, that's what we use when we finally adjust our restorations in the patient's mouth. If we can get as close to that as possible in the virtual world, using the modern ceramics (and preferably, in my opinion, the IPN ceramics), then the likelihood of having to do adjustments that will weaken the integrity and therefore the strength of those restorations is much diminished. That's an exciting future!

Finally, a word about complexity and a caveat. The digital world and the newer restorative materials have the potential to fool us into thinking we can do almost anything now. But it has taken some of us many decades to work out just what we should be doing when placing restorations into real, not virtual, mouths. In the UK, the National Health Service has developed levels of difficulty mainly in response to a billing system, but it has been suggested that this could also provide guidance as to who should be doing what. For example, in South Africa it takes four years of very intensive education and training to become a prosthodontist and a few more years to become an expert prosthodontist. Yet we are increasingly seeing general practitioners without such education and training carrying out full mouth rehabilitations, often at the chairside, and often 'instantly'. This has prompted the litigation insurers to express some considerable concern (McKelvie A, personal communication) as they are increasingly being

advised by expert witnesses to settle claims when general dental practitioners have exceeded their level of expertise. I mention this just as a caveat (and it is the topic of a future paper) to those practitioners embarking on complex treatment to understand the fullest extent of the knowledge they ought to have. That has been one of the reasons for writing this series of papers.

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