Clinical Considerations and Rationale for the Use of Simplified Instrumentation in Occlusal Rehabilitation. Part 1: Mounting of the Models on the Articulator

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The development of an occlusal scheme with an appropriate number and location of occlusal contacts is of utmost importance for the long-term success of any prosthetic rehabilitation. This, however, can be a time-consuming procedure. To avoid undue mistakes, a high degree of competence must be demonstrated by both the clinician and the technician. Especially when performing extensive rehabilitations, many operators believe that to have optimum control of the occlusal variables, it is necessary to employ rather sophisticated instruments and complicated procedures. This article presents a rationale for an approach that uses a simplified but sound instrumentation in the clinical and laboratory steps necessary to produce a successful prosthesis. In part 1, the registration of the spatial position of a patient's maxillary and mandibular arches will be described. (Int J Periodontics Restorative Dent 2003;23:xxx–xxx.)

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The temporomandibular joint (TMJ) is a complicated mechanism; not only does it allow pivoting, rotating, opening, and closing movements, but also movements of translation and laterotrusion. Furthermore, the structures that make it up are not rigid, precise, and unchangeable; rather, the muscles, ligaments, and bone have a certain degree of elasticity. Into this milieu, the clinician is asked to introduce a prosthesis that is within the adaptive capacity of the neuromuscular system.

In a rehabilitation, the development of the occlusion—that is, the development of an occlusal scheme incorporating an appropriate number and location of occlusal contacts with the condyle/disc assembly in an optimum position—is paramount for the transmission of the functional and parafunctional forces generated. This should be done regardless of the extent of the restoration. The primary reasons for this are: *(1)* to avoid damaging the TMJ, teeth and muscles, since what is done at the tooth level can have consequences at the level of all these structures[1]; and *(2)* to design and manufacture

Table 1 Types of instruments

Articulator type	Facebow	Parameters that can be modified
Hinge	No	None
Fixed condylar path	No	None
Semiadjustable	Earbow or kinematic	Condylar inclination, immediate side shift, progressive side shift
Fully adjustable	Kinematic	Condylar inclination, immediate side shift, progressive side shift, upper and rear wall inclination, morphology of fossae, intercondylar distance

long-lasting rehabilitations. In general, the clinician is always looking for ways to simplify the procedures for the fabrication of a prosthesis and decrease the time necessary to integrate it into the mouth of the patient. This article will provide some suggestions on how to achieve these goals.

The assumption for this discussion is that the occlusal scheme to be created is one that is currently viewed as the "ideal" occlusal scheme—that of "mutual protection" with either "canine guidance" or "group function."[2] (For definitions of these and any other subsequent terms used, the reader is referred to The Glossary of Prosthodontic Terms.[3]) The two schemes have the following requirements in common:

- The incisal guidance should be sufficiently steep to allow for disclusion of all posterior teeth during protrusion.
- The lateral excursive guidance should be sufficiently steep to allow for disclusion of all teeth on the nonworking side during lateral excursions (no posterior interferences).
- In maximum intercuspation (MI), posterior teeth should make bilateral simultaneous contact with occlusal forces applied axially.

Both schemes can be acceptable. The decision of which scheme is appropriate can be made, case by case, depending on preexisting skeletal/dental relationships.

The purpose of this article is to provide guidelines in occlusal rehabilitation for the selection of an articulator, and to discuss the equipment and the clinical procedures necessary for the proper mounting of casts.

The equipment for an occlusal rehabilitation

When developing an occlusal scheme and trying to define the proper number and location of occlusal contacts, in most cases it is certainly useful and necessary to use an instrument that, to a certain extent, reproduces the static and dynamic relationships of the masticatory system.[4] Certainly, it is necessary when: *(1)* performing a functional occlusal analysis; *(2)* determining the changes to be made to the maxillary anterior teeth or occlusal plane; or *(3)* fabricating a provisional or definitive restoration that incorporates these changes or includes a large enough number of teeth that it would be impractical not to work with mounted casts. However, the question of how sophisticated or complicated this equipment needs to be remains.

Articulators are mechanical instruments that represent the maxilla, mandible, and TMJs. Their main task is to provide a frame where it is possible to relate, in the three planes of space, the maxillary cast with the mandibular cast relative to the hinge axis of the patient and of the instrument. There are four types of articulators available[5] (Table 1).

