Successful treatment of patients requiring complex dental restoration requires a comprehensive evaluation of their existing occlusion. Using a systematic and ordered sequence for relating this occlusion to a physiologic standard greatly facilitates the treatment planning process of reconstruction. Reconstructing the occlusion in this same orderly sequence then significantly enhances the control and predictability of the procedures performed by all practitioners involved in management of the case. Six closely inter-related elements of an occlusion must be evaluated and frequently modified in treatment. Part 1 of this article will discuss two elements of the occlusion, in the order of their evaluation—centric relation position of the mandible and vertical dimension of occlusion. (Int J Periodontics Restorative Dent 2003;23:237–247.)

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Successful reconstruction and long-term maintenance of patients with extensive dental disease are highly dependent upon making the correct diagnosis of the nature of the problems and developing a proper treatment plan for the implementation of solutions. However, the extent of problems for many of these patients frequently makes diagnosis and successful treatment planning a very difficult task. Patients with skeletal and dental abnormalities, severe occlusal disease, or extensive periodontal disease coupled with multiple missing teeth, collapsed occlusions, and years of dental neglect and/or inadequate dental care can present with an extremely complicated and initially confusing set of circumstances. Add in the increasing complexity of treatment procedures and techniques used to solve various problems, and it becomes very easy for the clinician to lose sight of the full extent of a patient’s needs and possible treatment solutions. It is mandatory that practitioners be able to assess the entire situation and plan treatment based on the overall needs of the patient, without first
getting caught up in planning intricate procedures that may be available for solving specific problems. Therefore, it is imperative that a consistent and systematic approach to planning treatment for the complex reconstruction patient be used. Although these patients require multidisciplinary treatment, the most logical and orderly approach to planning is through an evaluation of the existing occlusal condition and a comparison of that condition to an occlusal scheme that would be considered physiologic, protective, and maintainable. From this comparison, a plan for reconstructing a final occlusal scheme that meets these requirements can be developed, and the final treatment plan will evolve. This is a reasonable approach, as the establishment of a physiologic, esthetic, and maintainable occlusion is the primary goal in the reconstruction of a patient's dentition.

Using a step-by-step approach to first evaluate, then design, and subsequently construct a patient's occlusion not only facilitates the treatment planning process, but also the sequencing of therapy during treatment. Realization of the requirements necessary to construct and then maintain an occlusion will greatly aid the practitioner in deciding the possible need for orthodontic therapy or the nature of potential periodontal therapy. Decisions regarding the use of endodontically treated teeth, root-resected teeth, or the number and position of dental implants that may be used to support the prosthesis can be made more intelligently once the occlusal scheme has been visualized. The ultimate long-term success of the prosthesis is dependent upon force control, and occlusal design and construction are all about force control. Equally important are the control and distribution of forces acting on the supporting abutments, periodontium, and temporomandibular joints (TMJ). This is also done through the occlusion; therefore, careful planning of the occlusal scheme is the first step in the process.

For many years, clinicians have been evaluating and treating occlusions as part of the reconstruction process. Beyron1 stated that one of the most important phases of the reconstructive procedure is the planning of occlusal therapy. Others2,3 have attributed the success of fixed bridgework in patients with reduced periodontal support to an occlusal design that precludes the concentration of undue stress in the remaining periodontal tissues. More recently, the success of implant-supported restorations has also been directly attributed to a control of the forces placed on these prostheses, which are managed, according to some,4,5 in large part through the design of the occlusion. Currently, with the profession's heightened interest in esthetics and cosmetic procedures, the occlusal condition of a patient may frequently be overlooked, but this is to the detriment of the patient. Much of the wear and breakage seen in teeth requiring cosmetic enhancement is the direct result of occlusal dysfunction and parafunctional habits.6 Miller7 has also reaffirmed the interdependence of the "esthetic zone," the anterior teeth, with the rest of the masticatory system. It is clear that an adherence to the requirements of a physiologic occlusion is applicable to all patients requiring restorative endeavors (Fig 1). The concept that the dictates of esthetics and the requirements of a physiologic occlusion may be in conflict with one another is totally unfounded. Successful esthetic treatment of many patients cannot be accomplished without consideration and modification of various elements of the occlusion. The metal-free restorations that many practitioners are now using simply do not withstand occlusal forces as well as the metal-based restorations of the past.