The simple hinge and fixed condylar path articulators should be used only in those situations where it may be possible to avoid using any instrument, such as in the fabrication of individual inlays, onlays, or single crowns. The primary detriment to the use of these simple instruments for the fabrication of

more extensive restorations is that their size, shape, and options for movement do not have any anatomic resemblance. Many authors have therefore recommended articulator systems that incorporate the use of a facebow,[6–8] ie, semiadjustable and fully adjustable articulators. In making the choice between these two, it may be useful to understand the indications for a pantographic tracing, and thus for the latter device: *(1)* when the anterior guidance is absent and will not be restored/created (Class III skeletal relationship, anterior open bite, extensive wear of the anterior teeth); or *(2)* when group function is desired on the working side.

When any of the muscles of mastication exhibit spasms, it is not worthwhile to record a tracing since it is not possible to record the full range of mandibular movements, unless the tracing is intended as a diagnostic aid.[9] Pantographic tracing requires the pantograph to be assembled on the patient and related to the hinge axis determined by a kinematic facebow. Even in "normal" or "asymptomatic" patients, recording the position of the hinge axis is a technique-sensitive procedure. Positioning of the facebow and its transfer to the articulator are procedures where mistakes are easily incorporated.[10–13] When the benefits of using a kinematic facebow and pantographic tracings are clear, their use is justified.

It is not true that the more complex the articulator is, the more precise the clinical result will be.[14] This is due, in part, to the fact that in a rehabilitation: *(1)* the main objective at the occlusal level during excursive movements is the disclusion of all posterior teeth by the anterior guidance, and not a bilaterally balanced occlusion; and *(2)* the condylar guidance (principally, but not entirely, the inclination of the articular eminence) does not determine the anterior tooth guidance, but does influence its effectiveness. As a consequence, it is possible to use more simplified instruments than fully adjustable articulators. Semiadjustable articulators allow the operator to modify the determinants of occlusion that play the largest role in determining occlusal morphology (immediate side shift and, in some cases, progressive side shift). They are constructed with average values as far as the other determinants of occlusion are concerned. However, to avoid mistakes, undue complications, or wasted time, it is important to follow certain rules and understand the limitations of the equipment used.

Procedures for mounting models on the articulator

Recording the position of the maxillary arch

Positioning the maxillary cast on an articulator is the preliminary essential step to develop and control tooth morphology and position, and thus develop a physiologic occlusion for the patient. The objective of recording the maxillary arch position is to transfer that position, in all three planes of space, to the articulator. This means the following: *(1)* the relationships between the upper model and articulator's hinge axis and that between the maxillary arch and the patient's true axis should be the same as much as is practical; and *(2)* the maxillary model should have a precise orientation in space with respect to the reference plane selected. To do this, it is indispensible to use a facebow. The facebow identifies a plane by using three points—two posterior and one anterior (Table 2 and Fig 1).

Posterior references. For the posterior reference points, the possible choices are:

1. The position of the hinge axis extensions recorded with a kinematic facebow, often tattooed on the skin
2. An arbitrary point 12 to 13 mm anterior to the posterior border of the tragus on tragus-canthus line
3. The axis determined by an earbow placed in the patient's auditory meati

Table 2 Anterior and posterior points of reference for the determination of a reference plane

Posterior point	Anterior point	Resulting plane
Porion (midpoint of upper border of external auditory meatus)	Infraorbital point (orbitale)	Frankfort's
Hinge axis (or arbitrary axis)	Infraorbital point (orbitale)	Axis-orbital
Hinge axis (or arbitrary axis)	Nasion minus 23 mm	Axis-orbital (approximate)
Arbitrary axis (given by an earbow or average landmarks)	Arbitrary point measured from incisal margin	Arbitrary
Superior portion of tragus (center of external auditory meatus)	Ala of the nose	Camper's

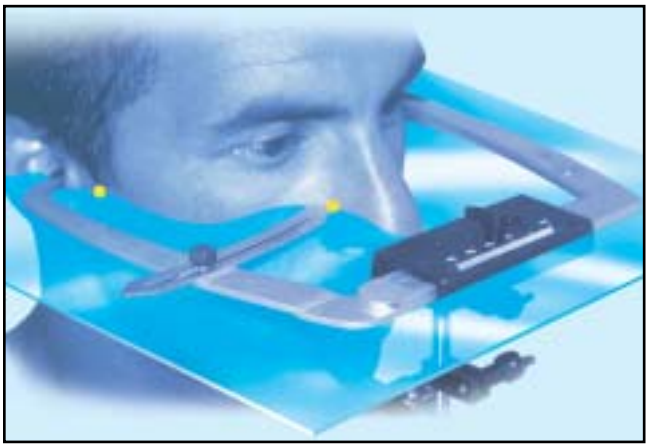

Fig 1 (left) *Facebow identifies a plane by using three points—two posterior and one anterior.*

Fig 2a (below left) *Superimposition of the articulator on the side view of the patient (1:1 ratio) using the earbow as the common reference shows the position of the axis that an earbow determines.*

Fig 2b (below) *By keeping the earbow attached to the bite fork assembly mounted on the articulator, the position of the arbitrary axis (which is coincident with the articulator axis) is evident.*

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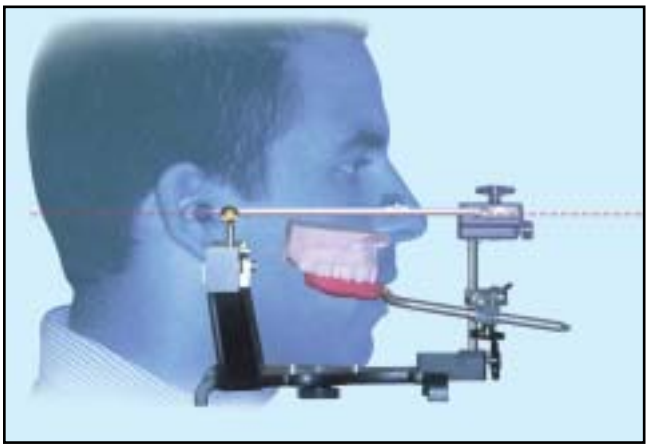
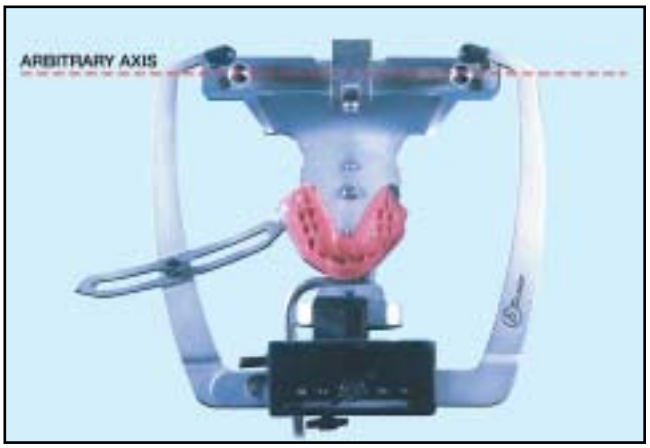
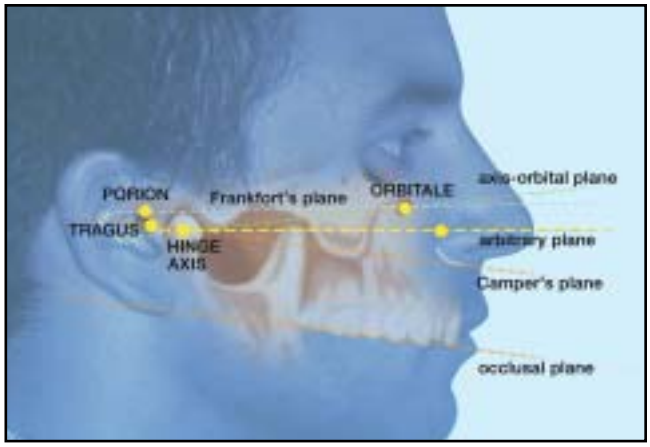




The hinge axis can be certainly the most precise, since it is found with a kinematic facebow. This landmark is certainly indicated whenever the operator plans to change the articulator's vertical dimension of occlusion (VDO) after the models have been mounted (if, eg, the centric relation [CR] position is recorded with a gothic arch that requires opening the VDO on the patient).