Dawson8 has stated that with regard to treatment planning for occlusal problems, restorative procedures should not be undertaken unless the end result can be visualized. However, there has frequently been controversy and confusion as to what that end result should be, what therapy should consist of, and how the occlusion should be established. Taylor et al9 stated that although anatomic occlusal characteristics for implant-supported restorations have been empirically described, they have not been examined scientifically. Further,

Cusp height, angulation, type of excursive contact, occlusal table width, and other considerations have... never been examined scientifically as they apply to natural teeth either. The generation of sufficient data for making meaningful conclusions will require studies of...
Fig 1a  Patient requesting cosmetic dental procedures to restore worn and chipped maxillary and mandibular incisors. Patient is unaware of parafunctional habits.

Fig 1b  Mounted models demonstrate initial contact in centric relation of the molars only. Premature occlusal contacts in centric, which may result in parafunctional habits and tooth wear, must be addressed prior to cosmetic procedures.

Fig 1c  Prognosis for success of ceramic veneers is greatly enhanced when forces are controlled and a physiologic occlusion is established as part of therapy.

such magnitude and expense that they will never likely be done, and human occlusion will remain in the realm of anecdote and empiricism.

A successful physiologic occlusion may be described as one that enables the patient to function with efficiency and comfort, and one that is well-tolerated by the periodontium, teeth, and TMJs. It acts to minimize activity of the muscles of mastication, creating neuromuscular harmony, and it does not create any pathologic symptoms in these muscles. There are several generally accepted criteria for this occlusion:

1. Stable, simultaneous bilateral maximal intercuspation of all teeth with the mandible in the centric relation or terminal hinge position; no interferences to closure between maximal intercuspation and the terminal hinge position of the mandible.
2. Freedom of mandibular movement in lateral and protrusive movement to and from the maximal intercuspation position, without posterior or anterior interferences.
3. Occlusal forces are distributed as widely as possible, with attempts made to minimize horizontal forces on both posterior and anterior teeth.

Establishment of a physiologic occlusion encompasses much more than just evaluation and use of a specific condylar position or modification of the restored anatomy of the posterior teeth. Six separate but closely inter-related elements must be evaluated and frequently altered. Through an understanding of the significance, inter-relationships, and workings of these various elements, a functional and esthetic treatment plan can be achieved. Orderly and systematic comparison of those aspects of a patient's occlusion to a physiologic and esthetic standard makes treatment decisions much easier.

The first step is an evaluation of the centric relation position of the mandible. Most patients must be restored with this position coincident with.

In today's environment of "evidence-based therapy," the reliance upon empirical long-term observation and evaluation is discounted. However, if Taylor et al's assessment of the situation is accurate, one is forced to look at those concepts of occlusal design that have had success over time, in spite of their empirical nature. Since the design of an occlusion is a complicated and elusive area, decades of treatment and observation are not without value. Many of these successful occlusal concepts have been described for the so-called periodontal prosthetic patient; however, they have been just as applicable to patients with occlusal disease, implant-supported restorations, and even nonextensive restorations.
with maximal intercuspation. Second, the vertical dimension of occlusion (VDO) must be evaluated. The joints, muscles, and teeth must be placed at an acceptable VDO in the final restoration. Third, the patient should be restored with an appropriate posterior occlusal plane. This has a direct effect on posterior cusp height and vertical overlap of the anterior teeth. Study models mounted in centric relation by means of a facebow allow proper evaluation of both the VDO and posterior occlusal plane. The fourth element to evaluate is the maxillary anterior incisal edge location, which represents an extension of the maxillary posterior plane of occlusion. Finally, a protective posterior occlusal surface design must be established. The occlusal anatomy of the posterior teeth is modified to fit the functional and esthetic dictates of the previous five components of the occlusion. If approached in this sequence, a complicated set of dental problems becomes much easier to resolve. Once problems have been fully recognized, solutions are easier to devise. This, in turn, facilitates communication among the different members of the team.

**Elements of an occlusion**

**Centric relation**

Several condylar positions have been used as a reference or starting position from which to establish an occlusion. The centric relation position has been described and advocated by many authors.17-19 Centric occlusion has also been used, and still others have recommended the use of the patient's neuromuscular centric occlusion.20,21 However, the preponderance of evidence does not support the use of the latter positions; neither has proven to be physiologic.22

Centric relation may be defined as "the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the shapes of the articular eminences."23 The first step in the diagnostic phase of therapy is to analyze the relationship between this defined centric relation position of the condyle-disc assemblies and the maximal intercuspation position of the teeth.24 This relationship must be understood to both evaluate and test the current state of health of the patient's TMJs, as well as to relate the intercuspal position of the teeth to the terminal hinge position. Normal, properly aligned, and functioning condyle-disc assemblies can be functionally loaded without pain and support an occlusion, and they are the most stable in the long term. This is of utmost importance, as the TMJs are the foundation upon which we build the occlusion. Many TMJs have undergone structural changes and adapted through remodeling of the soft tissues,25 but they may also accept firm loading in function without discomfort. Condylar movement of these joints, however, may not be as reproducible over time,26 and the occlusion may require additional adjustment as the case is completed, but they will support a properly designed occlusal scheme. Definitive treatment of patients whose TMJs cannot be maximally loaded without pain should not be undertaken until the cause of the pain has been determined and resolved.27

One must be able to freely locate the terminal hinge position, as it is the reference of the condyles to which the restored maximal intercuspal position will be established (Fig 2). The terminal hinge, centric relation position is used for several important reasons. It is reproducible over a fairly narrow range and stable over the length of time required to complete the reconstruction process. This is an important consideration, for many complex cases take months to a year or more to complete. Centric relation is also a border position on the envelope of function, and the mandible will function from this position if there are no interferences preventing closure into it. From this position, all mandibular movement begins. Its use in reconstruction will ensure that all movements of the condyle from this position act to separate the posterior teeth.

Finally, one of the tenets of a physiologic occlusion is
Fig 2a  Patient requesting dental reconstruction after many years of neglect. Evidence of prior occlusal parafunction is demonstrated by extensive wear of remaining mandibular incisors.

Fig 2b (right) Radiographic survey demonstrates extent of tooth damage and loss.

Fig 2c  Basic concepts of denture technique may also be used with completely or partially dentate patients. For this patient, a maxillary wax rim is useful in establishing the plane of occlusion and incisor position.

Fig 2d  Teeth positioned on maxillary wax rim establish desired position for final prosthesis. Wax rims are used to record centric relation position of the mandible, which must be located prior to therapy.

Fig 2e  Tooth position transferred to study models mounted in centric relation. Maxillary occlusal plane also used to facilitate location of mandibular implants. Class II position of mandible dictates final incisal guidance and posterior occlusal anatomy.

Fig 2f (left) Diagnostic information is converted into initial treatment procedures through the formation of processed acrylic resin provisional restorations.

Fig 2g (right) Facial view of final prosthesis. Shallow incisal guidance and level occlusal plane facilitate accommodation of patient's parafunctional habits.
neuromuscular harmony. Therefore, a goal of reconstruction is to create the lowest level of muscle activity during both function and parafunction. Complete seating of the condyles into centric relation during maximal intercuspation results in minimal electromyographic activity of the inferior head of the lateral pterygoid muscle. Any other reference position, which places the condyle-disc assembly down and forward on the slope of the eminence during maximal intercuspation, will require activity of the inferior head to maintain this position. The resulting antagonistic activity between the lateral pterygoid and elevator muscles acting to seat the condyles results in heightened and uncoordinated activity of all of these muscles and frequent pain in the pterygoids. Although there is controversy over the direct relationship between premature occlusal contacts to centric closure and occlusal muscle disorders, or temporomandibular disorders, clinicians have long recognized that many patients do demonstrate a direct relationship, and every effort should be made to prevent these interferences to minimize the possibility of muscle pain or dysfunction.