The second landmark is not considered very reliable. Studies done to determine the variation between

Fig 3 *Anterior and posterior references and resulting planes.*



a located hinge axis and various arbitrary axes show wide disparities. In one study[15] 95% of the points located 13 mm anterior to the posterior border of the tragus on the tragus-canthus line were within a 5-mm radius from the true hinge axis. In two other studies,[16,17,] the percentages recorded were 33% and 20%, respectively.

Determining the axis by an earbow provides a quicker and simpler manner in which to record the position of the maxillary arch. The earbow takes advantage of the relationship that the auditory meati have with the glenoid fossae (Fig 2). Teteruck and Lundeen[18] demonstrated in a sample of 47 patients that 75.5% of the arbitrary axes determined by the earbow fell within a 6-mm radius from the true hinge axis. A study of 18 patients found that 89% of the axes determined were within the same radius magnitude of discrepancy.[19] Although it is true that the axis determined by the earbow rarely coincides with the true hinge axis, the potential error in any patient caused by the deviation plays little role at the occlusal level if the intermaxillary registration is made without an alteration in occlusal vertical dimension.

Anterior references. The third point of reference employed when using a facebow can be one of the following[20,21] (Fig 3):

1. Orbitale
2. A point at a fixed distance from nasion (eg, nasion minus 23 mm, which corresponds approximately to orbitale)
3. An arbitrary point measured up from the incisal edge of the maxillary lateral incisor.

When using either of the first two reference points in combination with porion **[AU: Please verify spelling "porion." (Also in Table 2, Fig 3.)]** or axis, the resulting planes (the Frankfort plane and the axis-orbital plane, respectively) tend to produce an excessively steep anteroposterior angulation of the occlusal plane on the articulator.[22] This is due to the fact that neither of these planes is parallel to the horizon, since both posterior landmarks are below the orbitale point. According to one study,[21] the orbitale is located on the average 18 mm above a true horizontal plane passing through the axis. As a consequence, the Frankfort plane forms an angle of about 8 degrees with this arbitrary plane (also called the "esthetic plane"), while the axis-orbital plane forms an angle of 13 degrees with the same plane.

Guichet[23] recommends a method that places the incisal edges (and possibly the entire occlusal plane) roughly in the middle of the articulator (Fig 4). This prevents any space problems when mounting the stone casts. For this reason, he suggests using a ruler that identifies a point at a fixed distance from the incisal edge of the maxillary right lateral incisor (for the Denar articulator, it is 43 mm). At the same time, this anterior landmark, being at least 7 to 10 mm below the orbitale, defines a plane that, when the patient is standing erect with their eyes directed straight forward in a horizontal plane,

Fig 4a *Mounting of the upper model using an arbitrary anterior reference at a fixed distance from the occlusal plane. Measurement on the face 43 mm from the incisal edge of the maxillary right lateral incisor.*

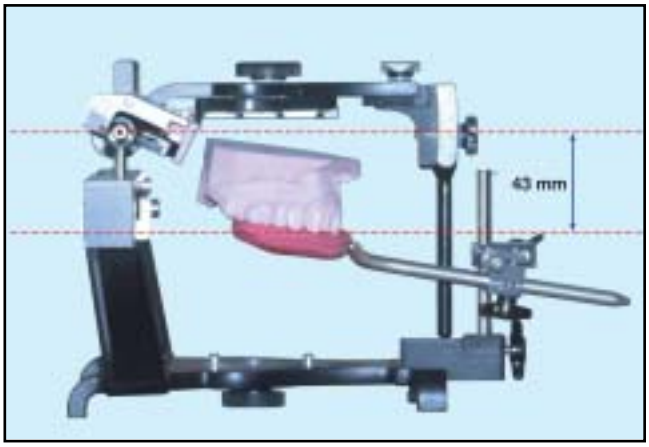


Fig 4b *Relationship of the maxillary cast to the reference plane* (top dotted line) *and to the upper part of the articulator.*

tends to be more parallel to the horizon than the traditional planes of reference. This gives the occlusal plane an anteroposterior inclination similar to what the clinician observes when looking at the patient standing in front of him or her.

On the frontal plane. By observing the two posterior reference points on the frontal plane, regardless of whether they are the superficial projections of the rotation centers of the hinge axis or those given by the auditory meati, it should be realized that in many patients their level is not symmetric—one tends to be higher than the other. As a consequence, the line that connects them is not horizontal (Fig 5).