Increased muscle activity will also act to create greater load on the TMJs. Under load, the superior head of the lateral pterygoid is thought to become most active, and hyperactivity of this muscle may disrupt the normal relationship of the condyle-disc assembly, resulting in transitory or permanent disc derangement. This is an important consideration in patients with parafunctional habits, where the joints
may be under heavy loads many hours a day. Some investigators have shown that interfering contacts between centric relation and maximal intercuspation are a prime factor triggering the initiation of bruxism, although the role of defective occlusal contacts is still controversial. Although the causes are not fully known, the destructive nature of these forces is well-documented.

Thus, every effort should be made to prevent centric interferences and any parafunctional habits that may consequently result, and to minimize muscle activity should these habits persist following reconstruction.

The relationship between centric relation of the condyles and maximal intercuspation can only be demonstrated with axis-oriented casts mounted on an articulator. Mounted casts will show which pairs of teeth contact prematurely on the arc of centric closure. The effect these contacts have on the magnitude and direction of condylar displacement down the slope of the eminences may then be quantified to begin to provide a basis for formulating a treatment plan.

### Vertical dimension of occlusion

Following evaluation of the centric relation position, the VDO—the distance "between two points when the occluding members are in contact"—is assessed. Clinicians tend to relate the VDO to two fixed reference points of the anterior teeth. In reality, most patients present with two different vertical dimensions in the anterior segment; one, with the occluding surfaces of the teeth in maximal intercuspation, does not consider the location of the condyles, and a second may be measured with the condyles seated in centric relation and the mandible closed on the arc of closure until the teeth first touch. However, in this position, the anterior segments may not be in contact. This second anterior vertical dimension is usually greater than the first, with the difference representing the vertical component to the slide from contact in centric relation to maximal intercuspation. With a few exceptions, reconstruction should occur with the mandible placed in centric relation, or the position of adapted centric posture. Therefore, if the VDO of maximal intercuspation is acceptable, an occlusal equilibration may be performed, which eliminates the prematurities to closure, and occlusal contact in centric relation is made coincident with maximal intercuspation. Should the VDO with the condyles already positioned in centric relation prove acceptable, the provisional restorations may be made with maximum intercuspation at that position; through provisionalization, that VDO is established as the one VDO for the patient.

Many patients, however, require a VDO that is neither of these (Fig 3), and an alternative is needed, although this has long been a topic of controversy. For example, many patients with "posterior bite collapse" do not present with enough interarch space to accommodate a new prosthesis. Implant-supported prostheses require adequate space for components, and restorative materials require a certain dimension for strength and esthetics; it is frequently necessary to increase the VDO. Second, gaining room for occlusal thickness of posterior restorations by increasing the VDO may also minimize or eliminate the need for clinical crown lengthening of the posterior teeth. This may be especially important in the restoration of bruxers with extreme posterior tooth wear and diminished crown height, and may also help reduce the necessity for endodontic therapy of these teeth by reducing the amount of occlusal reduction that would be required if the VDO were not increased. A third and very important reason to alter the VDO is to change the overbite-overjet relationship of the anterior teeth. Patients with posterior bite collapse, loss of posterior teeth, or severely worn posterior teeth may present with an excessively steep overbite that results in a steep angle of incisal guidance. This, in turn, results in an increased horizontal vector of force on the anterior teeth. Increasing the VDO will decrease the overbite relationship.
allowing for the restoration of a shallower anterior guidance, which allows for a reduction of the horizontal forces acting on the anterior teeth.\textsuperscript{35} This is very important for patients with weakened anterior teeth. Modification of the overbite relationship is also significant for patients with uncontrollable bruxing habits. A diminished angle of incisal contact not only reduces horizontal forces on teeth, but has also been shown to minimize masticatory muscle activity.\textsuperscript{36}

Although increasing the VDO can greatly facilitate restoration of some patients, this procedure may cause difficulties in managing the overjet relationship of the anterior teeth. Increasing the VDO also increases the overjet relationship of the anterior teeth, which may make establishing contact of these teeth in centric relation difficult. Contact of the anterior teeth in centric relation, and especially during excursive movements, must occur if the posterior teeth are to be separated and the phenomenon of proprioceptive inhibition is to occur. A reduction of activity in the muscles of mastication through contact of the anterior teeth has been documented\textsuperscript{37} and is an important aspect of controlling forces on the prosthesis through control of the occlusion. Instances of excessive overjet will frequently require the building of lingual platforms on the maxillary canines to allow this contact.