If the operator is using a kinematic facebow, because he or she wants to locate and record the true hinge axis, the eventual slant of the facebow has to be accepted. Then, to communicate to the laboratory technician the true spatial position of the dental arch, he or she needs to draw directly on the model the projection of the midline, the true vertical line, and the corrections to be incorporated in the provisional restorations (eg, lengthening or shortening certain teeth). For a definitive restoration, the same should be done on the model of the provisionals in the mouth of the patient. With this method, the technician cannot base judgment on what is seen when analyzing the orientation of the occlusal plane of the mounted cast with respect to the top of the working bench, unless he or she raises the right or left back supports of the articulator by an amount clearly indicated by the dentist.[24]

With the earbow, it is possible to correct its inclination by manually leveling it in the frontal plane before tightening the screws.[14,25] Most often, the correction to be made is minimal. Thus, it is possible for the endpoints of the arbitrary axis to be within a few millimeters of the true axis's end points. However, to many this still sounds "heretical."

Those who adhere to this approach value it for the possibility that it gives them to communicate in an effective and error-free manner with the laboratory technician. As a matter of fact, when the technician observes the models mounted from such a "corrected" facebow, he or she can evaluate the features of that dentition (length of the different teeth, cant of the occlusal plane, inclination of the midline, etc), being certain of the relationship that they have with the horizon. The technician will be able to look at the models on the articulator in the same way the clinician observes the patient. But this would not be enough to justify this approach if the method were to produce occlusal repercussions that would be difficult to correct or compensate for.

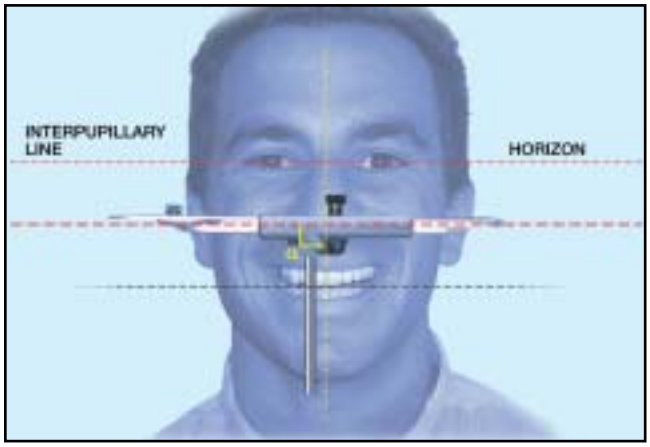


Fig 5a *Implications of the facebow position on the mounting of the upper model (in the frontal plane). If the ears are level, the earbow will be parallel to the interpupillary line or to the horizon and perpendicular to the midline (α = 90 degrees).*

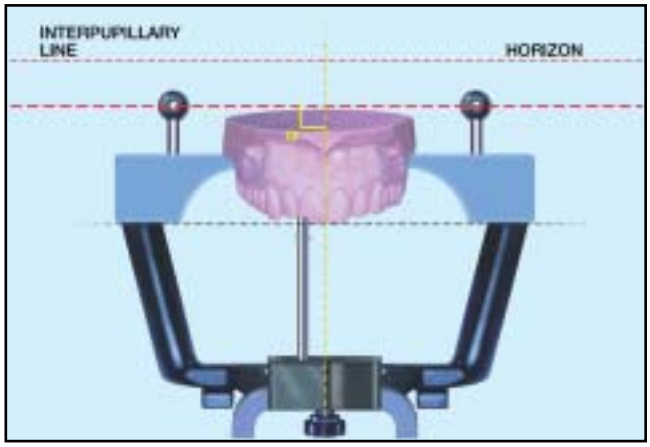


Fig 5b *As a consequence, the inclination of the maxillary model will be consistent with that observed on the patient.*

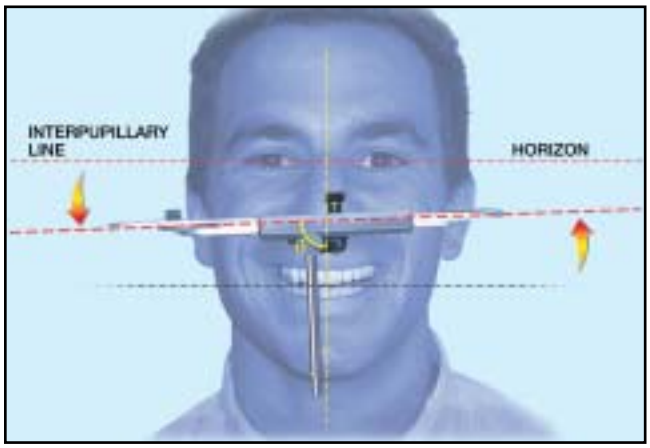


Fig 5c *If one ear's position is higher than the other (in this example, the left ear), the earbow will NOT be parallel any longer to the interpupillary line or to the horizon, nor to the midline (β < 90 degrees), but the bite fork assembly will still be perpendicular to it.*

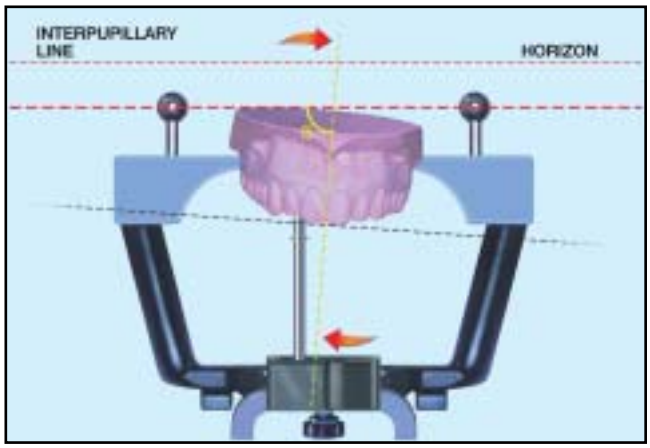


Fig 5d *Thus, when placing on the articulator the bite fork assembly that is perpendicular to its base, the model will be involuntarily mounted with a cant toward the opposite side.*

Intermaxillary registration

Registering the mandibular position is the second step of the procedures for mounting the models on the articulator. This is the key step[26] that compensates for the "inaccuracies" of what has just been described, and for the arbitrariness of what will be done subsequently, ie, the setting of the instrument with values that are not individual. As Pameijer[7] said, "An incorrect registration (either of centric relation or maximum intercuspation) will have repercussions on the occlusal relationships which will be far greater than those that could result from the setting of condylar inclination and Bennett angle with arbitrary values rather than with the patient's individual values." Before any intermaxillary registration is made, two important decisions should be considered.

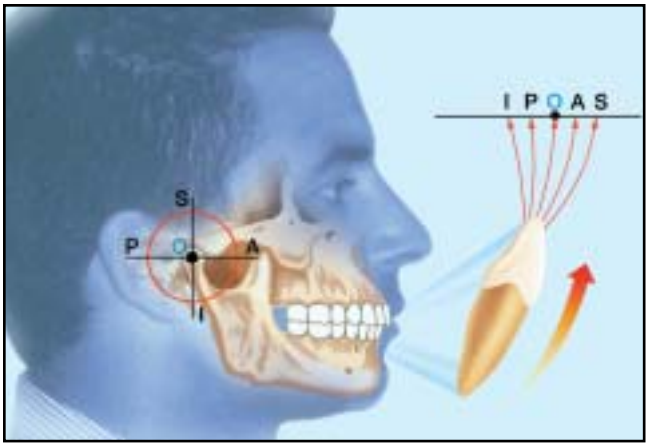


Fig 6 *When the arbitrary axis is not coincident with the patient's true hinge axis, by closing the articulator, an error is introduced at the occlusal level. The magnitude of the error is larger when the axis recorded is inferior* (I) *or superior* (S) *with respect to the true hinge axis, rather than when it is posterior* (P) *or anterior* (A) *(adapted from Zuckerman[29]).* **[AU: What does "O" indicate?]**

First, the clinician has to decide whether to use as the mandibular position CR (ie, a "reorganized" approach) or MI (ie, a "conforming" approach). This decision depends on the extent of the rehabilitation—the more extensive it is, the more common the tendency to use CR.[27] This position is indicated when precise references (or conditioning landmarks) are lacking at the tooth level, since this is a border position, fairly stable, and, to a certain extent, reproducible in the time frame necessary to complete the treatment.[28] On the other hand, "Use of the intercuspal position for the restoration of individual natural teeth in situations where mandibular function is in health is most appropriate, provided that a stable intercuspal position can be identified."[8] This is the situation where only a few teeth have been prepared and the rest of the dentition is in good occlusal condition and in a proper occlusal relationship with the antagonists. If a restoration is fabricated in the patient's MI position, however, at the time of insertion it will be necessary to check that there are no interferences in CR on the prosthesis.