A final benefit of altering the VDO is in creating esthetic change. A loss of VDO may result in a collapse of midfacial height, altering the overall facial esthetics. In fact, the esthetic evaluation of the patient's face has been used as a guideline in VDO assessment.\textsuperscript{38}

Although an evaluation of facial proportions may be helpful in analyzing the VDO, this should not be a primary factor in VDO alteration. This or other esthetic changes should not be made without first considering their functional ramifications. For example, in the current literature, many advocate that patients with severely worn anterior and posterior teeth—the typical horizontal bruxer—be restored with long anterior teeth, a 3- to 4-mm overbite relationship, and the resulting steep anterior guidance as a means of reestablishing optimum esthetics and eliminating the bruxing behavior. Establishing longer anterior teeth for esthetics may be desirable; however, establishing a steep anterior guidance in the hope of eliminating horizontal bruxism is dangerous. Although this approach may be successful for some, the behavior will
continue for many others. For these patients, restorations with this incisal guidance will fail, just as their own dentitions have failed. Consequently, the clinician must determine with each patient whether increased anterior guidance will in fact minimize the bruxing behavior.

Once the decision that the VDO must be altered has been made, the appropriate increase must be determined. Although various techniques have been recommended for determining an acceptable VDO, none have proven to be definitively accurate. The most commonly used guideline, the 3-mm freeway space, is particularly unreliable, being highly variable based on head position and time of day and adaptable to changes in the VDO itself. The guideline is that the minimal amount of anterior vertical increase necessary to meet the objectives of reconstruction should be used. Practically speaking, this is generally from 1 to 3 mm of opening in the anterior segment. The use of sibilant sounds, the "closest speaking space," is a practical if not totally accurate guide to determine if the altered VDO may have exceeded the adaptive range of the patient. However, this is rarely a problem with this amount of opening.

The stability of an altered VDO is a concern for many clinicians, and it is speculated that any increase in the contracted length of the masseter muscle will result in an unstable situation following restoration. However, as a means of further assessing the amount of increase, Spear has described two posterior dimensions of the VDO that directly impact the stability of its alteration—vertical positioning of the condyle within the joint space itself and length of the masseter muscle. Because of the geometry of the mandible as a class III lever, a 3-mm increase in opening in the anterior segment results in an approximate 1-mm opening in the posterior segment. This is also the location of the masseter muscle. Therefore, a 3-mm opening of the anterior VDO could potentially result in a 1-mm increase in the length of the masseter muscle. However, the vast majority of patients presenting for reconstruction demonstrate a condylar slide from centric relation to maximal intercuspation, and Spear has also reported this discrepancy to average approximately 1 mm in a vertical direction. Elimination of this slide will therefore result in an approximate seating of the condyles 1 mm superiorly in the fossae, with the result that the masseter muscles are also shortened by 1 mm. Consequently, for the average patient, a 3-mm increase in the anterior VDO, with the condyles repositioned to the most superior position in the fossae, will result in no change in the length of the masseter muscles. It is rare that an increase greater than 3 mm would be done; however, it can occur.

Because of the rotation of the condyles on the terminal hinge, each additional millimeter of opening potentially results in only a 0.33-mm lengthening of the masseter muscles. Indeed, other researchers have reported stable long-term results following an increase in the VDO. There appears to be a range of neuromuscular adaptability that is highly individual and will allow for some slight increase in muscle length, within limits. The objective, then, is to prevent or minimize increasing muscle length when possible; it is possible to do so, however, with careful monitoring of the joints and muscular function throughout the course of therapy.

The inter-relationship of the centric relation position of the mandible and the VDO is unique and becomes more significant if an alteration of the VDO is contemplated. The remaining elements of an occlusion may be more precisely evaluated and established once the location of these two has been determined.
References