Regardless of the outcome of the first choice, it is necessary to make a second decision, ie, at which VDO to record the intermaxillary position. Having positioned the upper model with the earbow, if the articulator's vertical dimension is changed (eg, if it is closed) after mounting the lower model, it is very likely that the mandible's condyles and those of the articulator will rotate around two different axes.[29] When the arbitrary axis is not coincident with the patient's true hinge axis, by closing the articulator after having removed the recording material, an error is introduced at the occlusal level (Fig 6). This means that the occlusal contacts on the models will differ from those in the mouth. The magnitude of this occlusal error is directly proportional to the angular, vertical, or horizontal discrepancy between the two axes and the vertical dimension where the intermaxillary registration is made. Therefore, if an average-setting facebow (earbow) is employed, it is essential to record the CR or MI position at the same vertical dimension to which the patient will be restored.

In those situations where only a few teeth are to be restored and the remaining teeth form a stable intercuspation, the new restorations have to conform to the existing occlusion. No registration material is necessary or, if it is used, it is placed only at the level of the prepared abutments while the intact teeth occlude in the patient's MI position.[30] In both cases, it is essential to record the teeth that do have a definitive contact and transfer this information to the technician.

Fig 7a (right) *Clinical example of how the anterior portion of a complete-arch maxillary provisional is kept in place to record the intermaxillary position at the correct vertical dimension and spatial position. The provisional is in place.*

Fig 7b (below) *Anterior six units and right second molar (the only intact tooth) maintain the correct spatial position of the mandible.*

Fig 7c (below right) *Registration material is introduced in the posterior space while allowing verification of the correct centric relation position. The set zinc oxide eugenol paste has encompassed enough posterior abutments to ensure that the models of the prepared abutments will not rock, even without an anterior stop.*

In extensive rehabilitations, when there are no intact teeth to help identify the correct position, it is useful to keep portions of the provisional restorations—generally a few units in the anterior—to register CR at the VDO where the patient has been functioning. These retained anterior provisionals act as a deprogramming jig, since there are no posterior contacts.[31,32] It is mandatory, at this stage, for the musculature to be relaxed; otherwise, the reliability of the technique used, whether active or passive, is compromised.[33,34] The provisionals maintain the correct vertical dimension and the right space for the registration material that is placed only at the level of the prepared abutments (Fig 7).

The ideal material for intermaxillary registrations should not offer any resistance to the teeth during the registration process and should be fast setting. Once hardened, it should be stiff and not distort. The author prefers a zinc oxide eugenol bite-registration paste (Superbite, Bosworth) supported by a stiff wax (Moyco Beauty Pink Extra-Hard Wax, Thompson Dental).

Conclusions and recommendations

On the basis of the rationale proposed in this article, the following conclusions are drawn and recommendations made by the author when selecting the instrumentation and procedures in preparation for a prosthetic rehabilitation:

1. A semiadjustable articulator may be employed without fear of introducing gross occlusal discrepancies for the majority of patients.

2. The earbow is an adequate instrument to position the upper model in the articulator in a proper relationship relative to the hinge axis and the reference plane; the third point of reference should be identified in the infraorbital region at a level such that the incisal edges of the maxillary incisors are located near the middle of the articulator and the occlusal plane has an anteroposterior inclination comparable to that seen in the patient.
3. The condylar position recorded should be stable, reproducible, and comfortable; the precision of the intermaxillary registration is the key factor for a successful and efficient restoration from an occlusal point of view.
4. The centric relation or maximum intercuspation position should be recorded at the vertical dimension to which the patient will be rehabilitated.

Part 2 will clarify how to set up the articulator to take advantage of the findings of many studies on the posterior determinants of occlusion. Also, the role of the provisionals in the development of the proper occlusal scheme of the definitive restoration will be analyzed. Finally, some indications will be given on how to minimize the possibility that the prosthesis fabricated will be found in hyperocclusion once placed into the mouth.

Acknowledgments

The author wishes to thank Drs Robert Faucher, Anselm Wiskott, and Jan H. N. Pameijer for the advice given in reviewing this manuscript.

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